AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited
Suite 600 – 4445 Lougheed Highway,
Burnaby, BC, Canada V5C 0E4
Tel +1 (604) 294-3811
Fax +1 (604) 294-4664
www.amec.com

MOUNT NANSEN REMEDIATION PROJECT
30% DESIGN PHASE REPORT

Submitted to:

Assessment and Abandoned Mines
Energy Mines and Resources
Whitehorse, YT

Submitted by:

AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited
Burnaby, BC

April 9, 2014

AMEC File: VM00605F

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (cont'd)

TABLE OF CONTENTS (cont'd)

Page

LIST OF FIGURES

TABLE OF CONTENTS (cont'd)

Page

LIST OF TABLES

TABLE OF CONTENTS (cont'd)

Page

TABLE OF CONTENTS (cont'd)

LIST OF DRAWINGS

TABLE OF CONTENTS (cont'd)

LIST OF APPENDICES

1 PROJECT BACKGROUND AND SCOPE

1.1 Introduction

Mount Nansen has been the site of mining exploration activity and/or active mining since the 1940s. The site location is shown on Drawing D001 and a current plan of the site is provided on Drawing D002. The most extensive stage of mining occurred between November 1996 and February 1999 in the Brown-McDade Open Pit. It involved construction of the existing tailings dam and deposition of approximately 240,000 m^3 of tailings within the tailings impoundment. A waste rock storage area containing approximately 360,000 m^3 of waste rock was also created adjacent to the Brown-McDade Open Pit. Earlier periods of mining contributed to smaller amounts of tailings, some of which are still present near the mill site, and localized zones of waste rock at the mill site and elsewhere on the site. Other site infrastructure includes the mill and camp facilities as well as various ancillary structures, power lines and pipelines.

In 1999, mining was halted because it was no longer economical, and sulphide ore was being mined in contravention of the water licence. The company operating the Mount Nansen property was put into receivership in March 1999. The site is now managed by the Yukon Government through Assessment and Abandoned Mines (AAM).

In support of site remediation, many studies and investigations have been carried out over the past decade to define the closure objectives and to explore various closure options. Detailed discussion of the closure objectives can be found in Yukon Government (2008) and are presented below.

1.2 Project Objectives and Scope

1.2.1 Objectives

Broadly speaking, the closure objectives for the Mount Nansen Remediation Project (MNRP) are as follows:

- protect human health and safety;
- protect and restore the environment including land, air, water, as well as fish and wildlife and their habitats;
- return the site to an acceptable state that reflects original, traditional, and pre-mining land use;
- maximize local, Yukon and First Nations benefits; and
- manage risk in a cost effective manner.

1.2.2 Scope

The final remediation alternatives study (LORAX, 2011) presented technical information regarding four remediation options. The options were evaluated by representatives of Government of Yukon, Aboriginal Affairs and Northern Development Canada (AANDC) and the Little Salmon/Carmacks First Nation (LSCFN). Option 4, as described in LORAX (2011), has since been selected as the remediation option for the site. This remediation plan is comprised of the following:

- relocating the tailings and underlying affected soils from the existing tailings impoundment to the Open Pit;
- removing the main tailings dam and downstream seepage dam;
- relocating mineralized waste rock to the Open Pit;
- backfilling the Open Pit so that the tailings are located above the groundwater table and a stable final surface and topography is provided;
- developing a management method for the water currently in the tailings facility and Open Pit and for the short term seepage from the backfilled pit;
- covering the Open Pit area with an engineered low infiltration cover to substantially limit water contact within the tailings deposit;
- understanding the backfilled pit's hydrogeology so that seepage can be appropriately managed;
- remediating the mill area including building demolition, removing the rail tanker, restoring the water course, removing mineralized rock, removing hazardous waste, removing historic tailings, decommissioning historic settling ponds, providing compliant water quality and, if shown to be necessary, remediating the old landfill;
- remediating the camp area including demolishing existing buildings except those required for maintenance following closure, and removing hazardous waste;
- decommissioning all non-public roads, where not required for future monitoring;
- removing existing infrastructure (power lines, pipelines, sediment ponds, ancillary buildings, etc.);
- remediating hydrocarbon contaminated soils;
- remediating exploration trenches and disturbed areas as appropriate;
- decommissioning the Victoria Creek Wellhouse and existing artesian well;
- reconstructing and reclaiming the Dome Creek channel and valley following removal of the tailings storage facility; and
- creating a remediated landscape that complements the natural topography and vegetation.

2 PROJECT DEVELOPMENT STATUS

2.1 30% Design Phase Objectives

The current phase of design development is referenced in AAM's process as the 30% Design Development phase. This phase is intended to:

- characterize the technical feasibility of Option 4;
- identify a base case design which can be further optimized and refined;
- provide bracketed predictions of the likely performance of the base case design (e.g. predicted ranges of downstream water quality relative to CCME criteria);
- provide a bracketed understanding of the risks associated with key project features and outcomes;
- characterize the nature and scale of uncertainties related to predictions of performance and risk;
- outline the basic elements of any adaptive management plans that may be needed to manage risks and uncertainties; and
- develop a project execution cost estimate with enough utility and reliability to support the next level of Partner decision making (generally equivalent to an AACE (Association for Advancement of Cost Engineering) Class 3 Estimate).

2.2 Design Base Case

2.2.1 Description

Following completion of the 2013 Site Investigation (AMEC, 2014), and at the onset of 30% design phase development work, the AMEC team outlined a Design Base Case for the MNRP. This Base Case is a design development tool, not a final statement of the execution scope, and reflects the design team's consensus on the most likely methods for executing Option 4. The Base Case served to focus design activity, improve the efficiency of the development process and evolved through the design process. Alternatives to the Base Case were considered as key design assumptions and were validated.

The evolution of the MNRP Design Base Case through the 30% design phase was reviewed with the Project Partners during meetings on November 28, 2013 and January 27, 2014. The current Base Case was originally presented in the Project Design Basis Memorandum (DBM) (AMEC, 2014a) and is replicated in Table 2.1. The table also outlines the key design issues that have been addressed during the 30% design phase in support of the Base Case and identifies issues that will require additional consideration in subsequent phases of design. The Base Case, as presented in Table 2.1, will be the starting point for refinements during the 60% and 100% design phases.

Table 2.1: MNRP Design Base Case

Element	Description of Current Base Case	Design Issues Addressed in Phase One (30% Design)	Design Issues Requiring Resolution Post Phase One
Tailings Relocation	▪ Tailings will be dewatered to the extent possible prior to excavation with a vacuum wellpoint dewatering facility. ▪ Tailings pond water and wellpoint production will be directed to a water treatment capability. ▪ Dewatered tailings will be relocated using a conventional truck and shovel operation. ▪ Adjustments to conventional equipment and methods will be incorporated to address the relatively small proportion of tailings that cannot be dewatered. ▪ Relocation will be completed via an integrated process of dewatering, tailings removal and dam removal undertaken over at least two summer construction seasons. ▪ The dam (or a portion of it) will likely remain following tailings removal as a sediment control measure until all work is complete and then be removed as a final layer for reclamation or cover.	▪ The option of excavating wet tailings was discounted for the following reasons: - excavating tailings in the wet will have very slow production so the costs of a dewatering operation are not likely to be significantly greater than inefficient truck/shovel operations; - wet excavation is subject to safety concerns as saturated loose tailings are subject to static liquefaction which can occur with little to no warning (i.e. creating a potential to engulf people and equipment); - dewatering tailings is aligned with “dry” Option 4 objectives. Tailings are placed “dry” so seepage is reduced and there is less time required to meet the general remediation objectives of Option 4; - “dry” tailings can be placed in a denser state and/or compacted if this is determined to be the most cost effective placement option (as opposed to end dumping from the pit walls). This will reduce post placement settlement in the Open Pit so cover performance may be improved; and - the storage volume available in the pit requires that tailings be stored above ground. Placing wet tailings above ground would introduce more significant stability concerns and would be particularly challenging in the areas constrained by the public road. ▪ Materials will be excavated with a conventional truck and shovel operation because alternatives (i.e. conveying, dredging) are impractical (i.e. insufficiently flexible to accommodate the particulars of the site and/or work scope), because truck/shovel operations align better with a local procurement strategy/preference and because mobilizing large equipment to site would be constrained by the road access. A dredging operation would be counter-productive relative to the “dry” tailings objective.	▪ More detailed assessments of the uncertainties associated with the proposed tailings relocation methods with a view towards defining the need for tailings excavation trials as an early component of project execution (e.g. excavation methods validation, adjustment and potentially, repricing, as an early task in the field execution contract).

Element	Description of Current Base Case	Design Issues Addressed in Phase One (30% Design)	Design Issues Requiring Resolution Post Phase One
		▪ Assessments of the tailings and of the capabilities of vacuum wellpoint dewatering technology have confirmed that dewatering followed by truck/shovel excavation and relocation will likely be feasible for most, but not all of the tailings inventory. ▪ About 30% of the tailings inventory will probably not be dewaterable and will be transported wet. Excavation, haulage and pit placement for wet materials will use equipment and methods largely common to the drier materials with some adjustments in handling and sequencing. ▪ Current and predicted air temperatures indicate that it is unlikely backfill placed into the pit will freeze/remain frozen (i.e. the design will need to assume thawed conditions in pit backfills post remediation). ▪ The pit backfilling approaches described above (i.e. either controlled placement or end dumping) for the current Design Base Case will not invoke the requirements of the Canadian Dam Association's (CDA's) Dam Safety Guidelines in the pit.	
Dam Material Excavation and Relocation	▪ Dam materials will be excavated with a conventional truck and shovel operation. ▪ Dam material excavation will be integrated with tailings relocation and removed in stages consistent with geotechnical stability and sediment control (construction water quality) requirements. ▪ Uncontaminated dam materials will be utilized for: - reclamation requirements (to improve revegetation performance in granular surface soil profiles); - backfill required for the restoration of Dome Creek (in this case, sands will be utilized with other materials as needed to provide non-erodible surfaces); - source of material for the cover over the backfilled pit; and	▪ Assessments of the dam materials suggest that a large proportion of the materials will be classified as uncontaminated (i.e. not exhibiting significant, anthropogenically derived parameter excursions) and will, therefore, be available for other project purposes (e.g. reclamation requirements, cushions/filters for cover or liner geosynthetics, general fill for site grading).	▪ More definitive assessments of background soil, sand and rock metal levels for the Mount Nansen area. Current determinations that these levels are likely elevated naturally will require confirmation via technically robust and statistically valid methods. ▪ Additional assessments of dam removal sequencing

Element	Description of Current Base Case	Design Issues Addressed in Phase One (30% Design)	Design Issues Requiring Resolution Post Phase One
	- general fill to restore ground surfaces to proposed profiles and topographies. ▪ Contaminated dam materials will be directed to the Open Pit and may be used to facilitate the handling, transport and placement of that portion of the tailings inventory that is not amenable to wellpoint dewatering.		
Open Pit Cover	▪ An interim pit cover will be required over the period following tailings relocation because the limits on differential settlements needed to permanently maintain cover integrity cannot be provided initially (even with placement of "dry" tailings). ▪ Pit covers will be constructed with geosynthetic materials and/or granular materials that are available, or can be processed, within or near the OIC (i.e. there are insufficient fine grained material volumes within economically practical distances of the site to warrant consideration of earth based barrier systems). ▪ A permanent cover constructed after differential settlements have declined to tolerable levels will be included in the initial project execution scope (i.e. this component will be a defined scope item, not an adaptive management element that may, or may not be necessary). ▪ The impacts of large differential settlements in both interim and permanent covers will be mitigated by an ongoing program of cover monitoring and maintenance/repair. ▪ Interim and permanent cover designs will minimize infiltration by utilizing contours and configurations that redirect precipitation to Pony and/or Dome Creeks. ▪ The cover will be configured to avoid encroaching on the public road at the north end of the Open Pit that will remain post closure.	▪ Differential settlements will result from the consolidation of tailings and settling of waste rock (the latter cannot be reduced as they might typically be accomplished by sluicing, because of the increase in the contaminated pit water inventory that would result from sluicing). ▪ The maximum differential settlements during the interim cover period (due largely to consolidation of the tailings) are anticipated to be large and well beyond the capabilities of any cover system to accommodate without damage. Similarly, maximum differential settlements over the long term (i.e. after the permanent cover has been installed, and largely the consequence of water induced collapses of tailings, or earthquake induced settlements) will, in all likelihood, exceed the accommodative capabilities of any cover system. In both cases (i.e. for both the interim and permanent covers), the most practical mitigation for large differential settlements will be monitoring, maintenance and/or repair (i.e. design mitigations for the range of differential settlements are not available). ▪ The length of time over which an interim cover is required will depend on the settlement of the backfilled pit. There will be uncertainty associated with these settlement timelines (although it is known they will be measured in years) and that uncertainty will be influenced by the details of the tailings/dam relocation method selected (i.e. end-dumping tailings from the pit wall will produce a more uncertain settlement behaviour than controlled placement and compaction of tailings within the pit itself). ▪ Modelling indicates that surface water quality outcomes at likely receiving environments are not	▪ Assessments of the benefits of more robust predictions of settlement timelines (i.e. are there any material benefits provided via settlement predictions over observational monitoring of cover settlements and performance). ▪ Assess relative cost of providing a long term geosynthetic liner (i.e. Coletanche) versus Bentonite Admixture.

Element	Description of Current Base Case	Design Issues Addressed in Phase One (30% Design)	Design Issues Requiring Resolution Post Phase One
		highly sensitive to short term degradations in interim cover performance, in part because the tailings will be largely unoxidized/acidified during this period. That said, monitoring interim cover condition and performance and responding to evident settlement damage will be required.	
Open Pit Containment Structure	▪ Open Pit pond water removed prior to tailings and waste rock will be relocated and treated prior to discharge. ▪ The Pony Creek Adit will be decommissioned. ▪ A non Potentially Acid Generating (PAG) waste rock bench will be constructed at the base of the Open Pit to maintain the base of the tailings above the likely maximum groundwater level. ▪ Tailings will be placed in the pit with two options advanced – end dumping and direct bottom up placement. ▪ The low grade ore at the south end of the pit will be relocated within the drainage catchment of the pit footprint. ▪ Other contaminated materials will be placed above the tailings within the footprint of the pit. ▪ NPAG (Non-Potentially Acid Generating) waste rock will be placed above the tailings and the existing low grade ore for physical stabilization and to provide suitable topography for surface drainage and end land use. ▪ NPAG will be used to fill in the ramp and re-contour the south end of the pit and may be used to flatten the slopes of the final pit cover once the final cover system is in place. ▪ Diversion ditches will redirect runoff originating upstream of the pit structure and protect portions of the cover from erosion and collect and control runoff from the cover. Long term surface water management	▪ The existing quality of the Open Pit pond water is not compatible with direct discharge requirements and will require treatment prior to release. ▪ Characterizations of the pit water balance suggest that post remediation groundwater levels are unlikely to rise above the Pony Creek Adit. If levels do, on an infrequent basis, rise temporarily above the base of the tailings, there would be a short term increase in contaminant mass transport from the pit. However, this increase is unlikely to cause an unacceptable degradation of surface water quality at receiving environments (i.e. groundwater level increases are likely to be low probability, low consequence events). ▪ Current pit outflows are strongly influenced by precipitation and are likely to be reduced post remediation to levels that are small in relation to the local/regional surface water flow regime. ▪ These assessments of pit hydrogeology and surface water quality have concluded that groundwater level control via the Pony Creek Adit (or some alternate level control structure) will not be necessary. ▪ The current “most likely” modelling estimate suggests that the mass transport of contaminants from the pit post remediation will not likely create an unacceptable incremental impact at surface water receiving environments in Victoria Creek. There are uncertainties with this finding and scenarios where unacceptable water quality for specific parameters could occur. These uncertainties could be mitigated by cover maintenance or replacement and/or pit design contingencies that would provide for the containment, collection and management of pit outflows (e.g. via pit liners and sidewall drainage that would be produced via wells completed in the waste rock bench, discharging	▪ Additional assessments of the uncertainties related to post remediation water quality predictions leading to a decision on the need for providing active containment, collection and treatment of pit flows and contaminants in the Design Base Case. ▪ Additional development of the regional model of groundwater flow to confirm the assumptions inherent in the water quality model. ▪ Confirmation that the Pony Creek Adit does not need to be hydrogeologically sealed (i.e. groundwater flows restricted) to maintain downstream water quality. ▪ Additional adit investigations will be required to fully understand the current state and performance of the existing adit bulkhead.

Element	Description of Current Base Case	Design Issues Addressed in Phase One (30% Design)	Design Issues Requiring Resolution Post Phase One
	will be provided by the contouring of the pit which will be designed to shed water. ▪ Contaminant fluxes from the pit will be passively reduced during transport in the local/regional hydrogeological flow regime to meet water quality criteria at an agreed upon compliance point.	to a water treatment facility), if at any time, post remediation monitoring identifies unacceptable degradations in surface water quality. At the 30% design stage, these contingencies will be indentified and conceptually developed. ▪ The following qualifiers apply to the modelling estimates described above: - discussions with Project Partners and regulators will be required to establish site specific water quality criteria that reflect the influence of elevated parameter levels upstream of the site (i.e. will require relief on some typical aquatic life criteria (e.g. CCME criteria) to reflect background water quality conditions applicable to the Mount Nansen site); - the water quality modelling conclusions are influenced by the location of the compliance point. Compliance at Victoria Creek is more feasible than at various points upstream; - the predicted risks to water quality are sensitive to the assumed characteristics and conditions of the tailings source terms. This is particularly true for the period following tailings acidification, the critical period with respect to water quality impacts and a condition that is not anticipated to occur until many years (potentially measured in decades) after tailings placement in the pit; and - the nature of the modelling platform used (GoldSim), while appropriate for this level of design, has inherent limitations in its predictive capabilities that require consideration in the characterization of, and response to, modelling uncertainties.	
Water Treatment	▪ All contaminated waters produced before and during remediation (i.e. pond waters at the Open Pit and Tailings Storage Facility, pore waters produced by the wellpoint dewatering system, surface runoff incompatible with agreed upon discharge criteria) will be directed to a single, fixed (i.e.	▪ The water treatment capacity required to treat pond and pore water volumes over timelines that would support the desired base case schedule (one month to drain the tailings pond) is beyond that which can practically be provided by mobile, skid mounted facilities.	▪ Additional assessments to optimize the balance between water treatment capacity and onsite water storage (i.e. determining if schedule objectives can be realized more economically via the provision of storage with a lower water treatment flow capacity).

Element	Description of Current Base Case	Design Issues Addressed in Phase One (30% Design)	Design Issues Requiring Resolution Post Phase One
	non-mobile) water treatment plant constructed for, and dedicated to, the project.	▪ Project flows will be managed and directed to a single, fixed water treatment location.	▪ Additional assessments of the potential range in raw water qualities to refine estimates of reagent requirements.
Mill Area Remediation	▪ Non-hazardous contaminated soils, tailings and PAG waste rock will be removed and directed to dedicated areas of the pit containment structures with methods of placement and/or containment engineered appropriately for the nature of the materials involved. ▪ Hazardous contaminated soils will be removed and directed to appropriate offsite treatment and/or disposal facilities.	▪ Utilizing the air space that can be developed within the Open Pit containment structure for non-hazardous mill area soils will be more cost effective than developing dedicated facilities elsewhere onsite, or directing the materials to offsite facilities. ▪ The non-PAG waste rock inventory in the mill area will be left in place, or recontoured to suit the area regrading plan, consistent with the general site philosophy that non-PAG waste rocks do not require remediation and/or management. ▪ The Huestis Adit does not appear to be producing any significant deterioration of downstream water quality. ▪ The upstream reaches of Dome Creek have high background metals concentrations.	▪ More definitive assessments of background soil, sand and rock metal levels for the Mount Nansen area will be needed to finalize the mill area volumes requiring removal. Current determinations that these levels are likely elevated naturally will require confirmation via technically robust methods vetted by the Project Partners. ▪ Assessments of the potential utility of human health and/or ecological risk assessments as a cost efficient method for limiting excavation requirements, particularly for materials at depth.
Structures	▪ Site structures will be brought to grade in accordance with structure specific dismantling and/or demolition plans. ▪ Non-hazardous materials generated by dismantling/demolition activity will be directed to offsite reuse or recycling options, or to dedicated areas of the pit containment structure with methods of placement and/or containment engineered appropriately for the nature of the materials involved. ▪ Structural elements containing or incorporating hazardous materials will be cleaned of these materials prior to onsite disposition, or directed to appropriate offsite treatment and/or disposal facilities. ▪ Hazardous materials stored in containers within, or ancillary to, site structures will be directed to appropriate offsite treatment and/or disposal facilities. ▪ Victoria Creek well will be used as a water source during remediation activities and subsequently decommissioned and the Wellhouse dismantled/demolished.	▪ Utilizing the available disposal capacity that can be developed within the Open Pit containment structure for non-hazardous dismantling/demolition wastes will be more cost effective than developing dedicated facilities elsewhere onsite, or directing the materials to offsite facilities. ▪ The quantities of hazardous materials generated by the project are expected to be small and below thresholds that would warrant assessments of options with lower unit costs than commercial, offsite treatment and/or disposal facilities.	

Element	Description of Current Base Case	Design Issues Addressed in Phase One (30% Design)	Design Issues Requiring Resolution Post Phase One
General Site Reclamation	▪ Final surfaces will be restored largely with materials available locally. ▪ The capabilities of surfaces restored with non-erodible granular materials will be enhanced by rebuilding local environments compatible with the surrounding landscape. ▪ Vegetated zones will be re-established within the disturbed area footprint using local sand sources (borrow and clean dam materials) supplemented (in relatively low volumes) with appropriate amendments to satisfy fines requirements and to support revegetation objectives.	▪ The project will not have silt and finer materials available in quantity for reclamation (sources are generally too distant to be economically viable). ▪ The proportion of the site disturbed area that can potentially be revegetated is limited by the local sand volumes (from dam removal and/or site borrow) that can be made available for reclamation purposes. ▪ There is uncertainty about the potential success of revegetation efforts relying on materials no finer than sands. ▪ Lands within the disturbed area that are not revegetated will be surfaced, contoured and/or configured in ways that, while different from the surrounding lands, meet the broad objective of providing compatible, complementary and/or equivalent land uses.	▪ More definitive assessments of background soil metal levels for the Mount Nansen area will be needed to accurately define the volumes of sand (both from the dam and site borrow areas) that can be devoted to reclamation. Current determinations that these levels are likely elevated naturally will require confirmation via technically robust methods vetted by the Project Partners. ▪ Additional assessments of the nature and long term viability of vegetated lands that can be supported with soil profiles incorporating materials no finer than sands including an examination of the potential utility of field trials. ▪ Additional assessment of the specific reclamation configuration proposed for lands outside revegetated zones in consultation with the Project Partners (to ensure that the more subjective elements of providing land use compatibility and/or equivalency are considered and incorporated into final plans).
Dome Creek Valley Reclamation	▪ Contaminated organic debris underlying the tailings and/or dam materials will be removed and directed to a dedicated location within the pit containment structure. ▪ Uncontaminated organic debris or silt beneath the tailings will be removed, stockpiled and dewatered for potential use as a reclamation material or amendment (although the volumes involved will not be large enough to materially impact the need for a reclamation plan based largely on no/low minus sands materials gradations). ▪ The original ground will be secured soon after exposure through placement of free draining and erosion resistant materials. ▪ The creek channel and disturbed valley slopes will be restored with layers of sand	▪ Sediment quality downstream of the tailings facility suggests that tailings may be present in localized areas. These areas will require sediment removal and creek bed restoration. ▪ The lack of local organic reclamation materials requires a creek valley restoration Base Case relying largely on granular, non-erodible materials. ▪ The impact of warming air temperatures that is evident from the meteorological record over the last few decades will be considered in the stability assessments and design of restored valley slopes. ▪ The stability of the slopes considers the impact of thaw induced pore pressures.	▪ Additional assessment of Dome Creek downstream of the tailings pond with regards to sediment quality and possibility of tailings migration /deposition in the lower portions of Dome Creek. ▪ Assessments of the potential utility of constructed wetlands in the restored Dome Creek Valley, both to improve the aesthetics of the reclaimed area and potentially as a means of improving creek water quality. ▪ Development of details for the tie-ins between the reclaimed and undisturbed areas to minimize degradation of permafrost. ▪ Shallow probing/hand core auguring of near surface active layers in undisturbed terrain in the tailings area slopes that must be “connected” to reclaimed surfaces.

Element	Description of Current Base Case	Design Issues Addressed in Phase One (30% Design)	Design Issues Requiring Resolution Post Phase One
	overlain by stable and non-erodible rock materials (e.g. NAG rock). ▪ The aesthetics of the creek valley restoration concept may be enhanced by incorporating stream restoration techniques that create natural features without compromising the fundamental hydrologic properties and/or capabilities of the restored channel, or the geotechnical stability of valley walls.		
Exploration Trench Reclamation	▪ Reclamation will be completed for trenches that: - are likely to create major erosion, water quality or land use constraints if left unreclaimed; and - can be reclaimed without creating a reclamation liability greater than that being mitigated (e.g. where machine access will not cause inordinate damage). ▪ Those trenches that are reclaimed will use a common reclamation specification. That method will be comprised of: - replacing available side cast materials back into the trench; no new fill will be imported or incorporated; and - vegetation that has become established on side cast materials will be stripped prior to moving the side cast material; produced mulch will be placed over side cast materials replaced in trench.	▪ Trench reclamation requirements will need to be established on an individual basis giving due consideration to the intrusive impacts that reclamation activity will inevitably create, revegetation that has occurred naturally and the resulting fact that in some areas, reclamation efforts will cause damage disproportionate to the available benefits. ▪ Trench reclamation will proceed without the large scale import or placement of materials.	▪ Additional assessments of the need for more detailed characterization of individual trench reclamation requirements, likely in consultation with the project Partners or alternatively, an execution specification that equips the field execution team with the flexibility to adjust reclamation specifics to the particular characteristics and circumstances of each trench.
Climate Change	▪ Has been accounted for by considering two scenarios (1) today's temperatures continuing on, and (2) making an allowance for warming as per IPCC/ Canadian guidelines. In both scenarios the long term expectation is that most permafrost will thaw out. If colder conditions eventuate permafrost that has been lost will reform and pit infill tailings will freeze.	▪ Current seepage patterns from the Pit to receiving waters are understood at a conceptual level based on limited hydrogeological and permafrost data. As future permafrost patterns evolve, seepage patterns may change in unpredictable ways. Maintaining a "dry" pit will help mitigate this risk. ▪ The Adaptive Management measures proposed for responding to water quality excursions are intended to mitigate the impacts of unpredictable, climate related changes in seepage patterns.	

2.2.2 Current Design Status

The current design Base Case represents, for the most part, a single, integrated approach to executing Option 4 (i.e. it does not carry forward multiple options for completing the work). The departures from this general statement are as follows:

- Tailings Relocation: the Base Case brings forward two methods for placing tailings into the Open Pit: dumping from the pit walls and controlled placement from the bottom of the pit up. Both of these methods will be described in the Design Report (Section 4.0) to comparable levels of definition, consistent with the objectives for the 30% design phase. If these two methods or procedures are found to have equal merit, they may be carried forward into final design to allow contractors to competitively bid the work.
- Design Contingencies: design contingencies refer to measures or features that may be incorporated into the Base Case in subsequent phases of design (i.e. post the 30% design phase) to mitigate risks and/or uncertainties. The major design contingency identified in the current Base Case relates to the potential need for pit water containment and collection measures to facilitate future adaptive management efforts, should they be required, to address deteriorations in downstream water quality. These measures have been described and costed during this design phase, but not to the same level of definition as the balance of the design (i.e. contingent measures have not been developed to the same level as Base Case components).
- Adaptive Management: This Design Report references some specific techniques that may be considered post remediation to support any Adaptive Management efforts and responses. These techniques have been outlined conceptually (i.e. not to a level of definition comparable to the Base Case, or to the Design Contingencies) because their development and design will be contingent on the specific circumstances and requirements that ultimately give rise to the need for some kind of future Adaptive Management response.

3 REPORT ORGANIZATION

The Project Design Report begins with an outline of the project background and the AMEC/AE Scope of Work. A description of the Design Base Case for the 30% Design Phase (Section 2) is then provided. The balance of the document outlines the development of the various plans that form part of, or support, the Design Base Case, or the associated design contingencies and Adaptive Management Plans. Specifically, the report includes the following plans:

- Section 4: Materials Management and Containment Plan (MMCP):
  - describes how contaminated materials will be relocated to, and secured within, the Open Pit.
- Section 5: Water Quality Management Plan (WQMP)
  - describes predictive water quality modelling outcomes and the associated influences on the MMCP;
  - describes water treatment and/or management requirements and methods; and
  - describes water quality monitoring requirements.
- Section 6: Site Infrastructure Decommissioning, Demolition and Disposition Plan:
  - describes plans for bringing structures to grade and directing the materials generated to appropriate disposition facilities/locations.
- Section 7: Site Reclamation Plan:
  - describes methods and plans for restoring disturbed lands.

The report provides all of the 30% Design Phase drawings in a dedicated section (just ahead of the Appendices). The various report figures are interspersed within the document as they are referenced in the text.

4 MATERIALS MANAGEMENT AND CONTAINMENT PLAN

Upon remediation of the Mount Nansen site, all contaminated materials and materials of concern, except for special waste material, will be contained within the Open Pit footprint. Any non-contaminated demolition waste that remains onsite will be located within the same landform, placed immediately adjacent to the Open Pit or incorporated with the PAG and tailings backfill depending on the detailed schedule. It is considered preferable to manage all the materials within a single storage area, as opposed to having several areas around the site for different material streams, because it simplifies post remediation monitoring and any maintenance that may be required. Furthermore, a single storage location is considered to be less disruptive to future land use. Non acid generating (NAG) waste rock that is not needed as construction material will be left in place or locally regraded as appropriate.

At the outset of this 30% design phase, the project partners identified that achieving “dry” tailings was a key objective of the remediation option that had been selected for Mount Nansen. The materials management methods described herein, therefore, include dewatering the tailings prior to excavation because this is considered to be the most feasible way of meeting this objective, and it facilitates excavation, transport and placement of the tailings. It must be noted, however, that completely dry tailings cannot be achieved. Given the climate and the nature of the tailings and groundwater conditions (especially under threat of long term loss of permafrost), there will always be some moisture associated with the tailings, although it is expected that the tailings will be unsaturated in the long term. Dewatering the tailings also has several technical advantages with regards to placement and stability of the tailings as described subsequently.

The materials to be contained within the footprint of the Open Pit are presented in Table 4.1 below. The table also summarizes the material that is required as construction material for the cover and other elements of the backfill. The volumes presented are the best estimate values; except for the use of bulking factors, they have not been increased to provide contingency storage. Contingency amounts will be included in the cost estimates. The potential for increased storage requirement and how that would impact the design configuration are discussed subsequently. The location of the contaminated soils and PAG waste rock are shown in Drawings D003 through D006.

A summary of all earth materials requiring movement during the remediation effort is included in Section 4.7.

Table 4.1: Materials to be Placed in the Open Pit

Material	Insitu Volume (m^3)	In pit Volume (m^3)[1]
To be contained within the footprint of the pit rim:		
Base platform (including filter) - NAG material	43,300	43,300
Tailings from tailings facility	237,100	260,900
Tailings from mill area	2,200	2,500
Contaminated soils/tailings from downstream Dome Creek (allowance, volume to be determined)	1,000	1,000
Contaminated soils from mill, camp, roads and former Ketza Shop	9,500	10,800
Contaminated insitu soils in tailings/seepage dam area	50,600	57,700
Low grade ore (currently on ramp to Open Pit)	8,000	8,800
Dam Fill (upstream buttress)	5,800	6,400
PAG rock from waste rock area	354,700	354,700
PAG rock from mill area, site roads and Ketza Shop	38,500	38,500
Contaminated Demolition Waste	n/a	300
Total Storage Capacity Required	750,700	784,900
To be placed as part of pit backfill but does not required storage within the footprint of the pit rim:		
Inert demolition waste (concrete) may be placed within the pit rim footprint depending on schedule but is not required to be within the pit drainage boundary[2]	2,600	3,000
NAG buttress at south end of pit (minimum requirement, can be increased to flatten slopes and/or to increase storage capacity as a contingency measure)		68,200
Interim cover granular filter (300 mm thick well graded gravel and sand)		24,000
Interim cover barrier layer (1,000 mm thick Victoria Creek well graded silty sand with gravel, may be screened from NAG waste rock)		80,000
Final cover cushion layer (300 mm sand layer)		24,000
Final cover drainage layer (300 mm coarse sand)		24,000
Final cover surficial layer (300 mm fine sand for vegetation growth)		24,000
Total Material Required Outside Contaminated Zone		247,200

Notes:

1. *For tailings, the in-pit volume assumes a 10% bulking factor to provide a conservative estimate of the required storage capacity. Insitu soils requiring relocation have a net bulking factor of 1.14 between insitu and in pit conditions. The waste rock is assumed to have the same volume in the pit as it currently does insitu. For materials used as construction material, a 10% factor for wastage and bulking has been applied to provide a conservative estimate of the material requirements.*
2. *Demolition waste volumes are based on a significant amount of recycling. This requires further assessment in the next phase of design to confirm feasibility given the remote northern location. The disposition of the demolition waste onsite will then require further refinement.*

4.1 Backfilled Open Pit Configuration

The final Open Pit configuration is shown in Drawing D007 and Drawing D008. The main elements of the backfilled pit include:

- waste rock platform including filter to elevation 1,190 m;
- dewatered tailings combined with some amount of PAG waste rock deposited above the waste rock platform either by end-dumping or by direct bottom up placement;
- buttress constructed from NAG waste rock required on the south side to increase storage volume;
- remaining PAG waste rock placed above the tailings;
- insitu material from the tailings storage area co-deposited with the tailings;
- demolition waste that is to remain onsite crushed and co-disposed with tailings and PAG if considered contaminated or if inert placed as gravity fill outside the pit rim footprint;
- hydrocarbon contaminated soils placed in a dedicated area above the PAG waste rock;
- granular interim cover system placed above the PAG waste rock / contaminated soils;
- final cover system consisting of geosynthetics placed after settlement rates have reduced; and
- final ridge-shaped landform with maximum slopes of 3H:1V rising from the pit rim up to a final elevation of 1,237 m.

The Open Pit configuration was defined by the required storage volume for contaminated materials. The geometry was constrained by the following considerations:

- In order to ensure that infiltration into contaminated materials stays within the pit rather than exiting as seepage to the adjacent ground surface, the contaminated materials were restricted to the footprint defined by the original ground drainage boundary as shown in Figure 1. This requires that the low grade ore currently located on the ramp to the Open Pit be relocated within the pit drainage boundary.
- The final configuration cannot encroach any further upon the public road than the current configuration of the Open Pit and waste rock area.

The storage elevation curve for the Open Pit is shown in Figure 2. The elevation of the drainage boundary varies between 1,200 and 1,225 m. As can be seen in the figure, in order to provide storage for the expected volume of contaminated materials, there is a need for the contaminated soils to rise above the elevation of the drainage boundary. There are two options for providing this storage. The simplest option is that the contaminated materials slope in from the location of the drainage boundary at an angle compatible with stability requirements. This, however, limits the storage volume that is available and requires that the materials being placed have sufficient strength to support a slope.

Figure 1: Open Pit Drainage Boundary - Limits to Contaminated Materials Footprint

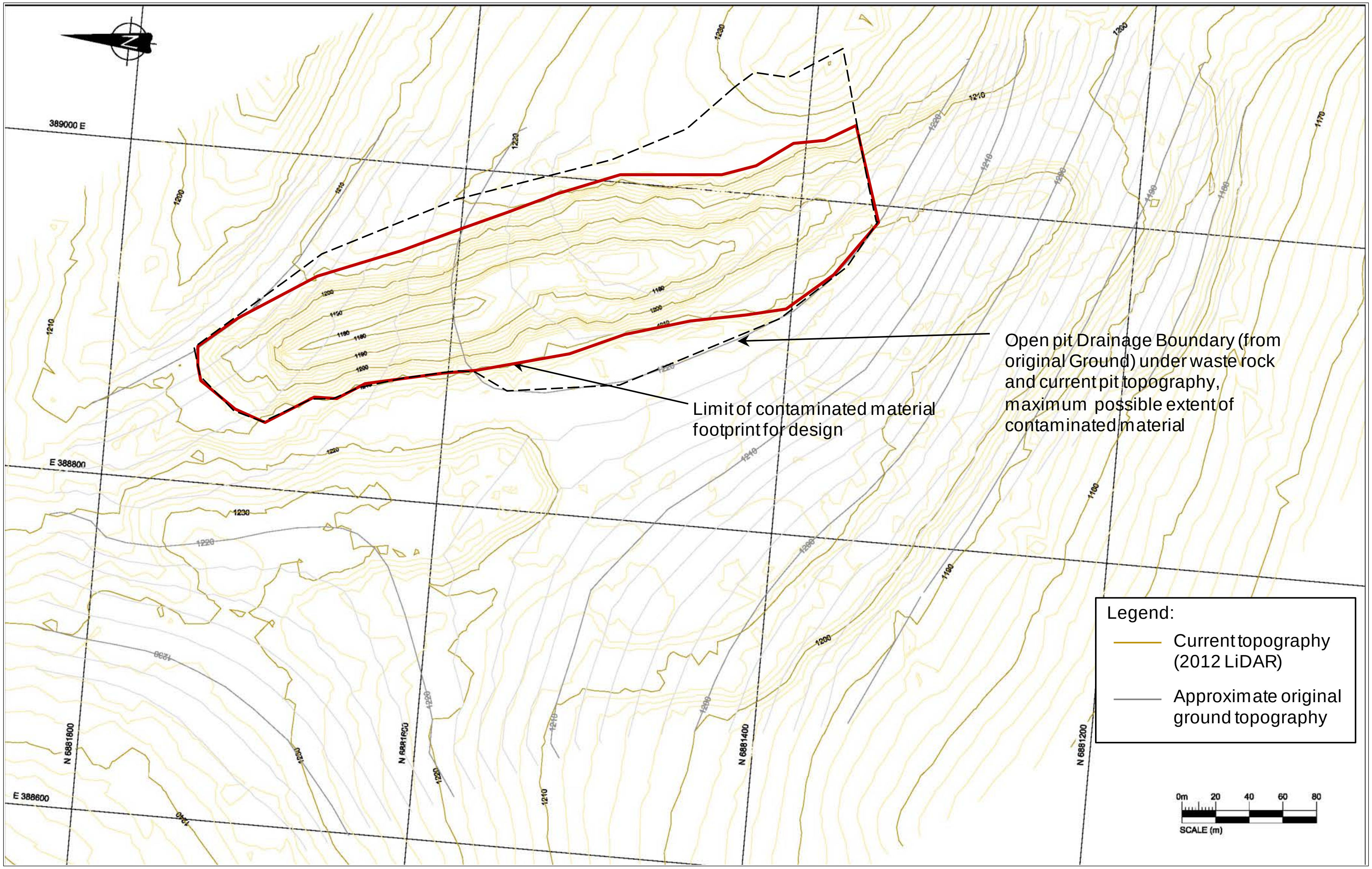
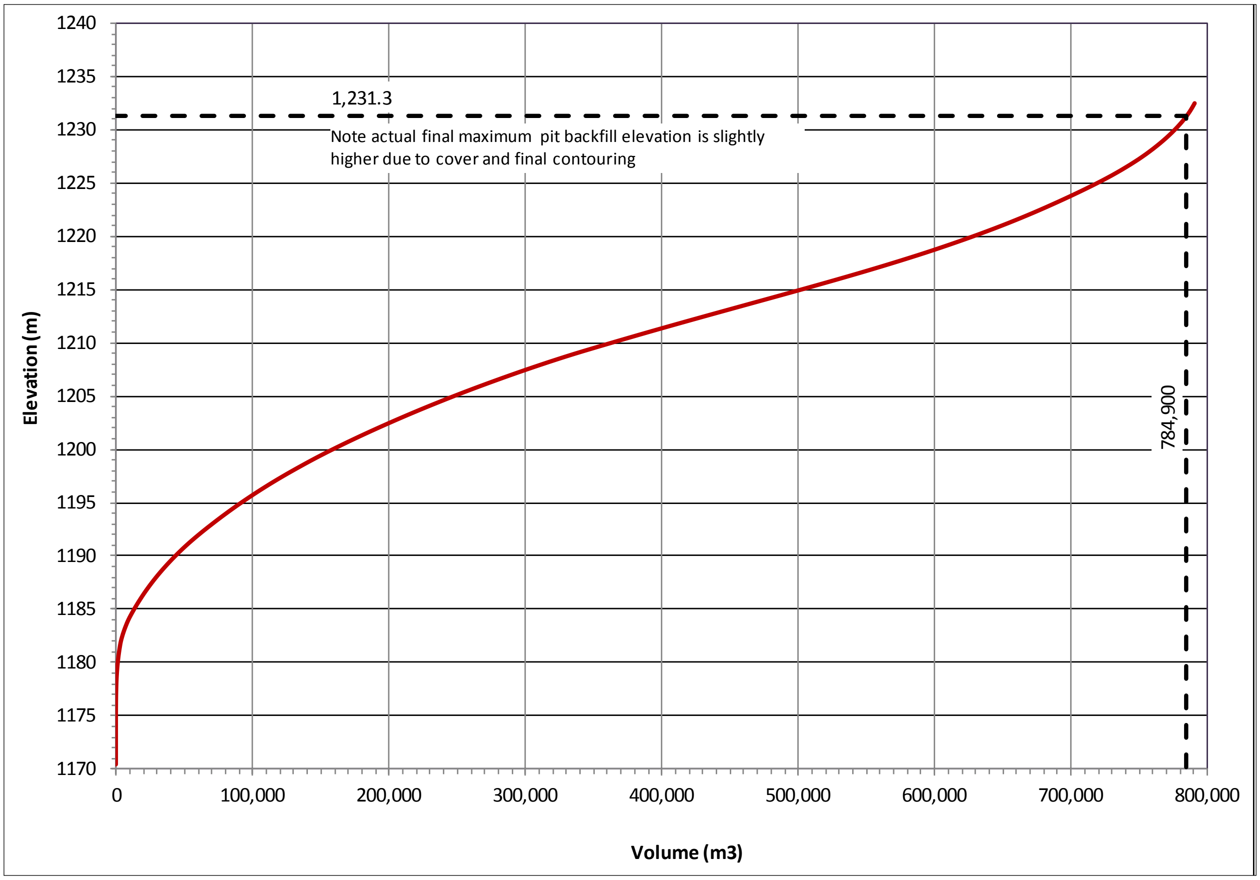


Figure 2: Storage Elevation Curve for the Open Pit



If more storage volume is required than can be provided by the sloped configuration or if the materials have insufficient strength to be self supporting, then a supporting buttress constructed of NAG waste rock or other non-contaminated material must be raised in conjunction with the placement of contaminated soils. This allows the contaminated soils to rise in a nearly vertical line above the drainage boundary increasing the available storage volume. The buttressing option, however, is constrained at the north and northeast sides of the pit where the public road does not allow room for buttresses outside the existing pit rim. This area is, therefore, critical with respect to stability and imposes restrictions on the strength of the materials placed in this area. Elsewhere, where there are no space constraints around the Open Pit, particularly on the west side, a significant additional storage volume could be provided above the elevation of the pit rim by building higher. If there is a need for increased storage volume, the design configuration would be modified by raising the elevation of the Open Pit backfill, particularly in the south and western portions of the pit. The buttresses required outside the pit footprint in this case would increase the overall footprint of the backfilled Open Pit. The current material balance uses up essentially all of the available NAG waste rock and, therefore, additional buttressing would require development of a borrow area onsite.

4.2 Relocation of Material from Tailings Storage Facility Area

4.2.1 Insitu Tailings Condition

The insitu condition of the tailings has been investigated through various field programs, although limited geotechnical characterization was completed prior to the fall of 2013. A detailed characterization of the tailings is presented in AMEC (2014). The main findings that impact the tailings relocation are summarized herein.

Tailings deposition occurred largely sub-aqueously over a two year period. The tailings are saturated, highly sensitive and prone to liquefaction. As shown in Drawing D009, the deepest part of the tailings is located next to the dam somewhat south of the centre of the facility where the elevation of the Dome Creek Valley was the lowest. Based on the measured grain size distributions, the tailings vary from a clayey silt material to a fine to medium sand with the majority of the tailings classified as a silty fine sand. The Atterberg limit results range from non plastic through to high plastic silt, typically plotting around the "A" line with a plasticity index less than 20%. The fine tailings appear to be concentrated in the area of deeper tailings as shown in Drawings D010, D011 and D012 with the coarser tailings generally around the perimeter of the facility and in layers within the central portion. Layers and zone of fine tailings also exist within the areas dominated by coarse tailings. Based on the slug test results and the dynamic pore pressures measured during CPT testing, there appear to be zones and layers of coarse tailings within the generally fine grained tailings zone. From the various borehole logs available, it is estimated that the fine tailings make up approximately 30% of the total volume of tailings corresponding to 76,000 m^3.

The specific gravity of the tailings solids has been measured between 2.6 and 2.9. Gravimetric moisture contents (mass water / mass solids) measured from samples of the tailings ranged from lows of 11% in unsaturated tailings above the water table to 52%. The high moisture contents were associated with the fine tailings, while the coarser samples typically had moisture contents in the mid to high twenties. This corresponds to insitu void ratios of 0.7 to 1.4; however, given the sandy nature of the tailings, these values are likely significantly affected by samples disturbance. Typical ranges of void ratios for gold tailings slimes are 1.1 to 1.2, while the void ratio of sand tailings are typically 0.6 to 0.9 (Vick, 1990).

The hydraulic conductivity of the tailings has been measured through slug tests, interpretation of CPT dissipations and in various laboratory tests. Values ranged from $3x10^{-5}$ m/s to $5x10^{-10}$ m/s with the highest values measure in the field slug tests, possibly reflecting macro features such as sandy zones and the lowest values measured in the lab with reconstituted, mixed samples. The low values measured in the laboratory are considered unlikely to represent widespread field conditions. Soil water characteristic curves and consolidation parameters have also been assessed through laboratory testing and these properties are discussed in the following relevant sections.

4.2.2 Tailings Removal

The extent of the tailings removal operation is shown in Drawing D013. The tailings removal operations will begin by pumping and treating the tailings pond water so that it can be discharged. Water treatment requirements are discussed in Section 5.2.

Following removal of the tailings pond water, it is proposed that the tailings be dewatered by vacuum wellpoints and excavated with a truck and shovel operation. There are various reasons why this has been identified as the preferred method including:

- the overall project objective of providing "dry" tailings;
- improved characteristics and safety for tailings excavation;
- the need to place tailings above the pit rim without major buttressing outside the pit on the north and northeast sides of the pit;
- the potential to improve the strength characteristics, increase placement densities and reduce settlement;
- the local availability of truck fleets and difficulty with obtaining and operating specialized equipment; and
- lower environmental risks from transporting dewatered tailings as compared to wet tailings.

General Hauling Considerations

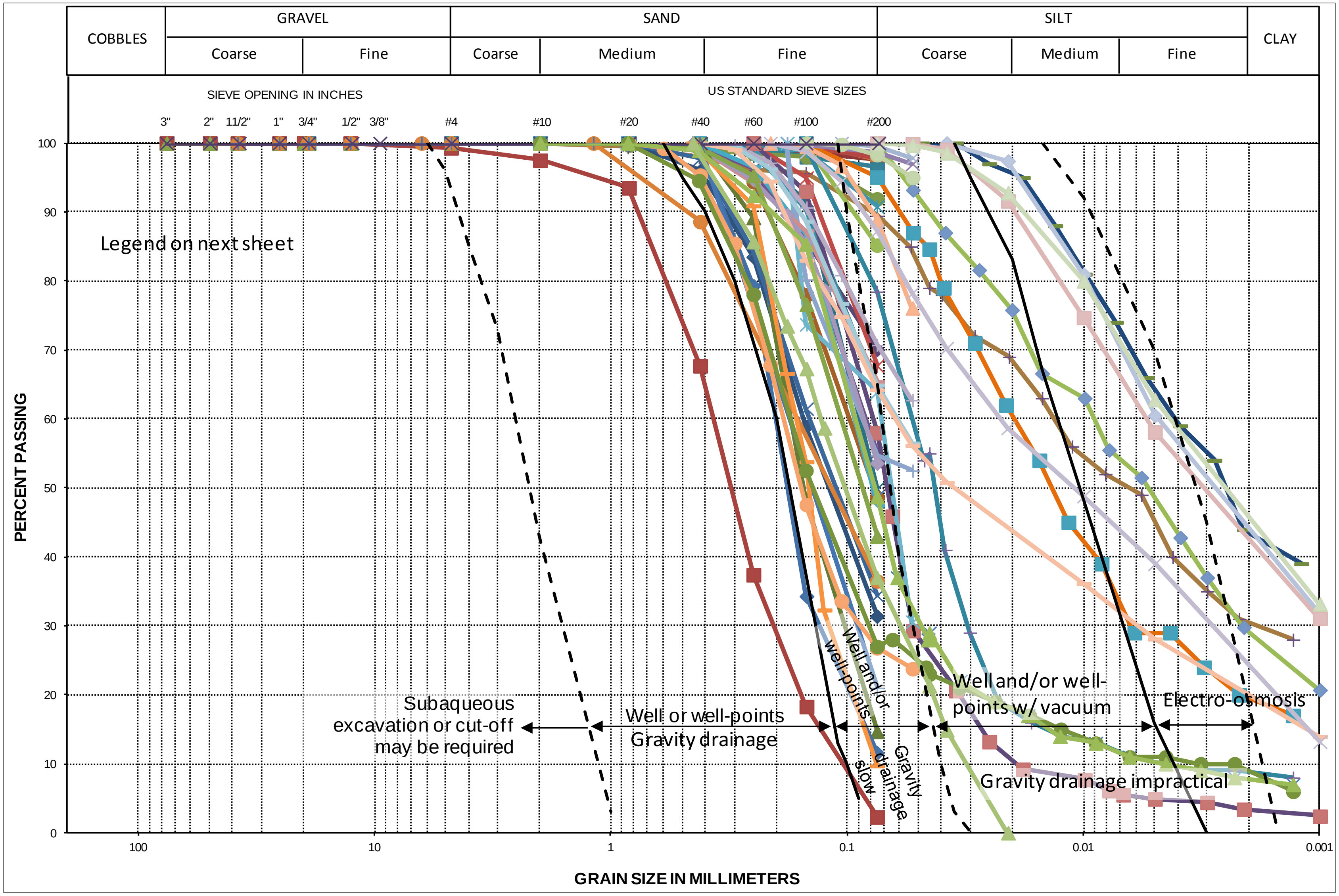
The hauling operation would be carried out on existing site roads using 40 ton or smaller articulated trucks as shown on Drawing D014. Forty ton trucks have been selected as the maximum truck size in consideration of the trafficability conditions in the tailings area and in the pit for the direct placement option and because of the size constraints in the pit and tailings areas.

A haul loop would be created so that most of the roads are one-way traffic minimizing the need to modify or upgrade the existing roads. The portion of the road near the tailings pond will require widening and rerouting to allow two-way traffic, to remove the tight turn that currently exists, and to reduce the grade. Typical road sections are shown on Drawing D014. Rerouting the road involves creating a new crossing of the diversion ditch. A typical ditch crossing section is shown on Drawing D014. The culverts shown in the ditch crossing will require provisions for clearing ice and will require significant maintenance around freshet. Alternatively, the crossing could potentially be removed during the winter and reconstructed following the freshet.

General Dewatering Considerations

Vacuum wellpoint systems are typically used to dewater silty soils and work best when D_{15} is 0.005 mm and greater (15 percent of the material is finer than the D_{15} particle size). As shown in Figure 3, much of the tailings are expected to be dewaterable by conventional vacuum wellpoints. The fine tailings, however, will not dewater to the same degree by this method.

Figure 3: Tailings Grain Sizes Compared to Typical Dewatering Limits



Dewatering operations can be expected to achieve a vacuum lift in the order of 5.5 m to 6.0 m, i.e. about 60% of the 10 m theoretical maximum, arising from siltation over time, frictional and pipe seal losses. Based on the soil water characteristic curves (SWCC) that have been measured for the tailings (refer to Figures 4 and 5) at 55 kPa of suction (that is, approximately half an atmosphere), the fine tailings are expected to retain a significant amount of water. Depending on the volume change that accompanies dewatering, saturation of the fine tailings could be about 85 to 90 % after dewatering. In contrast, the typical to coarser tailings tested show that at 55 kPa of suction, there will be significant dewatering and low saturation, 30 to 40 %, can be achieved. The saturations achieved for a variety of initial conditions and dewatered void ratios are shown on Figures 6 and 7 for fine and typical to coarser tailings, respectively. Also as shown in the figures, the saturation of the tailings when placed in the pit will depend on the void ratio achieved with a denser deposit initially having a higher saturation than a looser deposit. As discussed subsequently, blending dewatered coarser tailings with finer tailings has the potential to result in a material with saturation values between the coarse and fine dewatered values.

Because of the inherent variability in the tailings and the associated variability in achievable saturations, a specific criterion for required saturation is not identified. Dewatering would continue until the flow abates and where required, blending would be used to create an acceptable material. Method procedures would be developed as an initial part of trials or construction. Additional dewatering could be achieved via other systems such as electro osmosis or filters; however, it is AMEC's view that these methods would not be cost effective and that the expected dewatered characteristics from well point dewatering coupled with blending will provide a material that can be transported and placed consistent with the design assumptions included herein.

General Excavation Method

A key component of the tailings excavation will be water management so that the excavation remains as stable to equipment and operators as possible. There is a significant potential for groundwater seepage, particularly on the north side of the tailings facility. It is considered necessary to intercept as much of the shallow seepage as possible and direct it away from the tailings area. At this stage of design, to minimize stability concerns, it has been assumed that pumping wells would be installed along the perimeter of the tailings facility which would operate throughout the tailings excavation operation. The water produced from these wells would require testing to determine if the water is suitable for discharge. It is possible that tailings pore water could be captured in these wells and thus it may require treatment in the water treatment plant. In the current design, the dewatering flows are not the critical flow; however, if the treatment plant design is optimized for reduced flows, the potential flows from this dewatering exercise should be assessed in more detail. As a design optimization, the use of a perimeter ditch to intercept groundwater seepage instead of pumping wells should be considered.

Figure 4: Grain Size Distribution of Tailings for SWCC Samples

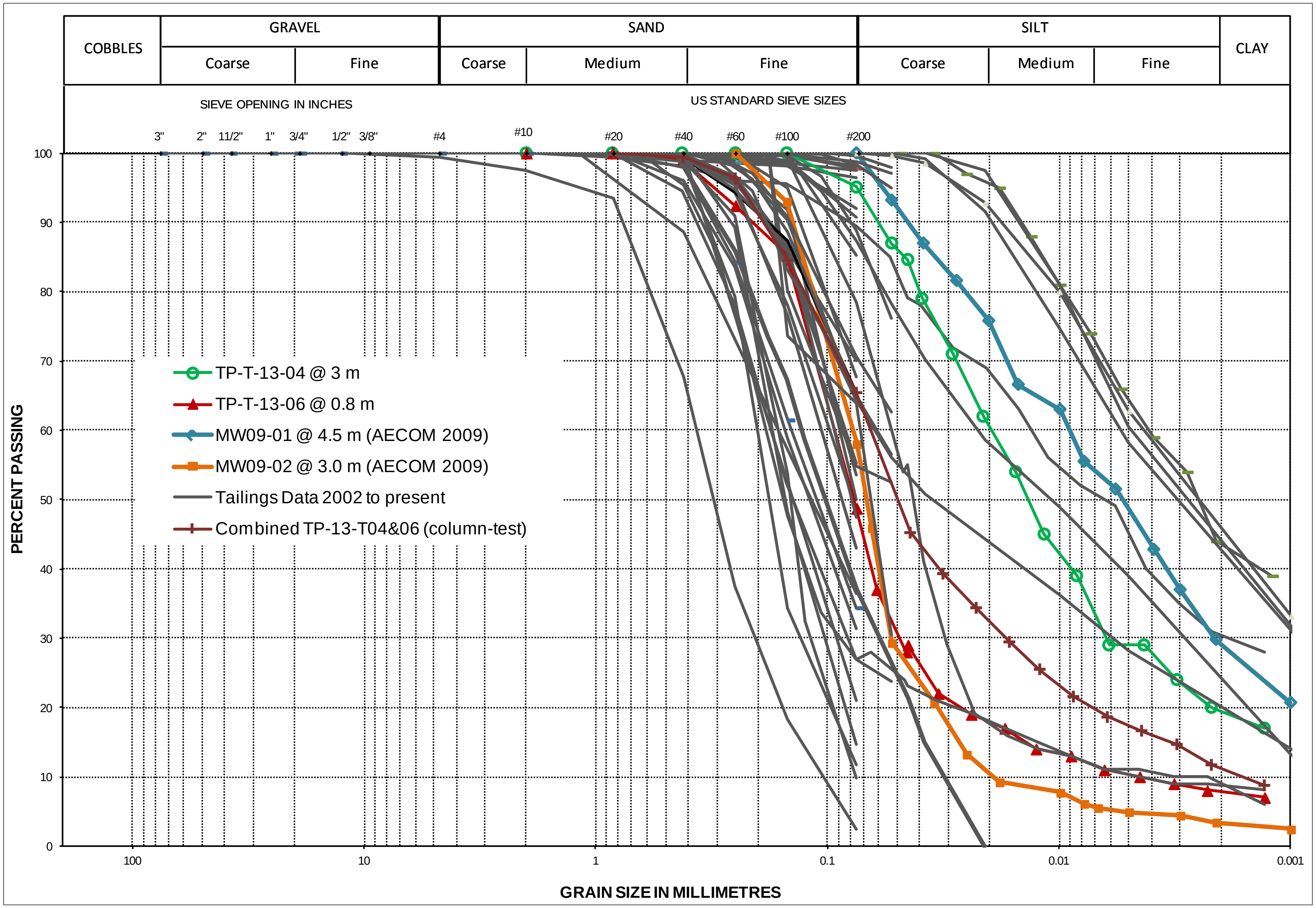


Figure 5: Tailings Measured Soil Water Characteristic Curves

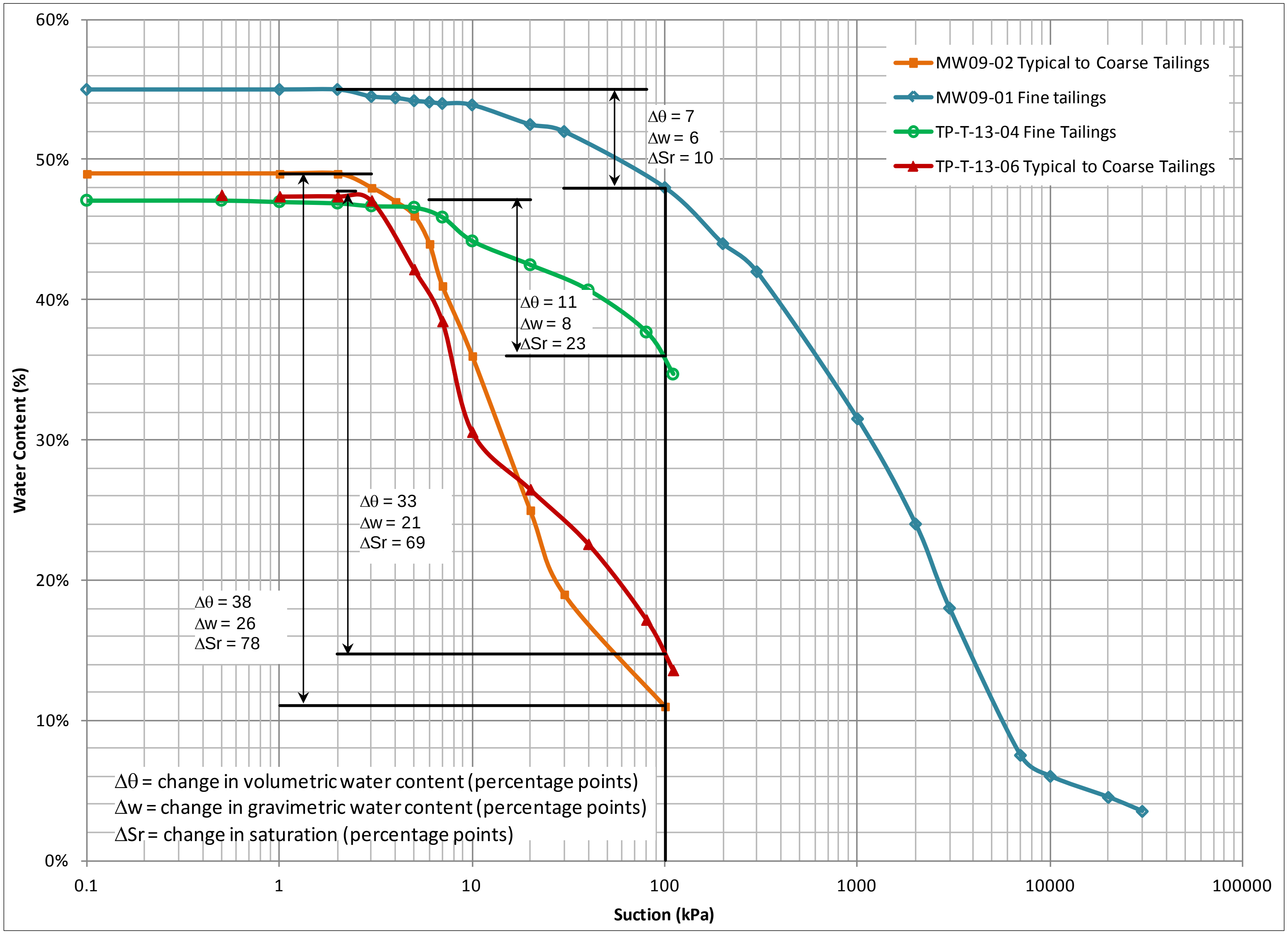


Figure 6: Saturation Versus Void Ratio for Various Fine Tailings Dewatering Conditions

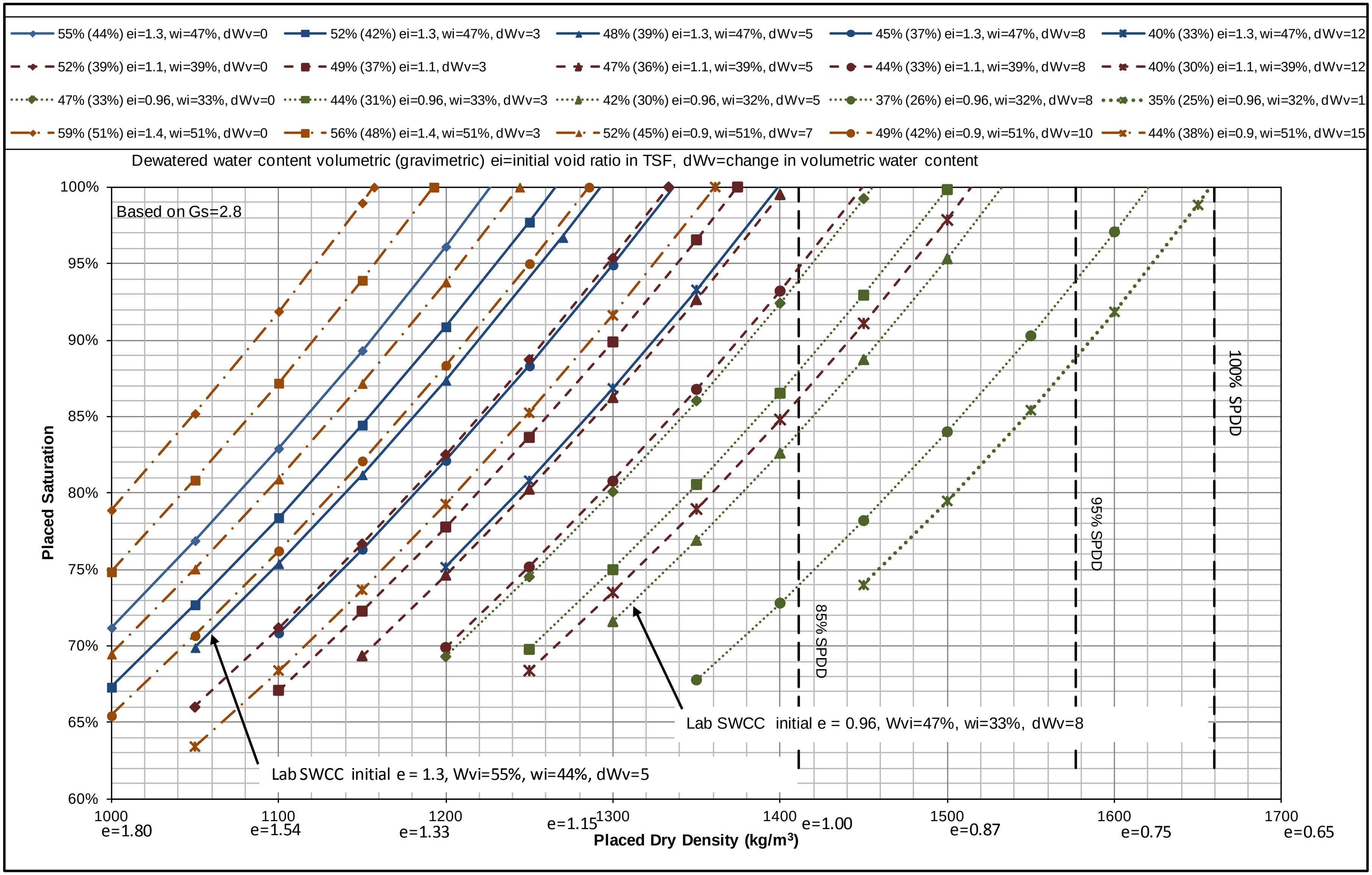
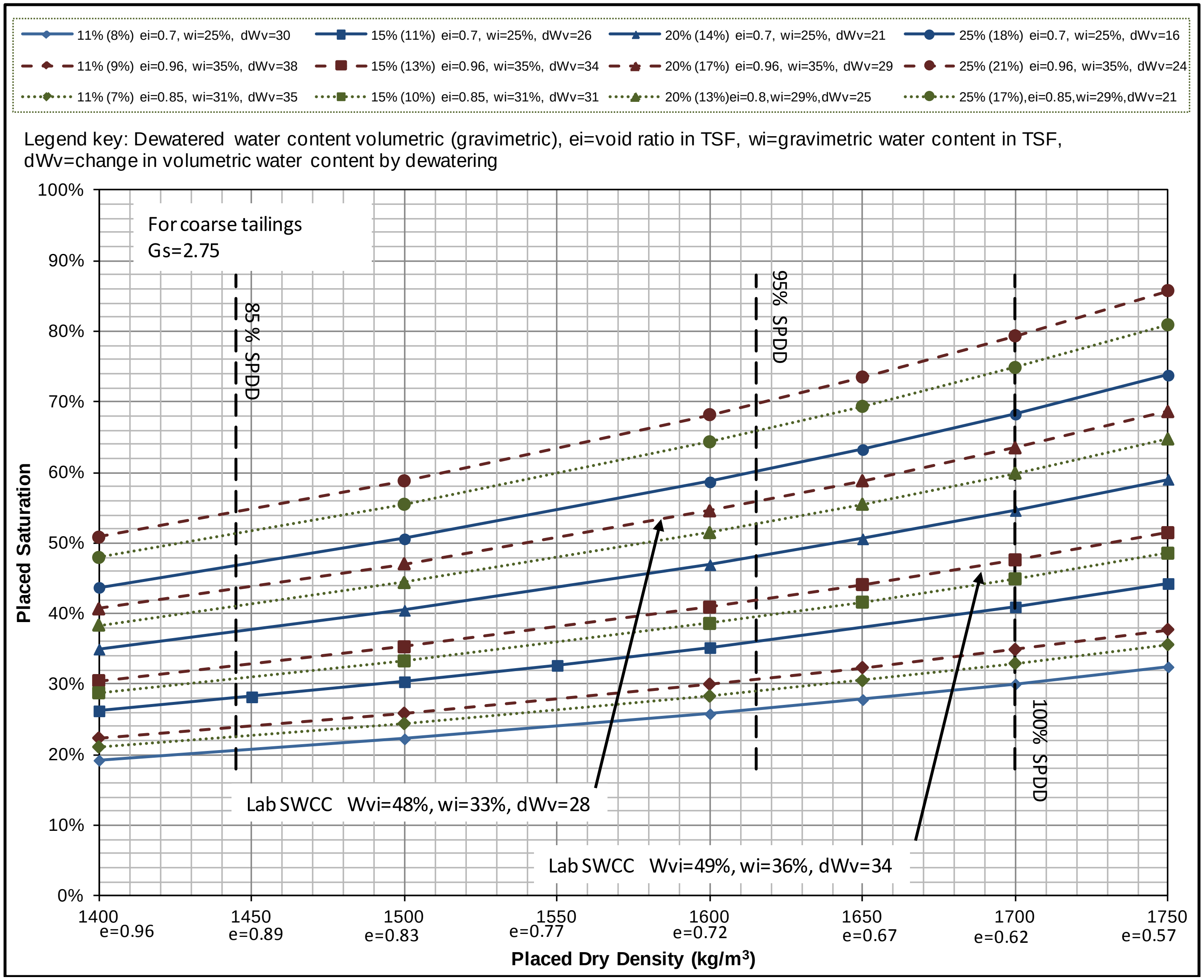


Figure 7: Saturation Versus Void Ratio for Various Typical to Coarse Tailings Dewatering Conditions



Management of runoff water within the tailings facility will also be critical. This will require that ditches and a water storage location / sump within the tailings storage facility be developed to control and direct surface runoff and to store water from the dewatering system if needed (Section 5.3.1). Water collected from tailings runoff and tailings dewatering will be treated in the water treatment plant and discharged. The ditches and sumps will be actively maintained throughout the tailings relocation effort.

Trafficability on the initial tailings surface will be provided by placing a layer of PAG waste rock over the tailings. Essentially, the rock fill maintains a sufficient void space to store tailings and permit trafficability on the deposit for smaller articulated haul trucks. This will allow installation of the initial wellpoint system. The PAG rock will then be excavated with the tailings material and placed in the Open Pit. The tailings will be excavated in short cuts with PAG rock placed on each newly exposed bench to improve trafficability. It is estimated that this will result in incorporation of PAG rock in the tailings at a ratio of about 1:2 or 2.5 (PAG rock: tailings).

The PAG rock is generally not yet acid generating and it is expected that it will still take a significant amount of time (e.g. years) for the material to go acid. Using the PAG rock at the tailings facility will not significantly alter that timeline. Increased saturation decreases the oxygen availability and reduces the amount of potential ARD generation; therefore, combining the PAG rock with the tailings is not considered to increase the risk of ARD. If some “hot” (i.e. currently generating acid) PAG rock is taken to the tailings facility, it will be in a more contained environment than it currently is and any seepage or runoff would be captured and treated as part of the ongoing water management efforts. In any event, relocating the PAG rock from its current location to the Open Pit will result in a similar temporary exposure of the material to air.

The logistics of backfilling the Open Pit and final stability considerations make it desirable to excavate the finer tailings first because they have the greatest potential for high saturation (refer to subsequent discussion). In order to excavate the finer tailings, a perimeter system of vacuum wellpoints would be established near the edge of the thicker fine tailings area. This will reduce drainage into the finer tailings and locally improve the stability of the excavation. A lateral grid, or ‘panel’, wellpoint layout would be established within the main headers, involving sub-areas of parallel vacuum header lines, each maintaining vacuum on a row of wellpoints.

Contractors typically base the initial spacing for vacuum wellpoints on empirical nomographs and then adjust based on field performance. For the anticipated conditions in the tailings impoundment (fine sand to stratified fine sand), the nomographs suggest a wellpoint spacing of between 1.5 and 2.5 m. Specific layouts of the wellpoints are typically completed by the contractor; however, if needed, it can form part of the 60 or 100% design phases. It is expected that early on during construction, a trial would be completed to confirm wellpoint performance.

The dimensions of each sub-area will be refined using the observations of a dewatering field trial, conducted to include the fine tailings area. A common practice is for dewatering to be initiated on a sufficient number of sub-areas so that the dewatering commencement of subsequent sub-areas is sequenced to reuse wellpoints from the first sub-area. The number of sub-areas, dimensions, numbers of vacuum header lines, wellpoint-to-wellpoint spacings, the need for supplementary ground stabilization measures, if any, etc., will be finalized with observations of excavation stability during a field trial.

The grid system would dewater the upper 3 to 4 metres in a specific sub-area. The initial dewatering phase is expected to take in the order of 10 to 14 days in areas outside the fine tailings, based on experience in similar conditions. Excavation would then proceed in small cut benches across each sub-area, with PAG waste rock placed at every bench to create a trafficable working platform. This is shown schematically in Drawing D015.

The wellpoint system is expected to aid in stabilizing the excavation completed in the finer tailings and is expected to significantly reduce the saturation of the typical to coarse tailings. The fine tailings will, however, retain a high degree of saturation and will require special consideration with regards to truck transportation. Two methods have been identified for handling high moisture content tailings. The preferred method would be to mix any high water content tailings with dewatered coarser tailings and/or with relatively dry PAG waste rock. Based on the SWCC of the fine and typical tailings and the assumed void ratios, a one to one ratio of dewatered coarse tailings to fine tailings would provide a material with a gravimetric water content in the order of 20 to 25% corresponding to a saturation in the order of 60 to 70% at current insitu void ratios. The PAG rock has a similar to lower water content as compared to the dewatered coarser tailings and would result in a mix with similar or lower saturation. This blended material would likely be sufficiently unsaturated to produce a manageable material. AMEC has used this blending technique successfully on other projects. If, however, a sufficiently unsaturated material cannot be created, a dam or plug can be created in the back of the truck either with PAG or dewatered coarser tailings and the wet material placed behind that. AMEC has employed this method in situations where adequate mixing material wasn't available.

4.2.3 Insitu Soils Removal

The existing insitu soils beneath the tailings will be excavated to an average depth of approximately 1 m to remove the zone that has been identified as having elevated metals (refer to AMEC (2014) for the characterization of metals concentrations in the insitu soils). The zone of elevated metals does not appear to extend beneath the dam. The excavated insitu soils will be co-disposed of with the tailings to distribute the insitu soils throughout the backfill. It is currently considered that the dispersion of organic rich soils in a much larger volume of tailings will reduce the gas generation potential of the organics sufficiently to avoid any issues related to the covered backfilled pit. This should be further assessed in later stages of design.

During excavation of the insitu soils, field screening should be completed to confirm the extent of elevated metals and to avoid over excavation and generation of more material requiring storage than is necessary. Field screening would be completed using an X-ray fluorescence (XRF) tool with backup confirmation through laboratory testing. If there is loose, ice rich or wet silt or organic rich soil remaining that does not have elevated metals, it is recommended that these materials be removed and stockpiled for reclamation purposes. There is a significant lack of fine grained soils in the project vicinity and any amount of material would be valuable for reclamation. Removal of this material will also improve the stability of the reclaimed slopes (see Section 7.6.2).

A critical aspect of the excavation will be to rapidly stabilize exposed original ground. This will involve placing 30 cm of sand over the insitu soils followed by a minimum of 120 cm of smaller sized select or crushed NAG waste rock for a total cover layer thickness of 1.5 m. The sand will be obtained from the dam fill. Soils should be covered as quickly as possible after being exposed in a panel like fashion. Widespread areas should never be left open as it will accelerate degradation of permafrost and pose a significant erosion potential. Permafrost thaw is discussed further in Section 7.6. The total excavation limits are shown on Drawing D013 and a typical section through Dome Creek valley showing the stabilized slopes is shown on Drawing D048. The stability analyses carried out in support of the reclaimed Dome Creek slopes is presented in Section 7.6.2.

4.2.4 Tailings Dam Removal and Relocation

The tailings dam will be removed in conjunction with the removal of the tailings via articulated trucks (i.e. 40 ton or smaller) and appropriately sized excavators. A sufficient height of dam will be required throughout tailings excavation to provide containment to the tailings and also to provide the required stormwater storage. Following removal of the tailings, the dam may be required at some reduced elevation as part of the construction water management plan. The phreatic surface in the dam appears to fluctuate with the pond level and, therefore, it is expected that once the tailings pond is removed, the water levels within the dam will reduce fairly rapidly. This drawdown will be within the downstream portion of the dam and is, therefore, not a stability concern; the upstream side of the dam will remain supported by the tailings during pond drawdown.

Geochemical testing of the dam has indicated that the dam fill is not contaminated, although this finding would have to be confirmed throughout construction. If any of the material was contaminated, it would likely be within the lower portions of the dam at or below the phreatic surface. With the exception of the 6,000 m^3 of fill in the upstream buttress which is located above the geosynthetic clay liner, the 160,000 m^3 of material in the dam is considered available as a borrow source. It will be used as an initial layer to cover the exposed insitu soils in Dome Creek, potentially as a filter layer within the interim cover system and as reclamation material.

Stability assessments of the dam have not been completed as part of this phase of design because although these assessments are required in the next phase of design, it is not a critical issue that will affect the final design. The dam is currently stable (Worley Parsons, 2013) and removal of the tailings pond and tailings will lower the phreatic surface and reduce the driving forces, improving stability. The upstream slopes of the dam were designed to be stable during construction; therefore, although foundation conditions have deteriorated and the phreatic surface in the dam may be higher than during construction, it is expected that stability of the dam during excavation should be manageable and largely an issue that will affect scheduling. In particular, the dam height at which the upstream buttress can be removed will require assessment during later phases of design. The geosynthetic clay liner on the upstream face of the dam can be removed as it is encountered and disposed of with the tailings.

4.2.5 Seepage Collection Dyke Removal

The seepage collection dyke will remain in place throughout the excavation of the tailings and removal of the tailings dam so that it can act as a final sediment control pond, particularly while the final portions of tailings dam removal and stabilization of the insitu slopes occur.

When it is no longer needed for sediment control, the seepage collection dyke would be excavated and removed via a trucking operation. Prior to removal of the seepage collection dyke, the seepage pond would be pumped dry and any material in the bottom of the pond including any insitu soils with elevated metals (currently assumed to be a 1 m depth) excavated and removed to the Open Pit. There are various details of the dyke removal that require consideration during the next phase of design such as the removal of thermosyphons. The exposed slopes would be stabilized with 0.3 m of sand and 1.2 m of NAG rock as elsewhere in Dome Creek.

4.2.6 Considerations for Multi Season Operations

It is expected that excavation of the tailings will require at least two summer construction seasons as presented in Section 8.0. The key considerations of a multi season excavation operation are:

- to ensure that all insitu slopes have been stabilized and covered as described in Sections 4.2.3 and 4.7.2, at the end of each construction season;
- to ensure that the remaining tailings areas are graded to appropriately direct surface flows during freshet;
- to ensure that the construction ditches and sumps / water storage areas are prepared to handle the freshet flows and are maintained throughout the winter and in particular during freshet;
- to ensure that maintenance of the diversion ditch and any temporary culverts continues throughout the winter and during freshet;
- to pump and treat water (as needed) that accumulates in the tailings storage facility; and
- to maintain the seepage pond operation throughout the entire construction phase

4.3 Other Materials Requiring Removal

In addition to the materials from the tailings storage facility, there are other materials that require removal from their current locations to the Open Pit or that will be completely removed from site. Materials that require relocation to the Open Pit are shown in Drawings D003 through D006 and are listed below with the relevant report sections indicated for reference:

- tailings from the mill area (Section 6.2);
- tailings within the Dome Creek watercourse outside the tailings facility (Section 7.6);
- PAG waste rock from the mill and road areas (Section 6.2);
- hydrocarbon contaminated soils from the mill, camp, Ketza Shop and roadways (Section 6.2); and
- demolition materials (Sections 6.1 and 6.5).

4.4 Material Placement in Open Pit

Backfilling of the Open Pit will require a series of steps as follows:

- stabilization of the Open Pit walls;
- removal and treatment of the Open Pit pond water (refer to Section 5.2);
- construction of the NAG waste rock bench including an upper filter layer in the base of the Open Pit;
- decommissioning the Pony Creek Adit, potentially including upgrading the seal (this can occur at any point prior to placement of the tailings in the Open Pit);
- placement of the tailings, insitu soils from the tailings and seepage collection pond area, any dam fill materials with elevated metals content, and PAG waste rock;
- relocation of the low grade ore currently located on the ramp to the Open Pit (this must occur before the backfill reaches elevation 1,200 m);
- placement of tailings and insitu soils from Dome Creek downstream of the seepage collection pond and mill area (this can occur at any point depending on the overall construction schedule);
- construction of NAG buttresses in conjunction with pit backfilling;
- placement of the hydrocarbon contaminated soils from the mill, road and Ketza Shop areas in a dedicated area above the PAG waste rock and below the cover;
- incorporation of demolition waste into the final backfilled landform;
- placement of the interim cover;
- monitoring and maintenance period; and
- placement of final cover and final regrading of the backfilled pit landform and surrounding area.

4.4.1 Stabilization of Open Pit Walls

Prior to commencing work in the Open Pit, the Open Pit walls require stabilization and procedural work methods confirmed to minimize the risk of rockfall hazards. Required stabilization measures have been presented in detail in EBA (2012). The recommendations include sector by sector requirements for machine scaling, hand scaling, and/or trim blasting. Additionally, it is recommended that the pit be limited to vehicular access only and that the placement of fill include slopes down from the placement elevation to the pit wall to create ditches to catch rockfall. Consistent with the qualifications in the EBA report, these recommendations will have to be revisited prior to beginning construction to confirm that rock conditions have not deteriorated and that the stabilization methods remain valid.

Additional measures for managing pit wall stability may be required in the event that a basal liner and wall drainage layer is required to manage long term acid rock drainage from the unsaturated tailings (refer to the design contingency in Section 5.5.1).

4.4.2 Placement of Platform Base

Once the pond in the Open Pit has been removed, a platform will be constructed in the base of the pit. The bench is a key element of Option 4 as its purpose is to elevate the base of the PAG material (tailings and waste rock) above the predicted long term groundwater levels in the Open Pit so that they can be maintained in an unsaturated state. The platform, therefore, must be created using NAG materials. If found to be necessary, this basal rock zone can act as a collection zone for the management of water quality, although it may require design measures to enhance the collection of water to the bottom of the presumptive sump. This is discussed further in Section 5.5.

It is necessary to remove the water from the Open Pit prior to placement of the platform because placement of the waste rock would displace the water upwards and since the pond is largely surface water fed (AMEC, 2014), it could take a significant amount of time for the water levels to drop. Having water above the waste rock platform would be counterproductive to providing dry tailings and is contraindicated by the effort to dewater the tailings insitu prior to placement.

Long Term Groundwater Levels

The average groundwater flows at the Open Pit derived from the three wintertime pond elevation declines (0.4 L/s) is greater than that quantified from water balance methods (0.2 L/s), which were purposely done to produce a conservative estimate on the low side and contain an unquantified, although assumed to be low, bias from Pony Creek seepage. The pit pond decline method of evaluating groundwater outflow is unaffected by this bias and is also more selective for quantifying groundwater exchange, compared to the water balance method, arising from the different measurement scales, i.e. metres of pit pond elevation range versus millimetre summations of surface water inputs and evaporative losses.

The long-term Open Pit pond elevation, arising from groundwater exchange alone, after pond removal and tailings disposal, was evaluated to provide a design value for the implementation of remediation Option 4.

Quantifying a piezometric elevation, or range, within the deeper rock mass underlying the Open Pit, was the objective of instrumentation installed into Corehole CH-P-13-05 drilled vertically down from the base of the pit (refer to AMEC, 2014). The corehole includes a conventional, short-screen, monitoring well and a companion vibrating wire piezometer attached to the monitoring well base, installed to 50 m depth (elevation 1,135 m), below the Open Pit floor. Monitoring well and piezometer data can then be interpreted over a time period that includes the wintertime decline minima and September to November pond elevation (‘head’) maxima. With these data, annual and seasonal changes in piezometric elevations and vertical groundwater gradient can be quantified and implications evaluated for the long-term groundwater condition of the Open Pit.

The Corehole 5 monitoring well provided a manually measured groundwater elevation of 1,166 m, in October 2013, shortly after completion of the well. Further measurement of the water level should be made manually and by downloading of the data logger to increase the database available for analysis in the next phase of design. Currently, the monitoring well groundwater elevation of 1,166 m, provides a lower bound value for the piezometric range, within the deeper rock mass underlying the Open Pit, applicable to the period of maximum pond storage in September-October 2013.

An upper bound value for the piezometric range, within the deeper rock mass underlying the Open Pit, was derived by reviewing the pond elevation wintertime minima of five winters, each exhibiting a linear decline. As described in the previous sub-section, these declines represent a period of only groundwater outflow from the pit pond, without surface inputs or biases. These five data points are summarized in Table 4.2.

Table 4.2: Wintertime Minima Pond Elevations

Date	Approximate Pit Pond Elevation Minima (m)
April 2002**	1,182.7
mid-April 2003**	1,181.0
April 24, 2011	1,182.6
April 11, 2012	1,182.7
May 3, 2013	1,181.2

(**) denotes data reported by Gartner Lee (2004).

Note: the conversion for in-pond logger data from water level to elevation is not final; therefore, the pond elevations for 2011, 2012 and 2013 are subject to possible minor adjustment.

On this basis, elevation 1,181 m was interpreted as an indication of the upper bound value for the piezometric range, within the deeper rock mass underlying the Open Pit, applicable to the period of minimum pond storage in April-May.

In the next phase of design, new data logger information from Corehole CH-P-13-05 will be used to update the lower and upper bound piezometric range values of 1,166 m and 1,181 m, respectively, for the rock mass underlying the Open Pit. The implication of the upper bound value 'daylighting' between the pit base elevation of 1,174 m and the interim upper bound of 1,181 m, is that a hydraulic vertical gradient would exist, under which, groundwater would have the potential to enter the Open Pit.

Material Placement

Elevation 1,190 m has been retained as the top elevation of the bench, consistent with the Option 4 configuration advanced in LORAX (2010). This provides a significant margin of safety above the estimated current long term groundwater levels to allow for some settlement of the waste rock bench as a result of increased load from the overlying materials and downward seepage, and to potentially accommodate a modest increase in groundwater levels should widespread permafrost degradation occur as a result of climate change. Subsequent phases of design could optimize the platform elevation and should consider the effect of potential permafrost degradation in more detail. The potential increase in contaminated materials storage volume created by reducing the elevation of the platform would be relatively small however because of the small area at the bottom of the pit.

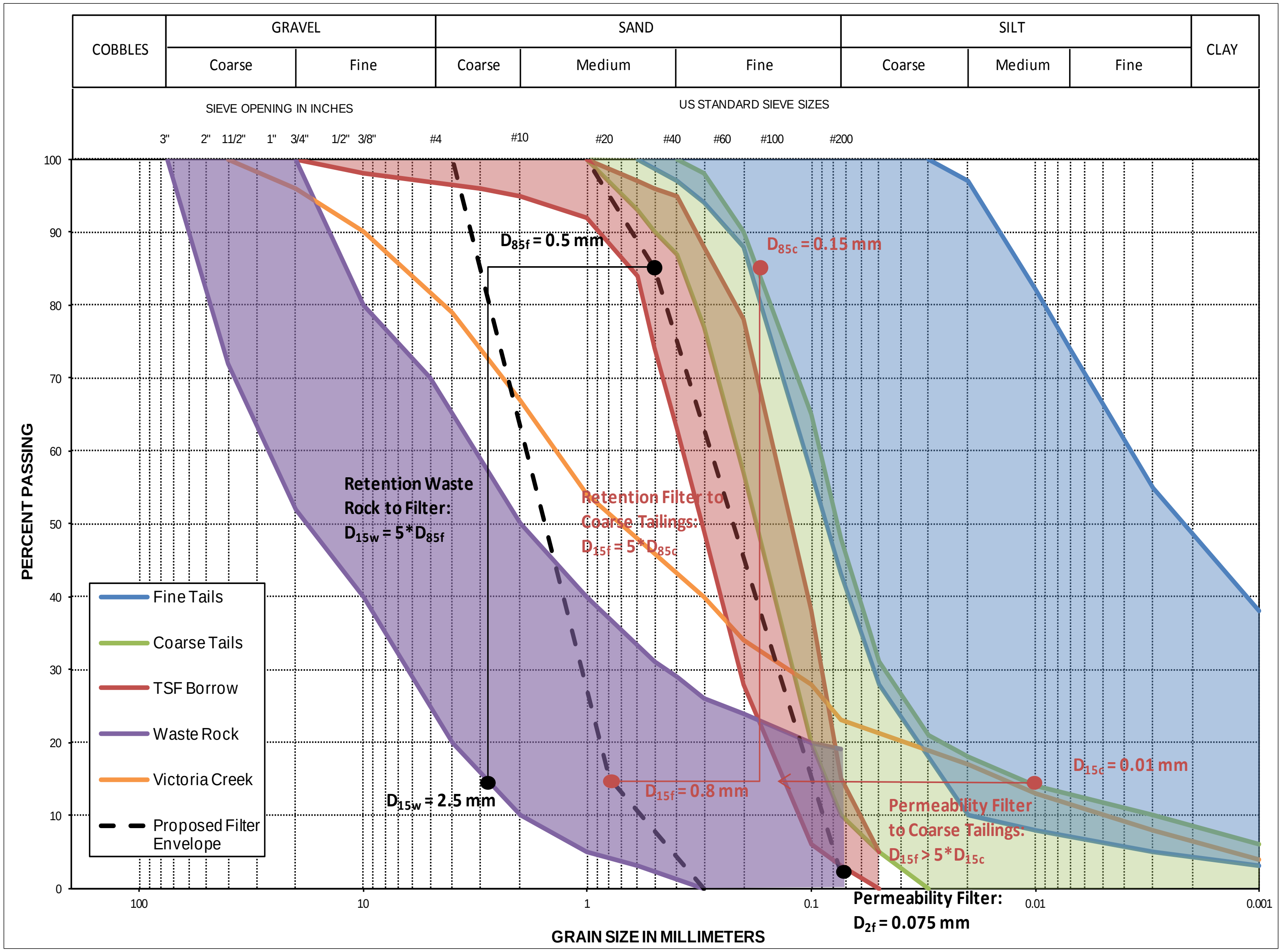
Material for the waste rock platform will be sourced from the NAG zones of the waste area as shown on Drawing D005. The pit is very narrow at its base and, therefore, the lower portion of the platform to elevation 1,183 will be created using progressive end dumping from the south end of the pit. Above this level, the waste rock will be placed in 1 m lifts and compacted by truck and dozer traffic. As shown on Drawing D016, the material will be placed such that there are slopes at angles of repose along the edges of the pit to limit the proximity of the equipment to the pit walls and to provide ditches to catch rockfall. The use of specific compaction equipment is not planned and is not consistent with the procedural safety measures for the pit. The use of compactors and the need for placement quality control testing would require significantly more stabilization of the Open Pit walls.

Plan and section drawings showing the waste rock platform and an example of haul traffic within the Open Pit is included on Drawing D016. The NAG waste rock with slopes at angles of repose along the edges of the pit will be placed up to elevation 1,189.5 m. At this point, the sloped section of waste rock along the pit edge will be backfilled with waste rock to create a level surface for filter placement. Above this elevation, a filter zone 0.5 m thick will be placed bringing the elevation of the waste rock platform to elevation 1,190 m. The filter zone is designed to create compatibility between the placed tailings and the underlying coarse waste rock thus reducing the potential for tailings migration into the waste rock during the period of tailings drainage. The gradations of the tailings and the soil matrix (75 mm minus) portion of the waste rock are shown on Figure 8 along with a preliminary gradation for the filter zone. Also shown on the figure are the gradations of the locally available borrow materials. None of the naturally occurring materials have the required gradation to act as a filter between the tailings and unscreened waste rock and, therefore, the filter material will be created by screening or crushing the NAG waste rock. During subsequent phases of design, it may be possible to consider this in more detail and develop confidence that segregation of the waste rock during placement could result in a sufficiently fine layer at the top so that either a specific filter unit is not required or that the filter can be sourced from the existing sand terraces around the tailings facility.

4.4.3 Pony Creek Adit Remediation

The long term water levels are not predicted to remain above the level of the Pony Creek Adit. There is, however, some uncertainty with this conclusion, particularly if widespread permafrost degradation as a result of climate change is considered. It is also possible that there could be seasonal fluctuations of the groundwater that would rise above the level of the Pony Creek Adit, although this likelihood seems low. Further data regarding deeper groundwater levels below the pit is being collected and will be used to further define likely water level fluctuations. Another possibility that cannot be completely discounted is that initial large seepage fluxes from the tailings could cause a temporary mounding of water within the backfilled Open Pit above the level of the Pony Creek Adit. It is, therefore, considered prudent at this stage to include an allowance for upgrading the bulkhead in the Pony Creek Adit. The need for this may be able to be discounted in later design stages depending on the more detailed assessments.

Figure 8: Waste Rock Platform Filter Gradation



As outlined in AMEC (2014), there is significant uncertainty surrounding the bulkhead that was constructed in the Pony Creek Adit. As designed, the bulkhead appears appropriate; however, there are no construction records to indicate that the construction specifications were met. During detailed design phases, the adit should be examined to assess the condition of the bulkhead and determine the extent of any upgrades that may be required. The inspection and any work to be carried out in the adit will most likely require upgrading of the adit support. Under the supervision of a qualified rock mechanics specialist, the required support can be assessed in the field and installed with the support of two labourers with appropriately sized timbers. The specific requirements of the adit upgrades will not be known until current conditions can be assessed.

In addition to improving the hydraulic seal in the adit, the entrance to the adit must be physically sealed to prevent people from entering. This would involve removing the timbers at the portal and placing large boulders (i.e. that cannot be moved by hand) over the entrance to enhance security.

4.4.4 Placement of Tailings, Insitu Soils and PAG Waste Rock

For the 30 percent design phase, two methods of tailings placement have been advanced in equal detail; end dumping and direct bottom up placement. The reason for advancing the two methods is to allow a comparison between the costs and the performance of the backfill pit. As is discussed in the following sections, the direct placement method appears to provide the best performance and has fewer uncertainties. From a cost perspective, however, initially it appeared that the end dumped method may be preferable. The cost estimate developed after the initial design work was completed (AMEC, 2014b) has, however, indicated that there is only a modest cost savings achieved by end dumping. Furthermore, in certain situations, there could be added complexities with end dumped construction due to stability concerns. Nevertheless, the end dumped method is included herein as an option to consider and at a minimum would be available as a design contingency should it be needed and to provide flexibility in contracting strategies should a contractor advance end dumping as an alternative.

The direct bottom up placement method would be expected to result in higher densities and thus a lower overall required storage volume than the end dumped method. This difference in placed material densities has not been considered in the layout configurations at this stage however. That is both methods have been based on the material volumes presented in Table 4.1. The final surface geometry is, therefore, the same for both the end dumped and direct placement methods, although the internal configuration of the backfill will differ. The difference in expected density and other characteristics between the two placement methods has been included in the assessment of backfill performance discussed in Section 4.6.

Throughout this section, for ease of reading, the deposited material is referred to as tailings; however, it could be insitu soils, tailings mixed with PAG waste rock, or other contaminated soil materials requiring placement in the Open Pit.

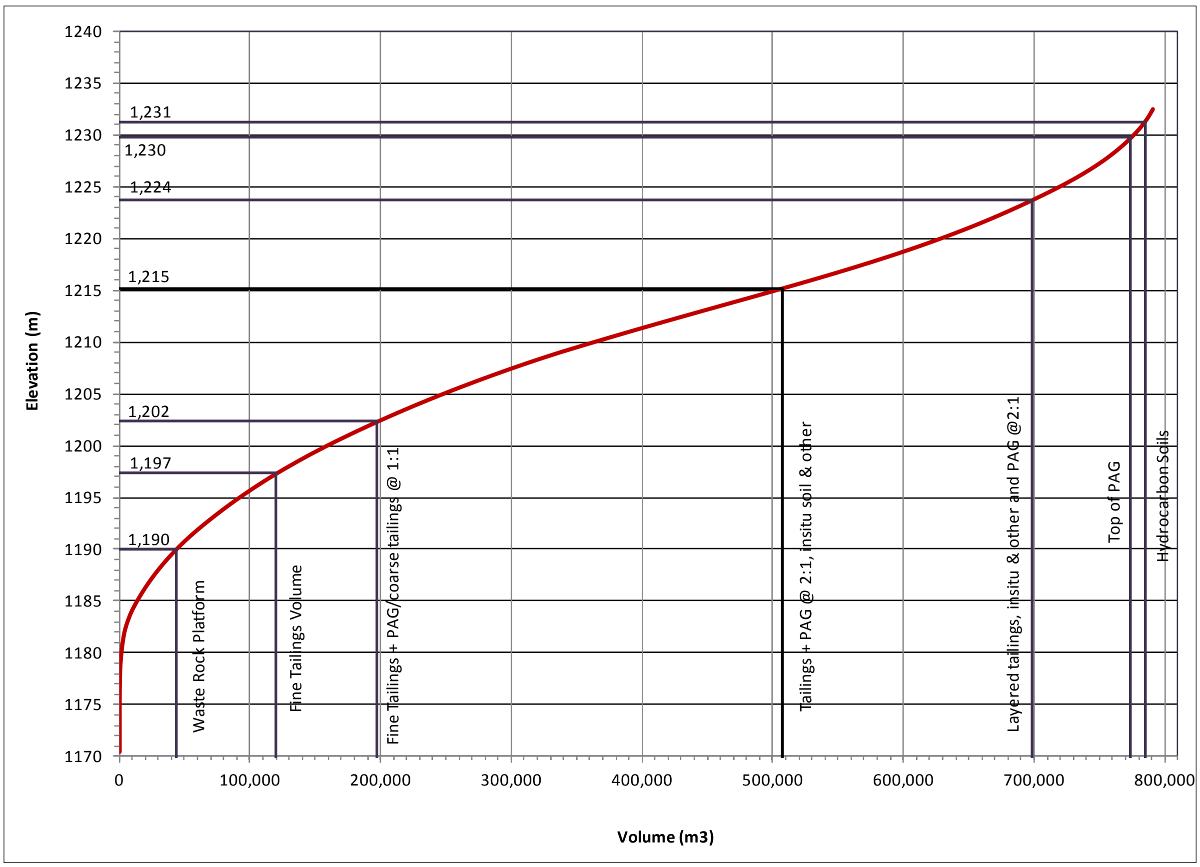
Direct Placement Method

The direct placement method involves conventional bottom up placement of tailings, insitu soils and PAG waste rock. Although it is not intended to employ compaction equipment, this method still provides significantly more control than the end dumped method and will result in a backfill less likely to undergo consolidation or settlement. Dedicated compaction equipment and specified performance criteria have not been proposed because the perceived benefit to cost ratio is not considered justifiable. Furthermore, this type of operation would not be consistent with the safe work practices in the Open Pit advanced as part of this design. This can be reconsidered and optimized in the next phase of design if warranted. Given the geometry of the pit and access ramp, the direct placement operation will be constrained by truck access and traffic restrictions (see Drawing D017). The scheduling and cost estimating exercise (AMEC, 2014b) has suggested, however, that the constraints on production rate imposed by the tailings dewatering and excavation operation, are such that the restrictions caused by the pit placement rate have a relatively small impact on the project schedule or cost.

Given the nature of the tailings, even if significant dewatering is achieved, trafficability in the Open Pit will have to be addressed. Trafficability could be provided by constructing roads that essentially form dump cells throughout the Open Pit. This would, however, tend to build in the potential for high differential settlements because the roads would be well compacted and the internal dump areas would be relatively loose. The direct placement of tailings method advanced, therefore, includes placement of waste rock and tailings in layers. This will not only provide trafficability but the layers will also improve tailings drainage and settlement behaviour. To facilitate trafficability in both the pit and the tailings facility and in consideration of the constraints imposed by the size of the pit, it is assumed that placement would be completed using maximum 40 ton articulated trucks. Forty ton trucks require a turning radius of 9 m, which has been considered in the traffic layout included in Drawing D017. Using 40 ton or smaller trucks, it is expected that sufficient trafficability will be provided in the Open Pit by placing 1 m thick layers of rockfill in horizontal lifts between 2 m thick layers of tailings.

Placement of the first tailings lift could begin with tailings deposited at the far (north end) of the pit with trucks travelling on a horseshoe shaped loop around the pit and dumping off the end of the horseshoe as shown on Drawing D017. Deposition would work backwards to the south end of the pit. Next rockfill would be dumped over the tailings starting at the south end of the pit, working northward with the placed rockfill providing the trafficking surface. Other alternatives could be considered by a contractor to improve productivity such as placing the tailings and rockfill layers at the same time. If the tailings are too saturated to stack into a sufficiently thick layer when dumped from the truck, which may be possible particularly for the finer portion of the tailings, the mix ratio of PAG rock or drier tailings to wet tailings would be increased or else mini berms could be created in the pit from PAG waste rock to locally contain the tailings and allow placement of a 2 m thickness. With the layered configuration and the PAG rock:tailings ratios assumed herein, the final elevation of tailings dominated materials is estimated to be at approximately elevation 1,224 m as shown on Figure 9 and in Drawings D007 and D008. This elevation will, however, vary depending on the actual waste rock to tailings ratio developed from field procedures. The elevation of the pit rim ranges between elevation 1,209 m at the northeast side of the Open Pit and 1,225 m, while the maximum elevation of the original ground in the access ramp to the pit is at elevation 1,200 m. This means that tailings dominated material will rise above the rim of the pit. The backfill will slope up and inward from the pit rim at 3H:1V (see Section 4.6.1 for stability considerations). A PAG waste rock shell 2 m in thickness, measured perpendicular to the slope face, will be constructed in conjunction with the rising backfill. The PAG rockfill shell has been included mainly to provide erosion protection during construction and the interim cover period. It does provide some benefit with regards to stability; however, if there were significant stability concerns, the width of the PAG shell would be widened.

Figure 9: Open Pit Storage Capacity



Another key consideration is the containment of the volume of fine tailings that could potentially have higher saturation values than the rest of the coarser tailings backfill. As shown on Figure 9, provided that the fine tailings are preferentially excavated early in the relocation process, the fine tailings or blended fine tailings can be maintained below the pit rim everywhere except possibly at the ramp at the south end of the Open Pit. A supporting buttress is required at the south end of the pit regardless of the occurrence of saturated tailings so that the contaminated materials can rise vertically at this pit boundary and provide the required storage volume. The buttress will be constructed by placing NAG waste rock outside the pit drainage boundary in conjunction with tailings placement creating a nearly vertical interface between the PAG and NAG materials as shown in Drawing D007.

End Dump Placement Method

After direct placement of the waste rock platform, end dumping tailings into the Open Pit would be done from dump pockets constructed around the entire perimeter of the Open Pit at a spacing of about 100 m as shown schematically in Drawing D018. In concept, end dumping maximizes the placement rate and also facilitates the placement of wet material since there is no requirement to traffic on the tailings until the tailings reach the elevation of the pit rim. It also maximizes the volume of tailings placed below grade because there are no PAG rock layers occupying the available space. Furthermore, there is a reduced safety risk with regards to the stability of the Open Pit walls because work inside the Open Pit is limited. It appears, however, that the increased placement rate may not be realized, because of the constraints on the excavation operations at the tailings facility. In addition, as discussed in Section 4.6.1, there are stability concerns with regards to end dumped tailings if saturated conditions occur within the fill. In such a situation, there would be restrictions on the location of material placement which would complicate dumping sequencing and/or require local densification in the upper portion of the pit. It is expected, however, that dewatering and blending of fine and coarse tailings and/or tailings and waste rock will produce a material with sufficiently low saturation to allow end dumping in a simple manner.

In an unconstrained scenario where the placed tailings have low saturation, tailings, insitu soils and/or PAG would be end dumped until the material approaches the elevation of the rim of the Open Pit. At that point, tailings would be dumped at the rim of the pit and dozed into the valleys created between the dump locations. The dozing operation may require placement of additional PAG rock to improve trafficability. Once the valleys are infilled and the backfill is level with the pit rim, the backfill will be raised using conventional direct placement methods with material dumped and dozed into place. A PAG waste rock shell would be raised in conjunction with general tailings / insitu soil placement. This is shown on Drawings D019 and D020.

The volume of material that can be end dumped (as opposed to dozer pushed to infill the lower segment between dump slopes) will depend on the angle achieved by the end dumped tailings. This angle of repose slope will be a function of the strength of the material which will be strongly influenced by the degree of saturation that is achieved by the dewatering operation. If low degrees of saturation are achieved, consistent with the typical to coarse tailings SWCC, angles as steep as 3H:1V could be achieved. Higher degrees of saturation could result in slopes as flat as 10H:1V being achieved.

Steeper end dumped slopes will result in fairly significant “valleys” between the dump pockets and reduce the volume of material that can be directly placed by end dumping. However, in order to achieve steep end dumped slopes, the material must have a high strength. For example, an achieved end dump slope of 3H:1V would require a mobilized effective friction angle of 18 to 32 degrees depending on saturation; a 5H:1V slope requires a mobilized effective friction angle of 10 to 20 degrees depending on saturation. For 3H:1V end dumped slopes, the valleys between dump pockets spaced 100 m apart would be about 15 m deep. In this case, because of the high tailings strength, trafficability for the dozer operation would be good and valley infilling would be a relatively straightforward process to push out a platform over the end dumped tailings. If needed, however, the construction of intermediate dump locations could be considered to reduce the “valley” depth. More saturated material with lower strength will infill the pit more evenly requiring that a smaller volume of material be placed through dozer push. For example, a material with an undrained strength ratio (undrained strength to effective pressure, c/p') of 0.1 would have a slope of about 10H:1V. In this case, the valley between the dump pockets would be a maximum of about 5 m. The trafficability of the tailings in this scenario will be more of a concern, however, because of the low strength, and an increased proportion of PAG rock may have to be included with the dozer pushed tailings to develop a trafficable surface. The actual infilling operations will to some extent hinge on the success of the dewatering and an observational approach will have to be employed to develop a safe infilling plan. In the final analysis, the required methodology cannot be specified and will be determined by a competent contractor's work plan.

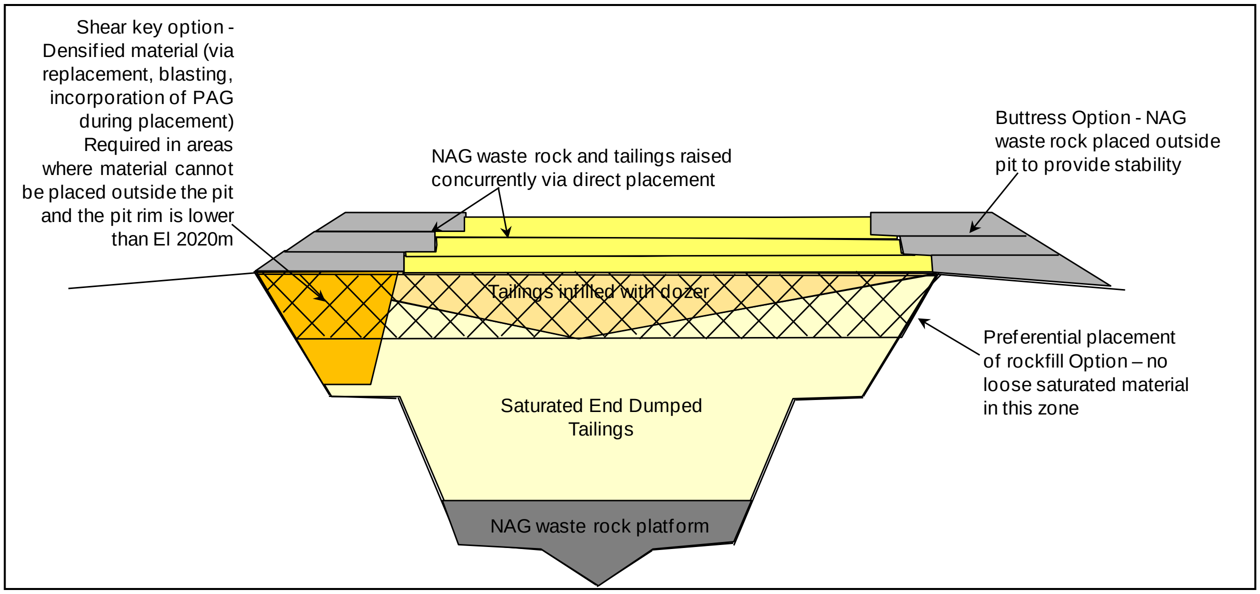
As discussed in Section 4.2.2, a certain amount of PAG waste rock will be mixed with the tailings in order to provide trafficability at the tailings facility. The amount of PAG required depends on the maximum allowable bench height during tailings excavation, the effective wellpoint dewatering depth and the thickness of rock required to provide trafficable surface. Based on these considerations, it is expected that, on average, for every two to two and a half unit volumes of tailings, there will be a unit volume of PAG rock incorporated. This results in about 390,000 m^3 of tailings and PAG. In addition, there is a further 68,000 m^3 of material including insitu soils and upstream dam fill that will be excavated in conjunction with the tailings and 8,000 m^3 of ore that need to be relocated within the footprint of the pit resulting in a total of about 466,000 m^3 of tailings dominated material that has to be placed in the pit. As can be seen on Figure 9, the tailings dominated material would fill the pit to a flat elevation of about 1,215 m.

Over most of the pit, the tailings dominated backfill will be located near the elevation of the pit rim. There are, however, several critical areas where the pit rim is lower than elevation 1,215 m.

As discussed in Section 4.6.1, the north and northeast sides of the pit are the critical sections with regards to stability. The pit rim is low in this area with a minimum elevation of 1,209 m and because of the constraints imposed by the proximity of the public road in this area of the pit, it is not possible to provide a buttress to increase PAG storage volume. Therefore, the backfilled material must slope up and inward from the rim of the pit in this area. As shown on Drawings D019 and D020, the maximum elevation of the backfill in this area is approximately 1,222 m, corresponding to a 13 m height above the pit rim.

By the time the pit is filled to elevation 1,209 m, over 80% of the tailings should be excavated including the fine tailings. The material remaining to be placed should, therefore, be in a relatively good dewatered state and be able to support such a slope. As discussed in Section 4.6.1, however, if the potential that the tailings could either be placed saturated or become saturated through drainage and infiltration cannot be discounted then stabilizing features must be constructed for short term stability considerations anywhere saturated tailings might exist within 5 to 10 m of the pit rim and where a rockfill shell cannot be constructed on the outside of the slope (i.e. in the northeast side of the pit). As illustrated schematically in Figure 10, the stabilizing features could consist of a combination of various design features. The most straightforward method would involve preferential placement of unsaturated PAG rockfill within 4 m of the pit rim elevation (or effective pit rim if there is a buttress) in zones where the pit rim is low. Tailings dominated material would then be placed preferentially in areas where the pit rim is at higher elevations or where sufficient buttressing outside the Open Pit could be provided. If this is not feasible, a densified shear key feature would be required. The densified zone could likely not be constructed by end dumping. It would likely require techniques such as blasting or replacement. These details will be optimized and finalized in future stages of design should the end dumping method warrant advancement.

Figure 10: Schematic of Stabilization Measures Required for Saturated End Dumped Material



Consideration of Multi Season Operations in the Open Pit

It is expected that it will take more than one summer season to backfill the Open Pit. The main concerns with regards to multi season operations are that water could be introduced into tailings that have been placed in an unsaturated state and that a layer of snow or ice could be incorporated into the backfill at the interface between the two seasons of placement.

In order to minimize the effects of a multi season operation, planning of the backfilling operations will be essential to ensure that prior to winter, the fill elevations are such that positive surface drainage can be provided. Measures that should be considered to avoid negative impacts of winter weather on the placed material include:

- achieving minimum backfill elevations of 1,200 m at the south end of the Open Pit and 1,205 m at the north end of the pit before the winter shutdown to provide a minimum 2% grade to promote drainage to the south and down the ramp;
- consideration of covering the area with sacrificial tarps prior to winter shutdown;
- snow removal prior to spring melt; and
- providing pumps during freshet to pump out any water that does accumulate and direct it to the treatment plant (as needed). In addition, it may be possible to construct a sump within the rockfill platform that can be used to capture and manage runoff.

4.4.5 Relocation of the Low Grade Ore

The low grade ore must be removed from the ramp of the Open Pit after the NAG waste rock platform is placed at the bottom of the pit and before the pit backfill reaches elevation 1,200 m. The volume of material is relatively small (8,000 m^3) and will be unsaturated so will not introduce any placement issues. It can be end dumped into the pit or placed within either the tailings or PAG waste rock layers in the direct bottom up placement method.

4.4.6 Contaminated Soils Placement

The hydrocarbon contaminated soils from the mill, camp, former Ketza Shop and roads and the limited amount of nitrogen contaminated soils from the former explosive storage area will be located on the flat area above the PAG waste rock shell over the tailings. The volume of this material is roughly 10,000 m^3 and it will form a layer with a thickness of approximately 3 m. It will be placed in lifts using conventional dump and doze operations. The hydrocarbon contaminated material has been kept in a localized area at this stage of the design should it be determined that dedicated containment measures, incremental to those provided by the general pit design, will be required. AMEC/AE has not identified technical benefits and/or imperatives that would support the need for dedicated containment (it will be beneficial if disposal without these measures can be supported to minimize the potential for creating an incremental long term leachate management liability). In addition, if dedicated containment is not necessary, the material could be incorporated with the PAG and/or tailings deposition.

Landfarming the hydrocarbon contaminated soils is not included in the design because it is unlikely that the contaminant levels would be lowered sufficiently to mitigate the need for engineered containment in a landfill. It is, therefore, more cost effective and efficient to simply incorporate the contaminated soils directly into the backfilled Open Pit and manage them with the other materials of concerns.

4.4.7 Dismantling and Demolition Waste Management/Placement

As outlined in Section 6.5, the demolition waste materials that require storage onsite are limited to 3,000 m^3 of concrete and a total of 300 m^3 of wood, drywall gypsum and masonry. The concrete is considered inert material and can be incorporated into the NAG buttress on the south side of the Open Pit or can be placed in conjunction with the tailings and PAG waste rock depending on scheduling. The other 300 m^3 of material is potentially contaminated and, therefore, requires placement in conjunction with the PAG or tailings. Demolition waste volumes are based on a significant amount of recycling. This requires further assessment in the next phase of design to confirm feasibility given the remote northern location. The disposition of the demolition waste onsite will then require further refinement. Conceptually, provided that the waste can be crushed and placed without significant voids, its incorporation within the Open Pit backfill should be relatively straightforward.

4.4.8 Surface Water Management

Introduction

The purpose of the surface water management plan is to evaluate the most effective strategies for minimizing impact on surface water during the implementation of the Base Case remediation design of Mount Nansen Site.

The overall water management plan covers the two main periods of the project:

- construction period (refer to Section 5.3); and
- post-remediation period.

The water management plan focuses spatially on two key physical areas:

- restoration of Dome Creek including the tailings area; seepage pond and mill area; and
- diversion channels around the Brown McDade Pit area (water to be diverted from the cover and any upstream areas to the northwest) and cover surface drainage.

A diversion channel will be designed around the pit to keep upstream runoff away from the pit area and to protect the cover from erosion. On the downstream end of the pit, diversion channels will route collected runoff to Dome or Pony Creek watersheds.

The objective of the cover surface drainage is to prevent direct precipitation from collecting on the cover and infiltrating through the cover. The cover is designed with a slope of 3H to 1V facilitating surface drainage to the perimeter diversion channels. The perimeter diversion channels will be designed with erosion protection.

Design Criteria

Although typically diversion channels are designed to the 1 in 200 year flood at closed sites, the channels around the pit area will be designed to the 1 in 1,000 year storm, because of very low flows on the site and small incremental difference between the 1 in 200 year and the 1 in 1,000 year peak flow.

Design Flow, Channel Sizing and Alignment

The layout of the open pit after closure is presented on Drawing D007.

The peak flow of the diversion channel is estimated using HEC-HMS as described in Section 7.6.3 (Channel Design). A catchment area of 0.1 km^2 was assumed to contribute to the flow in the diversion channel. The 1 in 1,000 year peak flow of 0.040 m^3/s was used for sizing the channel.

A triangular channel with side slopes of 2 to 1 was assumed. The slope of the channel ranges from 1% to 10%. The design depth of flow in the channel was estimated to be 0.15 m. A required freeboard of 0.40 was assumed resulting in a channel with total depth of 0.5 m.

Table 4.3: Design of Diversion Channel Around the Pit Cover

Channel Type	Triangular
Design Parameter	Value
Flow (m^3/s)	0.04
Slope (%)	1 - 8
Water depth (m)	0.15
Total depth (m)	0.5
Side slopes (horizontal versus vertical)	2 to 1
Approximate maximum flow velocity (m^3/s)	1.15
Minimum D50 of Erosion protection (mm)	50

The approximate maximum velocity in the channel was estimated to be 1.15 m/s. Therefore, the channel will be lined with granular material with D50 of 50 mm to provide erosion protection. This material can be sourced from screened NAG waste rock.

Details of the channel design are presented on Drawing D022.

4.5 Pit Cover Design

4.5.1 Introduction

Previous conceptual assessments of low infiltration cover options have been conducted by Golder Associates (2010). As part of their work, Golder evaluated the performance of a number of earthen and geosynthetic covers with predicted infiltration / percolation rates ranging from 1% to 20% of annual precipitation. As cover performance was deemed critical to the success of the Mount Nansen Remediation Project (MNRP), AMEC focused on designing a cover that would provide the best achievable results (i.e. in the order of 1%).

4.5.2 Design Objectives

The cover system is an integral component of the design required to meet closure objectives for the MNRP. Due to the effects of potential large and differential settlements associated with tailings relocation, construction of the final cover will need to be delayed until these settlements are within acceptable levels. This necessitates the requirement for an interim cover to be in place during the stabilization period. A discussion of design objectives for both the interim and final covers follows.

Physical Stabilization

Both the interim and final covers are designed to prevent wind and water erosion of waste materials. They will also act as a barrier to prevent direct contact of the waste by flora and fauna.

Chemical Stabilization

Both the interim and final covers are designed to minimize contaminant release by controlling infiltration / percolation through the respective barrier layers. Further, the final cover will provide additional chemical stabilization through the control of oxygen ingress.

Land Use

The final cover will provide a growth medium for establishment of limited vegetation cover as described in the Site Reclamation Plan (Section 7). The presence of vegetation has not been assumed for the interim cover as annual maintenance will likely be required to ensure a continuous 1,000 mm thickness over the waste materials.

4.5.3 Design Elements

The cover system is comprised of a number of elements that work together to meet the above design objectives. These components include a granular filter layer, interim barrier layer (silty sand), cushion layer (sand), final barrier layer (geomembrane & geosynthetic clay liner), drainage layer (sand), and a vegetative layer (silty sand & vegetation). A brief description of the components are presented in Table 4.4 and illustrated on Drawing D022.

4.5.4 Cover Performance

Cover performance was assessed using an unsaturated flow model (HYDRUS) for the interim cover and a saturated flow model (HELP) for the final cover. The methodology and outputs for each model are presented in Sections 4.5.6 through 4.5.8, while a summary of results follow. For the interim cover, percolation rates varied from between 5% (best case) and 30% (worst case). For the final cover, percolation rates varied from between 0.01% (best case) and 5% (worst case).

Design Basis

Modelling of cover performance was conducted to develop a sense of what the upper and lower bounds of infiltration/percolation through the interim and final covers could be. Average rainfall data and favourable material properties were selected for the best case scenarios. Wet rainfall data (approximately 1:100 year event) and degraded material properties were selected for the worst case scenarios.

Table 4.4: Description and Rationale for Principal Design Components for Interim and Final Covers

Component	Description	Rationale
Interim Cover – From the Waste Rock Up		
Granular Filter	Well graded waste rock, gravel and sand layer.	A granular filter may be required to keep the finer Victoria Creek materials from migrating into the void spaces of the waste rock thereby resulting in less than 1,000 mm thickness being present.
Barrier Layer	1,000 mm thick layer of well graded silty sand with gravel (Victoria Creek material).	This component will act as a water balance cover (i.e. store and release). The granular filter layer beneath it will reside upon relocated coarse waste rock which will act as a capillary break and enhance the moisture retention capabilities of the barrier system.
Final Cover – From the Interim Cover Up		
Cushion Layer	300 mm thick layer of sand.	Depending on the size and angularity of gravel present in the Victoria Creek material, a sand cushion layer may be required to protect the geosynthetic liners against puncture.
Barrier Layer	A composite barrier comprised of a geomembrane overtop of a geosynthetic clay liner (GCL).	A composite liner system has been selected as it offers the best overall performance for a barrier layer. The composite liner will consist of a geomembrane in intimate contact with a GCL.
Drainage Layer	300 mm thick layer of coarse sand.	As percolation through the composite barrier is very low, a drainage layer must be provided above it to prevent veneer stability failure of the vegetative layer.
Vegetative Layer	300 mm thick layer of silty sand seeded with appropriate vegetation.	This component will prevent surface erosion and promote runoff and evapotranspiration of moisture. The interim barrier layer is to be removed and reused for the vegetative layer during placement of the final cover.

4.5.5 Cover Integrity

As the tailings placement methodology hasn't been selected, the magnitude of long term and differential settlements cannot be accurately determined at this point. In either placement scenario that is being considered, however, the potential differential settlements are sufficient such that the placement of the final cover will need to be delayed a number of years and that significant care and maintenance of the interim cover will be required over this period (refer to Section 4.6.2). Prior to placement of the final cover, it is recommended that the interim barrier layer (silty sand) be removed so that it can be reused for the vegetative layer. The removal and reuse of the interim barrier layer is recommended because it is expected that this layer will have high moisture content. A silty material with high moisture content introduces the potential for frost heaving beneath the geosynthetics which would result in differential movement and possible tearing of the liner. If at the time of construction it is found that the interim cover soils have low moisture content, they could remain in place as the required bedding layers.

Physical Integrity

Cover System Inspection and Maintenance

The integrity of the final cover system must be maintained to ensure that the waste materials are contained, and to ensure that breaches in the cover do not result in an increase in the generation of leachate. The cover system should be inspected to confirm its integrity, and to enable corrective actions to be taken in the event that the cover is eroded or affected by settlement of the waste rock and tailings. Inspections should identify any actual or possible evidence of:

- erosion;
- subsidence or heaving of the waste or soils that results in ponding of water on the cover;
- subsidence or heaving of the waste or soils that results in cracks or fissures appearing in the cover;
- evidence of damage created by burrowing animals; or
- adverse effects on vegetation.

Inspections of the cover should be comprised of visual assessment of the cover surface and vegetation. Corrective measures should be undertaken as soon as possible after identifying any erosion, subsidence, heaving, ponding water, cracks or fissures, animal burrows or vegetation impacts.

Surface Water Drainage System Inspection and Maintenance

It will be important that the surface drainage systems be maintained to prevent ponding of water so that infiltration is minimized, and to ensure that erosion is not occurring in, or as a result of the drainage system. Corrective actions should be undertaken as soon as possible following identification of problems with the drainage system including:

- blockage in the drainage system that results in the collection and accumulation of surface water on, or around, the cover; or
- erosion within the drainage ditches, outfalls or other structures.

Estimated Design Life

Estimating the service life of geosynthetic materials is an area of active research. Through the Geo-Engineering Centre at Queen's University, AMEC is a partner in some of this research. To date, much of the research has focused on High Density Polyethylene (HDPE) and Geosynthetic Clay Liners in municipal landfill environments. While the exact type of geomembrane for use in the MNRP final cover remains to be determined, some generalizations regarding design life can be provided. The research at Queen's has shown that temperature and leachate characteristics are the two main factors affecting service life. High temperatures and high conductivity leachates have been shown to have detrimental effects on polyethylene and bentonite. Fortunately for the MNRP, cover temperatures are expected to be quite low and rainfall will be the primary liquid contacting the geomembrane and GCL. In such a configuration, the design life is expected to be in excess of 100 years.

4.5.6 Cover Modelling Methodology

Percolation through composite liners and covers is often simulated using the HELP model, which was developed by the EPA to simulate landfill hydrology (Khire et al., 1997). The HELP model uses simplified algorithms to describe two-dimensional water flow in soil and geosynthetic layers (Benson et al., 2010). The strength of the HELP model is in describing the build-up of head in a drainage layer underlain by a barrier layer. Percolation through the final cover will be governed primarily by flow through defects in the geomembrane, and the flow rate through such defects is a function of the head on the geomembrane. HELP is capable of accurately estimating the head on the geomembrane and, therefore, the HELP model was chosen for the final cover simulation. Two simulations were run using HELP: the first representing the best case scenario with respect to installation quality and hydraulic performance of the geosynthetics, and the second representing the worst case scenario (see model outputs in Appendix D).

The HELP model tends to overestimate percolation in the unsaturated zone, and does not simulate hydrological processes within soil covers with sufficient accuracy to be used for water balance modelling (Khire et al., 1997). Models used to simulate unsaturated flow employ numerical methods to solve Richards' equation at a number of nodes throughout the cover profile. HYDRUS-1D Version 4.17 was used to model percolation through the interim cover. This software uses a finite element implementation of Richard's equation to describe one-dimensional unsaturated water and vapour flow in soil layers (Benson et al., 2010).

Input for the models can be divided into three categories: meteorological data, hydraulic properties of the cover materials, and cover geometry.

4.5.7 Meteorological Data

Precipitation data for the Mount Nansen site is presented in the Site Characterization Report. Additional meteorological data used in the cover models is presented in Table 4.5. The data was recorded by a weather station located at latitude 62˚, and elevation 1,265 m. The measurement height was 9.5 m above ground elevation.

Table 4.5: Average Meteorological Data for Mount Nansen Site

Avg. Year Total Precip. (mm)	1:100 Year Total Precip. (mm)	Avg. Solar Radiation (MJ/m^2/ day)	Avg. Max. Air Temp. (C)	Avg. Min. Air Temp. (C)	Avg. Relative Humidity (%)	Avg. Wind Speed (km/day)
310	522	6	1	-7	71	117

**Daily values were used for model input.*

Modelling for both the interim and final covers was run over timelines that allowed the models to reach equilibrium with the average meteorological conditions. This required different modelling timelines for each cover. The interim cover simulation was run using six consecutive average years, followed by one wet year, followed by three consecutive average years. The final cover simulations were run using five consecutive average years, followed by one wet year.

4.5.8 Hydraulic Properties of the Cover Materials

Hydraulic properties of the insitu soils (to be used in the covers) were based on the information presented in the Site Characterization Report. The hydraulic properties of the geosynthetics were based on recent research (Giroud et al., 1997; Benson et al., 2005; Rowe, Kerry, 2012).

Table 4.6: Hydraulic Properties of the Cover Materials

Model	Initial Water Content (w.c.)	Sat. w.c.	Field Capacity w.c.	Wilting Point w.c.	Residual w.c.	Saturated Hydraulic Conductivity (cm/sec)	No. of Defects per Hectare
Interim Cover							
Victoria Creek Borrow	-	0.43		-	0.06	0.003	-
Waste Rock	-	0.43		-	0.03	0.014	-
Final Cover -Best Case							
Victoria Creek Borrow	0.31	-	0.31	0.16	-	0.003	-
Sand Borrow	0.08	-	0.08	0.03	-	0.003	-
Geomembrane	-	-	-	-	-	4×10^{-13}	4
GCL	0.75	-	0.75	0.4	-	3×10^{-8}	-
Final Cover -Worst Case							
Victoria Creek Borrow	0.31	-	0.31	0.16	-	0.003	-
Sand Borrow	0.13	-	0.13	0.06	-	0.001	-
Geomembrane	-	-	-	-	-	4×10^{-13}	6
GCL	0.75	-	0.75	0.4	-	3×10^{-5}	-

For the final cover worst case model, the hydraulic conductivity of the GCL was increased by three orders of magnitude to represent potential long term degradation due to cation exchange, frost heave, and bentonite migration (Benson et al., 2005; Rowe, Kerry, 2012). The lateral transmissivity of the sand drainage layer (above the liner) was also reduced for the final cover worst case, but this was found to have little effect on the output.

The percolation rate through the final cover will be strongly affected by the number (and size) of defects in the geomembrane. For the final cover models, the number of (1 cm$^{\phi}$) installation defects was varied from 4 (best case) to 6 (worst case) (Rowe, Kerry, 2012). A leak location survey (or equivalent level of construction quality assurance) would likely be required in order to achieve these results in the field.

4.5.9 Cover Geometry

The cover profiles are shown in Drawing D022. A slope of 3:1 was used for each layer of the cover profile. The total cover surface area is 3.6 hectares, and the slope length is 50 m.

4.5.10 Cover Modelling Results

Interim Cover

For the proposed interim cover profile shown in Figure 11, we can expect total annual percolation to vary between 5% and 30% of total annual precipitation. The greatest percolation rates (in terms of total percolation, percent percolation, and bottom flux) occurred in Year 8 of the simulation, the year after a wet year.

Table 4.7: Interim Cover Model Results

	total annual precipitation (mm)	total annual percolation (mm)	percent percolation (%)
Average year	310	14	5
Wet year (Year 7)	522	77	15
Average year following a wet year (Year 8)	310	95	30

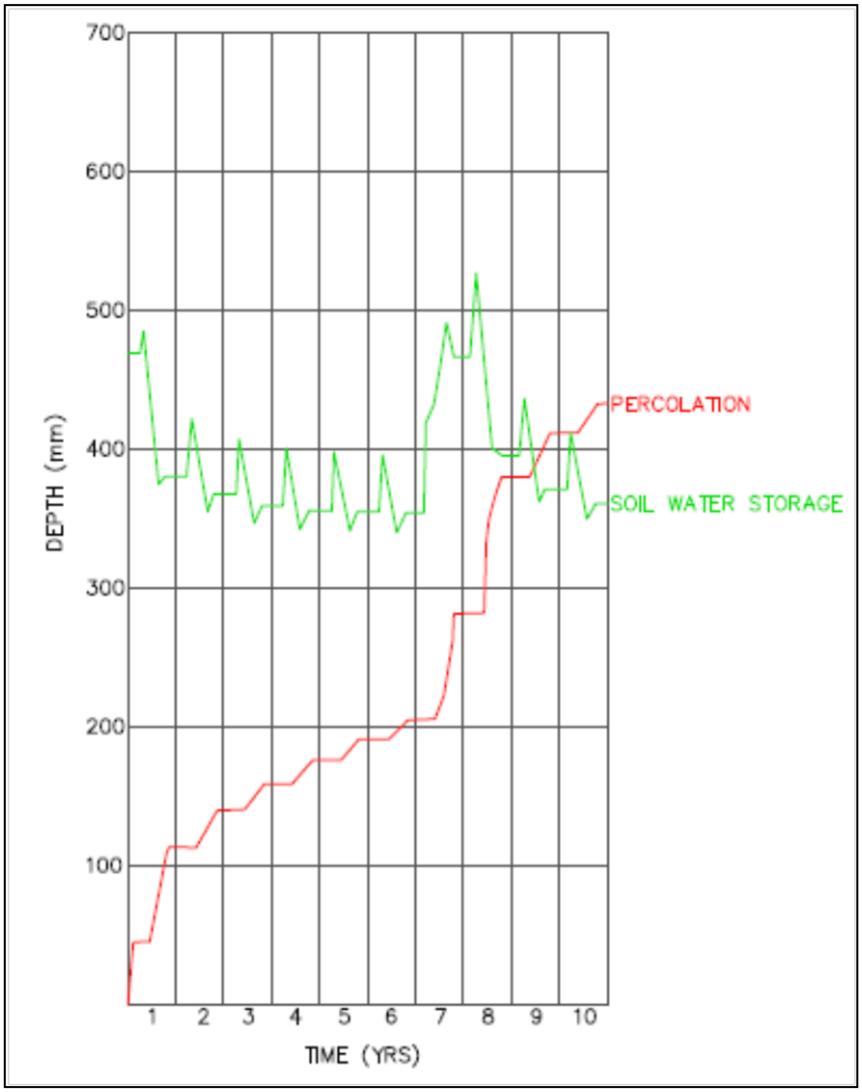
4.5.11 Final Cover

For the proposed final cover profile shown in Drawing D022, we can expect total annual percolation to vary between 0.01% and 5% of total annual precipitation. The total area of defects in the geomembrane, the hydraulic conductivity of the GCL, and the quality of contact between the geomembrane and the GCL are the variables that most affect the model output. Variations in total annual rainfall have a negligible effect on the percent percolation.

Table 4.8: Final Cover Model Results

	Total Annual Precipitation (mm)	Total Annual Percolation (mm)	Percent Percolation (%)
Best Case	522	0.04	0.01
Worst Case	522	28	5

Figure 11: Interim Cover Model – Soil Water Storage & Cumulative Percolation



4.6 Performance of Backfilled Pit

4.6.1 Stability Analyses

Preliminary stability analyses have been completed for the final backfilled pit configuration. The analyses are presented in Appendix B and summarized in the following section. The backfilled pit is most similar to a waste dump structure and the criteria adopted for the stability analyses, as discussed in Appendix A, have been selected in consideration of this and the consequence of failure. The design criteria with regards to stability are:

- Minimum short term factor of safety: 1.3;
- Minimum long term factor of safety: 1.5;
- Minimum factor of safety with earthquake loading: 1.1 (1 in 2,500 earthquake); and
- Minimum factor of safety post earthquake: 1.2 (1 in 2,500 earthquake).

At this stage of design, one critical section with regards to stability was identified where the pit rim is at the lowest elevation adjacent to the public road. This corresponds to Section BB in Drawing D007. In later stages of design, other sections should be considered and the details of the backfill configuration optimized and refined.

At the critical section, the pit rim is at elevation 1,209 m and there is no room outside the pit to provide a stabilizing buttress. The backfill rises to an elevation of 1,222 m for a slope height of 13 m. This is less than the maximum slope height elsewhere around this pit rim which is 17 m. The stability section was adjusted to reflect the higher height in order to be applicable to other areas of the pit. Given the storage elevation curve shown in Figure 9, tailings must be located above elevation 1,209 m. As discussed in Section 4.2.2, it is expected that the majority of the dewatered tailings will be placed in an unsaturated state in either the end dumped or direct placement method. In an unsaturated state, the 3H:1V configuration with a compacted rockfill cover will not pose a stability issue. However, given that there remains some uncertainty about the dewatered characteristics of the tailings, the potential for saturated conditions were considered in the short term stability analyses.

The main difference between the end dumped configuration and the direct placement configuration is that the end dumped tailings have the potential to be loose and contractant; therefore, if they are in a saturated condition, there exists the potential for static liquefaction. Once liquefied, the tailings would have a very low strength. In contrast the direct placement method, with layers of rockfill and increased compactive effort during placement, will result in a denser material with low potential to generate excess pore pressures upon shear and will have a higher average mobilized shear strength than for the end dumped configuration.

Stability analyses were completed for the following scenarios:

- End Dumped Configuration:
  - end of construction, assuming static liquefaction of saturated tailings;
  - end of construction, assuming unsaturated tailings;
  - long term stability, assuming drained tailings;
  - earthquake loading on long term configuration (drained); and
  - post earthquake = end of construction.
- Direct Placement Configuration:
  - end of construction, assuming saturated conditions with dilatant behaviour;
  - long term stability = post earthquake, assuming drained tailings; and
  - earthquake loading.

The material properties used in the analyses are summarized in Table 4.9. The various scenarios, target factors of safety and calculated factor of safety are summarized in Table 4.10. Additional details are provided in Appendix B.

Table 4.9: Material Properties Used in Stability Analyses

Material	Unit Weight	Effective Cohesion	Effective Friction Angle	C/P'
	(γ) kN/m³	(c') kPa	(ϕ°)	(unitless)
Waste Rock	19	-	34	-
End Dumped Tailings - Undrained	18	-	-	0.1
End Dumped Tailings – Drained	18	-	25	-
Layered Waste rock and tailings	19	-	27	-
Bedrock	Impenetrable			

Table 4.10: Open Pit Stability Summary

Case[1]	Geometry[2]	Tailings Parameter	Seismic k[3]	GWT (m)[4]	Condition	Target FoS[5]	Calculated FoS
1 – ED	Flat 1209 m	C/P' = 0.1	No	1,209	Short Term	1.3	0.7
2 – ED	Flat 1204 m	C/P' = 0.1	No	1,204	Short Term	1.3	1.3
3 – ED	shear key	C/P' = 0.1	No	1,209	Short Term	1.3	1.3
4 – ED	shear key	phi=25	No	1,190	Long Term	1.5	1.9
5 – ED	shear key	phi=25	0.11 g	1,190	Long Term with Seismic	1.1	1.6
6 – ED	shear key	C/P' = 0.1	0.11 g	1,209	Short Term with Seismic	1.0	1.0
7 – DP	Co-Disposal	phi=27	No	1,209	Short Term	1.3	1.6
8 – DP	Co-Disposal	phi=27	0.11 g	1,209	Short Term with Seismic	1.0	1.2
9- DP	Co-Disposal	phi=27	No	1,190	Long Term	1.5	>1.6
10-DP	Co-Disposal	phi=27	0.11 g	1,190	Long Term with Seismic	1.1	>1.2

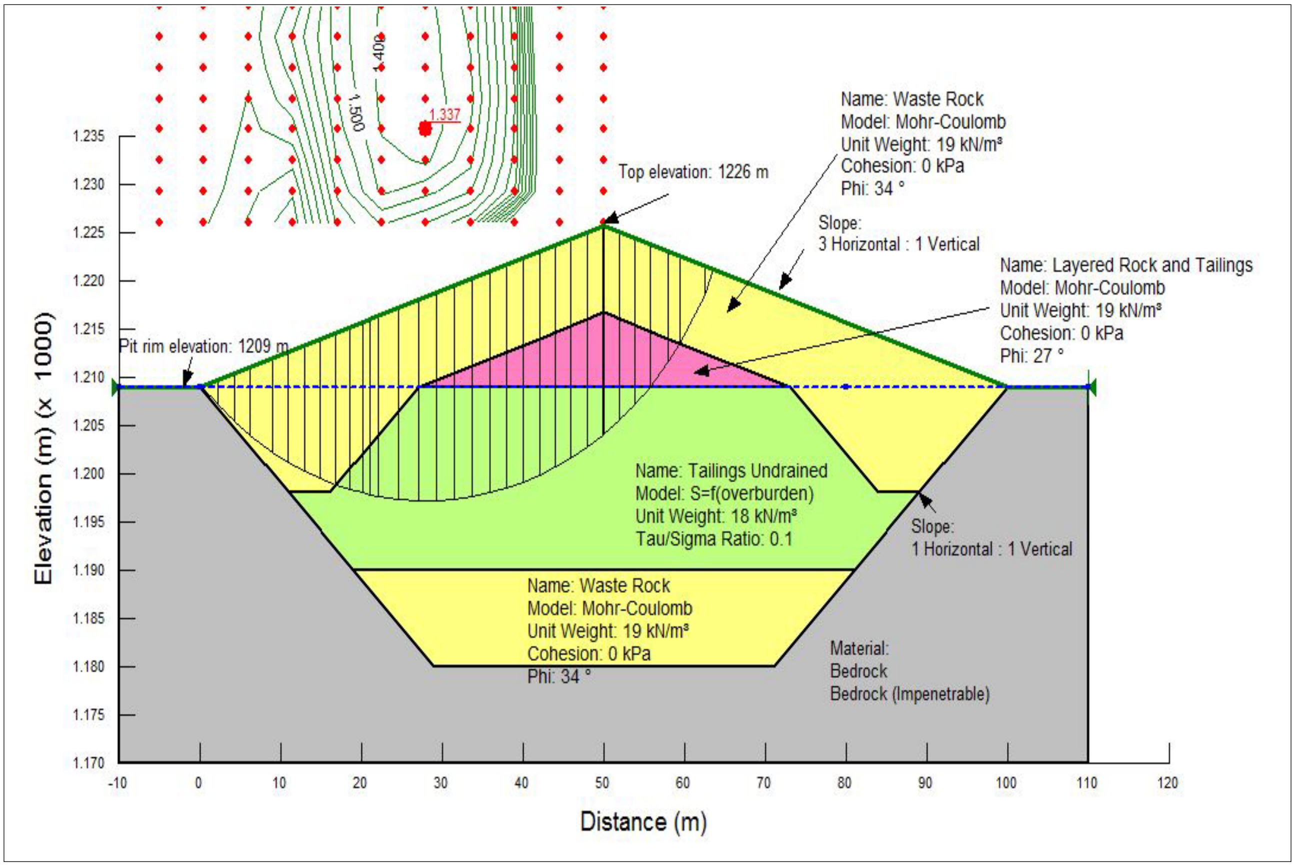
Notes:

1. *ED = end dumped, DP = direct placement*
2. *Flat indicates tailings are deposited to the elevation indicated with PAG rock only above that elevation. Shear key indicates that tailings rise above the pit rim and PAG rock properties are modelled in a shear key type feature below the pit rim with a PAG waste rock shell above. Co-disposal indicates layered tailings and PAG rise above the pit rim with a narrow outer PAG rock shell.*
3. *The applied horizontal seismic force was set equal to the design PGA. Typically the PGA is reduced by a factor of about 0.5 for pseudo static analyses; however, the full PGA was applied as a preliminary screening to assess the yield acceleration should it be necessary to assess displacements. The factors of safety calculated even with ky=PGA are high and this additional analysis was therefore not completed.*
4. *GWT = groundwater table elevation*
5. *FoS = Factor of Safety. Refer to Appendix A for a discussion of the Factor of safety criteria.*

As shown in the previous table, for the unlikely short term condition of end dumped tailings which statically liquefy an unacceptable factor of safety is calculated if the tailings come up to the pit rim. An adequate factor of safety against instability for saturated end dumped tailings can be provided by:

- where there is room, providing a stabilizing shell outside of the footprint of the Open Pit.
- limiting the tailings to a minimum of 4 m below the rim of the pit. This would require that tailings be preferentially located in areas where buttressing can be provided or where the pit rim is at a higher elevation; or
- providing stabilizing shear key feature 27 m wide at the pit rim extending 10 m below the base of the pit as shown on Figure 12 and a PAG shell 10 m wide. Although the PAG shell improves the stability of the slope the shell width was based on having excess PAG volume rather than on a minimum width to satisfy stability requirements. The minimum required shell width could be assessed in later stages of design if warranted. There are several options for creating the shear key feature; however, they are not particularly simple and perhaps negate the simple concept of end dump construction.

Figure 12: Stabilization Measures Required for Short Term End of Construction Stability for Saturated End Dumped Tailings



For the direct placement of tailings and PAG layers, factors of safety meet the design criteria with a 2 m PAG rock shell and 3H:1V slopes 17 m high. Similarly, if the end dumped material within about 5 m of the pit rim is unsaturated, the calculated factors of safety meet the design criteria.

4.6.2 Consolidation / Settlement

The settlement and/or consolidation behaviour of the backfilled pit is difficult to assess with certainty because it is difficult to simulate the placement conditions in the laboratory setting. Furthermore, since the material is sandy, the consolidation curves are non unique making the placed densities a matter of judgment. That said, estimates of settlement of the backfilled Open Pit have been made on the basis of available laboratory and insitu characterization of the tailings using the theory of one dimensional consolidation and published data regarding collapse of unsaturated fills. Later project stages could consider coupled modelling of tailings placement to simulate loading, generation of pore pressures, increasing saturation and drainage. There would, however, remain a significant degree of uncertainty with regards to the appropriate initial conditions.

There are several mechanisms which can create settlement of the backfilled pit:

- consolidation as a result of dissipation of excess pore pressures induced by material placement;

- consolidation as a result of increased stress caused by drainage of saturated material;
- collapse of materials placed in a dry state that is subsequently subjected to water seepage from infiltration;
- delayed settlement resulting from incorporation of snow/ice and/or frozen tailings at the winter boundary between two seasons of construction; and
- earthquake induced settlement.

The scenarios which have been considered in order to develop settlement estimates were selected to bracket the range of potential behaviour and include:

- Tailings placed in the bottom 12 m of the pit in a nearly saturated state which then develop excess pore pressures in response to loading from placement of overlying partially saturated material (i.e. a Bbar type response). Consolidation of the bottom 12 m of tailings would then be expected with the upper material potentially subject to collapse.
- Placement of tailings to elevation 1,220 in a saturated or nearly saturated state such that consolidation occurs only as a result of gravity drainage. The material above elevation 1,220 could be subject to collapse settlement.
- Placement of tailings to elevation 1,220 with excess pore pressures developing during placement. Higher excess pore pressures are assumed to develop from end-dumping than placement of tailings and PAG waste rock layers. Material above 1,220 would be subject to collapse settlements.

The above scenarios were assessed using one dimensional consolidation and settlement estimates. Ranges in settlement parameters have been developed from the lab testing that is currently available, insitu measurements, and published data (e.g. Vick ,1990, AECOM, 2009, Lim and Miller, 2004, Tadepalli and Fredlund, 1991, Brooker, 1992, Charles et al., 1998, Ordemir and Ozkan, 1985) as summarized in Table 4.11.

Table 4.11: Settlement Parameters

Parameter	Range in Values
e_0	0.7 - 1.5
C_c	0.08-0.35
$c_v(m^2/yr)$	3 – 300
% collapse	1.5 – 10%

The preliminary calculations indicated that the settlement estimates are similar whether the entire column is considered unsaturated and subject to collapse or is considered saturated and subject to consolidation. The estimated total settlement of the backfilled pit accounting for consolidation and/or collapse and a minimal amount of settlement from incorporation of snow and ice in the backfill is:

- End dumped scenario: 10% likely occurring over a period of about 10 years. For the maximum fill height, this corresponds to about 4 m of settlement.

- Direct placement bottom up construction scenario: 4% potentially occurring over up to 10 years if the settlement is largely a result of collapse. For the maximum fill height, this corresponds to about 1.5 to 2 m of settlement.

These settlement estimates are shown superimposed over published data regarding settlement of unsaturated fills in Figure 13. Settlement values could potentially be reduced to in the order of 1.5 to 2% if controlled placement with compactors and quality control was carried out. As discussed previously, this can be considered during future design stages if desired but has not been currently proposed because of the perceived the cost/risk vs. benefit ratio.

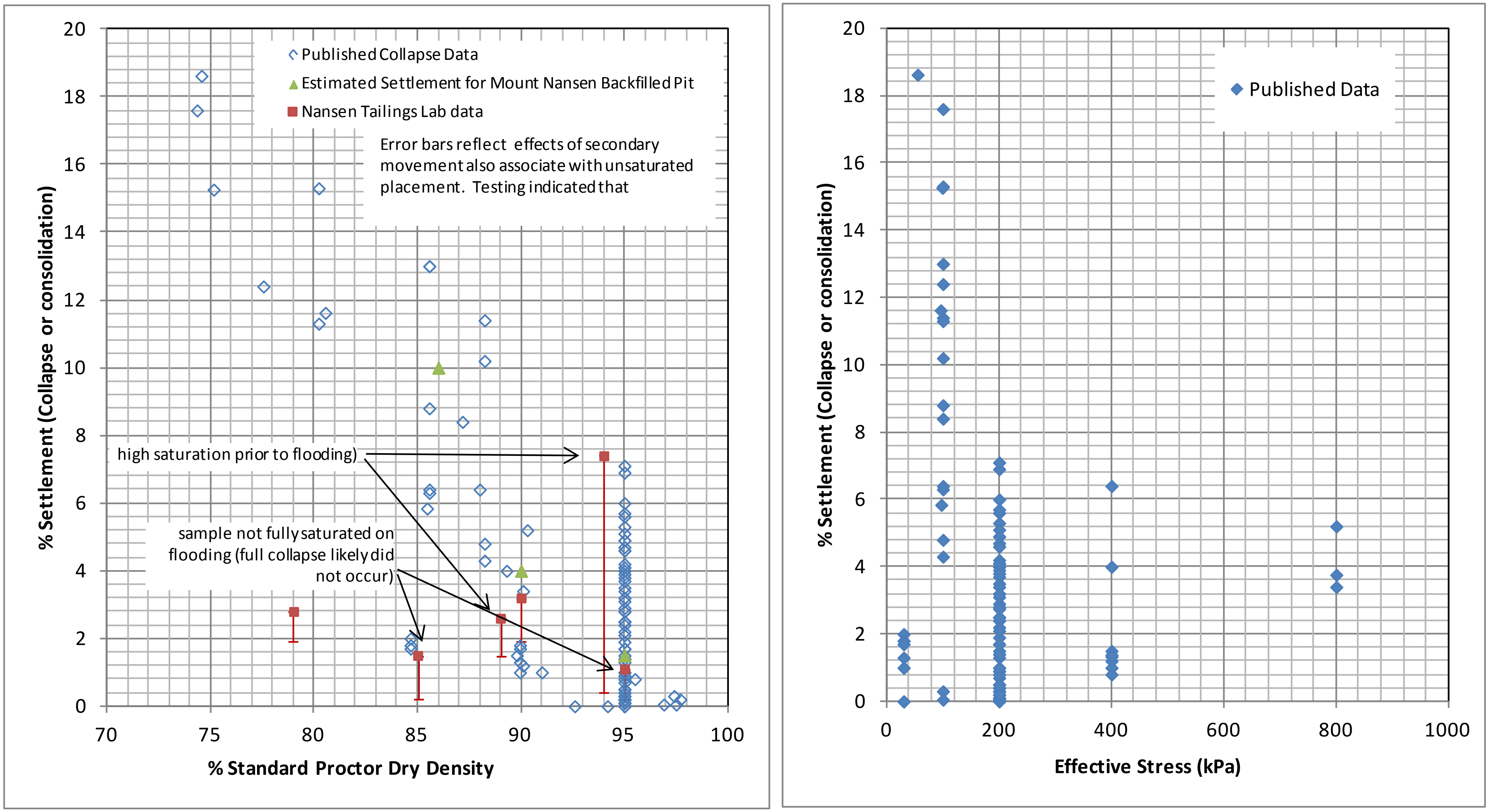
Differential settlements over the half width of the Open Pit (i.e. from the edge to the centre of the pit) would be equal to the entire estimated settlement. For shorter length intervals used to assess local strain in liner systems or likely local movement/cracking of the interim cover, differential settlements are likely in the order of half to three quarters of the total settlement for end dumped material and likely close to half for the direct placement method.

The backfilled pit configuration is a ridge shaped feature that rises about 17 m above the pit rim. This will allow the settlements estimated above to occur while still maintaining positive drainage of surface water from the backfilled pit. Maintenance and regrading will, however, be required to manage differential settlements and ensure that the interim cover integrity is maintained and to prevent development of local low spots which would collect rather than shed water. The predicted settlement will result in a long term slope somewhat flatter than 3H:1V.

The settlement estimates do not include an allowance for settlement due to significant ice or snow that could be incorporated into the backfill through poor construction practices. If significant zones of snow or ice are incorporated within the backfill, they will thaw slowly over decades and could introduce metres of settlement, most of which would likely be differential.

Earthquake induced settlement has not been directly calculated for the backfilled pit configuration. The shaking motion of the earthquake will tend to densify unsaturated granular deposits. Typical values for earthquake induced settlement are in the order of 1 to 2% with the end dumped scenarios likely exhibiting higher settlements than the direct placement scenario.

Figure 13: Settlement Estimates for Mount Nansen



Sources: Lim and Miller, 2004, Tadepalli and Fredlund, 1991, Brooker, 1992, Charles et al., 1998, Ordemir and Ozkan, 1985

4.6.3 Seepage

Seepage from the tailings due to gravity drainage of the tailings was estimated with a transient one-dimensional finite element model developed in Seep/W. A series of analyses were completed to assess the seepage flux, the details of which are presented in Appendix C. The model considered a 19 m height of tailings with waste rock located above and below the tailings. The actual maximum height of tailings dominated backfill presented in Section 4.4 is greater than 19 m because of the volume of PAG waste rock incorporated into the tailings. The PAG waste rock is unsaturated with low moisture content and will not contribute to seepage volumes in the Open Pit. The model, therefore, was based on the height of a column of pure tailings. The model conditions were as follows:

- waste rock with a hydraulic conductivity several order of magnitudes greater than the tailings located above and below a 19 m thick tailings unit;
- initial saturation of the tailings was set by specifying either an initial pore water pressure throughout the tailings or an initial groundwater level;
- a downward flux was applied at the top of the model to simulate infiltration (annual precipitation is 310 mm/yr or 9.83×10^{-9} $m^3/s/m^2$ and infiltration was taken as varying percentages of this total); and
- a constant head was specified within the waste rock below the tailings.

A transient simulation was run allowing the tailings to drain from the specified initial conditions. The scenarios considered were selected to bracket the range of potential behaviour. They included various combinations of hydraulic conductivity values, SWCC, and initial saturation conditions as summarized in Table 4.12 below. In addition, layered scenarios were considered to examine the effects of placing lower hydraulic conductivity material in the bottom of the pit. This lower hydraulic conductivity unit could occur as a result of preferential placement of fine tailings in the lower portion of the tailings and/or from decreased void ratio in the bottom of the pit as a result of higher stresses. The model results are summarized in Table 4.12 and presented in Figure 14.

Table 4.12: Seepage Analysis Scenarios

Case	Infiltration[1]	Layered	K Upper (m/s)	SWCC Upper	K Lower (m/s)	SWCC Lower	Initial Pore Pressure	Average Drainage Flux (m^3/s)[2]
1	30%	No	$1x10^{-7}$	coarse	n/a	n/a	Sat, PWP=0 throughout	1.48E-03
2	30%	No	$1x10^{-7}$	coarse	n/a	n/a	Sat, GWT=1,209 m	1.48E-03
3	100%	No	$1x10^{-7}$	coarse	n/a	n/a	Sat, GWT=1,209 m	1.49E-03
4	30%	No	$1x10^{-8}$	coarse	n/a	n/a	Sat, GWT=1,209 m	1.64E-04
5	30%	No	$1x10^{-8}$	fine	n/a	n/a	Sat, GWT=1,209 m	1.83E-04
6	100%	No	$1x10^{-8}$	fine	n/a	n/a	Sat, GWT=1,209 m	1.67E-04
7	30%	No	$1x10^{-9}$	fine	n/a	n/a	Sat, GWT=1,209 m	2.29E-05
8	30%	No	$1x10^{-7}$	coarse	n/a	n/a	Unsat, PWP=-0.5 m throughout	8.34E-04
9	30%	No	$1x10^{-8}$	coarse	n/a	n/a	Unsat, PWP=-0.5 m throughout	8.71E-05
10	30%	Yes	$1x10^{-7}$	coarse	$1x10^{-8}$	fine	Unsat upper w/ PWP=-0.5 m, sat lower GWT=1,200 m	2.06E-04
11	30%	Yes	$1x10^{-7}$	coarse	$1x10^{-8}$	fine	Sat GWT=1209 m	2.33E-04

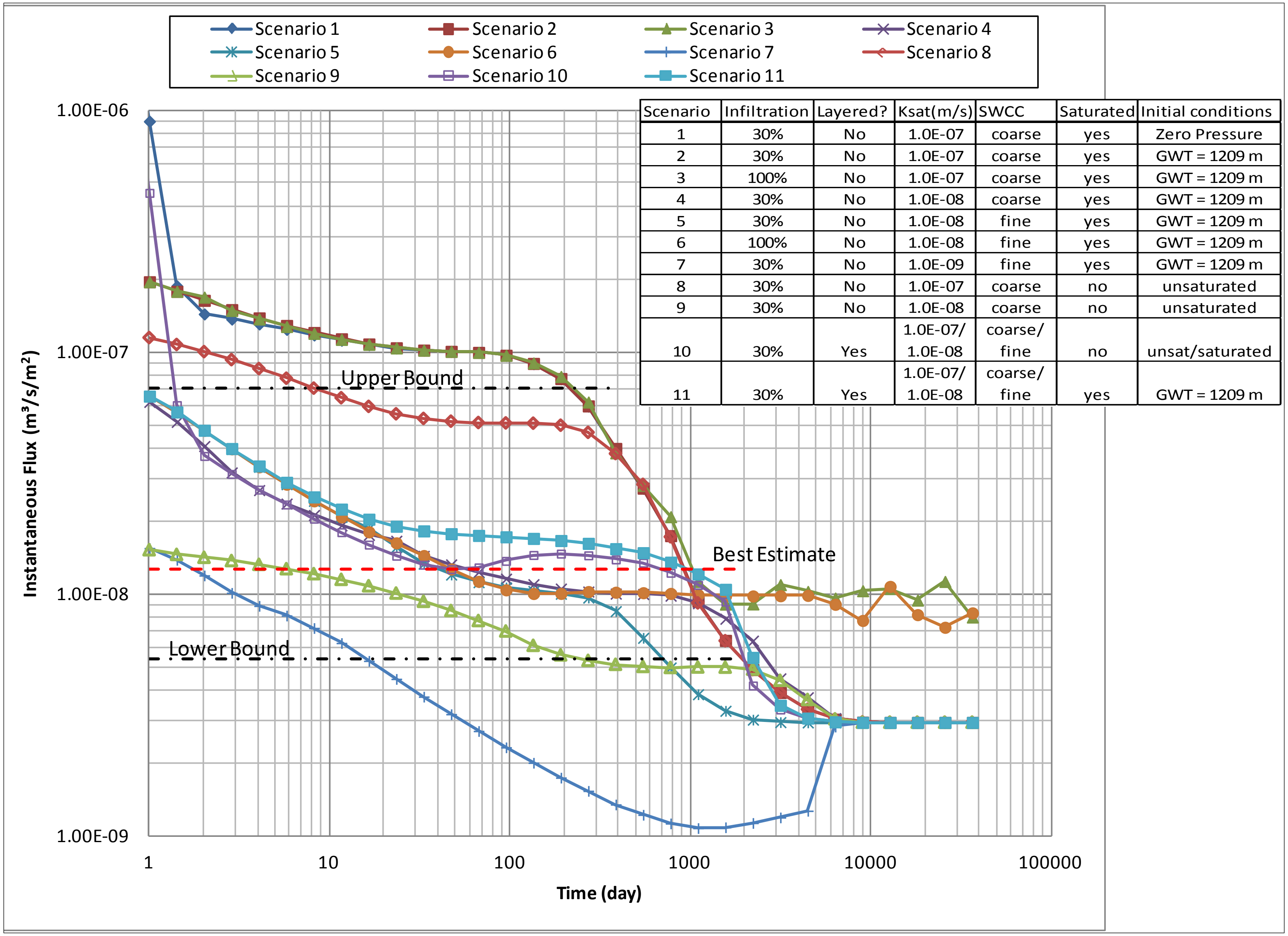
Notes:

1. *Infiltration expressed as percentage of annual precipitation. Total annual precipitation is 310 mm/yr or $0.98x10^{-9}$ $m^3/s/m^2$*
2. *Average Drainage Flux is the average instantaneous flux during the gravity drainage period calculated from the SeepW model multiplied by the area of the tailings at mid height (16,200 m^2)*

The results indicate that the SWCC and the initial saturation (which defines the initial water content) are the key factors controlling the volume of water that drains from the tailings while the hydraulic conductivity controls the magnitude of the instantaneous seepage flux. Scenarios with tailings having higher hydraulic conductivity and steeper SWCC release a significant amount of water quickly. Scenarios with shallower SWCC release lower volumes of water. If the average hydraulic conductivity of the tailings in the backfilled pits is in the order of 10^{-7} m/s, gravity drainage could occur quickly, within a year. This is consistent with the lower bound settlement time estimates developed from upper bound estimates of c_v. However, that would require that the groundwater flow regime be able to accept groundwater outflows in the order of 1 to 2 L/s which is greater than the calculated groundwater outflow from the pit under current conditions. In this case, the drainage may be slowed by the flow capacity of the bedrock. This potential constraint to flow from the tailings was not included in the seepage model. If the tailings hydraulic conductivity is lower, closer to 10^{-8} m/s, gravity drainage occurs over a period of five to six years at a rate in the order of 0.2 L/s. The latter estimate is generally consistent with the average settlement time estimate. This flow rate is within the low range of the estimated groundwater outflows calculated for the current pit pond elevation (1,181 to 1,183 m) conditions and, therefore, under this condition, the seepage flow may be controlled by the tailings.

The precipitation infiltration rates into the backfilled pit control the long term steady state seepage flux; in the long term the seepage from the tailings is equivalent to the infiltration. Because of the relatively small magnitude of the precipitation infiltration flux relative to the drainage flux and the hydraulic conductivity of the tailings, the assumed infiltration rates do not affect the initial gravity drainage of the tailings.

Figure 14: Tailings Fluxes Calculated from Seepage Modelling



Scenario	Infiltration	Layered?	Ksat(m/s)	SWCC	Saturated	Initial conditions
1	30%	No	1.0E-07	coarse	yes	Zero Pressure
2	30%	No	1.0E-07	coarse	yes	GWT = 1209 m
3	100%	No	1.0E-07	coarse	yes	GWT = 1209 m
4	30%	No	1.0E-08	coarse	yes	GWT = 1209 m
5	30%	No	1.0E-08	fine	yes	GWT = 1209 m
6	100%	No	1.0E-08	fine	yes	GWT = 1209 m
7	30%	No	1.0E-09	fine	yes	GWT = 1209 m
8	30%	No	1.0E-07	coarse	no	unsaturated
9	30%	No	1.0E-08	coarse	no	unsaturated
10	30%	Yes	1.0E-07/ 1.0E-08	coarse/ fine	no	unsat/saturated
11	30%	Yes	1.0E-07/ 1.0E-08	coarse/ fine	yes	GWT = 1209 m

The high flux estimates from Scenarios 1, 2 and 3 are considered unlikely to occur in reality because the combination of high hydraulic conductivity and steep SWCC would result in good dewatering performance and thus placement of tailings in unsaturated conditions. Given the current understanding of the tailings and the backfill methods, the best estimate, upper and lower bound estimates for potential seepage from the tailings during the period of gravity drainage are as listed below. These were provided as inputs to the water quality model and require consideration in the context of the regional groundwater system.

- Best estimate: Case 10 consisting of a lower zone of saturated tailings with lower hydraulic conductivity and an upper zone that is initially unsaturated.
  - Average instantaneous flux from total pit 0.2 L/s occurring over five years.
- Upper bound estimate: intermediate flux between Cases 8 and 2 where the tailings have high hydraulic conductivity but are placed largely unsaturated.
  - Average instantaneous flux from total pit 1.2 L/s occurring over one year.
- Lower bound estimate: Case 7 consisting of very low hydraulic conductivity saturated tailings.
  - Average instantaneous flux from total pit 0.09 L/s occurring over more than 10 years.
- Once the tailings are fully drained, the seepage fluxes through the tailings are equal to the infiltration through the cover. Even with infiltration through the cover equivalent to the annual precipitation, the infiltration fluxes are low compared to the tailings drainage and do not have a significant effect on the estimated seepage fluxes during drainage.

Average fluxes calculated based on the settlement estimates are of the same order of magnitude as those estimated from the SeepW analyses, particularly in the initial years following placement. The settlement estimates suggest that small flows, an order of magnitude lower than the estimates above could continue for about twice as long as suggested from the SeepW modelling as a result of ongoing consolidation.

4.7 Summary of Material Requirements for Remediation Efforts

The backfilled pit requires material to construct the waste rock platform and the interim and final cover systems. Tailings excavation requires material to stabilize the exposed insitu slopes. Other reclamation activities also require volumes of material including mill regrading and Dome Creek reclamation. The locally sourced soil materials required for the remediation of the Mount Nansen site and the identified source of the materials are summarized in Table 4.13 below. Table 4.13 excludes any non-soil materials required for reclamation such as mulch, seeds, geomembrane, etc. Table 4.14 presents a more detailed inventory of all the soil material volumes that require management during the remediation effort.

Table 4.13: Summary of Soil Material Requirements

Item	Material Required	Placed Volume (m^3)[1]	Source for Material
Open Pit platform	NAG waste rock	38,300	NAG waste rock area
	Gravel and sand filter	5,000	Crushed NAG waste rock
NAG buttress at Open Pit	Tailings and dam fill	68,200	NAG waste rock area
Interim Open Pit cover	Granular filter (sand and gravel)	24,000	Crushed NAG waste rock
	Barrier layer (well graded silty sand with gravel)	80,000	Victoria Creek, potential to screen from NAG
Final Open Pit cover	Sand cushion layer	24,000	Stockpiled Dam material or offsite
	Coarse sand drainage layer	24,000	Offsite
	Fine grained surficial	24,000	Possibly reuse interim barrier layer, stockpiled dam material or offsite
Stabilization of Dome Creek slopes	Sand	31,200	Dam Material
	Free draining gravel and sand	124,800	Screened NAG waste rock
Dome Creek channel	Cobbles D50>15 cm	1,000	Offsite
Diversion ditches at Open Pit	Cobbles D50>15 cm	1,000	Offsite
Mill regrading	n/a – balanced cut and fill		
Trench reclamation	Trench backfill and locally sourced mulch	Limited to what is available locally as stockpiled side cast material	
Road deactivation	n/a balance cut and fill for regrading		
Campsite regrading	n/a – balanced cut and fill		

Note 1. Placed m^3 is less than the loose cubic metres reported in next table. The loose cubic metre volume reflects the bulking factor assumed for transport.

Table 4.14: Earthworks Material Volumes

Material	Volumes (m^3)			Comments
	Insitu (m^3)	Relocated to Within Containment Portion of Pit (lcm)	Relocated as Construction Material (lcm)[1]	
Tailings in TSF	237,100	260,810		
Insitu soils under TSF tailings	50,000	60,000		
Main dam fill	103,000		38,000	Lower sand **filter** laye**r (0.3 m)** on exposed insitu slopes **within dam and tailings area**
			26,400	Potentially stockpile for use in final cover (cushion layer)
			48,900	Available or use as surficial fine grained material
Dam upstream buttress fill	5,800	6,380		
Seepage pond dam fill	1,215		1,458	Relocated to Open Pit and used in final cover
insitu soils in seepage pond area	600	720		
High metal content sediments / soils in Dome Creek downstream of sediment pond	1,000	1,000		
Waste Area, Northwest Pile - PAG	156,417	172,059		Portions of this materials will be transferred to TSF, then back to pit
Waste Area, East Pile -PAG	20,000	22,000		

Material	Volumes (m^3)			Comments
	Insitu (m^3)	Relocated to Within Containment Portion of Pit (lcm)	Relocated as Construction Material (lcm)[1]	
Waste Area, South Pile -NAG	81,600	42,630		To be placed in NAG platform at the bottom of the pit
			47,130	Placed in NAG buttress at the south side of the pit.
Waste Area, Southwest Upper Pile -NAG	75,494		27,870	Placed in NAG buttress at the south side of the pit.
			55,173	To be crushed and relocated to Dome Creek as granular fill (1.2 m thick)
Waste Area, Southwest Lower Pile - PAG	46,500	46,500		This materials will be transfer to TSF, then back to Open Pit
Waste Area, West Lower Pile - NAG	86,000		63,200	To be crushed and relocated to Dome Creek as granular fill **(1.2 m thick)**
			5,000	To be crushed and used as **0.5 m thick** filter at top of **NAG** waste rock platform
			26,400	To be crushed and used as filter in interim granular cover
				Remaining volume will be stockpiled for use in maintenance of interim cover and for regrading of final cover if required.
Waste Area, West Mid Pile - PAG	129,901	142,891		This materials will be transferred to TSF, then back to Open Pit
Ore Stockpile - PAG	1,812	1,993		
Low grade ore material relocated to Open Pit in 2009, currently on ramp	8,000	8,800		This area will be backfilled with NAG buttress material already accounted for.
Ketza Shop PAG waste rock	1,787	1,966		
Ketza Shop hydrocarbon contaminated soils	1,338	1,409		To be placed at the top near surface and under the cover
Tailings / insitu soils at mill Pond #1	1,250	1,375		
			1,375	To be backfilled with NAG from Mill
Tailings / insitu soils at mill Pond #2	950	1,045		
			1,045	To be backfilled with NAG from Mill
Tailings / insitu soils at mill Pond #3	0	0		Lack of material to be reconfirmed in next phase of design.
Mill area PAG waste rock	21,175	23,293		
			23,293	To be backfilled with NAG from Mill
Mill area hydrocarbon contaminated waste rock	7,959	8,378		To be placed at the top near surface and under the cover
			8,378	To be backfilled as needed consistent with regrading plan with NAG from Mill
Mill area Special Waste- Metals	2,076	removed offsite		Special waste to be transferred and disposed from the site - Ft. Nelson
Upper mill road PAG waste rock	6,196	6,816		
			6,816	To be backfilled with NAG from Mill

Material	Volumes (m^3)			Comments
	Insitu (m^3)	Relocated to Within Containment Portion of Pit (lcm)	Relocated as Construction Material (lcm)[1]	
Upper mill road hydrocarbon contaminated	1,303	1,372		To be placed at the top near surface and under the cover
			1,257	To be backfilled with NAG from Mill as needed consistent with regrading plan
Mine road from camp to Open Pit PAG waste rock	8,300	9,130		Regrade area as needed
Mine road berm PAG from camp to Open Pit PAG waste rock	1,000	1,100		Regrade area as needed
Mine road hydrocarbon contaminated material from camp to Open Pit	0	0		To be placed at the top near surface and under the cover, regrade area as needed.
Explosives Storage (Nitrogen)	128	154		
			154	To be backfilled with NAG from Mill as needed consistent with regrading plan
Mill Area NAG waste rock	130,000		18,907	To be crushed and relocated to Dome Creek TSF area as granular fill (1.2 m thick)
				Balance of 124.093 will be used in regrading where PAG and contaminated soils have been removed from mill area / upper Dome Creek Valley or left in place
Campsite NAG waste rock	not determined			No net cut or fill, material will be used to regrade area as needed
Road NAG waste rock	not determined			No net cut or fill, material will be used to regrade area as needed
Contaminated demolition waste (wood, drywall gypsum, masonry)[2]	n/a	300		
Concrete demolition waste[2]	2,600		3,000	This material is not considered contaminated. Depending on schedule, this may be located within the rim of the Open Pit.
Interim cover granular filter (300 mm thick well graded gravel and sand)	24,000		26,400	
Victoria Creek well graded silty sand	80,000		88,000	To form a 1 m thick barrier layer in interim cover
Offsite sand borrow	24,000		26,400	To form a 300 mm thick sand cushion layer in the final cover, likely not worth processing and then stockpiling for 5 to 10 years
Offsite borrow, coarse sand	24,000		26,400	To form a 300 mm thick sand drainage layer in the final cover, likely not worth processing and stockpiling for 5 to 10 years

Material	Volumes (m^3)			Comments
	Insitu (m^3)	Relocated to Within Containment Portion of Pit (lcm)	Relocated as Construction Material (lcm)[1]	
Offsite fine borrow	24,000		26,400	To form a 300 mm thick vegetative layer in the final cover, could source from dam fill but may not be worth stockpiling for 5 to 10 years
Offsite cobble borrow			1,000	D50>15 cm for diversion Dome Creek channel erosion protection
Offsite cobble borrow			1,000	D50>15 cm for diversion ditch erosion protection

Notes:

1. *lcm = loose cubic metres. Total is this column is greater than insitu volume to account for bulking that needs to be considered for transportation.*
2. *Demolition waste volumes are based on a significant amount of recycling. This requires further assessment in the next phase of design to confirm feasibility given the remote northern location. The disposition of the demolition waste onsite will then require further refinement.*

4.8 Design Contingencies and Adaptive Management Plans

Design contingencies are considered to be measures that are implemented during construction to address conditions that are encountered that are different than assumed in the base case design. Conversely, adaptive management plans are plans that are in place to handle performance outcomes after construction is complete that are different than expected.

The key risks related to the relocation and placement of materials to the Open Pit that may require implementation of design contingencies during construction are listed below. Note that risks related to water quality aspects are discussed in Section 5.5.

- Tailings do not dewater as anticipated resulting in a significant volume of tailings that remain highly saturated and need to be transported wet to the Open Pit.
- Increased volumes of materials requiring storage in the Open Pit. This could occur because there is more material to be excavated than expected; for example if a significant portion of the dam does require relocation to the Open Pit, because the depth of insitu soils to be removed are greater than expected, or because the placed densities that are achieved are lower than assumed.

There are several contingencies that can be implemented during construction to deal with larger than anticipated volumes of highly saturated tailings that need to be transported from the tailings facility. The entire inventory could be moved wet through the use of temporary dams in the back of the trucks. The total load including the retention dam and the material behind would be dumped for every load. Material would be end dumped into the pit or placed from the bottom up using cell construction. In either case, additional NAG buttressing would likely be required to support the wet tailings.

A better management plan may be to incorporate additional PAG waste rock with the tailings to improve the consistency of the material. The volume of PAG waste rock that requires storage in the Open Pit somewhat exceeds the volume of tailings and, therefore, the two materials could be mixed at a ratio of 1:1 or more. Given the unsaturated nature of the PAG, this would significantly reduce the saturation of the blended material. The volume of PAG that requires double handling would increase and there would be a greater volume of tailings dominated material that requires placement in the backfilled Open Pit. This, in turn, may then require larger NAG buttresses to provide the increased storage, increasing the overall footprint of the backfilled Open Pit landform.

Another alternative would be to consider a switch to winter excavation to take advantage of the moisture to freeze some of the tailings prior to excavation and to improve trafficability in the tailings area. The technical concern with winter excavation, however, is that this will result in uncontrolled placement of material in frozen lumps with snow and ice unavoidably incorporated in the backfill. The air temperature trends for the last several decades suggest that the backfill will thaw slowly, resulting in long ongoing settlement and continual release of water into the tailings. This method does not appear to be the best contingency plan; however, it should be considered in more detail should the situation arise. Winter excavation would also require different equipment than summer excavation.

With regards to performance outcomes, a key risk with regards to the pit backfill that requires an adaptive management plan is that the backfilled pit settlement is greater than expected and/or takes longer than expected. There are also a variety of risks related to the water quality resulting from pit seepage. The latter issues are discussed in Section 5.5.

Longer and/or larger than expected settlement of the backfilled pit would be managed through maintenance of the interim granular cover and delayed placement of the final cover system. Maintenance would include regrading to promote surface runoff, placement of additional material to repair cracks, etc. This approach is only valid if settlements occur over the time period before there is a concern related to the waste rock and tailings turning acidic. As discussed in Section 5.1, however, the geosynthetic cover is an important barrier to limit the development of acidic drainage from tailings or waste rock. If large settlements continue into the period where there is a need to provide this barrier, then adaptive management would include the placement of a sacrificial geosynthetic cover or else collection and treatment of seepage as discussed in Section 5.5.

5 WATER QUALITY MANAGEMENT PLAN

The purpose of the water quality management plan is to quantitatively evaluate the proposed base case remediation design for Mount Nansen as described in Section 2.2, to predict the resulting water quality parameters at a selected target location for meeting the CCME guidelines downstream of the site in Victoria Creek and to provide recommendations for monitoring water quality both during and after remediation. The predicted water quality parameters are compared against CCME guidelines for compliance. The water quality management plan is evaluated using a water management/quality model (water quality model) developed in GoldSim.

5.1 Water Quality Modelling

The water quality model is used to evaluate the existing conditions at the site and the long-term performance of the base case remediation design. The model is developed to meet the following objectives:

- estimate mass loading and water quality from the Site as it discharges into Victoria Creek;
- evaluate the mass loading and water quality in Pony and Dome Creeks and direct groundwater discharge;
- predict water quality (particularly focusing on parameters of concern that include sulphate and metals (As, Cd, Cu, and Zn)) at the point of compliance and determine whether water quality will meet CCME guidelines;
- estimate surface water flow rates at select points;
- estimate groundwater flow rates;
- provide the basis for assessing requirements for water treatment and estimate water quantities and quality; and
- provide a quantitative understanding of the key input parameters which affect the resulting water quality through sensitive analysis.

The model is calibrated based on the existing site conditions.

5.1.1 Conceptual Model

An important step in developing the water quality model for Mount Nansen was to develop a conceptual model. The conceptual model captures the understanding of the key features, events and processes that define the current understanding of existing Site and how the Site is expected to respond when the proposed remediation measures are implemented. The schematic of the conceptual water management/quality model is presented in Drawings D023 and D024.

The following is the characterization of the conceptual model for Mount Nansen:

- Key spatial features
  - Contaminant sources

- Mill area;
- Tailings storage facility;
- Waste rock area; and
- Open Pit.

– Discharge and conveyance

- Dome Creek;
- Pony Creek;
- Back Creek; and
- Groundwater.

– Target location for meeting the CCME guidelines

- Victoria Creek.

- Temporal parameters
  - existing, remediation and post-remediation periods;
  - monthly time step;
  - total model coverage 30 years; and
  - average year, 1 in 100 year dry and 1 in 100 year wet conditions.
- Key Model Assumptions
  - Basis of the model is conservation of mass.
  - No attenuation (except for arsenic) is taken into account between the source of loading and the resulting water quality downstream. Simple mixing of flow and mass loading is used to estimate water quality.
  - The net flow at each model node is zero, meaning that the sum of inflows and outflows at each node are equal.
  - No memory or lag in the system is assumed, meaning that loading generated in a period of a month (timestep) is assumed to reach the target location for meeting the CCME guidelines within the same month.
- Quantification of input parameters
  - Key input parameter, include:
    - geometry;
    - water quantity (hydrology and hydrogeology);
    - water quality;
    - material quantities; and
    - source terms.

GoldSim is then used to solve the mathematical model.

5.1.2 GoldSim Model

GoldSim is a visual and dynamic modelling platform which allows for intuitive construction and presentation of the model relative to the problem being simulated. The GoldSim program is also inherently a dynamic simulator, allowing for ease of evaluation of time series data. Although GoldSim provides the stochastic modelling option, at this stage, the model is evaluated within the boundaries of a deterministic case.

The hierarchical nature of GoldSim and use of containers allows the construction and presentation of the model starting with the broad and bigger picture and revealing each detail one step at a time (top-down approach). This works well for a water balance model which is used by various people from different disciplines and interests, as it provides the users with the flexibility of focusing and looking only at elements of the model or model results that are relevant to them.

The GoldSim model was modified from an earlier version prepared by Gomm Environmental Engineering Consultants (GEEC) in 2011. The GEEC model version was designed to compare the relative differences between different remedial options over a 12 month period. The current version of the model is set up to run existing site conditions, followed by remediated conditions for the proposed option (i.e. Option 4). It is based on elapsed time for 30 years on a monthly time step. Measured data from 2010 to 2013 are used to calibrate the model.

5.1.3 Detailed Layout of the Model

The following section provides a detailed layout of the model and presents the main model hierarchy. The model has the following main containers:

- Global Parameters – contains most of the inputs.
- WQ Results – contains the results of the model.
- The Existing Conditions and Proposed Design containers are localized containers that hold all the elements of the water balance and load balance and are the main working engines of the model. Further details are provided below. The second level of the Existing Conditions and Proposed Design localized containers holds the water balance and the load balance.
- Continuous Conditions – merges the proposed design with the existing conditions water balance and load balance. The second level of the continuous conditions contains water balance, loadings and concentrations.
- Model controls – contains dashboards which are used for controlling the model. The advantage of the dashboard is that it allows anyone to use the model without requiring a detailed understanding of the model’s workings.

5.1.4 Model Inputs

This section presents all the model inputs, their sources, and any analyses performed on the data to prepare it for input. Table 5.1 presents the GoldSim input parameters.

Table 5.1: Summary of Input Parameters for GoldSim Model

	Input Parameters	Note
Conceptual Model		
	Existing Case	Dome Creek, Open Pit, Pony Creek and Tailings area
	Proposed design	
	Model duration	
	Model time step	
Hydrology		
	Annual precipitation	
	Monthly precipitation distribution	
	Snow accumulation	
	Monthly snowmelt fraction	
	Monthly evaporation	
	Sublimation	
	Runoff coefficients	
	Waste rock infiltration	
	Catchment area	
Hydrogeology		
	Groundwater inflow into Open Pit	Considered in net outflow calculations from pit. Discrete inflow not included in pit. Can be updated in next phase if warranted.
	Fraction of groundwater to Dome Creek	
	Fraction of groundwater to Victoria Creek	
Open Pit and Cover		
	Cover placement time	
	Cover footprint area	
	Cover infiltration	
	Cover flushing factor	
	Tailings volumes	
	Waste rock volumes	
	Waste rock void space	
	Ore volumes	
	Tailings drainage time	
	Fraction of consolidation drainage to the pit bottom	
	Flushing factor	
Geochemistry		
	Source terms from the pit	Loadings of waste rock, ore, and tailings in non acidic and acidic
	Parameters of interest	Arsenic, cadmium, copper, iron, manganese, zinc, sulphate, ammonia, calcium, magnesium, nitrate, nitrite, ammonia, total cyanide, WAD cyanide, and cyanate
Water Quality		
	Water quality data from the existing monitoring points	Source terms from non-pit area
	Parameters of interest	Arsenic, cadmium, copper, iron, manganese, zinc, sulphate, ammonia, calcium, magnesium, nitrate, nitrite, ammonia, total cyanide, WAD cyanide, and cyanate

Simulation Settings

The model is set up to run on a monthly time step on an elapsed time basis for 360 months (30 years). It models existing conditions for 12 months, at which time it switches to Option 4. The model run time can also be adjusted by the user.

Hydrology Input Parameters

The primary purpose of the hydrology input parameters is to estimate meteoric water sources in the model. Quantifying water sources is key to estimating the resulting concentrations of water quality parameters at the discharge and compliances points. As identified in Table 5.1, the main hydrological inputs to the model are precipitation, snowmelt, evaporation, runoff coefficients and catchment areas.

Precipitation

Precipitation values for the site were estimated on a monthly basis over a period of 30 years which corresponds to the total duration of the model. The Site precipitation data were estimated over a historical period from 1964 to current. Data from 2000 to current were based on actual data collected onsite. Since no consistent Site data are available from 1964 to 2000, Carmacks data were transposed to Mount Nansen.

For the purpose of modelling, the generated historical data were assumed to be representative of future precipitation.

Additional precipitation input for the model included the 1 in 100-year dry (192 mm), mean year (310.6 mm) and 1 in 100-year wet (522 mm). These parameters were estimated using statistical analyses of the historical data as presented in the Site Characterization Report (AMEC, 2014). The monthly distribution of precipitation used in GoldSim is presented in Table 5.2.

Table 5.2: Mount Nansen Average Monthly Distribution of Precipitation

Month	Monthly Distribution
Jan	0.038
Feb	0.020
Mar	0.029
Apr	0.051
May	0.074
Jun	0.178
Jul	0.211
Aug	0.153
Sep	0.116
Oct	0.058
Nov	0.035
Dec	0.036
Total	**1.0**

Snowmelt

The model assumes that all precipitation that falls between November 1 and March 31 is snow that remains on the ground. It is assumed that there is no runoff from November 1 to March 31. The accumulated snow is assumed to melt from April to June, which contributes to runoff. Accumulated snowpack on April 1 for average, dry and wet years is shown in Table 5.3 and is derived from (AMEC, 2014). It is assumed that 20% of the total snowpack is lost due to sublimation and the remainder contributes to runoff from April to June as presented in Table 5.4.

Table 5.3: April 1 Snowpack for 100 Year Wet and Dry Return Periods

Return Period	Snowpack on April 1 (mm)
1 in 100 Dry	41.6
Average	67.3
1 in 100 Wet	113.1

Table 5.4: Snowmelt Release Rate

Month	Percent of Net Snowpack Released
April	25%
May	50%
June	25%

Evaporation Data and Sublimation

Evaporation for the Mount Nansen site was estimated using regional data from Pelly Ranch as presented in Table 5.5. The data were adjusted for altitude and latitude. According to Coulson et al. (1998), evaporation rates decrease by approximately 10% for every 350 m of elevation increase. Evaporation also decreases by approximately 6% for each degree increase in latitude.

Table 5.5: Monthly Annual Lake Evaporation

Station	Estimated for Mount Nansen
Month	**Lake Evaporation**
Jan	0
Feb	0
Mar	0
Apr	0
May	90
Jun	100
Jul	93
Aug	67
Sept	32
Oct	0
Nov	0
Dec	0
Annual	**382**

Runoff Coefficients

Runoff coefficients were used based on precipitation and flow data on the Site from 2009 to 2012. Two sets of runoff coefficient were estimated, for pit walls and for the rest of the Site. Runoff coefficients are presented in Table 5.6. It was assumed that there is no runoff from November to March hence the runoff coefficient for those months were set to zero.

Table 5.6: Runoff Coefficients

Month	Pit Walls	Rest of the Site
Jan	0	0
Feb	0	0
Mar	0	0
Apr	0.9	0.2
May	0.9	0.2
Jun	0.9	0.2
Jul	0.9	0.4
Aug	0.9	0.6
Sept	0.9	0.5
Oct	0.9	0.5
Nov	0	0
Dec	0	0

Catchment Areas

The catchment areas used for the model are shown on Drawing D025. The catchment areas are presented in Table 5.7.

Table 5.7: Catchment Areas for Existing Configuration

Catchment Area Name	Node Name	Catchment Area (m^2)
Dome Creek Headwaters	DX	510,000
Dome Creek downstream of Mill Area	D1	1,219,193
Dome Creek upstream from tailings facility	DC-U2	2,320,000
Dome Creek downstream from tailings facility	DC-U (or DC-M)	3,560,000
Dome Creek at the road	DC-R	4,740,000
Dome Creek at Victoria Creek	DC1	4,860,000
Pony Creek upstream from Open Pit	PCU	680,000
Pony Creek downstream from Open Pit	PCD	1,050,000
Pony Creek upstream from Back Creek	PC-US-BC	1,380,000
Back Creek upstream from Pony Creek	BC-US-PC	7,250,000
Back Creek upstream from Victoria Creek	BC-US-VC	9,960,000
Victoria Creek upstream from Back Creek	VC-US-BC	64,350,000
Victoria Creek upstream from Dome Creek	VC-US-DC	80,563,000
Tailings facility catchment area	TP	120,000
Tailings facility pond area	TPW	25,000
Tailings facility beach area	TPB	68,000
Seepage pond catchment area	SP	88,000

Catchment Area Name	Node Name	Catchment Area (m^2)
Open Pit catchment area		63,107
Open Pit area		20,380
Pit pond area		3,254
Waste rock to Dome Creek		98,651
Waste rock to Pony Creek		4,325
Ore stock pile		862
Proposed Final Pit Cover Area		36,253

Hydrogeology

Open Pit Pond Groundwater Exchange

Pit pond level data, as recorded by the in-pond data logger, provided pond levels from August 2010 to June 2013, inclusive, which included three wintertime periods and pond level recession curves. These pond level data were analyzed to identify the following:

- the pond elevation relationship to groundwater inflow/outflow daily rates, as derived from water balance, i.e. the pond water 'head' dependency, if any; and
- the time relationship to groundwater inflow/outflow daily rates, as derived from water balance, i.e. seasonal dependency, if any.

The pond elevation and pond water temperature data are shown on Figure 15, as variables compared to daily groundwater inflow (positive values) and daily groundwater outflow (negative values). Note, the conversion for in-pond logger data from water level to elevation is not final; therefore, the pond elevations that follow are subject to possible minor adjustment.

Figure 15 Daily Groundwater Inflow/Outflow Vs Pond Elevation and Water Temperature

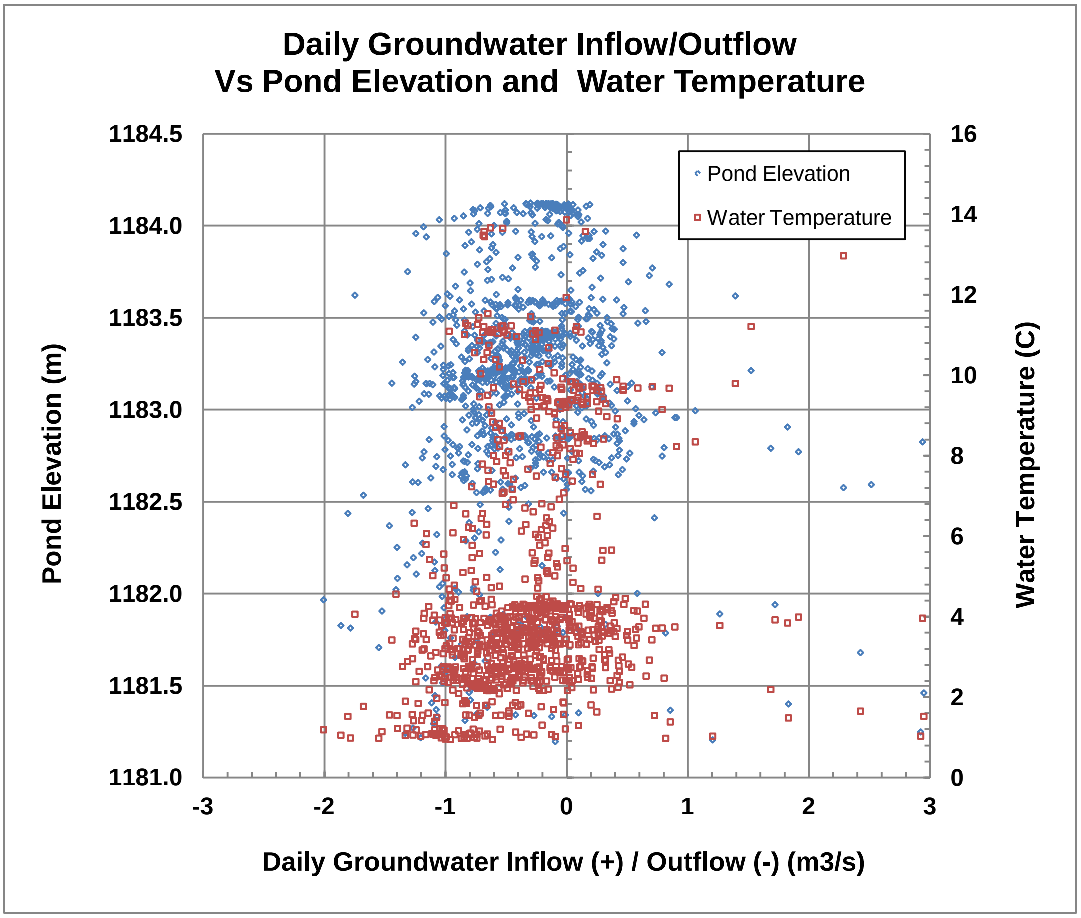
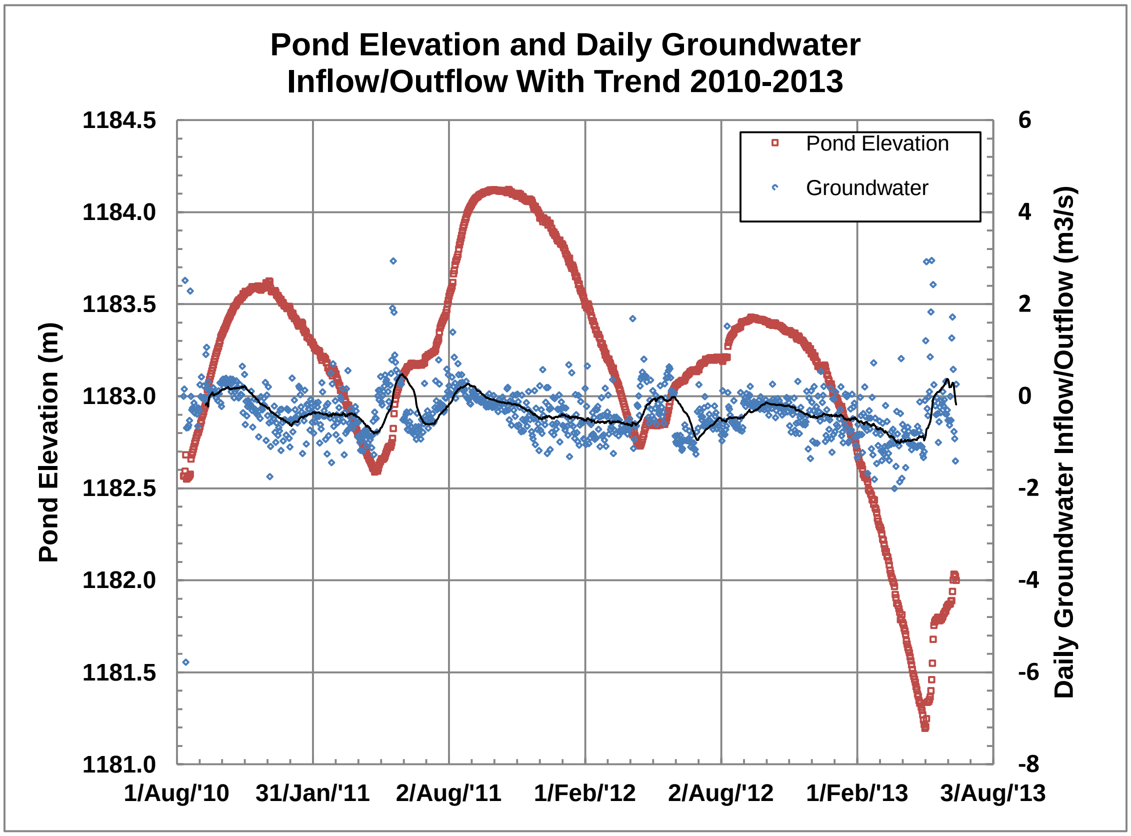


Figure 15 indicates the following:

- a correlation between the pond elevation and groundwater inflow/outflow values is not apparent, inferring the groundwater exchange with the Open Pit pond is not significantly controlled by pond elevation, i.e. water ‘head’, applicable to the range of pond level data, i.e. pond elevations 1,181 to 1,184 m; and
- a cluster of groundwater outflow points is associated with cooler water temperatures, inferring that the daily groundwater inflow/outflow parameter is more discernible in the wintertime data.

The annual periodicity of pond storage increases from the addition of water from the freshet, direct precipitation and runoff within the Open Pit catchment area, as shown on Figure 16, which shows pond elevation and daily groundwater inflow/outflow data for the 2010 to 2013 data period.

Figure 16: Pond Elevation and Daily Groundwater Inflow/Outflow With Trend 2010 to 2013

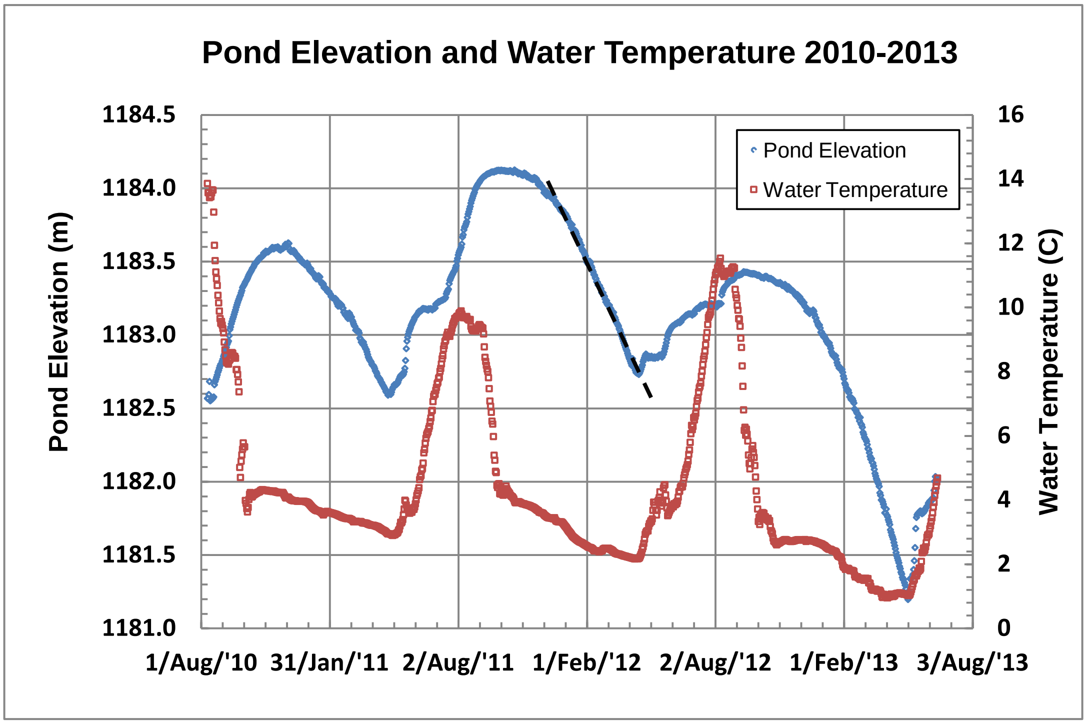


Annual pond elevation peaks for the August 2010 to June 2013 data period, occurred from September to November, followed by pond elevation declines with high linearity, through winter until the commencement of the following annual freshet and other surface sources. As the pit pond does not freeze to bottom, daily water levels were recorded for the three year data period.

One additional water source, not quantified to-date, with a bearing on the water balance is groundwater originating from Pony Creek that moves, via shallow bedrock, into the Open Pit. This was first documented in 2004, observed as wintertime icing on the north pit wall above the pond level. This Pony Creek seepage water reports to the north pit wall and potentially biases (positively) the derived groundwater inflow/outflow parameter, i.e. decreasing the apparent groundwater outflow and introducing groundwater inflow.

The linear declines in wintertime pond elevation, when the pit walls were frozen, were used to more selectively quantify groundwater leaving the Open Pit pond. Figure 17 shows pond elevation and water temperature for the data period and the linear wintertime pond elevation declines.

Figure 17: Pond Elevation and Water Temperature 2010 to 2013



Data points were picked for each of linear pond elevation decline, corresponding to the winters of 2010/2011, 2011/2012 and 2012/2013. These gradient values were factored for pond area and time to derive rates for groundwater loss, as shown in Table 5.8

Table 5.8: Wintertime Pit Pond Groundwater Outflow Rates

Data Period	Groundwater Outflow Volumes and Rates		
	m^3	m^3/day	L/s
February 25, 2011 to April 24, 2011	1,627	28.0	0.32
January 30, 2012 to April 11, 2012	2,603	36.2	0.42
February 10, 2013 to May 3, 2013	4,555	55.5	0.64
			Average 0.46 L/s

Groundwater Outflow Model Input

A previously-reported water balance, applicable to the Open Pit (Mount Nansen Site Characterization Report, AMEC, 2014), determined an average groundwater rate leaving the Open Pit of 0.5 L/sec. This finding was updated with local catchment and pit wall runoff coefficients that accounted for snow sublimation and also barometrically-compensated the pit pond level data. A revised water balance analyses derived an average groundwater outflow rate of 0.3 L/sec, applicable to the Open Pit pond for the August 2010 to June 2013, inclusive, climatic and pond level data period.

In the second method of quantifying pond water outflow described above, the annual recession portions of the pit pond level data were analyzed. Annual pond elevation peaks for the August 2010 to June 2013 data period, occurred each September to November followed by pond elevation declines with high linearity through winter until the following annual freshet and other surface inputs. As the pit pond does not freeze to bottom, these decline portions of the pond levels data were analyzed giving groundwater-only outflow rates averaging 0.4 L/sec.

An obvious correlation between pond level data and the daily derived groundwater outflow values is not apparent. This observation suggests that the rate of water leaving the Open Pit pond is not discernibly controlled by pond elevation (pond ‘head’), within the range of the pond level data, i.e. pond elevations 1,181 to 1,184 m.

From the water balance and pond recession methods of pond loss analyses, water leaving the Open Pit, as groundwater, was quantified as being in the 0.3 to 0.4 L/sec range, applicable year round. A value of 0.3 L/sec was used for the current GoldSim design.

Open Pit and Cover

Geometry and Volumes

The backfilled Open Pit and reclaimed Dome Creek will have the following geometrical characteristics that were included in the GoldSim model:

- pit footprint area for seepage into the pit = 36,000 m^2;
- waste rock platform area (seepage directly from the tailings into the waste rock platform) = 10,000 m^2;
- final cover area = 54,000 m^2 (surface area) or 44,000 m^2 (plan area). Approximately 1/3 of the area discharges water towards Pony Creek and 2/3 of the area discharges water towards Dome Creek;
- final NAG area outside the Open Pit = 10,000 m^2. The rest of the current waste rock area will be reclaimed to original ground; and
- reclaimed area of Dome Creek valley covered with 1 m of NAG = 50,000 m^2

Approximately 391,550 m^3 of waste rock material and 243,000 m^3 of tailings will be transferred to the pit. It was estimated that 43,875 m^3 of rock will be placed as filling material beneath the tailings, and the remaining waste rock will be placed above the tailings. The estimated volumes of material intended for transfer to the pit is presented in the Table 5.9.

Table 5.9: Estimated Volume of Rock from the Waste rock area, Road and Mill Area

Location	Waste rock area Sectors	Destination	Volume	PAG		Non-PAG	
			m^3	%	m^3	%	m^3
Waste rock area	North West	Inside the pit	156,417	52.4	81,933	47.6	74,484
	East	Inside the pit	20,000	37.5	7,500	62.5	12,500
	South Dump	Outside the pit	81,600	5.9	4,800	94.1	76,800
	South West Upper	Outside the pit	75,494	0.0	0	42.9	32,355
	South West Lower	Inside the pit	46,500	50.0	23,250	50.0	23,250
	West Lower	Outside the pit	86,000	15.4	13,231	84.6	72,769
	West Middle	Inside the pit	129,901	42.1	54,695	57.9	75,206
	Old Ore	Inside the pit	1,812	83.3	1,510	16.7	302
Road		Inside the pit	15,920	100	15,920	0	0
Mill Area		Inside the pit	21,000	100	21,000	0	0
Total		Inside the pit	391,550		205,808		185,742
		Outside the pit	243,094		18,031		181,924

Tailings Seepage

Seepage from the tailings will occur as a result of dissipation of construction induced pore pressures and gravity drainage as the tailings desaturate. Both processes are controlled by the hydraulic conductivity of the tailings. For excess pore pressures to develop consolidation to occur, the tailings need to have a relatively low hydraulic conductivity. A reasonable estimate of consolidation water flux is, therefore, based on an upper bound hydraulic conductivity that would allow consolidation to occur and then calculating the flux for a unit hydraulic gradient. This results in a flux of $10^{-8} m^3/s/m^{2.}$ Accounting for the contributory area of the pit, a reasonable estimate for consolidation water flux is in the order of 0.1 to 0.2 L/s. It is expected that consolidation could take about five years to occur.

Seep/W modelling was completed to estimate the flux from the tailings due to unconstrained gravity drainage. The analyses are summarized in Section 4.6.3 and are presented in Appendix C. As a result of the analyses, the following estimates of potential gravity drainage were developed:

- best estimate: Average instantaneous flux from total pit: 0.2 L/s occurring over five years;
- upper bound estimate: Average instantaneous flux from total pit: 1.2 L/s occurring over one year; and
- lower bound estimate: Average instantaneous flux from total pit: 0.09 L/s occurring over more than 10 years.

Geochemistry (Source Terms)

Mining material intended for relocation to the pit includes waste rock and ore from the waste rock area, tailings from the tailings impoundment facility, and contaminated rocks and soil from the road and mill area. The relocation needs to be assessed in terms of impact upon water quality downstream of the pit. A source term was developed to account for the material to be placed in the pit.

This section provides additional details and describes the data sources and assumptions used in the development of source terms.

Volume of Waste Rock and Tailings

The estimated volumes of material intended for transfer to the pit are presented in Table 5.9. An important factor in source term estimation is to determine the proportions (tonnages) of acid generating rock from the existing waste rock area and the other locations. Source term development requires an assessment of the existing acid base accounting (ABA) data for rock samples collected from the project area. ABA data is used to identify potentially acid generating (PAG) and Non-PAG rock and estimate the relative volumes.

Assessment of the potential for a sample to generate acidity is defined by the neutralization potential ratio (NPR), which is the ratio of the acid potential (AP) to neutralization potential (NP), and NPR = NP/AP. An NPR of 2 was used as a threshold value to classify PAG and non-PAG rock in the waste rock area. Rock samples with NPR<2 were classified as PAG. Rock samples with NPR>2 were identified as Non-PAG. It was assumed that the number of samples is representative of the volume of waste rock present in the waste rock area and the other area. It may not always be practical to separate PAG material from Non-PAG. Waste rock composed of a minimum 20% PAG rock or greater will be relocated to the pit.

Loading Rates of the Parameters of Interest

Tailings

Loading rates from tailings were determined from humidity cell testing that was initiated in 2009 and had been running for 98 weeks (LORAX, 2012). The tailings samples were distinguished by particle size representing sand-silt, silt-clay, and clay. A corresponding sample which had NP depleted pre-treatment were also set up for humidity cell testing. However, the NP depleted humidity cells were operational for only 58 weeks.

The rates were determined using the relatively steady portion the experimental data in the later period of the testing. The non acidic tailings condition was represented by the three untreated samples while the acidic condition was represented by rates obtained from the cells with the NP depleted samples. Proportional rates were calculated from the humidity cell test results based on the assumption that 60 to 70% of the tailings are composed of coarse material.

A single loading rate was used to represent best and worst cases. The summary of rates for the parameter of interest is presented in Table 5.10.

Table 5.10: Loadings Rates of the Parameters of Interest for Tailings

Parameters	Non Acidic Condition		Acidic Condition	
	Loading Rates	Concentrations	Loading Rates	Concentrations
	mg/kg/week	mg/L	mg/kg/week	mg/L
Arsenic	0.020		3.352	
Cadmium	0.001		0.028	
Copper	0.004		0.418	
Iron	0.003		97.1	
Manganese	0.004		0.117	
Zinc	0.015		1.704	
Sulphate	16.676		332.5	
Calcium	8.649		1.249	
Magnesium	1.870		0.325	
Ammonia		6.5		6.5
Nitrate		3		3
Nitrite		0.3		0.3
Total Cyanide		0.07		0.07
WAD Cyanide		0.03		0.03
Cyanate		2		2

Waste Rock and Ore

In the absence of laboratory kinetic testing for waste rock and ore, the expected loading rates were derived from site water quality data, which included waste rock area drainage, lysimeters in the waste rock area, and field bin kinetic test results. The monitoring was mainly performed in the 2009 and 2010 sampling program. One sample was collected during the site investigation conducted in September 2013.

The water quality of drainage from the waste rock area was assumed to represent the non acidic condition. As such, the loading rate calculation was based on the estimated tonnage of material in the waste rock area and the estimated seepage volume. Best estimates were derived from the mean concentration while the worst case scenario was based on the 90th percentile.

There was limited data directly related to the ore, hence, the data from the waste rock drainage were used to calculate loading rates. Best estimates and the worst case scenario were based on the 90th percentile and maximum concentrations, respectively.

The presence of PAG rock was confirmed in the waste rock, and ore. ABA samples indicate a possibility for ARD. Drainage from the waste rock area is consistently circum-neutral with respect to pH and the average sulphate concentration is 1,300 mg/L. This evidence indicates that sulphide oxidation is occurring but there is currently adequate neutralization potential to prevent the onset of acidic drainage from the waste rock area. Since acidic loading rates are not yet available from the current data, the source term representing the full acidic condition is assumed to have loading rates three times higher than the current waste rock area drainage loading rates.

A select summary of loading rates from the waste rock and ore is presented in Table 5.11.

Table 5.11: Selected Loadings Rates for Waste Rock and Ore

Parameters	Waste Rock Non Acidic Condition		Waste Rock Acidic Condition		Ore Non Acidic Condition		Ore Acidic Condition	
	Base Case	Worst Case	Base Case	Worst Case	Base Case	Worst Case	Base Case	Worst Case
	mg/kg/week		mg/kg/week		mg/kg/week		mg/kg/week	
Arsenic	2.65E-06	4.87E-06	7.96E-06	1.46E-05	4.87E-06	9.80E-06	4.87E-06	9.80E-06
Cadmium	1.69E-05	5.92E-05	5.07E-05	1.78E-04	5.92E-05	7.95E-05	5.92E-05	7.95E-05
Copper	1.88E-05	7.64E-05	5.63E-05	2.29E-04	7.64E-05	9.72E-05	7.64E-05	9.72E-05
Iron	1.17E-05	2.25E-05	3.50E-05	6.74E-05	2.25E-05	1.52E-04	2.25E-05	1.52E-04
Manganese	0.003	0.010	0.010	0.031	0.010	0.042	0.010	0.042
Zinc	0.002	0.010	0.007	0.030	0.010	0.015	0.010	0.015
Sulphate	0.575	0.881	1.726	2.642	0.881	1.270	0.881	1.270
Calcium	0.155	0.201	0.052	0.067	0.201	0.234	0.067	0.078
Magnesium	0.079	0.120	0.026	0.040	0.120	0.211	0.040	0.070

ARD Onset Time

The static test results indicate that the tailings are PAG. Based on the sulphide content of the tailings and NP depletion calculation from the humidity cell test results, it is expected to take less than 25 years for the clay tailings to generate acidic leachate under laboratory conditions, and as low as 6.4 years in the silty-sand tailings (LORAX, 2012). This ARD lag time for the tailings is expected to be longer at the field condition since the actual rate is expected to be much lower.

Since only limited field kinetic testing data are available for the waste rock, there is not yet enough information to calculate sulphide and neutralization potential depletion for the PAG waste rock to predict when the onset of acidic conditions will occur.

Oxygen Transfer

As part of the remediation program, the pit will be covered with the temporary granular sand cover and then the permanent geosynthetic cover will be placed over top once the tailings have drained. The temporary granular sand cover may reduce the infiltration into the pit, but it will have limited capability in reducing the oxygen entry. The performance of the geosynthetic cover is expected to be better in reducing infiltration and oxygen entry.

The approach used in the loading calculation accounts for the oxygen availability due to the cover placement. The loading of acid generation and metal leaching is assumed to be dependent on the rate of sulphide oxidation with pyrite as the primary sulphide bearing mineral in PAG rock and tailings. The predicted acid generation from the waste rock and tailings was governed by the following chemical reaction equation.

$$FeS_2 + H_2O + 7/2\ O_2 \longrightarrow 2\ H^+ + 2\ SO_4^{2-} + Fe^{2+}$$

Oxygen is transferred into the interior of the cover system by air diffusion and infiltrating water. Diffusive airflow through the cover was estimated using Fick's law which postulates that the oxygen concentration gradient is the driving force as shown in the following equation.

$$J = -D_e \frac{dC}{dz}$$

where J = diffusive flux of oxygen J ($mg/m^2/s$);
D_e = effective diffusivity (m^2/s);
dC = concentration gradient (mg/m^3); and
dz = thickness of cover (m).

The diffusion of oxygen through the cover was calculated as a function of the internal and external oxygen content in the pile (C/Co). Oxygen will pass through the waste rock layer first, and then the remaining unconsumed oxygen will continue to pass through the tailings layer. Sulphate and metal loadings from the waste rock and tailings layer were derived from the respective oxygen consumption rates.

Additional assumptions used for the oxygen diffusion and loadings calculations are as follows:

- the effective diffusivity, De, of the temporary sand cover was assumed to be $7.7x10^{-7}$ m^2/s and De of the geosynthetic layer was assumed to be $9.47x10^{-08}$ m^2/s (Aubertin et al., 2000);
- the oxygen content in air is 30,000 mg/m^3 and the oxygen concentration of infiltrating water is 10 mg/L;
- the diffusive flux through the cover was calculated as a function of the internal and external oxygen content (C/Co) on a yearly basis. A C/Co ratio of 0.9 and 0.65 was assumed for the sand cover and the geosynthetic cover, respectively;
- no oxygen was consumed within the sand cover;
- a steady state condition was achieved and the rate of sulphide oxidation was controlled by the rate of oxygen ingress via diffusion and infiltration through the cover;
- oxygen transfer by advection was disregarded since the majority of waste rock and tailings material will be contained by the pit wall;
- all oxygen that passed through the cover was consumed first by the waste rock at the upper tailings layer and the remaining unconsumed oxygen was transferred to and consumed by the tailings;
- it was assumed that the number of ABA samples is representative of the volume of waste rock present in the waste rock area;
- the temperature influence on loading rates was applied to the model by an Arrhenius correction factor (MEND, 1996). For months with average monthly temperatures below zero, the loading rates were assumed to be 20% of laboratory rates, while for the average months with average temperature above zero, the rates were the same as laboratory rates;

- a constant loading rate was used for the waste rock and tailings; and
- the waste rock beneath the tailings was not assumed to be reactive.

Since oxygen will be transferred through the waste rock pile first and only the unconsumed oxygen will be transferred to the tailings layer, several cases were identified for the source term calculation as follows.

- Condition 1A: Temporary granular cover with non acidic condition for PAG waste rock and non acidic condition for tailings with best case.
- Condition 1B: Temporary granular cover with non acidic condition for PAG waste rock and non acidic condition for tailings with worst case.
- Condition 2A: Temporary granular cover with non acidic condition for PAG waste rock and acidic condition for tailings with best case.
- Condition 2B: Temporary granular cover with non acidic condition for PAG waste rock and acidic condition for tailings with worst case.
- Condition 3A: Temporary granular cover with acidic condition for PAG waste rock with best case.
- Condition 3B: Temporary granular cover with acidic condition for PAG waste rock with worst case.
- Condition 4: Geosynthetic cover for PAG waste rock with non acidic condition.

For acidic and non acidic conditions, the performance of each cover is same in terms of oxygen transfer.

5.1.5 Existing Water Quality

Surface water quality monitoring was performed at multiple locations across the Mount Nansen property and surrounding areas encompassing Back Creek, Dome Creek, Minnesota Creek, Pony Creek and Victoria Creek. The duration of monitoring varied from station to station. Measured concentrations from water quality samples were compared to the CCME water quality guidelines for the protection of freshwater aquatic life to identify parameters of concern. Based on reoccurring exceedances, site-wide parameters of concern were determined and include total arsenic, cadmium, copper, iron, zinc and sulphate. Despite not having a CCME guideline, sulphate was included as a parameter of interest because it is a useful indicator of ARD.

A summary of concentration for the parameters of concern at each station is provided in Table 5.12.

Table 5.12: Summary of Existing Water Quality Data

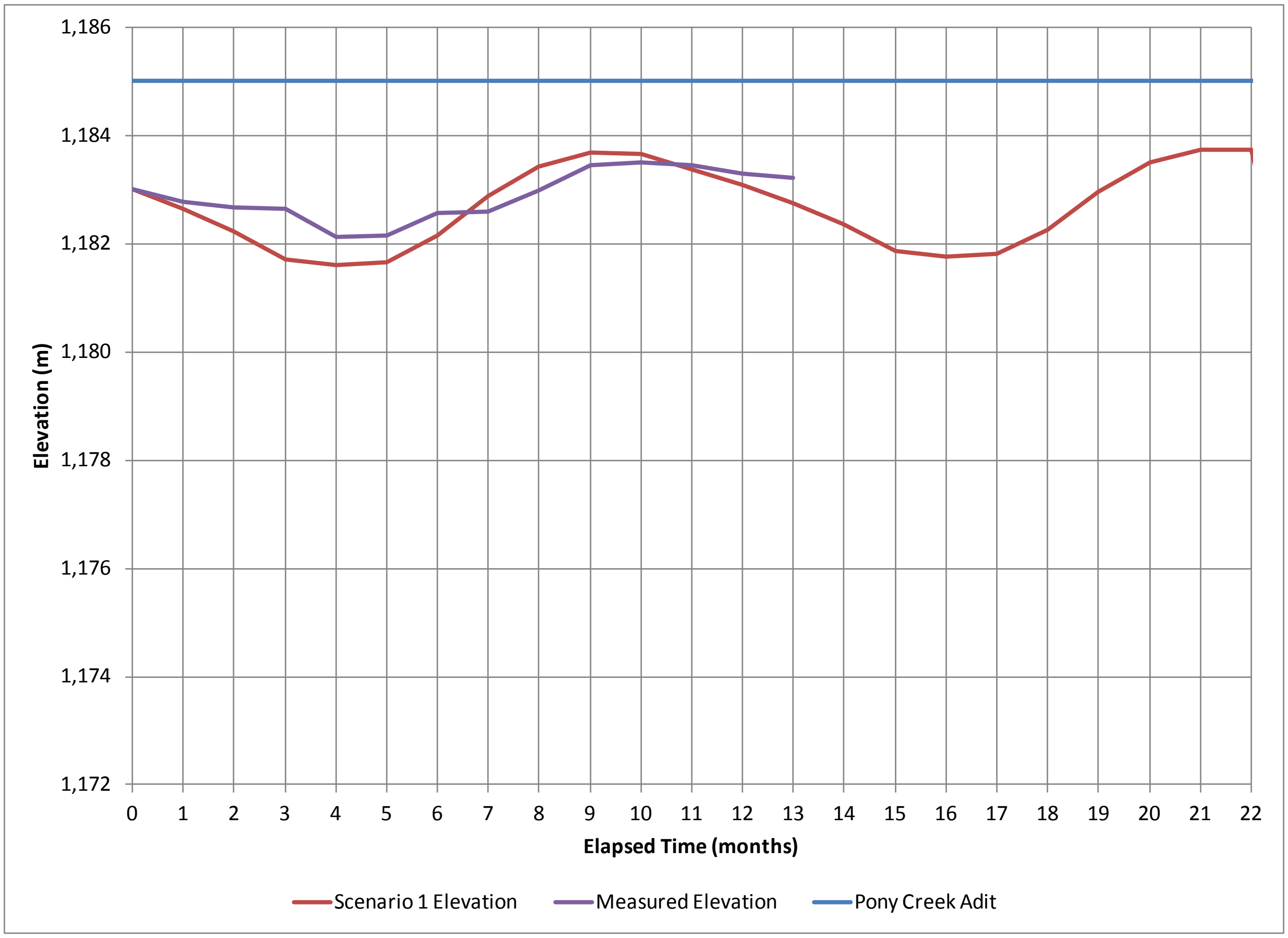
Station	Arsenic	Cadmium*	Copper*	Iron	Zinc	Sulphate
	CCME (mg/L)					
	0.005	**0.000028-0.00045**	**0.002-0.004**	**0.3**	**0.03**	**N/A**
Back Creek	0.0024-3.41	0.00017-0.0628	0.0019-1.5	0.138-995	0.0048-7.58	21-64.3
Dome Creek at D1	0.0098-0.0969	0.00188-0.00463	0.0006-0.0395	0.0124-22	0.467-1.19	162-484
Dome Creek at D1b	0.0145-0.0368	0.00183-0.00801	0.0008-0.004	0.434-3.57	0.452-1.39	512-625
Dome Creek at DX	0.0056-0.424	0.00001-0.00143	0.001-0.07	0.73-49	0.002-0.2	31.9-325
DX+105	0.0239-0.101	0.00324-0.00908	0.0005-0.016	0.137-5.2	0.564-1.5	121-494
Dome at Road	0.0198-0.0845	0.00009-0.00052	0.002-0.012	1.48-7.38	0.012-0.052	178-432
Upper Dome	0.0156-0.068	0.00016-0.00054	0.0005-0.019	3.05-12.4	0.005-0.083	235-691
Dome Creek at DC-U1-U2	0.00533-0.0768	0.00001-0.00011	0.0008-0.034	0.413-25.4	0.007-0.185	257-589
Minnesota Creek	0.0008-0.0024	0.00001-0.00006	0.002-0.005	0.639-4.06	0.002-0.013	1-5.3
WQ-MS	0.0413-0.364	0.00538-0.0299	0.001-0.0136	0.327-4.46	1.16-2.32	11-338
WQ-MS-03	0.15-0.686	0.00576-0.0201	0.0103-0.0234	6.16-14.2	1.44-2.45	448-469
Pony Creek d/s	0.00344-0.0115	0.00024-0.0054	0.003-0.013	0.01-0.398	0.02-0.591	34.9-135
Pony Creek u/s	0.00125-0.0042	0.00002-0.00005	0.0006-0.003	0.042-1.15	0.001-0.008	38.3-133
Pit-Top	0.0028-0.00967	0.00486-0.00633	0.003-0.0051	0.021-0.125	0.473-1.34	370-1120
Pit-Middle	0.0047-0.00946	0.00456-0.009	0.003-0.005	0.022-0.069	0.467-1.43	749-1120
Pit-Bottom	0.056-0.101	0.0049-0.0152	0.0006-0.0226	0.025-5.18	0.526-1.5	955-1750
Pumphouse Well	0.0002-0.0007	0.00001-0.00004	0.0002-0.002	0.002-0.013	0.0008-0.006	29-40.9
Seepage	0.0287-0.0529	0.00048-0.00071	0.0006-0.008	8.13-15.3	0.005-0.01	507-715
Tailings Pond	0.118-0.325	0.00105-0.00367	0.0194-0.116	0.293-1.72	0.08-0.823	394-1350
Victoria Creek d/s of Back Creek	0.0002-0.0113	0.00002-0.00065	0.001-0.014	0.028-13.5	0.0008-0.0382	9.2-23
Victoria Creek at Road	0.00072-0.0114	0.00001-0.00023	0.0002-0.0079	0.038-4.84	0.0011-0.022	9.1-119
Victoria Creek-Reference	0.00028-0.0124	0.00001-0.00036	0.001-0.0116	0.042-8.69	0.001-0.0382	6.9-21
Upper Victoria Creek	0.0002-0.0139	0.00001-0.00037	0.001-0.0154	0.033-9	0.001-0.0423	6.8-20.1
Victoria Creek u/s Minnesota Creek	0.00056-0.00067	0.00003-0.00021	0.0002-0.006	0.041-1.39	0.001-0.016	14-145

Exceedances in arsenic, cadmium, copper, iron and zinc were identified at most of the stations with some exceptions. For example, exceedances in arsenic, cadmium, and zinc guideline values were not reported for the Minnesota Creek and Pumphouse Well stations.

5.1.6 Model Calibration

There are three areas of the model that can be calibrated. The first was the pit water elevation, as shown in Figure 18. A good calibration for the pit water level means that the surface water balance for the pit is satisfactory and gives confidence in the surface water inputs for the remediated pit.

Figure 18: Pit Water Elevation Calibration



The second area of calibration was a check that the magnitude of simulated flows in Dome Creek and Victoria Creek were the same as measured flows. This was performed outside of GoldSim. It was satisfactory and no adjustments were made.

Finally, the simulated summer concentrations were compared to measured concentrations in Dome Creek at the Road, and Victoria Creek at the Road (surrogate for Victoria Creek downstream of Dome Creek). The comparison to Dome Creek at the Road is for reference only. The main calibration point for water quality is Victoria Creek at the Road, since all source loadings in the model are captured by that point.

The previous version of the GoldSim model had an attenuation factor for arsenic of 0.5. With no attenuation in the current model version, the simulated results are approximately one order of magnitude higher than measured concentrations for both Dome at the Road and Victoria at Dome (see Figure 19). This behaviour is not seen for the other parameters. This supports the assertion that arsenic attenuation is taking place and agrees with AMEC experience at other sites. With 80% attenuation built into the model, the post-remediation arsenic concentrations are within the range of measured concentrations, as shown in Figure 20. Therefore, 80% attenuation was included for the current conditions and predicted future conditions. The attenuation will occur between the discharge point and the target location for meeting the CCME guidelines. The remaining calibration figures show that all modelled concentrations are within the range of measured concentrations at the Victoria at Dome model node and, therefore, attenuation for other parameters was not explored at this time.

Figure 19: Model Calibration for Total Arsenic, No Attenuation

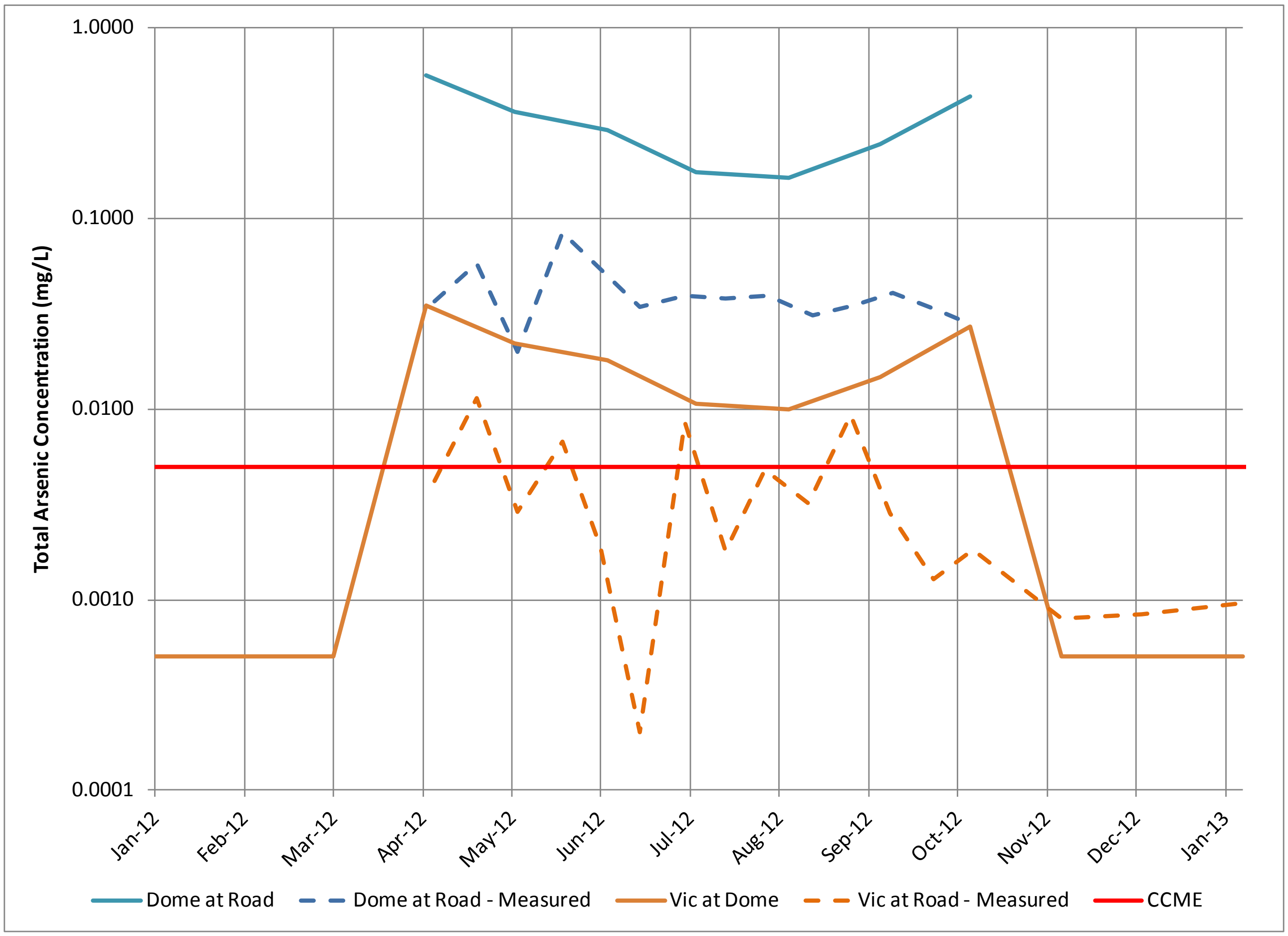
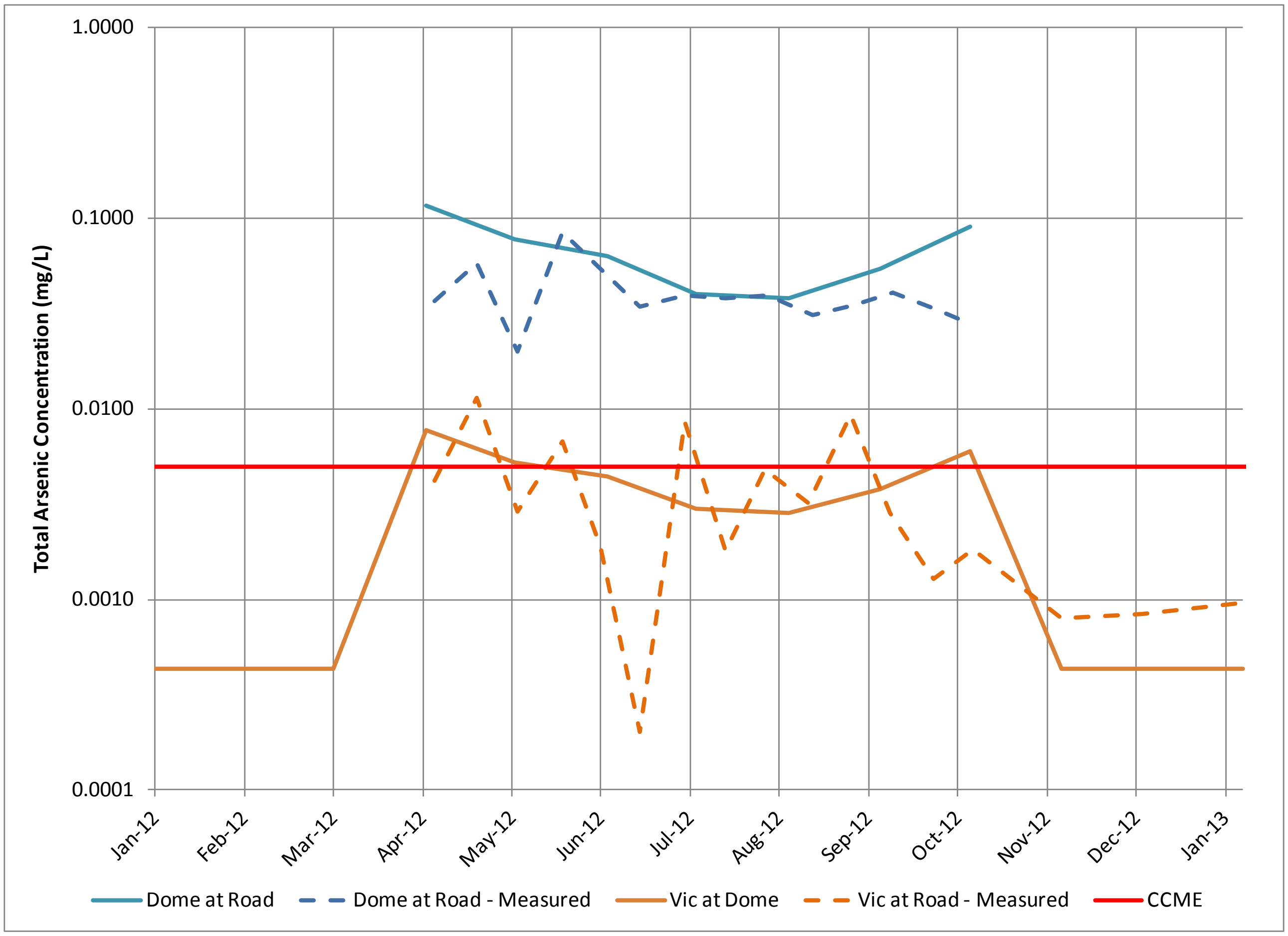
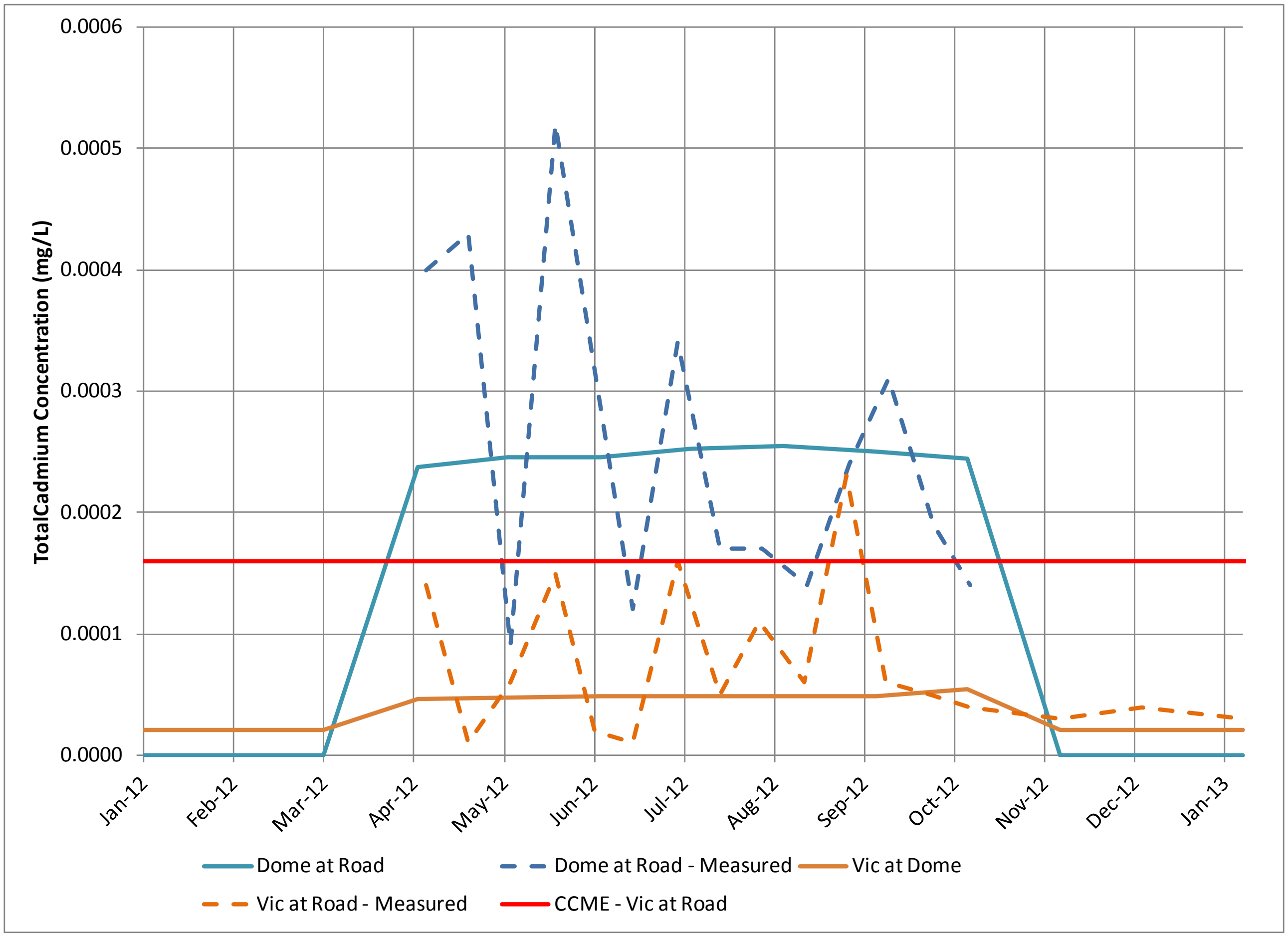


Figure 20: Model Calibration for Total Arsenic, 80% Attenuation



The GoldSim existing modelled conditions are based on the median 2012 measured concentrations. The model results for total cadmium (Figure 21) during this period are within the range of the measured concentrations for both Dome Creek and Victoria Creek. Measured 2012 total cadmium concentrations for Victoria Creek at the Road exceeded or came close to the CCME guideline once in May, July and September.

Figure 21: Model Calibration for Total Cadmium



The simulated total copper results in Dome Creek are within the media range of the measured concentrations, as shown in Figure 22. Victoria Creek simulated concentrations are within the median range of measured concentrations. It can be seen that total copper results exceed the hardness-dependent CCME guideline in Victoria Creek on a regular basis.

Figure 22: Model Calibration for Total Copper

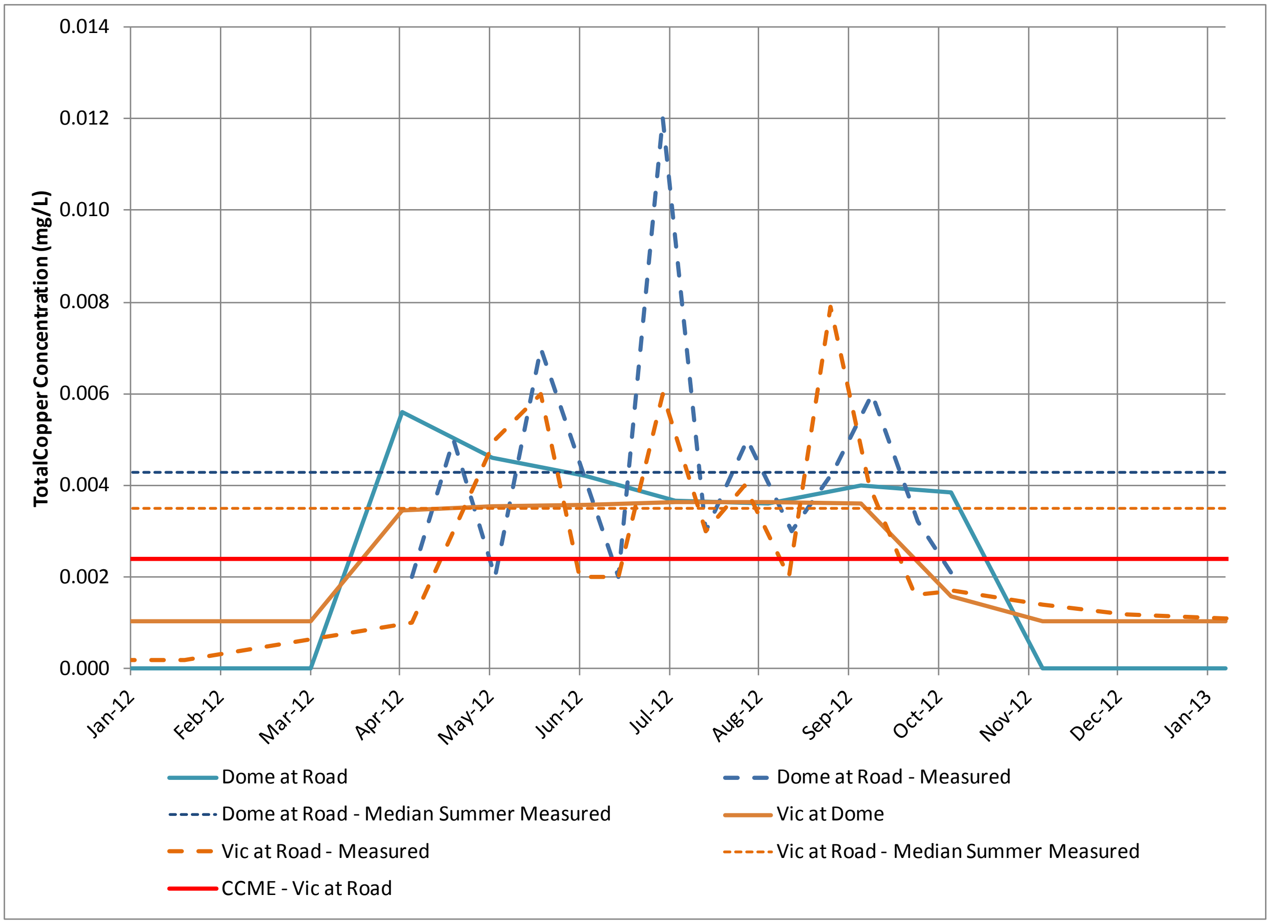


Figure 23 shows that the modelled total iron concentrations in Dome Creek and Victoria Creek are within the lower range of the measured concentrations.

Total iron concentrations in the MNRP area are generally much higher than dissolved iron concentrations. There is no way to generate ARD source terms for dissolved iron and, therefore, it cannot be modelled separately. For reference, the existing dissolved iron 2012 median concentration in Dome Creek at the Road was 0.51 mg/L and the 2012 median concentration in Victoria Creek at the road was 0.16 mg/L in 2012. All sample events with high total iron concentrations have correspondingly higher total suspended solids (TSS) concentrations, indicating high particulate content in the water at those times. TSS concentrations higher than normal could be due to precipitation events or upstream placer mining.

Figure 23: Model Calibration for Total Iron

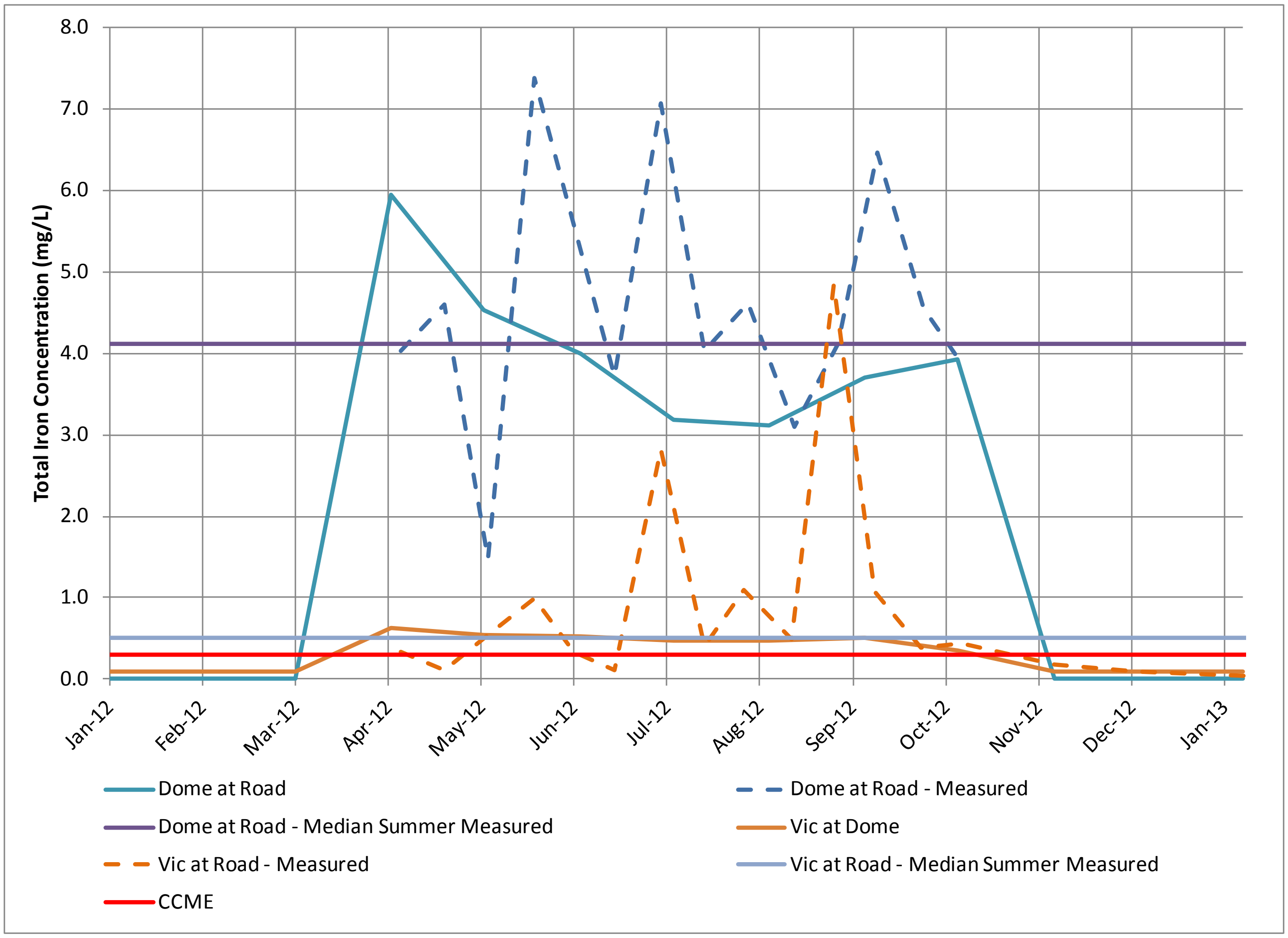
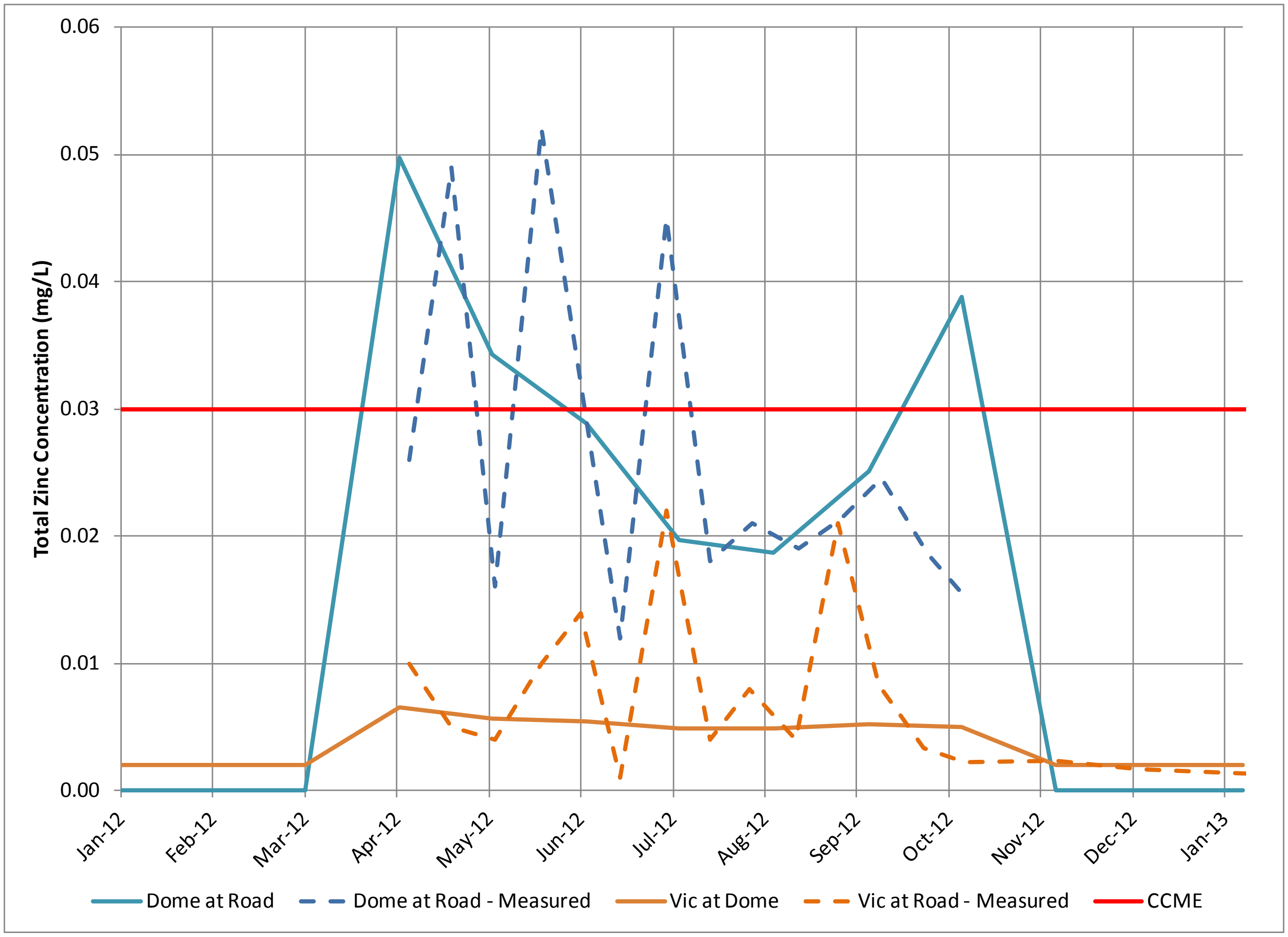


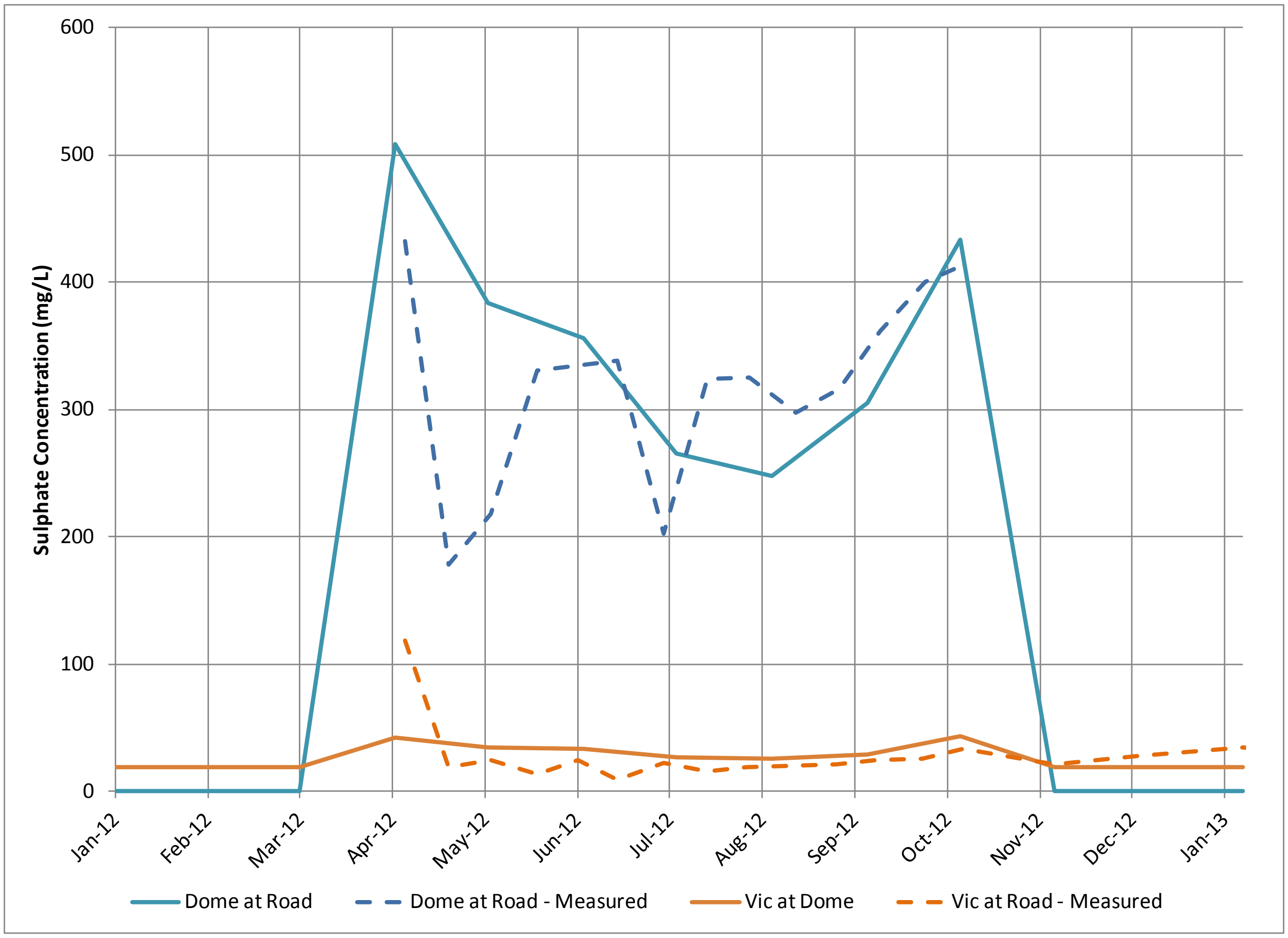
Figure 24 shows the model calibration for total zinc. The model overestimates zinc in Dome Creek, but zinc is within the range of measured concentrations in Victoria Creek. Therefore, the model calibration is acceptable at this time.

Figure 24: Model Calibration for Total Zinc



The simulated total sulphate is within the range of the measured concentration for both Dome Creek and Victoria Creek, as shown in Figure 25.

Figure 25: Model Calibration for Total Sulphate



Overall, the model calibration with no attenuation is adequate for Victoria Creek downstream of Dome Creek, with the exception of total arsenic. The total arsenic model results show good calibration to measured concentrations with 80% attenuation.

5.1.7 Model Outputs

Model Scenarios

AMEC/AE produced one model run (Scenario 1) for the design base case to execute Option 4. Scenario 1 is a long-term geosynthetic cover. It is the best estimate scenario for Option 4 and includes the post-remediation stages for the Open Pit noted in Table 5.13. A second scenario (Scenario 2) was produced to predict what would happen if the long-term geosynthetic cover placement is delayed for many years. Best estimate conditions are used in both scenarios for the tailings drainage term, waste rock and tailings source terms, cover infiltration and waste rock flushing factor.

Table 5.13: Model Scenarios

	Scenario 1 Long-Term Geosynthetic Cover	Scenario 2 Long-Term Granular Cover
Temporary cover conditions (Years 1 to 5)	Granular cover, non-acidic waste rock, tailings draining	Granular cover, non-acidic waste rock, tailings draining
Long-Term Cover Placement (Year 6)		
Stage 1 (Years 6 to 25?)	Non-acidic waste rock, no tailings source term	Non-acidic waste rock, non-acidic tailings
Stage 2 (Years 25? to unknown)	Non-acidic waste rock, no tailings source term	Non-acidic waste rock, acidic tailings
Stage 3 (Unknown year and beyond)	Non-acidic waste rock, no tailings source term	Acidic waste rock, no tailings source term

Note: Scenario 1 (Stages 1 to 3)-No source term for tailings, even under non-acidic condition oxygen is required to produce a source term.

The geosynthetic cover limits the oxygen ingress and precipitation infiltration to such a degree that there is insufficient oxygen for the PAG waste rock to go acidic or for reactions to take place within the tailings. With a granular cover, the oxygen ingress and precipitation infiltration rates are such that in time, a portion of the tailings or the PAG waste rock could become acidic, or both. If the PAG waste rock goes acidic first, it will consume enough of the available oxygen that there is insufficient oxygen for the tailings to react further and, therefore, Stage 3 would not take place. Based on very limited data, AMEC/AE believes that the tailings are more reactive and would become acidic before the waste rock.

A conservative key assumption is that all groundwater seepage from the waste rock and covered pit areas reaches Dome Creek in the summer months and flows through deeper groundwater to Victoria Creek in the winter months. The GoldSim model does not take into account the lag time for groundwater to travel to Dome and Victoria Creeks.

The following are the main GoldSim model outputs:

- pit water elevation;
- creek flows; and
- concentrations for key parameters in the creeks.

Scenario 1 Model Results – Pit Elevation and Creek Flows

One of the key assumptions for Option 4 is that the pit water elevation remains below the tailings after they are placed in the Open Pit. Figure 26 shows the simulated pit water elevation. For Scenario 1, once the pit pond is drained, the backfilled pit does not hold water after remedial activities are complete.

Figure 26: Pit Water Elevation

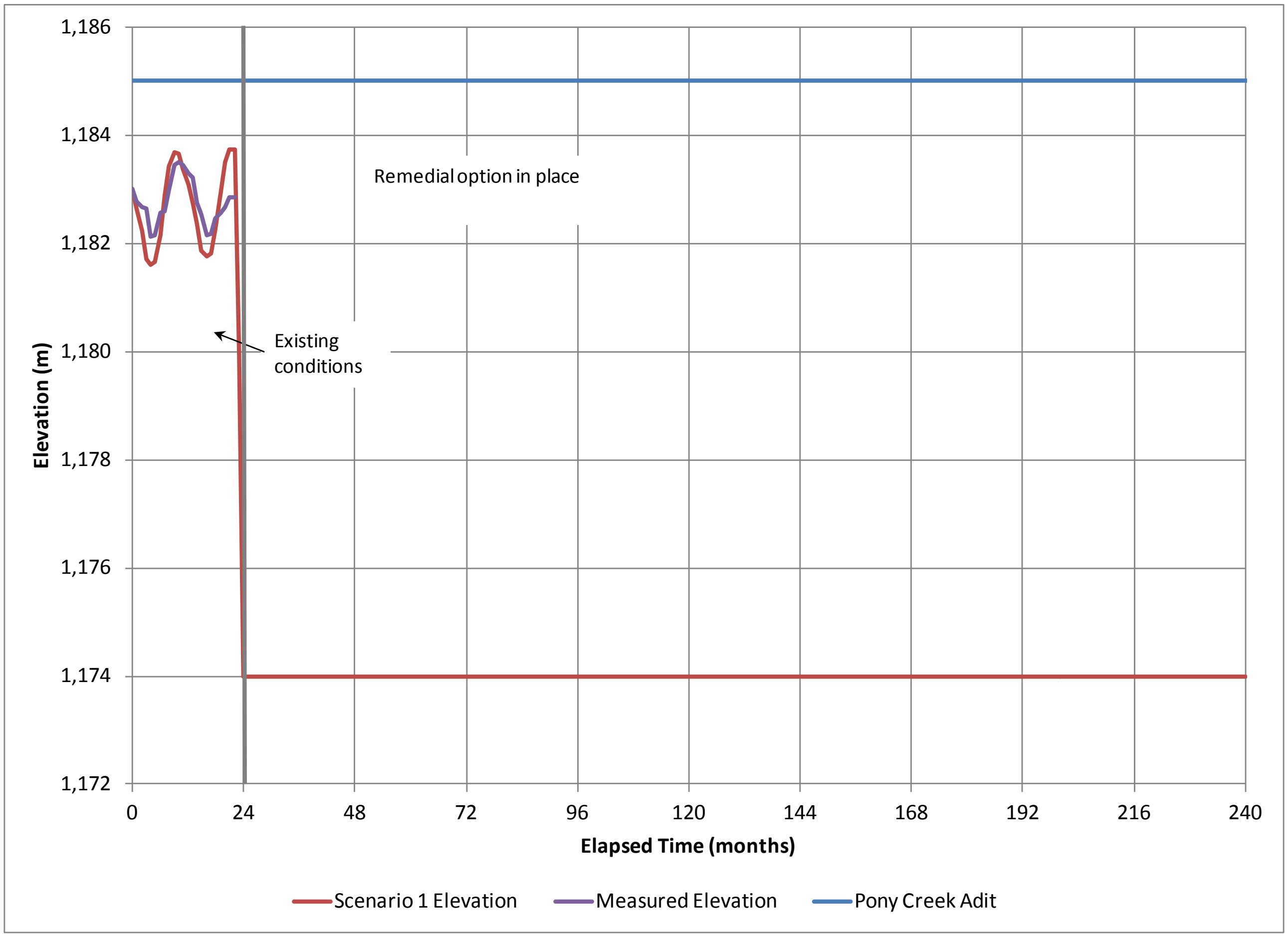
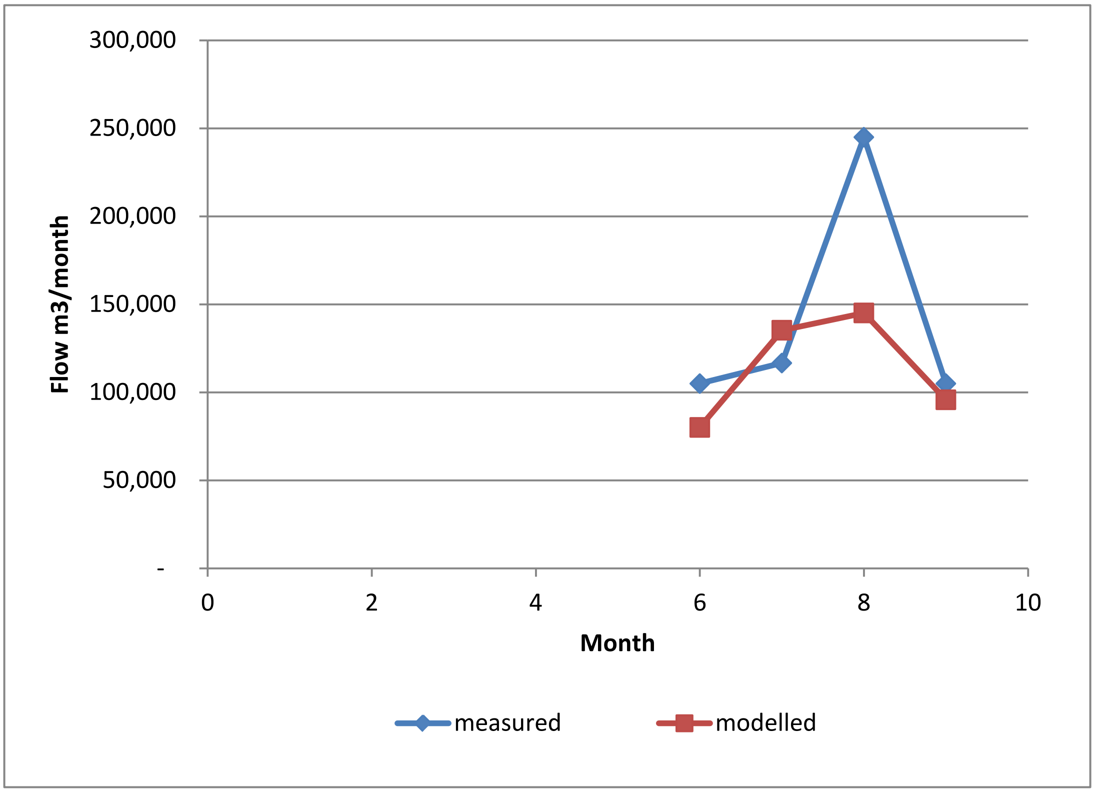


Figure 27 presents the calibration of flow in Dome Creek at Victoria based on 2011 data. The results show that modelled values are within the range of measured values. Dome Creek flows are shown on Figure 28. There are little or no flows in the winter from November 1 to March 31. Peak flows are observed in July of each year.

Figure 27: Model Calibration Flow Dome Creek at Victoria (based on 2011 data)



Dome Creek Flows are shown on Figure 28. There are no flows in the winter based on the assumption that all shallow base flow freezes from November 1 to March 31. Peak flows are observed in July of each year.

Figure 28: Simulated Flows at Stations along Dome Creek

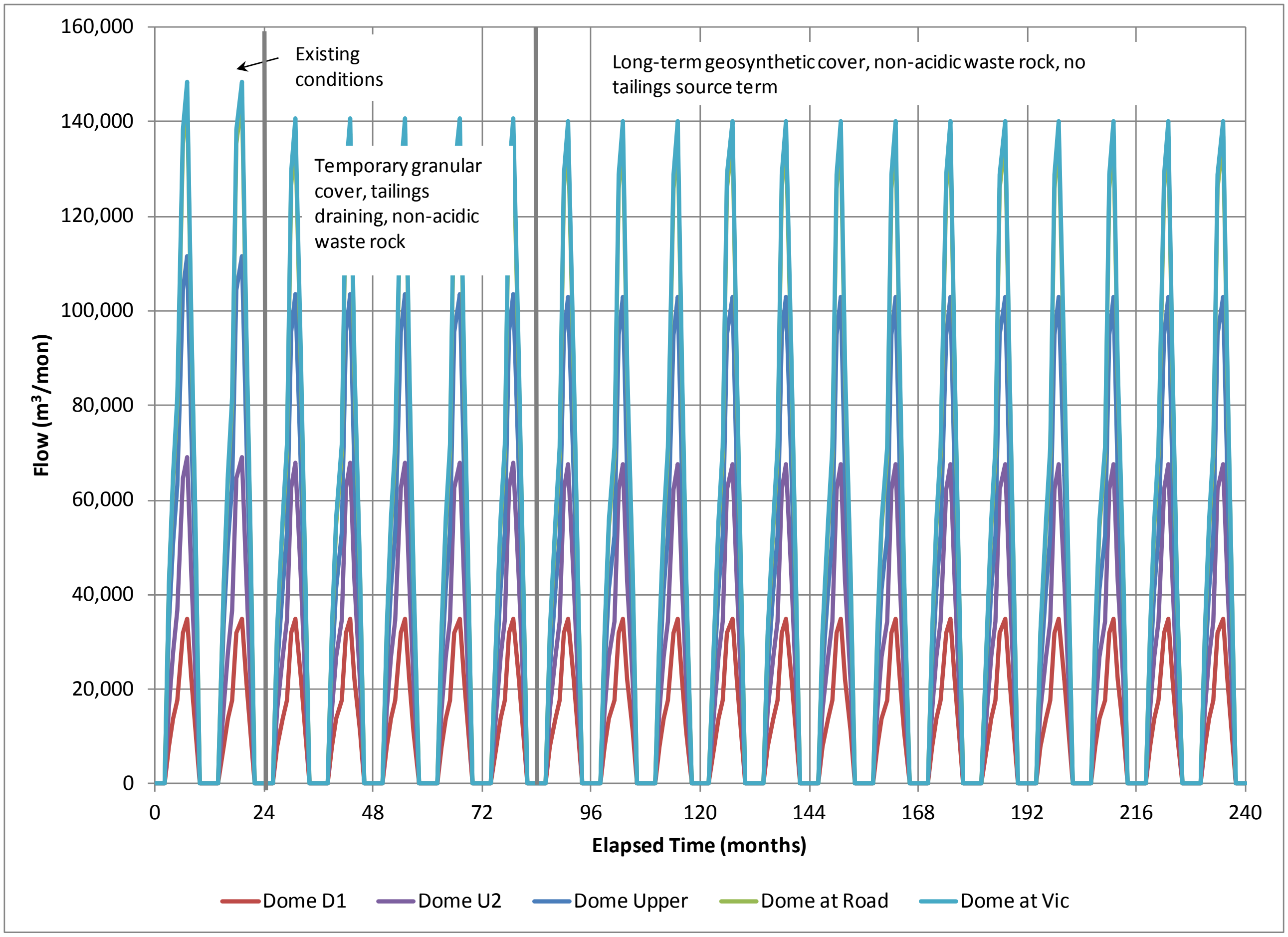
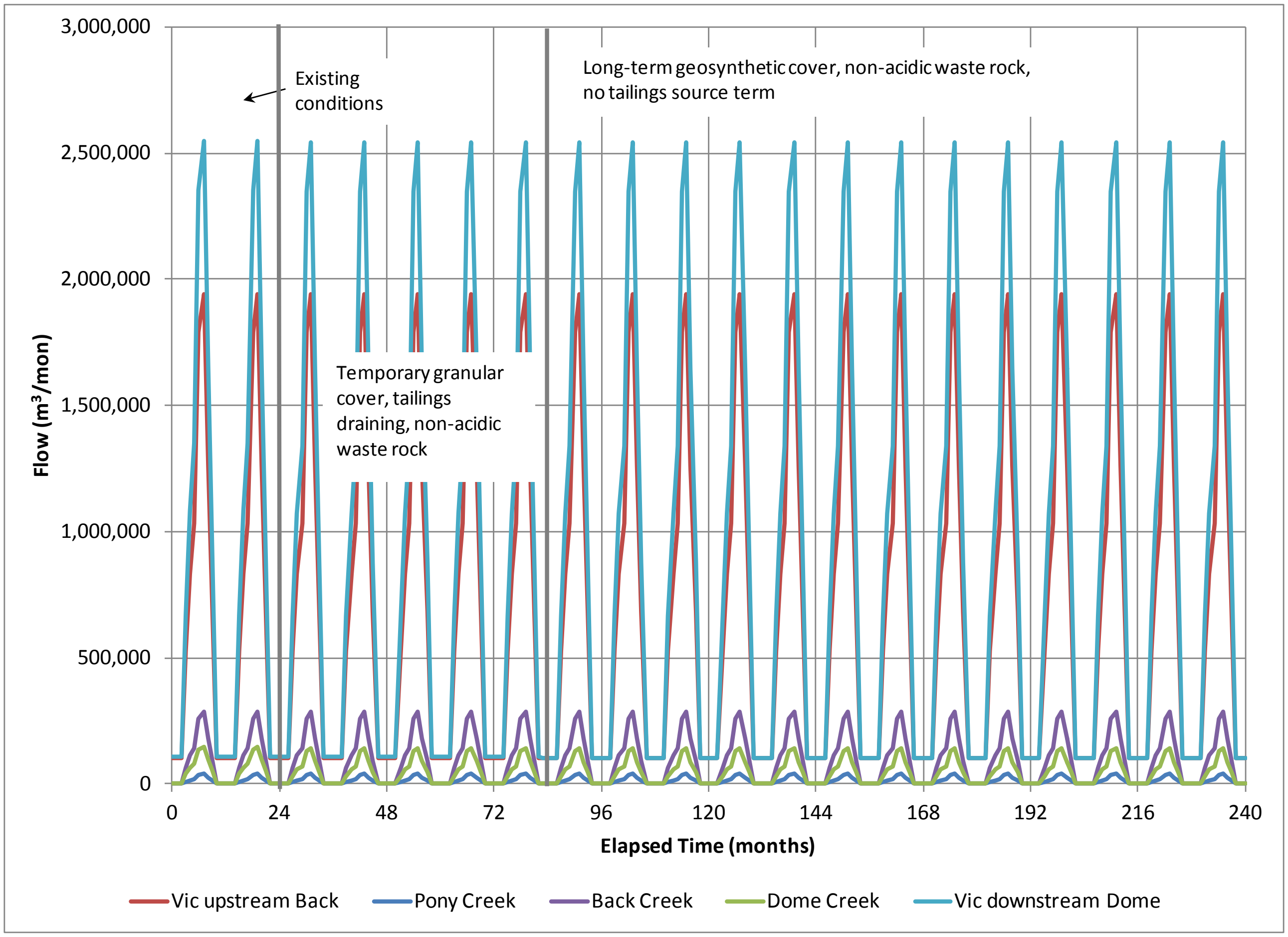


Figure 29 shows the relative scale of Victoria Creek and select tributaries. Note that Pony Creek and Dome Creek are both relatively small water bodies compared to Victoria Creek. Pony Creek flows into Back Creek before it reaches Victoria Creek. A base flow of 40 L/s was assumed for Victoria Creek to show flow in the winter months based on historical flows. It can be seen that Option 4 does not affect flows in Victoria Creek, which is expected.

Figure 29: Simulated Flows for Victoria Creek and Tributaries



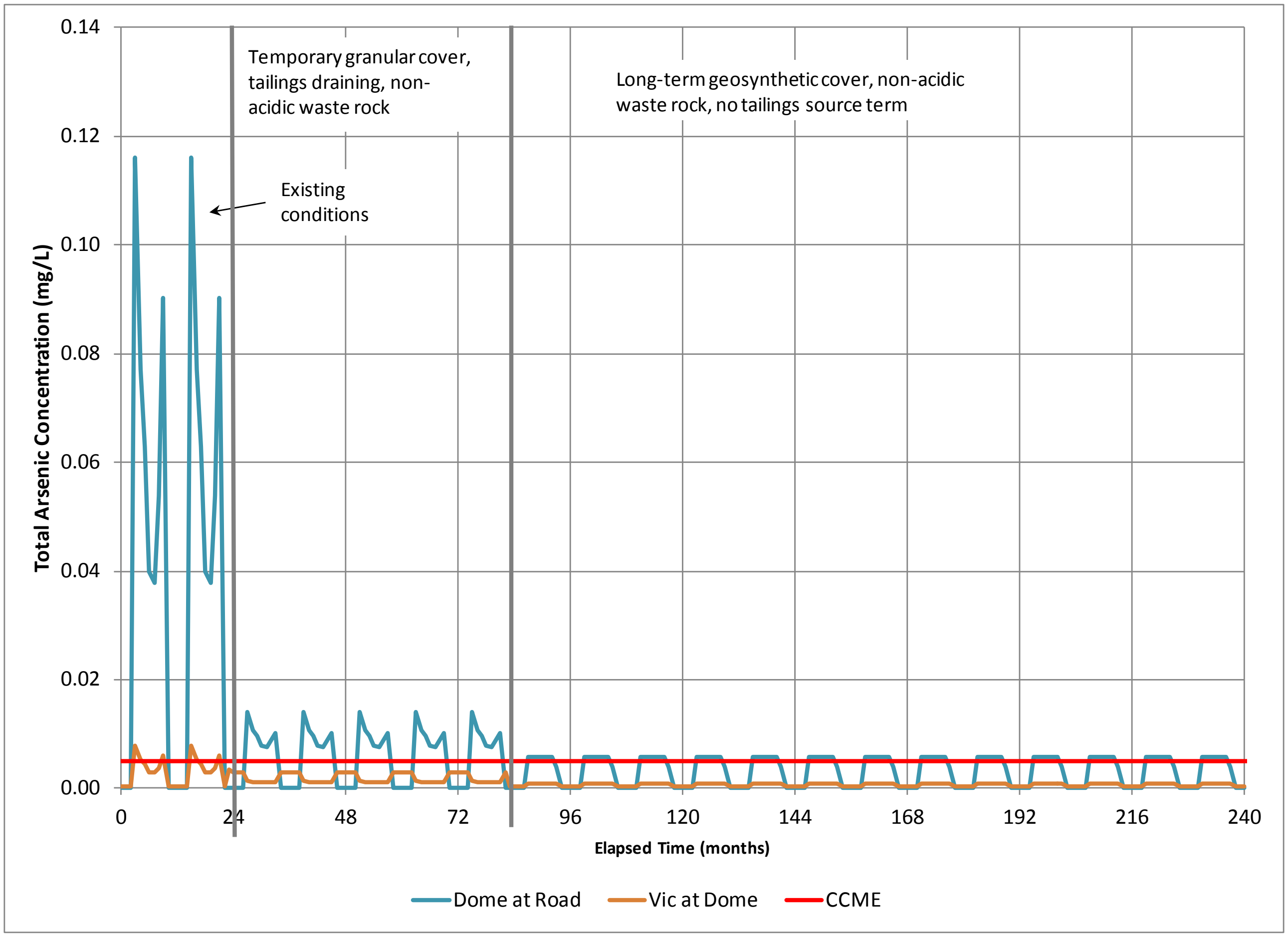
Scenario 1 Model Results – Water Quality

Scenario 1 model results for total arsenic, cadmium, copper, iron, zinc and sulphate are presented below. The results for Victoria at Dome are compared to CCME guidelines for freshwater aquatic life. The Victoria at Dome node in the model is being used as a surrogate for Victoria at the Road, which is downstream. Although sulphate does not have a CCME guideline, it is included in the analysis because it is an ARD indicator. Existing concentrations for total arsenic, cadmium, copper, iron and zinc currently exceed the CCME guidelines in Victoria Creek at the Road.

Figures 30 to 35 show predicted concentrations at select stations for Scenario 1. It is useful to interpret the graphs on a relative basis, rather than focusing exclusively on the actual values. Every effort was made to calibrate the existing conditions to be in the range of measured concentrations to give confidence in the relative behaviour of the predicted post-remediation concentrations. The model results give an indication of the predicted water quality, but AMEC/AE cannot guarantee there will be no short term peaks of water quality.

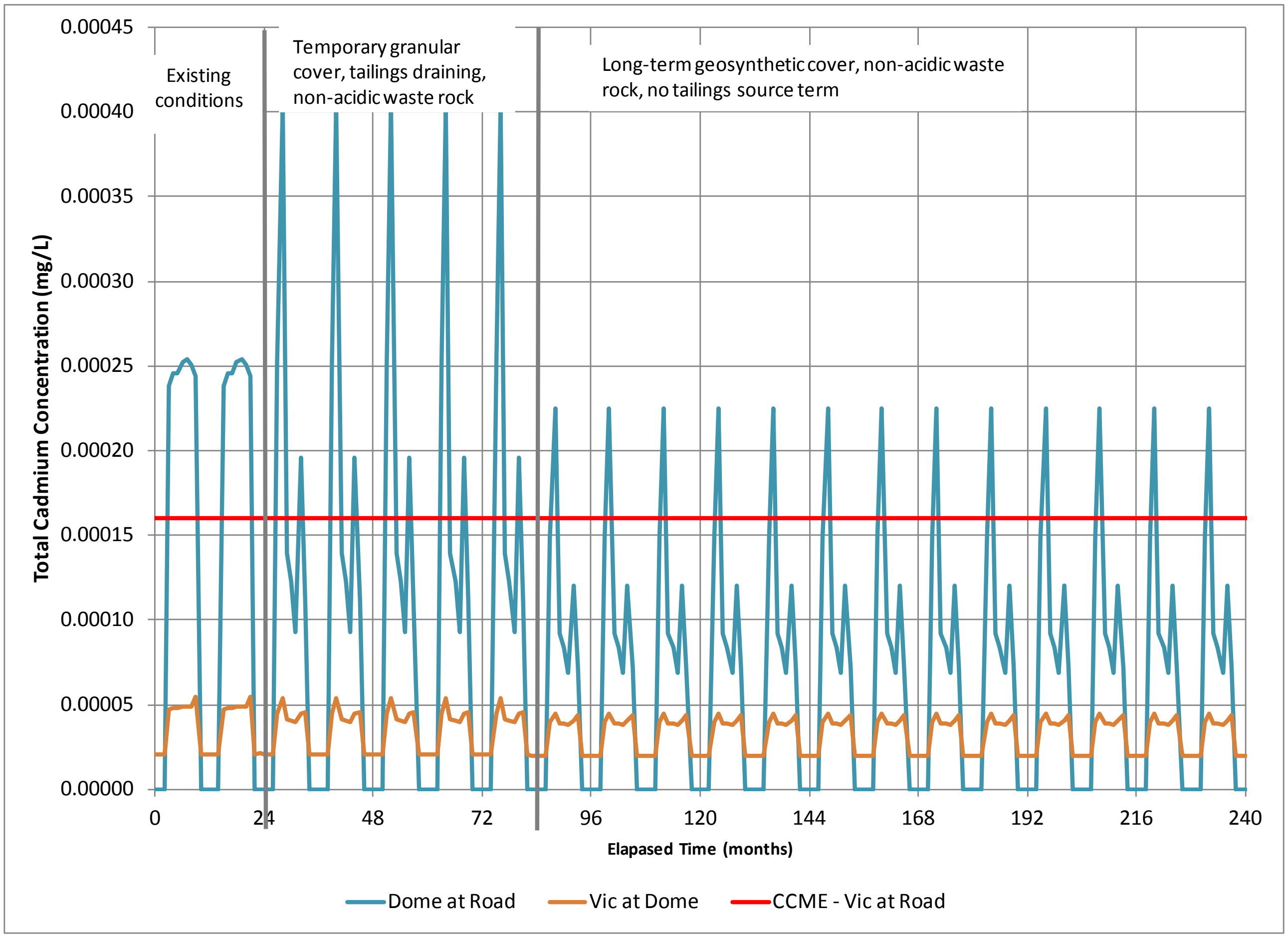
The GoldSim model predicts that total arsenic will be much improved by Option 4 (Figure 30). The long-term geosynthetic cover will further improve total arsenic concentrations in both Dome and Victoria Creeks. A quantitative discussion is included below in Section 5.4.

Figure 30: Predicted Arsenic Concentrations for Scenario 1, 80% Attenuation



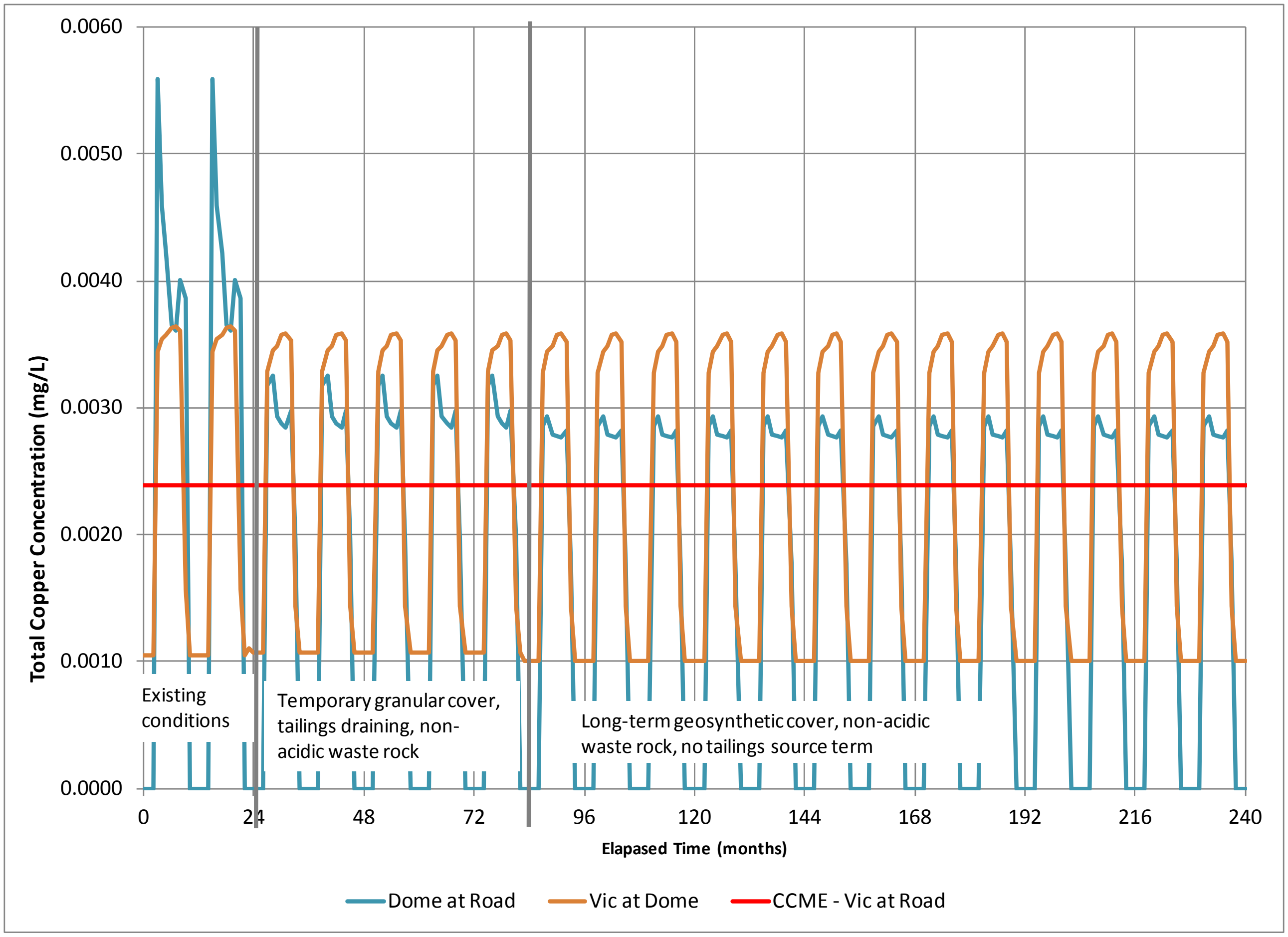
Although the post-remediation model results for total cadmium in Dome Creek vary widely, the median concentration is below the CCME guideline and is predicted to be an improvement over existing conditions (Figure 31). Short-term and long-term results for Victoria Creek predict total cadmium concentrations less than the applicable hardness-dependent CCME guideline.

Figure 31: Predicted Cadmium Concentrations for Scenario 1



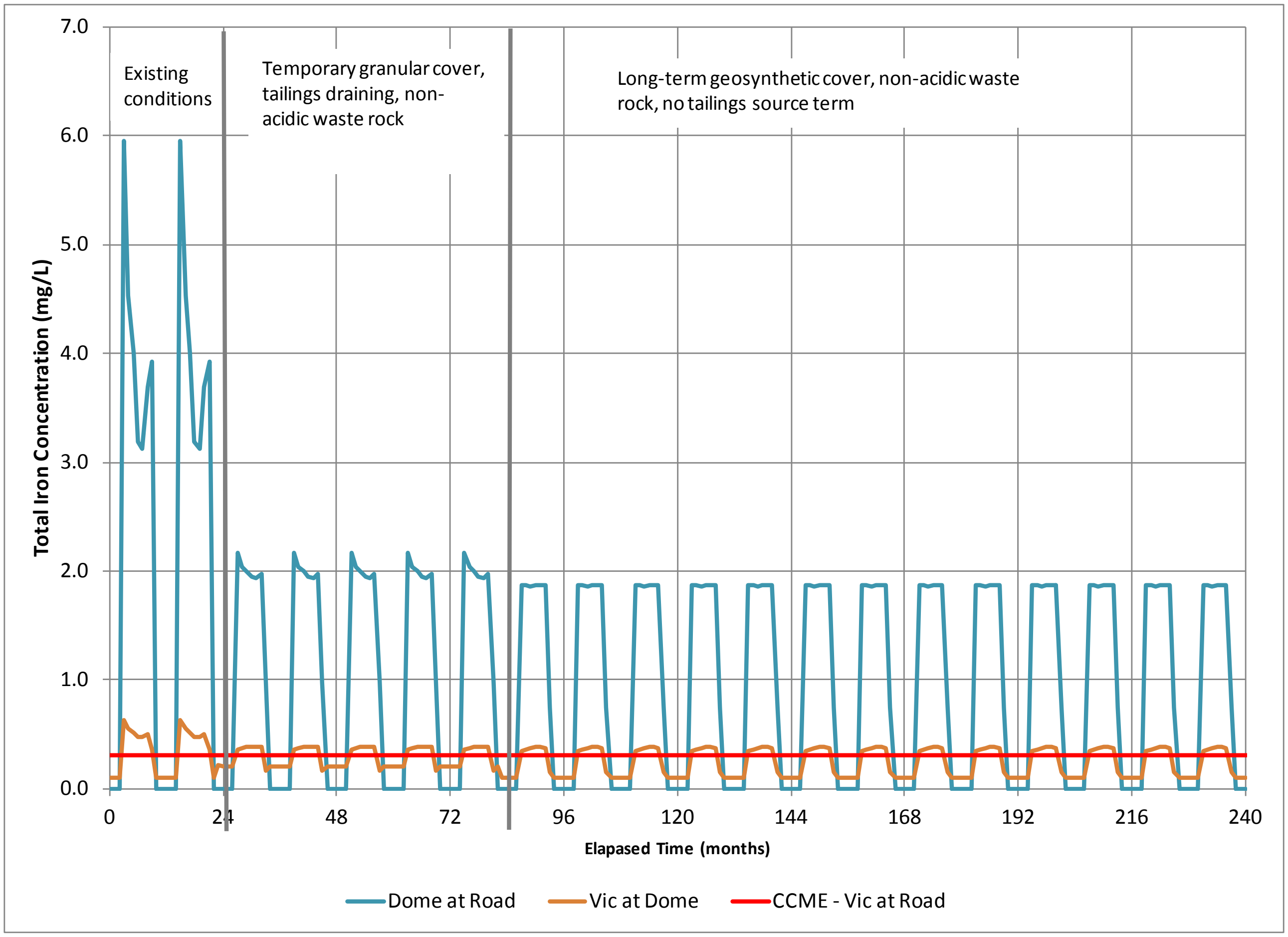
Total copper concentrations are already slightly higher than the CCME guideline in Victoria Creek at the Road (Figure 32). Option 4 lowers the concentrations in Victoria Creek slightly. It has a more pronounced positive effect on copper concentrations in Dome Creek.

Figure 32: Predicted Copper Concentrations for Scenario 1



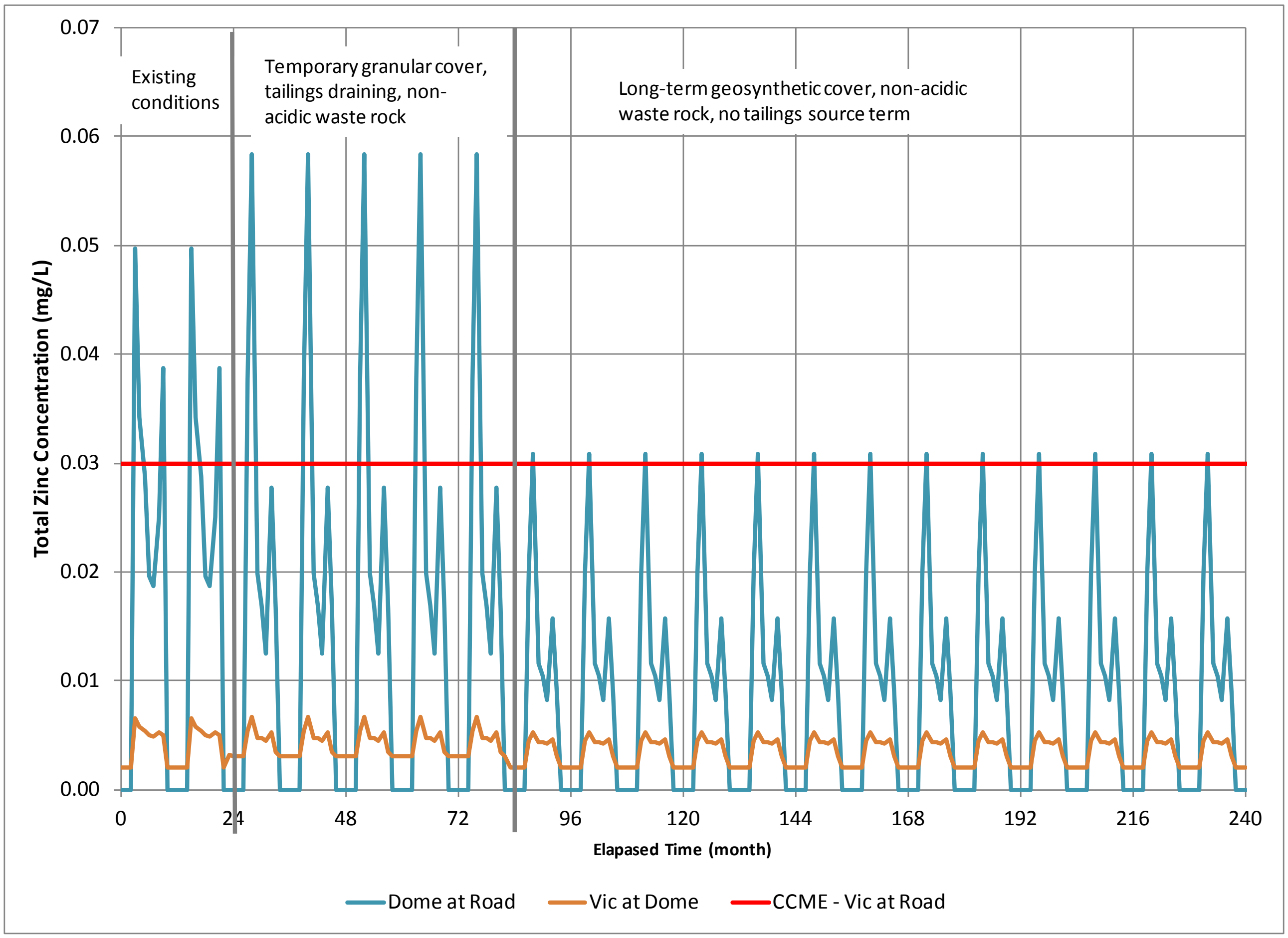
The total iron simulated results are similar to those for total copper, as shown in Figure 33. Scenario 1 provides a slight benefit to total iron concentrations in Victoria Creek and a larger benefit in Dome Creek. Winter concentrations may increase slightly in Victoria Creek when the pit source load reaches it, but the winter concentrations should remain well below the CCME guideline of 0.3 mg/L.

Figure 33: Predicted Total Iron Concentrations for Scenario 1



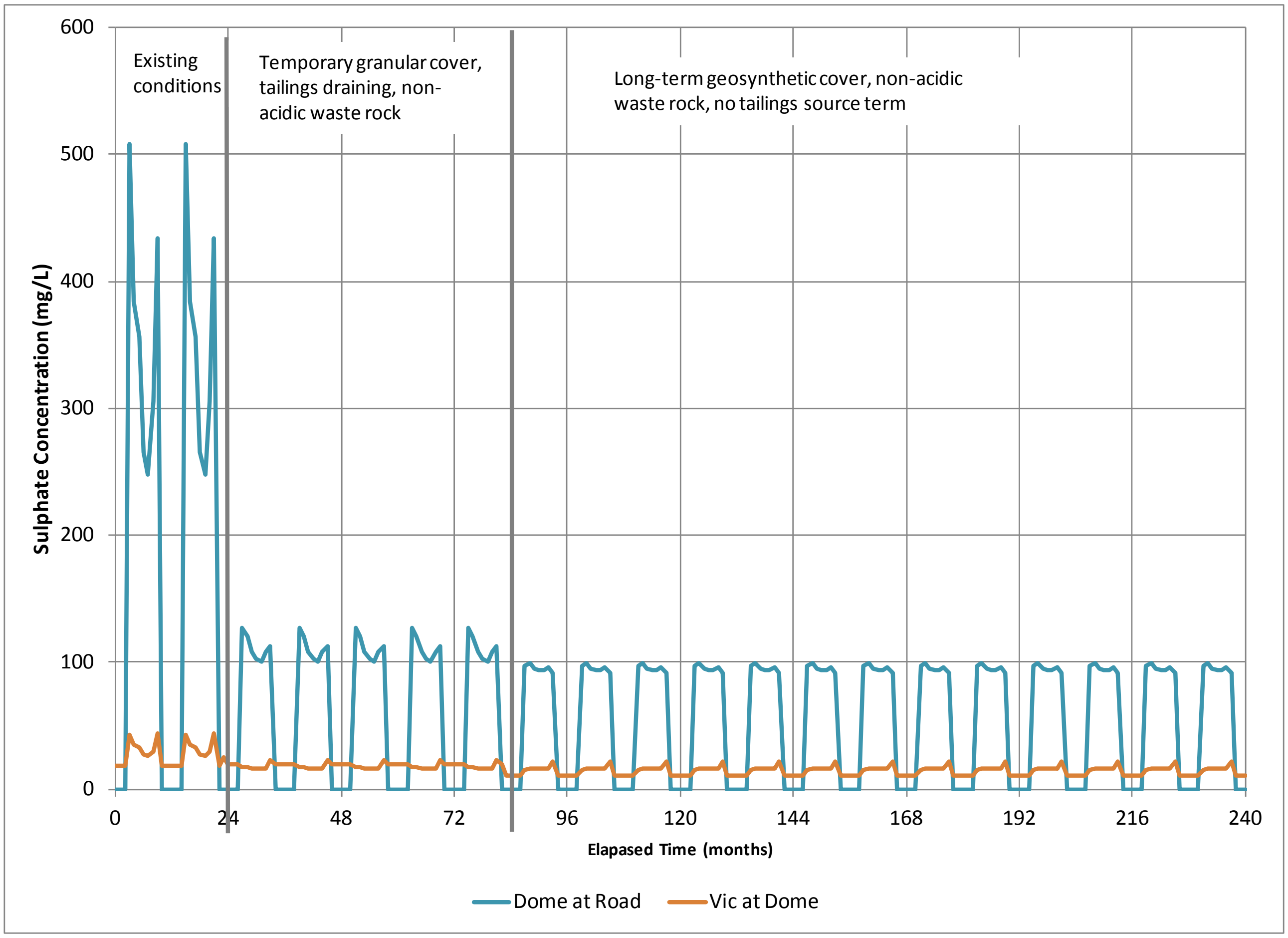
The model results for total zinc are shown in Figure 34. As discussed previously, the model is currently over predicting total zinc in Dome Creek, but the relative behaviour between existing conditions and post-remediation conditions should hold. There is an improvement in water quality post-remediation at all stations. Total zinc concentrations in Victoria Creek downstream of Dome Creek remain below the CCME guideline of 0.03 mg/L. Concentrations in Dome Creek are expected to improve. Since they only exceed the CCME guideline occasionally under current conditions, they should ultimately be less than the CCME guideline post-remediation.

Figure 34: Predicted Zinc Concentrations for Scenario 1



There is no CCME guideline for sulphate, but the model predicts an improvement with Scenario 1, as shown in Figure 35.

Figure 35: Predicted Sulphate Concentrations for Scenario 1



Comparison of Scenarios

Scenario 2 (long-term deferral of permanent geosynthetic cover) was run through the model to predict water quality if the temporary granular cover were left in place long-term. The results are described below for the modelled results in Victoria Creek downstream of Dome Creek. The results are similar but more pronounced for Dome Creek at the road, simply because it is a much smaller water body.

The differences between the two scenarios start after the tailings finish draining and the permanent cover is placed. The granular cover allows more oxygen ingress and precipitation infiltration, which means more oxidation reactions will take place within the tailings and waste rock. The first five years after the long-term cover placement represent the period of time when both waste rock and tailings are under non-acidic conditions. Figure 36 shows a comparison of both scenarios for total arsenic in Victoria Creek downstream of Dome Creek. Under non-acidic conditions, the predicted total arsenic concentrations for Scenario 2 are slightly higher than for Scenario 1. If the tailings go acidic, the model predicts that total arsenic concentrations could be up to five times higher than for non-acidic conditions. Conversely, if the waste rock goes acidic, it will consume all the available oxygen so that the tailings will no longer generate any reaction products.

Figure 36: Comparison of Scenarios 1 and 2 – Total Arsenic

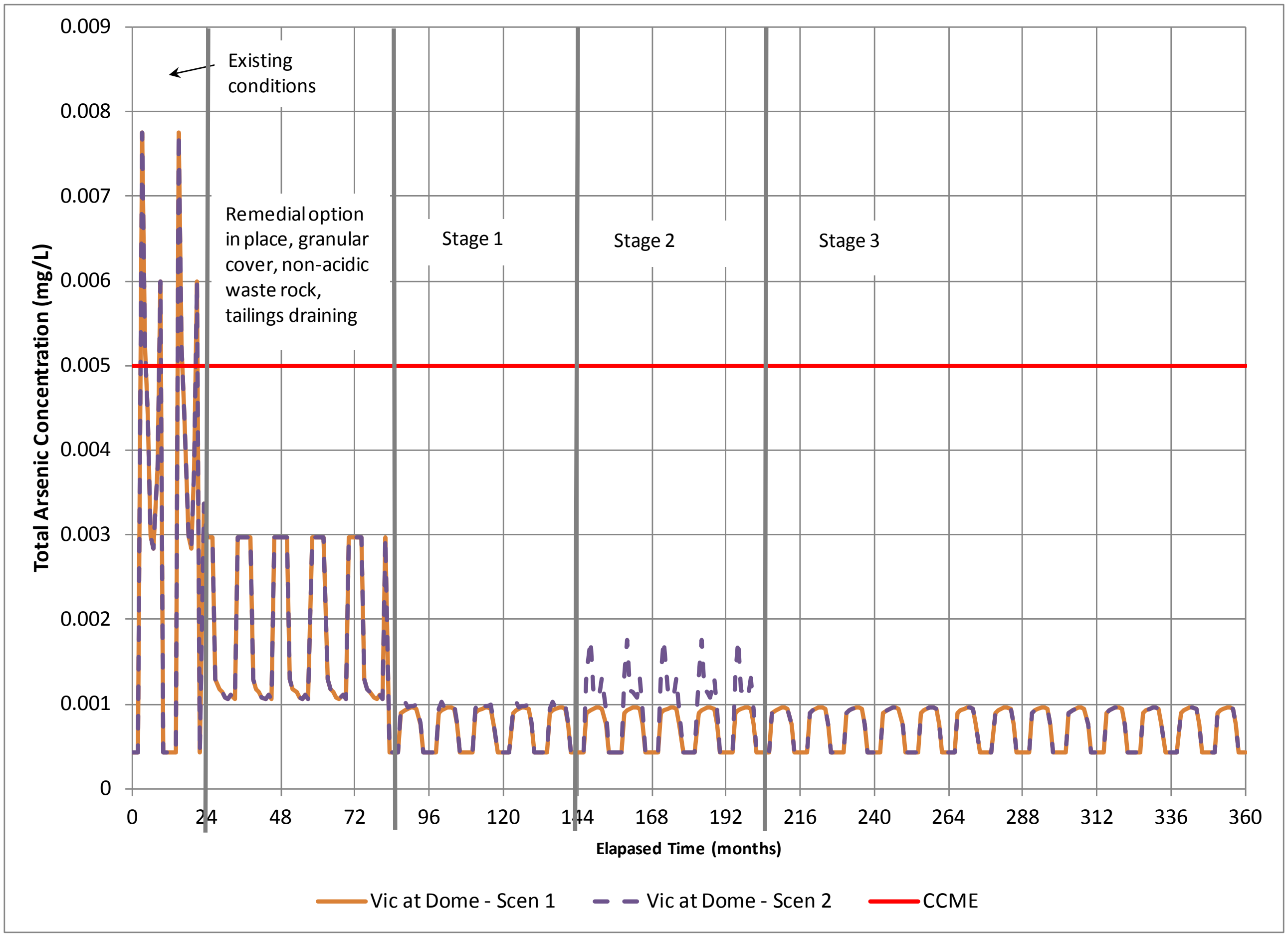
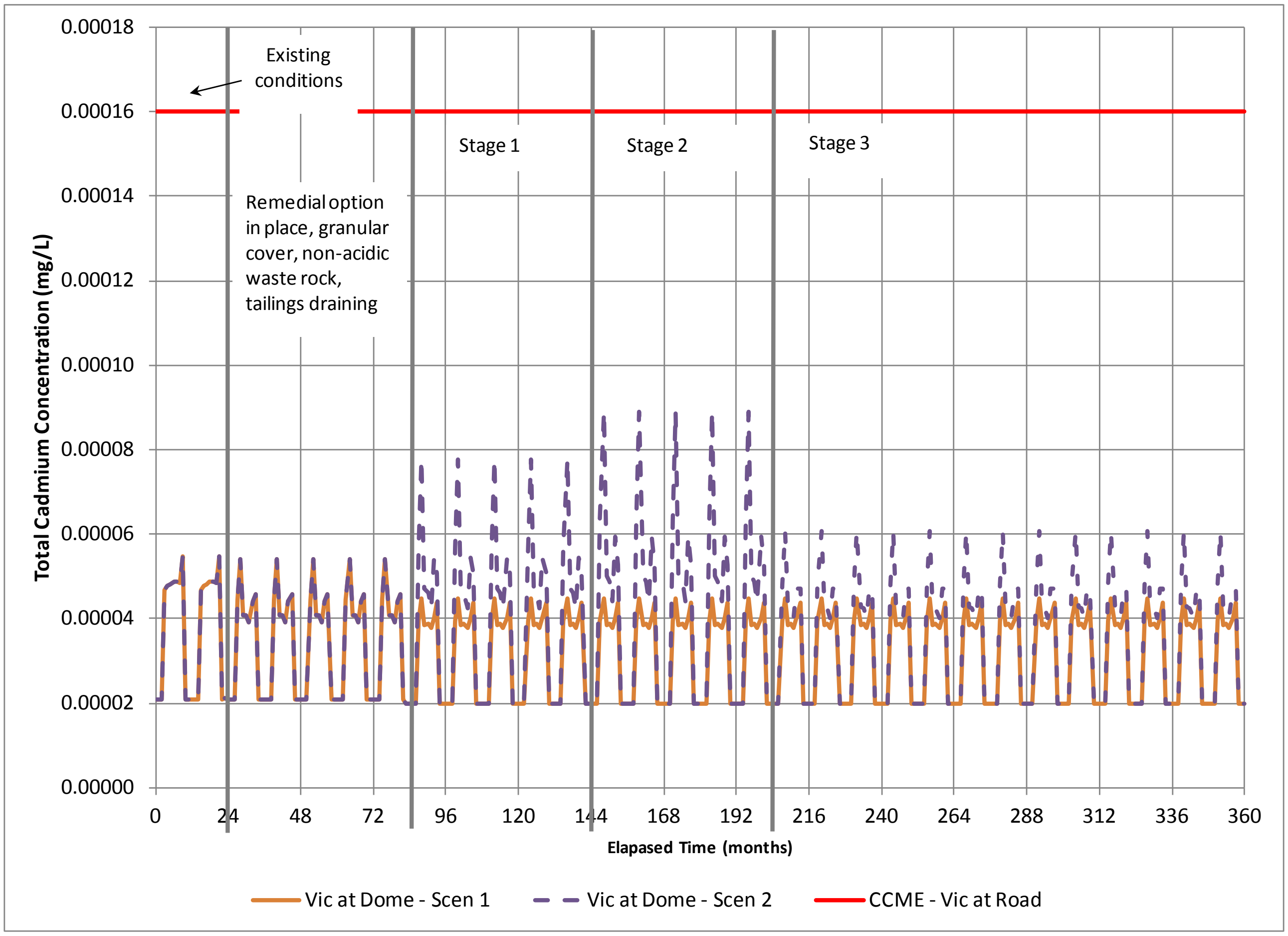


Figure 37 shows a comparison of simulated total cadmium results in Victoria Creek for Scenario 1 (long-term geosynthetic cover) and Scenario 2 (long-term temporary granular cover). It can be seen that placement of the geosynthetic cover has a large effect on the pit source terms, but that on average, the predicted concentrations should be less than the CCME guideline.

Figure 37: Comparison of Scenarios 1 and 2 – Total Cadmium



The relative behaviour of total copper and total iron between scenarios is the same as for total arsenic, as seen in Figures 38 and 39. The tailings could possibly become acidic under the long-term granular cover, which would be detrimental to water quality.

Figure 38: Comparison of Scenarios 1 and 2 – Total Copper

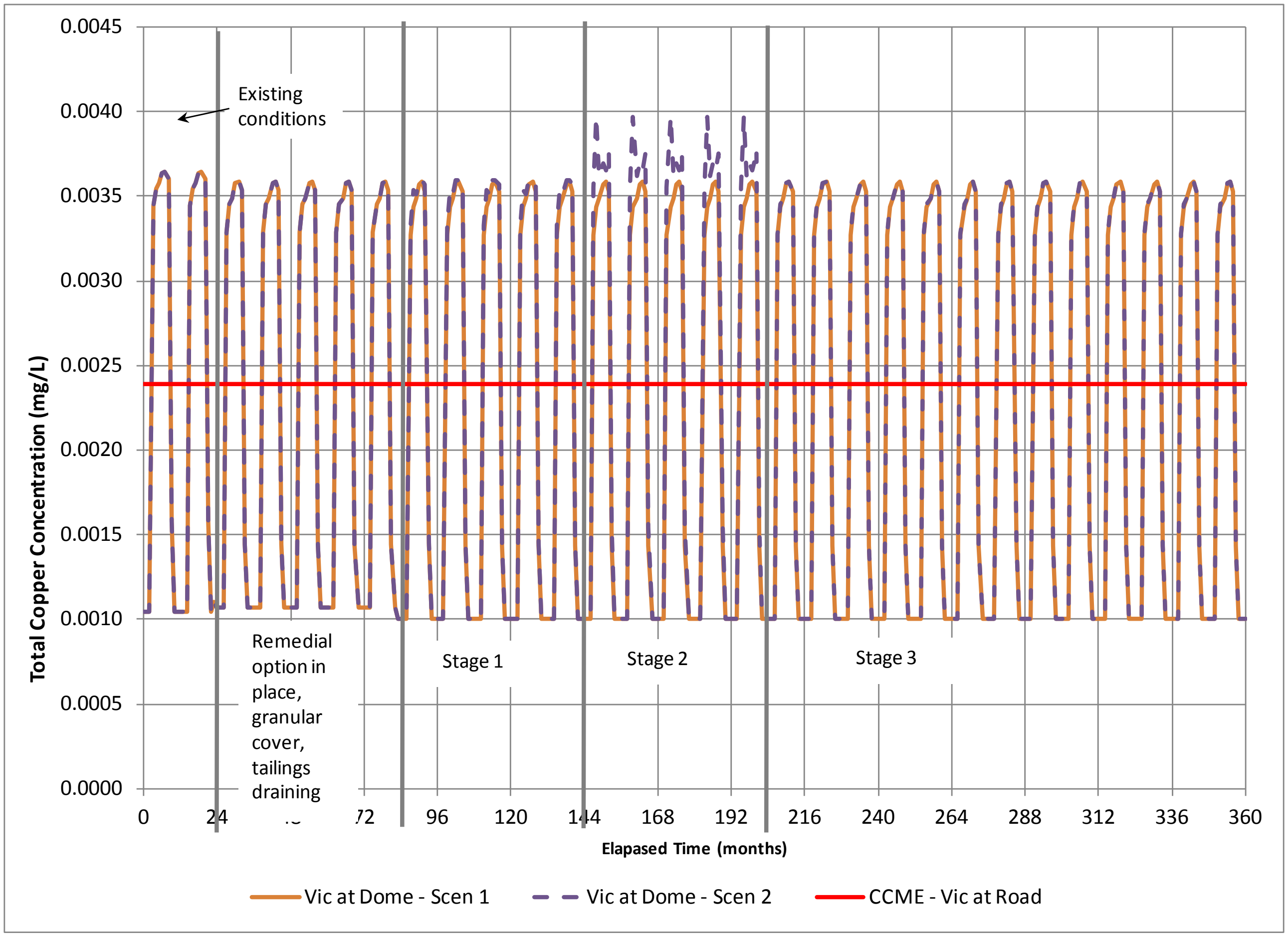
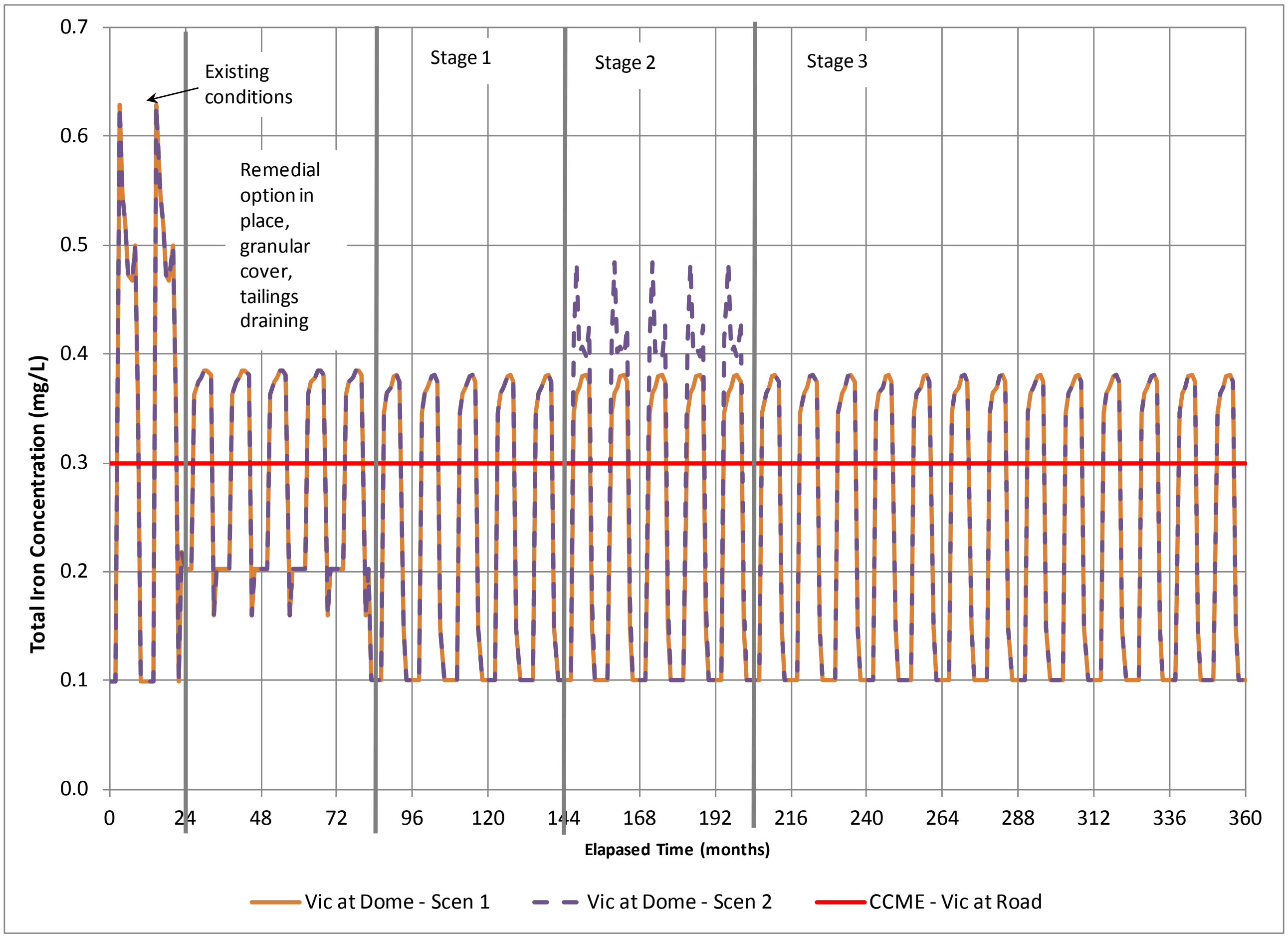


Figure 39: Comparison of Scenarios 1 and 2 – Total Iron



The comparison of scenarios shows similar behaviour for total zinc and sulphate as for total cadmium, as shown in Figures 40 and 41. Even with a long-term granular cover, the predicted total zinc concentrations are less than existing modelled concentrations and are all well below the CCME guideline. Sulphate concentrations are slightly higher for the long-term granular cover than for the geosynthetic cover, but are still relatively low.

Figure 40: Comparison of Scenarios 1 and 2 – Total Zinc

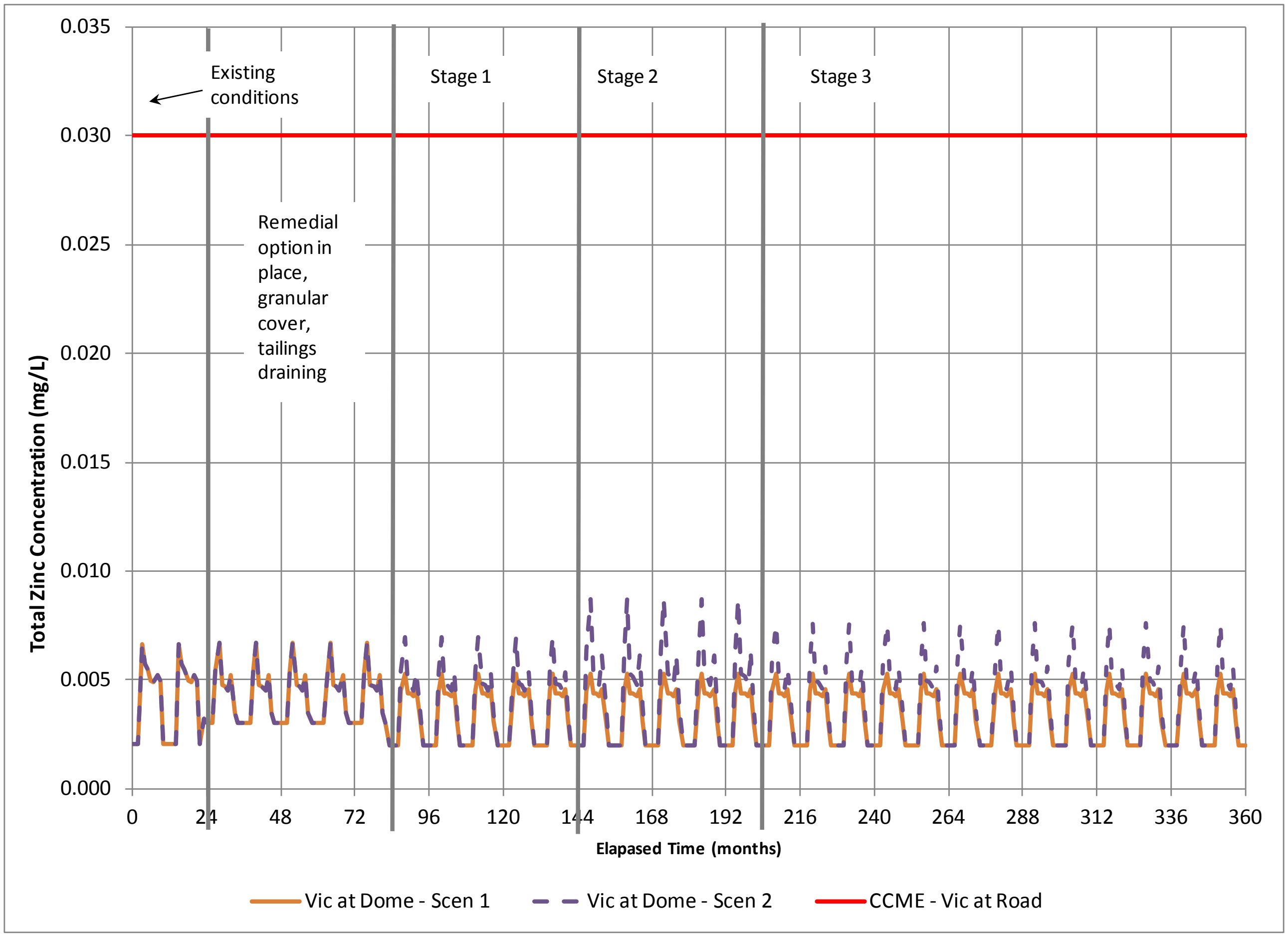
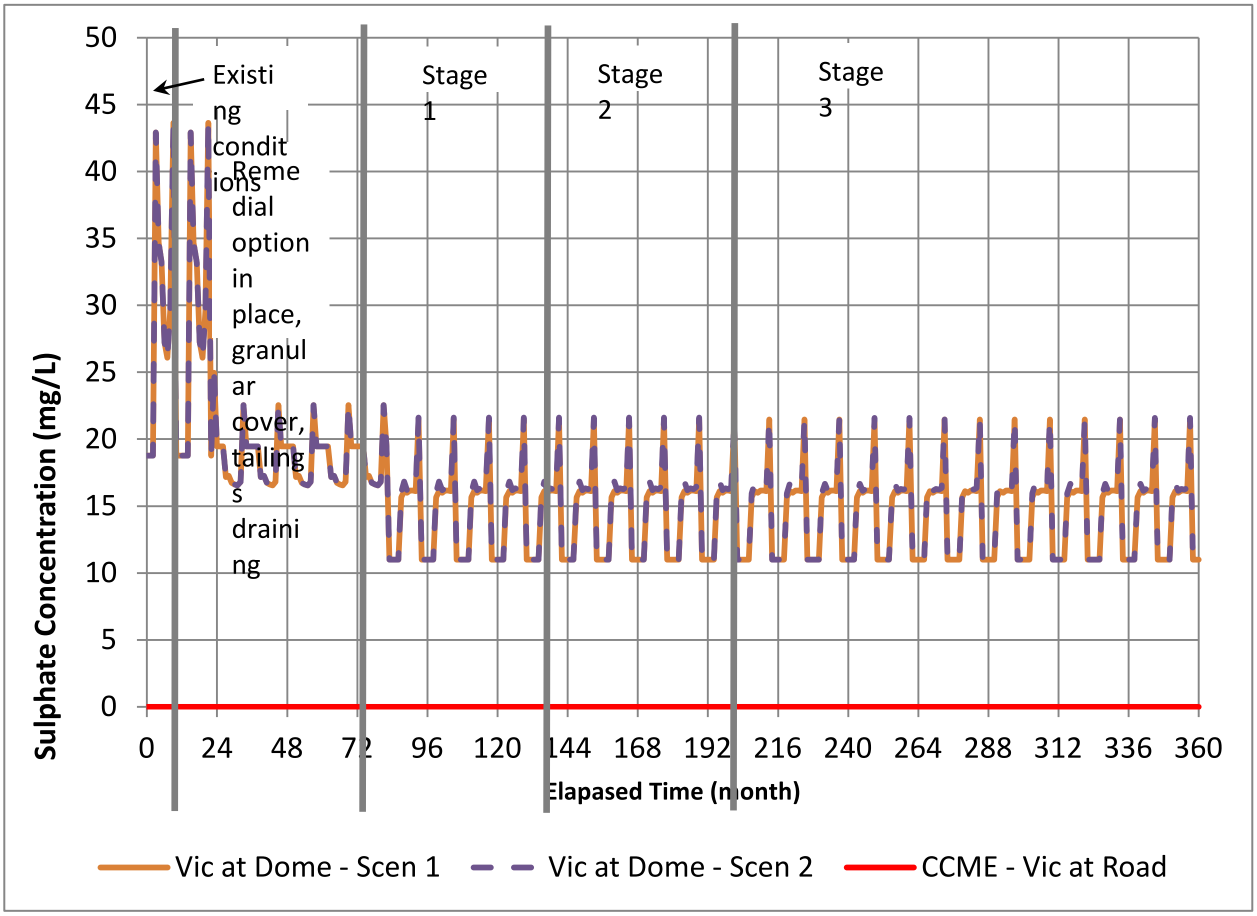


Figure 41: Comparison of Scenarios 1 and 2 – Sulphate



In summary, placing the long-term geosynthetic cover (Scenario 1) is important to reduce oxygen ingress and precipitation infiltration into the covered waste rock and tailings enough to prevent acidic conditions from forming within the waste rock or tailings or both. Time for settlement is expected to be less than the time for PAG waste rock or tailings to acidify. However, if placement of the long-term geosynthetic cover is delayed until the tailings acidify, the resulting downstream water quality will be a concern for total cadmium, copper and iron.

5.1.8 Post Remediation Water Quality

The two key water quality monitoring stations for measuring post-remediation effects are Dome Creek at Road and Victoria Creek at Road. A summary of existing measured concentrations and exceedances for the parameters of concern at those two stations are provided in Table 5.14.

Table 5.14: Summary of Measured Concentrations and Percentage of Exceedances at Dome Creek at Road and Victoria Creek at Road Stations.

Parameter	CCME	WQ-DC-R Dome Creek at Road			WQ-VIC-R Victoria Creek at Road		
		Concentrations	Number of Analysis	Exceedance	Concentrations	Number of Analysis	Exceedance
	mg/L	mg/L	N	%	mg/L	n	%
Arsenic	0.005	0.0198-0.0845	13	100	0.00072- 0.0114	18	22
Cadmium*	0.000028-0.00045	0.00009-0.00052	13	0	0.00001-0.00023	18	0
Copper*	0.002-0.004	0.002-0.012	13	46	0.0002-0.0079	20	35
Iron	0.3	1.48-7.38	13	100	0.038-4.84	18	67
Zinc	0.03	0.012-0.052	13	23	0.0011-0.022	20	0
Sulphate	N/A	178-432	13	N/A	9.1- 119	20	N/A

Notes:
All metals are total concentrations
** Hardness dependent guideline*
- Summary based on data from 2012 and 2013 (Jan and Feb)

At the Dome Creek at Road station, both total arsenic and iron exceeded the CCME guideline values in all collected samples. Total copper exceedances were reported in around 46% of the sample set. Zinc exceedances were reported in three of 13 samples. No total cadmium exceedances were reported in Dome Creek at the Road.

At the Victoria Creek at the Road station, fewer exceedances in CCME guideline values were reported. Total iron exceedances were reported in 12 out of 18 samples. Around 35% of the samples had total copper concentrations higher than the CCME guideline value. Total arsenic exceedances were reported in four out of 18 samples. No exceedances of total cadmium or zinc were reported for Victoria Creek at the Road.

The design base case includes the relocation of tailings from the tailings storage facility, PAG waste rock from stockpiles, road and mill areas, some non-PAG rock from the waste rock area, and contaminated materials from other areas into the open pit. As a result, the contaminated materials will be contained in the pit and the pit will be the single contaminant source during the post-remediation period. The target location for meeting the CCME guidelines for the Mount Nansen site is expected to be Victoria Creek at the Road. This station receives all potential loads from the site, including those discharged from Pony Creek and Dome Creek. During the winter months, the GoldSim model assumes drainage from the pit and waste rock areas flows directly to Victoria Creek at Road through deeper groundwater due to the shallow frozen ground conditions in Dome Creek. Modelled drainage from the pit is conveyed to Dome Creek at Road before it reaches Victoria Creek during the spring and summer months.

The estimated loadings of the selected parameters (arsenic, cadmium, copper, iron, zinc, and sulphate) at the Dome Creek at Road station from the GoldSim model for the design base case (Scenario 1) are presented in Table 5.15 and compared to the existing loadings from this station.

For Scenario 1, a temporary granular cover will be placed over the backfilled materials in the pit after the material relocation is completed. Tailings consolidation and drainage is expected to last in the range of five years, after which a long-term geosynthetic cover will be installed to further reduce water infiltration and oxygen ingress into the pit. Scenario 1 assumes non-acidic conditions for the waste rock and tailings for the duration of the temporary cover as well as the permanent geosynthetic cover. Since the tailings are assumed to be draining during the five years that the temporary cover is in place, the source term for the tailings consists of the existing tailings pore water concentrations rather than loadings derived from kinetic tests.

Table 5.15: Summary of Post-Remediation Predicted Loadings in Dome Creek

Location	Parameter	Average Loadings*		
		Temporary Granular Cover	Permanent Geosynthetic Cover	Existing Condition
		kg/month	kg/month	kg/month
Dome Creek at Road	Arsenic*	1.588	0.237	23.4
	Arsenic**	0.506	0.236	23.4
	Cadmium	0.012	0.008	0.022
	Copper	0.107	0.099	0.177
	Iron	39.735	34.688	147.690
	Zinc	1.895	1.083	6.413
	Sulphate	5,243	4,184	28,298

Note:
* *Total arsenic predictions do not include attenuation*
** *Total arsenic predictions includes attenuation*

The predicted loadings from the post remediation period at the Dome Creek at Road station are lower than the existing loadings. The placement of the geosynthetic cover will reduce ~99% of the existing arsenic loading for both the non attenuation and attenuation cases. The GoldSim model predicts the placement of a geosynthetic cover to reduce loadings by 85% for sulphate, 83% for zinc, 77% for iron, 66% for cadmium, and 44% for copper. The reduction in metal and sulphate loadings that results from the placement of a temporary granular cover is predicted to occur at a lower percentage compared to the reduction achieved by the placement of a geosynthetic cover (Table 5.15).

Estimated concentrations of selected parameters at the Victoria Creek at Road station for the design base case (Scenario 1) are presented in Table 5.16. These estimated concentrations were compared to the concentrations measured at this station and the relevant CCME guideline values.

Table 5.16: Summary of Post-Remediation Predicted Concentrations in Victoria Creek

Location	Parameter	Post Remediation				Existing Condition	CCME
		Temporary Granular Cover		Permanent Geosynthetic Cover			
		Nov.-Mar.	April-Oct.	Nov.-Mar.	April-Oct.		
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Victoria Creek at Road	Arsenic**	**0.01366**	0.0017-0.0032	0.0009	0.00115-0.00119	0.00072-0.0114	0.005
	Arsenic***	0.0035	0.0013-0.0016	0.0009	0.00115-0.00119		0.005
	Cadmium	0.00003	0.00008-0.00009	0.00003	0.000075-0.000083	0.00001-0.00023	0.00016*
	Copper	0.001	**0.0025-0.0027**	0.001	**0.0025-0.0027**	0.0002-0.0079	0.0024*
	Iron	0.147	**0.565-0.623**	0.099	**0.558-0.621**	0.038-4.84	0.3
	Zinc	0.006	0.0075-0.0097	0.005	0.0072-0.0083	0.0011-0.022	0.03
	Sulphate	23	18-20	15	18.2-18.6	9.1-119	N/A

** hardness dependent guideline*
*** Total arsenic predictions do not include attenuation*
**** Total arsenic predictions include attenuation*
bold indicates the predicted value is greater than the CCME guideline

The predicted post-remediation concentrations at Victoria Creek are lower than the average concentrations measured at the Victoria Creek at Road station with exception of some arsenic and zinc concentrations.

As a result of the placement of the permanent geosynthetic cover, the arsenic concentration is predicted to decrease by approximately 48% and 72% for the non-attenuation case and the attenuation case, respectively. The placement of the temporary cover is predicted to cause the arsenic concentration to decrease by 40% for the attenuation case and increase by 46% for the non-attenuation case.

The predicted long-term post remediation concentrations of cadmium, copper, iron and zinc at the Victoria Creek at Road station were lower than the average measured concentrations. The placement of the permanent geosynthetic cover is predicted to cause the concentrations of cadmium, copper, iron and sulphate to decrease by 18%, 32%, 51% and 42%, respectively. A reduction in concentration also occurs for those parameters during the placement of the temporary granular cover. However, a lower percentage of reduction was predicted for the placement of the temporary granular cover placement compared to the placement of the geosynthetic cover.

The zinc concentration is predicted to be 4% lower than the existing conditions at the Victoria Creek at Road station as a result of the placement of the geosynthetic cover. The placement of the temporary cover is expected to result in an increase in zinc concentration by approximately 10%.

The Victoria Creek at Road station is expected to be the target location for meeting the CCME guidelines for the Mount Nansen site. The concentrations of selected parameters of concern are compared to the CCME guideline values. The predicted post-remediation cadmium and zinc concentrations that result from the temporary and permanent cover placements are lower than the CCME values. The predicted arsenic concentrations that result from the permanent cover placements for the non-attenuation and attenuation cases are lower than the CCME guideline value. Predicted total arsenic concentrations that result from the placement of the temporary granular cover were lower than the CCME guideline value for the attenuation case but exceeded the CCME guideline value for the non-attenuation case. Elevated total arsenic concentrations are predicted to occur during the winter months (November to March), while the estimated arsenic concentrations for the remaining months are expected to be below the CCME guideline value for arsenic.

Post-remediation total iron concentrations that result from both the temporary granular cover and long-term geosynthetic cover placements are predicted to be higher than the CCME guideline values for the summer months. Sulphate concentrations are predicted to be relatively low (<20 mg/L) following the placement of both covers.

The estimated copper concentrations for the winter months during the placement of temporary and permanent covers are lower compared to the CCME guideline value. However, the estimated copper concentrations during the summer months are slightly higher than the CCME guideline value.

In summary, the design base case (Scenario 1) will reduce the loadings of selected metal parameters and sulphate in both Dome and Victoria Creeks and improve the long-term water quality at the Victoria Creek at Road target location. The selected metal parameters are predicted to remain below the CCME guideline values during the temporary cover placement, with the exception of arsenic concentrations (no-attenuation case) during the winter months and iron concentrations during the summer months. Exceedances in arsenic and iron were also identified in the existing concentrations measured at the Victoria Creek at Road station. The permanent geosynthetic cover placement is predicted to reduce the oxygen ingress into the pit and prevent acidification of tailings. As a result, the predicted concentrations for arsenic, cadmium, copper, and zinc are expected to meet CCME guideline values. Long-term total iron concentrations are predicted to exceed the CCME guideline value (0.3 mg/L) during the March to October period.

The GoldSim modelling predicts that the Design Base Case will provide water quality at Victoria Creek that meets CCME Aquatic Life guidelines for most parameters. A few parameters are predicted to exhibit slight to modest exceedances on a regular basis. However, in AMEC/AE's view, the nature of the parameters involved and/or the scale of the excursions predicted, are not likely to generate material impacts on the ecological character or health of downstream watercourses. This assumption will require additional consideration and validation during subsequent project development activities on the basis of site specific ecological assessments.

5.1.9 Water Quality Model Sensitivity Analyses

AMEC conducted a sensitivity analysis of the GoldSim model to assess the significance of selected input parameters on model outcomes. The following parameters were assessed:

- hydrology - estimated water quantity;
- geochemistry - tailings and waste rock source terms;
- Open Pit and cover - tailings drainage time, cover infiltration, flushing factor; and
- water quality - upstream Victoria Creek water quality.

The hydrology of the site creeks (Dome and Pony) was found to have minimal effects on water quality predictions because the creek flows are low relative to Victoria Creek.

For geochemistry, the tailings and waste rock source terms were increased to the 90^{th} percentile potential values to assess sensitivity. There were significant effects on cadmium and zinc predictions.

For the Open Pit and cover, the tailings drainage time, cover infiltration and flushing factor were all assessed together and were found to significantly impact arsenic, iron, zinc and sulphate predictions. Cadmium predictions were slightly affected. Parameter sensitivities are greatest while the temporary granular cover is in place.

The 75^{th} percentile and 90^{th} percentile water quality values for the Victoria Reference station were assessed to see how sensitive the model is to upstream water quality. The model predictions were sensitive for all parameters except sulphate, which was slightly sensitive.

5.2 Water Treatment Requirements and Designs

5.2.1 Introduction

To achieve final closure of the site, remediation activities are planned and include the treatment of four main contaminated water sources onsite. These sources include the Tailings Pond, Seep Pond, Pit Lake and Tailings Porewater (water trapped in the pores of the tailings solids). In addition to these primary sources, there are other waters onsite that may require treatment (e.g. mill area pond and tank supernatants); however, the treatment demands for these secondary sources will be less time sensitive than for the primary sources (i.e. primary sources will require treatment to provide access to schedule critical work areas). The current remediation plan is scheduled over two summer seasons in which the current Tailings Pond will be dewatered and the solids removed and transported to the Open Pit for permanent storage. For the remediation activities to begin, the Tailings Pond and Pit Lake must be treated as a priority. Once these two water sources are treated, the tailings solids can be excavated from the Tailings Pond and transported to the pit for permanent storage.

During the first year of site remediation, the entire volumes of the Tailings Pond, Seep Pond and Pit Lake will be treated as well as half of the Tailings Porewater, which will present itself as production from the wellpoint dewatering system. The remainder of the Tailings Porewater will be treated in the second year as tailings solids relocation is continued.

5.2.2 Design Basis

The main considerations for designing the water treatment plant are the flow rate of contaminated water, the raw water quality, and the required effluent quality. The primary design basis for the treatment rate is to treat the entire Tailings Pond (10,000 m^3), Seep Pond (2,000 m^3) and half of the Pit Lake (4,500 m^3) volume over 30 days. To meet these requirements, a daily flow rate of 550 m^3/day was calculated. A contingency was included to bring the design flow to 600 m^3/day (25 m^3/hr) for the water treatment plant (WTP). In addition, there may be in the range of 1,000 to 1,500 m^3 of waters from the mill area ponds and tanks requiring treatment. However, treatment of these waters can be sequenced outside of the execution schedule's critical path and, therefore, do not influence the plant's required throughput capacity.

The raw water quality to be treated was estimated using relevant historical water quality data taken at the locations where water volumes exist and require treatment. The four main water sources to be treated are listed below:

- Pit Lake: samples collected at different depths (2002-2013);
- Tailings Pond: samples collected from surface (2007-2013);
- Seep Pond: samples collected from surface (2007-2013); and
- Tailings Porewater: water quality not available, groundwater samples from the tailings area piezometers were used as a surrogate (2007-2013).

The 90th percentile of the water quality data for each of the sources listed above are shown in Table 5.17. The highest of the four sources 90th percentiles for each element of concern was then taken to represent the raw water quality design basis. In Table 5.17, the red values show the values taken to estimate the overall raw water quality design basis for the WTP.

Table 5.17: Raw Water Quality Design Basis

Parameter	Units	Final Effluent Criteria	Pit Lake	Tailings Pond	Seep Pond	Porewater	Design Basis
Max pH	-	9.5	8.1	8.2	7.6	**8.5**	8.5
Min pH	-	6.0	7.0	7.5	7.0	**6.7**	6.7
TSS	mg/L	15	35	25	**38**	29	38
Ammonia (as N)	mg/L	-	0.3	4.7	8.3	**13.6**	13.6
Arsenic	mg/L	0.5	0.2	0.2	0.2	**15.6**	15.6
Cyanide (as SAD)	mg/L	1.00	0.80	0.08	**4.30**	1.37	4.30
Cadmium	mg/L	-	**0.03**	0.01	0.01	0.01	0.03
Copper	mg/L	0.30	0.07	**0.10**	0.01	0.01	0.10
Iron	mg/L	-	3.6	0.1	17.3	**43.6**	43.6
Lead	mg/L	0.20	0.05	**0.08**	0.05	0.01	0.08
Nickel	mg/L	0.50	**0.05**	**0.05**	**0.05**	0.01	0.05
Zinc	mg/L	0.50	**2.61**	0.36	0.02	0.47	2.61

TSS – Total Suspended Solids
SAD – Strong Acid Dissociable

The final effluent criteria are based on the maximum monthly allowable mean of Metal Mining Effluent Regulations (MMER). Concentrations of some elements are included in the table (ammonia, iron and cadmium) although they are not regulated by MMER. They have been included because they are important for the design consideration of the plant despite not being regulated. Iron (Fe) must be treated to remove acidity and TSS, while ammonia can cause toxicity issues in final effluent.

Treatment System Options

Initially, it was considered to design two small mobile water treatment plants within maritime shipping containers. This was due to the distance separating the two main areas (pit area and tailings area) where the water sources are found. Based on the size of the equipment needed to meet the required treatment rates, this was found to not be feasible due to the size of the clarifier. Therefore, a decision was made to combine the flows into a single larger water treatment plant that would be constructed within a building at a location chosen at a later date.

Treatment System Rationale

The treatment rationale at the WTP was to design the process based on the raw water design criteria using the 90th percentile approach described in Section 5.2.2. This created a worst case scenario incoming feed which determined the reagent systems and unit operations required at the WTP.

Key target contaminants requiring treatment were found to be TSS, zinc (Zn), arsenic (As), cyanide (CN), and ammonia (NH_3). To manage TSS and Zn, and for pH neutralisation, a lime system was included in the design of the WTP. For As removal, the addition of ferric sulphate was needed for As co-precipitation. A peroxide addition system was included in the design in order to oxidize the CN. To promote solid liquid separation of the treated solution, a flocculant system as well as a clarifier was included in the WTP design. Finally a sulphuric acid dosing system was added to decrease the final effluent pH and to reduce ammonia toxicity.

Engineering Design Basis of the WTP

Table 5.18 gives a summary of the major WTP design criteria. In order to allow for remediation activities to begin, the need to treat the current water bodies onsite consistent with the proposed execution schedule is the main driver for the WTP capacity. The design flow was derived based on the requirement to treat the complete volume of the Tailings Pond and half of the Pit Lake over a period of 30 days. The minimum flow was taken to be half of the design flow, whereas the maximum flow was set to 20% higher than the design flow.

Table 5.18: Design Criteria for the Mount Nansen WTP

	Units	Minimum	Design	Maximum
Feed Rate				
	m^3/h	13	25	30
	m^3/d	300	600	720
	L/min	209	417	500
Retention Times (at specified flow)				
Lime/Sludge Mix Tank	min	5.2	5.0	4.0
Reactor #1	min	34	30	26
Reactor #2	min	34	30	26
pH Adjustment Reactor	min	5.2	5.0	4.0
Reagent Consumption				
Hydrated Lime - $Ca(OH)_{2+}$	g/L	0.01	0.10	0.15
Flocculant	mg/L	1	5	8
Ferric Sulphate (60%)	g/L	0	0.47	0.57
Peroxide (50%)	g/L	0	0.011	0.013
Sulphuric Acid (50%)	g/L	0	0.08	0.09
Sludge Production				
Solids Production	g/L	0.06	0.25	0.31

Retention Times

There are four reactors in the water treatment plant: the Lime/Sludge Mix Tank, two consecutive reaction tanks (Reactor #1 and Reactor #2), and a pH Adjustment Reactor. The Lime/Sludge Mix Tank and the pH Adjustment Reactor have retention times of 5 minutes, whereas Reactors #1 and #2 have retention times of 30 minutes.

Lime Consumption

Hydrated lime will be mixed with water to make a slurry of 20% solids which will be added directly to the Lime/Sludge Mix Tank that feeds Reactor #1. The hydrated lime consumption rate was based on a theoretical calculation of metal hydroxide precipitation and the raw water quality expected at the WTP. Due to Zn concentration being the highest of all the metals treated through lime precipitation, the pH will be controlled to 9.5 where hydroxide precipitation is sufficient. Assuming a 95% utilization efficiency of lime, the consumption rate was found to be 0.1 g of lime per litre of feed treated.

Ferric Sulphate Consumption

Ferric sulphate is required due to the incoming arsenic (As) recorded as high as 15.6 mg/L. Using a requirement of a Fe to As molar ratio of 5:1, the consumption rate was found to be 0.47 g of ferric sulphate solution per litre of feed treated.

Peroxide Addition

Total CN is regulated by MMER and a common water treatment approach to deal with CN bearing waters is oxidation through peroxide addition. For the purpose of this conceptual study, the consumption of peroxide was calculated using 1.26 kg of peroxide per kg of CN present (as recommended by US Peroxide for water treatment purposes). Based on this assumption, the design basis of the peroxide system is 0.005 g peroxide per L of water, or 0.011 g of 50% peroxide per L water (50% is the commercially available form).

Air Addition

To ensure that the peroxide is used for CN oxidation, air is added to the first reactor to oxidize other elements that may consume peroxide more readily than CN. Considering the potentially high concentrations of incoming Fe (44 mg/L) and its ability to oxidize easily, the design basis for the air addition system is based on the influent Fe concentration assuming a 20% oxygen transfer efficiency. The amount of air being added to Reactor #1 is 4 m^3/hour.

Flocculant Consumption

A flocculant will be added to the solution in order to promote settling of the solids in the clarifier. The flocculant addition rate is based on previous experience in other water treatment plants and was chosen to be dosed at a rate of 5 mg/L. Magnafloc 10 was chosen for costing but this may change in the future.

Acid Addition

Sulphuric acid will be added to the pH Adjustment Reactor prior to effluent discharge. Ammonia toxicity is influenced by pH and is reduced significantly with decreasing pH. The acid requirement was estimated by calculating the amount required to decrease the pH from 9.5 to 7, including the alkalinity from the ammonia itself. Using this approach, 0.08 g of 50% sulphuric acid is required per litre of feed.

Sludge Production

The sludge production was estimated through theoretical calculations of the amount of solids resulting from metal hydroxide precipitation, from incoming feed solids, and from 5% inert lime solids. All of the Fe in the raw water was assumed to be precipitated as ferric hydroxide ($Fe(OH)_3$) and all of the As as arsenate (AsO_4) adsorbed onto $Fe(OH)_3$. This resulted in 0.25 g of sludge production per litre of feed treated.

5.2.3 Water Treatment Plant Design

Drawings D026 through D032 contain the Process Flow Diagrams (PFD), the Process and Instrumentation Diagrams (P&ID, five drawings), the General Arrangement (GA), respectively. The appendix also Appendix L includes the list of selected mechanical equipment.

Based on the contaminants present in the raw water, five reagent systems are required: lime, ferric sulphate, peroxide, flocculant, and sulphuric acid. These systems are described in the following sections. Ancillary services and safety systems have been included in the water treatment design and are also discussed in subsequent sections.

As seen in the PFD, the raw feed coming from the pit area and the tailings area will be fed into Reactor #1 through two separate lines (3” HDPE piping). This feed will be contacted with the lime/ sludge mixture from the Lime/Sludge Mix Tank for pH neutralisation and hydroxide precipitation. A pH control of 9.5 will be targeted for Zn hydroxide precipitation. Ferric sulphate will also be added in this reactor to co-precipitate As in the feed and air will be sparged for Fe oxidation. The effluent from Reactor #1 is then gravity fed into Reactor #2 where peroxide for CN oxidation is added.

From Reactor #2, the process solution is mixed with flocculant in a small agitated tank that feeds the lamella clarifier. The precipitated solids will flocculate and settle in the clarifier allowing the clear water to rise in the clarifier. The liquid solution will be gravity fed from the clarifier to the pH Adjustment Reactor. A portion of the solids from the clarifier will be recycled back to the Lime/Sludge Mix Tank to be mixed with the incoming lime slurry. A purge line will remove sludge from the system for permanent storage. Sulphuric acid will be added in the pH Adjustment Reactor to decrease the pH to 7 prior to final discharge.

Location of the WTP

Considering that the main water sources requiring treatment are not found in the same geographical location, the optimal site of the WTP needs to be carefully selected. The Pit Lake is located higher in elevation than the Tailings Pond and Seep Pond; however, potential residual contaminated water from the site requiring long term treatment will most likely occur at the pit area. For the purposes of the conceptual level water treatment plant design, the preliminary location of the treatment plant will be in close proximity to the tailings area to reduce pumping requirements. This location may be changed or further refined at a later date when more site information is available and considered.

Raw Water Feed

The feed to the plant will originate from the pit area and from the tailings area. Two mobile diesel self-priming pumps will serve to extract water from the areas described above and feed the WTP. A reserve self priming pump will be available as a spare. As previously discussed in Section 5.2.2, the design feed is 600 m^3/day (25 m^3/hr).

Reagent Systems

To manage the different contaminants in the raw water, five reagent addition systems were developed and incorporated into the WTP.

Lime System

The lime system is made up of two main components: lime preparation and lime dosing. Lime will be delivered in 500 kg bags and stored in the plant. The lime preparation consists of a bag support system feeding lime to an overhead hopper with a screw feeding the material to an agitated reservoir where water is added to target a desired solids content.

The slurry is fed to a 400 L storage tank which is sized to provide 12 hours of continuous operation. The lime slurry is pumped to the Lime/Sludge Mix Tank through one of two Verderflex peristaltic pumps.

Ferric Sulphate System

Ferric sulphate solution will be received onsite in totes and transferred using a barrel pump to a 1,890 L storage tank capable of holding one and a half totes. From the storage tank, the ferric sulphate is dosed to Reactor #1 using one of two solenoid diaphragm metering pumps (Prominent Delta1608). The Prominent PROSIP turnkey vendor dosing system is made up of PVC SCH 80 piping and is equipped with safety valves, pressure indicator, vents and calibration column.

Peroxide System

A peroxide addition and dosing system by WaveControl and is also a turnkey vendor package. The reagent is planned to be received onsite in barrels of 50% peroxide. The turnkey package includes a transfer pump (air operated) package with 1” HDPE piping, and an injection pump (two RH Milton Roy pumps) package equipped with a flow metering system, a tank level display and alarm system.

All wiring and safety controls are mounted on a 304 SS frame. ½” Swagelok tubing and valves, as well as a carbon tote stand and a 300 L HDPE tank equipped with secondary containment is also included.

Air System

Air will feed the bottom of Reactor #1 at 4 m^3/hr through one of two Elmo Rietschle blowers, as quoted by Aircom Technologies.

Flocculant System

Flocculant will be received onsite as dry material and is planned to be mixed with water onsite through a flocculant makeup system. The dry material will be sucked through a tube into a hopper and transferred to a wetting cone through a double screw feeder, where water and the dry material are mixed. The resulting liquid solution is then transferred to a 300 L reservoir where preparation and maturation is completed, followed by gravity feeding a second 300 L reservoir for solution storage and dosage into the process. A turnkey vendor package by ChemAction is equipped with all of the necessary equipment, piping, valves, safety systems, wiring and controls.
The flocculant is then fed to an agitated Flocculation Tank that is included in the lamella clarifier vendor package. At this point the flocculant is contacted with the solids in the slurry and fed into the clarifier.

Acid System

Sulphuric acid at a strength of 50% will be received at the WTP in barrels and transferred into a 450 L HDPE acid holding tank using a barrel pump. The holding tank has been sized to hold one and a half times the capacity of a barrel. The same dosing system as the ferric sulphate addition system is used for acid, with the only difference being that the material of construction for the piping is PVDF in this case.

Reactors

Reactor #1

The volume of this reactor is based on the design feed rate and the desired retention time for pH neutralisation and metal precipitation. A reactor volume of 13 m^3 was selected based on a retention time of 30 minutes and a design feed rate of 25 m^3/hr. The typically available vendor tank for Reactor #1 is slightly smaller and constructed out of steel. Typically, the best engineering design to ensure efficient mixing is a cylindrical tank with a height-to-diameter ratio near 1. The diameter and height of this tank are 2.6 m and 2.7 m, respectively. An agitator will be mounted on the top frame of the tank to ensure blending of the chemicals. A top entry dual impeller agitator (GC-3) is provided.

Reactor #2

The reactor volume and dimensions and agitator specifications are identical to Reactor #1 as the retention time and feed rate are the same.

pH Adjustment Reactor

The volume of the pH Adjustment Reactor of 2 m^3 is based on a retention time of 5 minutes at the design feed rate. In this reactor, sulphuric acid is added to decrease the pH and, therefore, a long retention time is not required.

The vendor steel tank has a diameter of 1.35 m and height of 1.5 m and will also require an agitator to ensure mixing. A top entry dual impeller agitator (GC-2) by Hayward Gordon was used for the cost estimate.

Lime/Sludge Mix Tank

The Lime/Sludge Mix Tank volume was calculated to be 0.25 m^3 based on a retention time of 5 minutes and a combined flow of 3 m^3/hour (mix of lime slurry and sludge recycle). The lime slurry flow rate is based on a theoretical calculation of lime required for metal precipitation and the target slurry solids content. The sludge recycle flow rate is based on the assumption of a 10% volumetric recycle ratio of the plant inlet feed rate.

A 300 L Lime/Sludge Mix Tank built out of LLPE equipped with an agitator support is by ChemAction. The tank is slightly larger than required, with a diameter of 0.6 m. An agitator capable of mixing highly viscous fluid was estimated for this application.

Lamella Clarifier

A lamella clarifier was selected for this process in order to minimize the footprint required for the WTP. Feed exiting Reactor #2 is mixed with prepared flocculant in a Flocculation Tank that feeds the clarifier. A vendor package by Parkson is 3.4 m in length, 1.8 m in width and has a height requirement of 5.5 m.

Process Water System

Process water is required throughout the plant for flocculant dilution and for rinsing of lime pumps and other process lines. In addition, water will be supplied to hoses to allow for general plant cleanup. To meet the process water needs within the plant, two effluent return pumps by Hayward-Gordon will allow for the treated effluent to be returned within the plant for process water needs and will also be capable of returning off-spec effluent water to the Tailings Pond or a storage tank located within the plant if required.

Fresh Water System

Fresh water needs within the WTP include the chemical makeup of lime and flocculant, as well as for sinks, lavatories, and safety equipment (safety showers and eye wash stations).

High quality fresh water is available for extraction at a local well near the Victoria Creek. Extracted water will be transported to the WTP through a 2” HDPE line where it will be stored in a 3 m^3 water reservoir. A conventional water heater used in residential applications has been priced for heating. In addition, two 7.5 HP booster pumps mounted on a skid will supply the required water pressure in the WTP. Water will be drawn from the well to fill up the water reservoir and water heater located within the plant. To comply with safety shower regulations, this water will be disinfected with a UV system by Techneaulogic.

Compressed Air System

Compressed air will be supplied to instruments and air hoses. A skid mounted air compressor, with a 120 gallon horizontal air receiver tank, dryer and filtration system was by Comairco.

Process Air

Process air requirements include air addition to Reactor #1 through blowers by Aircom Technologies.

Sump Pumps

Three sumps will be located in the WTP building, one for the lime and flocculant system, one each for the acid and the ferric sulphate systems. The sumps will serve to collect spills and wash down water used for general plant cleanup. Each sump will be equipped with a 5 HP Weir sump pump which will send the collected slurry to Reactor #1. When the plant is not in operation, the sump pumps will be capable of returning the solution to the Tailings Pond or a storage tank within the plant.

Sewage Holding Tank

Sewage from the WTP building, lavatory, and sinks will flow to a septic tank and drainage field.

Instrumentation and Automation

The WTP is designed to operate automatically; however, the majority of the reagent handling and addition systems require manual intervention. Given the low reagent consumption rates, once the reagent systems have been topped up they are self-sufficient for periods greater than 12 hours. Within the reagent systems, the vendor packages selected include automation to regulate flow addition and safety requirements.

Both the lime and flocculation systems include level indicators, switches and alarms to control the amount of water and dry material addition. Flow control components for the dosing pumps are also included. The ferric sulphate and sulphuric acid systems include controls on the metering pumps and are equipped with the necessary pressure indicators and valves. The peroxide system has a more complex automation process as part of the vendor turnkey package. An Uninterruptable Chemical Supply (UCS) flow meter with an automated flow and level measurement system including stop flow and low level alarms are included in the package.

The raw water flow rate will be monitored and controlled for both incoming feed lines. Control of pH will be required at Reactor #1, as well as continuous turbidity and pH monitoring at the pH Adjustment Reactor. Chemical analysis of the discharge will also be necessary in order to ensure regulations are met. A beacon and alarm will be installed in the plant, and can include an automatic call out system. To monitor sulphuric acid, an H_2 gas analyzer will also be required where acid is unloaded and handled within the plant.

The instrumentation and controls will be further refined at the detailed engineering stage. For the current study, it is assumed that automation using a local PLC will be done.

Health and Safety

Three emergency showers and eye wash stations (ESES) will be present within the plant and are located at the following locations: the peroxide handling and dosing area, between the ferric sulphate and sulphuric acid systems, and finally between the clarifier and the pH Adjustment Reactor. A chemical fire suppressant system is planned and a cost based on similar sized WTP was used.

Sludge Production and Handling

The key sludge production numbers are summarized in Table 5.19 for the first year of operation. Approximately 300 m^3 of sludge will require disposal during the first year of operation when the entire Pit Lake and Tailings Pond volumes are treated as well as 40,000 m^3 of the Tailings Porewater. In subsequent years, when significantly smaller volumes require treatment, the sludge production will also be greatly reduced. Considering the bulk of the sludge production will occur while site remediation activities are underway, it is expected that the sludge produced in year 1 can be consolidated with the tailings solids that are being relocated to the pit.

Table 5.19: Expected Sludge Production at Design Flow for Year 1

	Value	Unit
Sludge generation rate	0.25	g/L
Daily sludge production rate (dry basis)	150	kg/d
Expected annual production (based on volume treated in year 1)	15,247	kg/yr
% solids (assumed)	5%	w/w
Sludge density (assumed at 5% solids)	1.02	kd/L
Expected annual production requiring disposal	300	m^3/yr

5.2.4 Uncertainties and Cost Implications

This is a preliminary design report, which required several assumptions and theoretical calculations to complete. Detailed plant design requires validated reagent consumption rates, attainable effluent quality, and sludge production rates. The best water treatment plant designs are based on pilot treatment of the representative water source. When this is not done, the next best level is based on laboratory trials of representative waters. These trials are then used to define the reagent consumption rates and sludge production rates to properly size the process systems.

In the case of Mount Nansen, for this report, the chemistry of some of the water sources was not fully defined. This is the case for the Tailings Porewater, which represents an important volume for treatment and which will influence the quality of the long-term plant influent after the wastes have been placed in the pit and covered. The Tailings Porewater quality was based on a surrogate source, groundwater samples taken from the tailings area. This water quality is different from other water sources and represented the design water quality for pH, ammonia, As, and Fe.

As explained in detail in the following sections, a significant decrease in the design concentration for some of the expected contaminants could result in the elimination altogether of some reagent systems. Water management may be used to best combine water sources during treatment and some parameters may be controlled without specific treatment.

The lime, ferric sulphate, and flocculant systems are considered necessary; however, the peroxide and sulphuric acid systems could potentially be eliminated pending confirmatory sampling and test work.

Reagent System Uncertainties

Lime System

The lime consumption was based on a theoretical calculation of expected raw water quality and metal hydroxide precipitation. It was assumed that all of the incoming metals that readily react with lime to form hydroxides would consume the reagent. A major consumer of lime is Fe, and the current design basis uses the 90th percentile value for all expected metal concentrations in the incoming feed. If the value of Fe used for the design is overestimated, this translates into an overestimation of lime consumption.

The design basis for Fe concentration issues from the Tailings Porewater surrogate groundwater samples. Specific sampling and laboratory work testing lime consumption should be done to better define the expected lime consumption rate.

Ferric Sulphate System

The ferric sulphate serves to co-precipitate As, as a coagulant to remove TSS, and can also improve the treatment efficiency of dilute heavy metals, such as Zn. The sizing of the system is based on the largest estimated consumer (As from the Tailings Porewater). Again, this concentration stems from the 90th percentile of a surrogate groundwater, which may be overestimating actual concentrations.

Furthermore, the ferric sulphate consumption for the design basis was calculated using a conservative molar ratio of 5:1 Fe to As, which can be as low 3:1 Fe to As ratio in some cases. This conservative estimate could be reduced through laboratory testing which could better define the required ratio for this water.

Also note that up to 44 mg/L of Fe could be present in the WTP feed (also from the Tailings Porewater surrogate). The presence of Fe in the feed would offset the amount of ferric sulphate addition required.

Although it is not expected that the ferric system could be altogether eliminated, it may be possible to reduce the system sizing with representative sampling and laboratory analyses.

Peroxide Addition System

Peroxide addition has been included in the WTP design to treat CN. Elevated CN levels (above MMER) were measured in the Seep Pond and the Tailings Porewater surrogate. The 90th percentile CN concentration was used for these sources. As the Seep Pond is a smaller volume, it may be possible to combine it with other feed waters to decrease the feed concentration to the WTP. Also, the addition of ferric sulphate to the process and the sludge recirculation may help to partially remove the CN as a ferro-cyanide complex in the solids.

The peroxide system is expensive and handling peroxide is a safety concern. If it can be removed from the system through optimized water management and partial treatment to meet MMER limits, this should be evaluated.

Also note that peroxide consumption is highly site-specific as organics or metals can consume some of the oxidising potential. This is why peroxide was added in the second reactor, after 30 minutes of aeration in the first reactor. Despite this design, the estimated peroxide consumption should be evaluated through laboratory studies with representative water if peroxide is to be used in the plant.

Sulphuric Acid Addition System

Sulphuric acid is added in the final stage of the WTP to lower the pH in order to reduce ammonia toxicity, which decreases considerably over the pH range of 9.5 to 7. The current sulphuric acid consumption rates are based on the 90th percentile of ammonia in the Tailings Porewater (using the groundwater surrogate). Ammonia is also present in the Seep Pond. Ammonia is not directly regulated in MMER, but it can cause toxicity, particularly at concentrations of more than 10 mg/L. The design values are in the order of 8 to 13 mg/L, and may not pose any significant toxicity issues.

If it is possible to remove the sulphuric acid from the system, this could significantly reduce capital costs. If sulphuric acid is needed, there is currently considerable uncertainty in the required dosages as they depend significantly on the alkalinity of the water to be neutralized. Laboratory testing could be used to provide treated water samples of sufficient size for dosage evaluation and toxicity testing.

Sludge Production and Disposal

The production of solids at the WTP is driven largely by the reagent addition rates. As the reagent systems are optimized, this will greatly reduce the amount of solids being produced at the plant.

WTP Operating Costs

Other cost saving opportunities may exist if logistics are managed efficiently. Elevated costs for freight are encountered for reagent transport. Current industry standard pricing is based on a full truckload, but considering the low reagent consumption rates, full truckloads will not be needed for most of the reagents throughout the life of the plant, which inflates the unit cost of reagents. The average freight cost for a full truck has been applied to each of the five reagents required onsite. This inflates the operating costs and can be reduced considerably at a later stage when logistics are optimized.

Other Cost Savings Opportunities

The cost estimate did not consider opportunities for lowering costs by utilizing services and equipment suppliers local, or relatively proximate, to the site. These cost reductions, through local sourcing opportunities, should be evaluated in subsequent phases of design.

5.2.5 Water Treatment Summary

A preliminary water treatment design was prepared to treat all expected contaminants for rehabilitation of the Mount Nansen site. All systems were designed to treat the worse case expected, based on the 90th percentile of concentrations from four water sources: Pit Lake, Tailings Pond, Tailings Porewater, and Seep Pond. Due to significant uncertainty in the expected concentrations of contaminants, the plant was conservatively designed to mitigate suspended solids, ammonia, arsenic, cyanide, iron, and zinc. To do this, five reagents were included in the design: lime, ferric sulphate, flocculant, sulphuric acid, and peroxide.

5.3 Water Quality Monitoring

5.3.1 Construction Water Management and Erosion and Sediment Control Plan

The construction water management plan (CWMP) and erosion and sediment control plan (ESCP) will cover all the areas onsite disturbed due to the remediation construction activities. These will include:

- Tailings area;
- Pit area;
- Waste rock areas;
- Mill/Camp area;
- Backfill trenches;
- Landfill area;
- Dome Creek; and
- Borrow areas.

Purpose and Objectives

The purpose of the CWMP and ESCP is to manage runoff and stormwater in a manner that maintains work areas to be in a suitably dewatered condition to allow construction to proceed, and that minimizes non-contact water from entering areas disturbed by construction activities, thus reducing potential erosion and sediment loading. The CWMP will also address the management of any water that may require treatment during and following the construction period (e.g. tailings dewatering at source or in-pit).

Design Criteria

Different elements of the water management plan have different design criteria but will be implemented using standard industry elements. Likely criteria will be as follows:

- sediment ponds - peak monthly flow, 1 in 10-year return interval;
- temporary diversion channels - 1 in 25-year return interval; and
- permanent diversion channels - 1 in 1,000-year return interval.

Construction Water Management Plan

The CWMP will involve the following key elements:

- Collecting non-contact water from upstream of the construction sites for routing and discharge downstream. Non-contact water will be collected in either diversion channels or diversion pipes from upstream of each construction area and discharged downstream.
- Minimizing erosion at the downstream discharge points. To minimize erosion, point water will be discharged in either pool areas or flat areas with erosion protection.
- Maintaining downstream water quality and quantity. Water quality will be monitored upstream and downstream of each construction area. Water quality parameters to be measured will include total suspended solids, sulphate, pH and metals of concern identified in Section 5.1. Frequency of water quality monitoring will be at least weekly and after a major storm event.

Specific details of the CWMP at each construction area will be provided in subsequent design stages.

Erosion and Sediment Control Plan

The purpose of the Erosion and Sediment Control Plan (ESCP) is to minimize erosion in areas disturbed by construction activities, and to prevent the release of construction water with excessive total suspended solids (TSS).

Activities that have the potential to result in erosion during the MNRP include:

- excavation and mobilization of tailings into the pit;
- filing and grading of the pit area;
- mobilization of potentially acid generating (PAG) waste rock material into the pit;

- demolition of mill and camp area;
- backfilling of trenches;
- restoration of Dome Creek;
- preparation and excavation of borrow material; and
- miscellaneous site reclamation activities.

Potential hazards, in the absence of planned mitigation measures, from these activities include:

- increased surface erosion from disturbed and rehabilitated areas;
- increased sediment and pollutant load entering the natural water system; and
- siltation or erosion of watercourses and water bodies.

The ESCP for the MNRP has been prepared to address the above potential hazards and to demonstrate effective management of clean surface water and sediment laden runoff. The ESCP will be implemented to meet the following objectives:

- minimize and route water leaving construction areas to local temporary sedimentation ponds (if required);
- stabilize disturbed land surfaces to minimize erosion and re-establish vegetation cover in accordance with the Reclamation Plan (Section 7);
- manage all surface water runoff from the project area, and prevent sediment-laden water derived from construction activities or site development from entering non-isolated watercourses;
- retain sediment within the disturbed or construction area;
- implement a monitoring and maintenance program;
- install sediment controls prior to disturbance of any land;
- minimize to the extent practical, the extent and duration of exposure of soils which may be at risk for erosion;
- reduce water velocity across the ground particularly on exposed surfaces and in areas where water concentrates;
- progressively rehabilitate disturbed land and construct drainage controls to improve the stability of rehabilitated land;
- rip/disc rehabilitation areas to promote infiltration;
- protect natural drainages and watercourses by constructing appropriate sediment control features such as collection and diversion ditches, holding ponds, sediment traps and sediment basins;
- install rock riprap, rock channel lining, sediment filters or other suitable measures on steep gradients, as required;
- restrict access to rehabilitated areas;

- construct surface drainage control to intercept surface runoff; and
- construct silt fences downslope of disturbed sites (where more permanent sediment control measures are not appropriate, or in combination with and as a supplement to more permanent measures).

These objectives will be met by application of appropriate stormwater management and erosion control Best Management Practices (BMPs) as presented in Appendix G.

5.3.2 Post Remediation Water Quality Monitoring Plan

The objective of the post remediation water quality monitoring plan is to evaluate the effectiveness of the remediation design implementation. This water quality monitoring plan covers the post remediation stage, after construction is completed.

The water quality monitoring plan for post remediation will be based on the following stages.

Stage 1
Dome Creek

- upstream and downstream of the mill area;
- upstream and downstream of the tailings area; and
- at the mouth just before discharging into Victoria Creek.

Pony Creek

- upstream and downstream of the pit location; and
- at the mouth just before discharging into Back Creek.

Back Creek

- upstream and downstream of Pony Creek confluence.

Victoria Creek

- upstream and downstream Back Creek confluence;
- upstream and downstream of Dome Creek confluence; and
- compliance point.

Groundwater

- Open Pit;
- upstream and downstream of the Open Pit (including in the Dome Creek Valley).

In the first year of Stage 1 monitoring, water quality sampling will be conducted on a monthly basis. After the first year, if the following stations demonstrate consistent compliance with CCME, the frequency will be reduced to two times a year:

- Dome Creek
  - upstream and downstream of the mill area; and
  - upstream and downstream of the tailings area.
- Pony Creek
  - upstream and downstream of the pit location.

In the second year of monitoring, the rest of the stations will be monitored quarterly provided that initial monitoring confirms that quarterly monitoring can offer notice of quality excursions consistent with Adaptive Management response requirements.

Stages 2 and 3
Stage 2 and 3 monitoring will include the following:

Dome Creek

- at the mouth just before discharging into Victoria Creek.

Pony Creek

- at the mouth just before discharging into Back Creek.

Back Creek

- upstream and downstream of Pony Creek confluence.

Victoria Creek

- upstream and downstream Back Creek confluence;
- upstream and downstream of Dome Creek confluence; and
- compliance point.

Groundwater

- Open Pit; and
- upstream and downstream of the Open Pit. (including in the Dome Creek Valley)

As the water quality consistently demonstrates compliance, the frequency of monitoring will be reduced to twice a year. The long-term monitoring will depend on the water quality results. As water quality improves and demonstrates consistent compliance with CCME, monitoring frequency will be reduced.

5.4 Huestis Adit Water Quality

Table 5.20 summarizes the water quality along Dome Creek extending from upstream of Huestis Adit (WQ-DC-DX), past Huestis Adit (HA series wells) and the Mill area and down to the Tailings Pond.

Table 5.20 presents a summary of the exceedances versus the CCME guidelines. Also presented are the total cation concentrations (expressed in milliequivalents per litre, meq/L). Water quality standards from the Yukon CSR are not evaluated in Table 5.20 as this evaluation is focused on the surface water quality in Dome Creek and CSR standards are designed to be applied to groundwater (i.e. a factor of 10 dilution is available upon discharge to surface water).

The analytical results presented in Table 5.20 are directly comparable with the exception that groundwater samples are for dissolved metals (i.e. filtered and acidified in the field) and the surface water samples are for total metals (i.e. acidified without filtration). This is a standard distinction applied to groundwater versus surface water for metals analyses.

Table 5.20: Summary of Water Quality Exceedances Along Dome Creek to the Tailings Pond Area

Sample Location	Water Type	Total Cations (meq/L)	Total Number of 2013 Exceedances	Iron	Zinc	Arsenic	Cadmium	Copper
WQ-DC-DX	Surface Water	6.5	5	x	x	x	x	x
WQ-MS-03		15.0	5	x	x	x	x	x
WQ-MS-08		18.0	3	x	x	x		
WQ-DC-DX+105		15.0	5	x	x	x	x	x
DC-02	Groundwater	14.2	2	x		x		
HA-01		13.2	1	x				
HA-02		13.9	2	x	x			
HA-03		12.9	3	x	x		x	
HA-04		4.0	1	x				
HA-05		13.0	3	x	x	x		
WQ-DC-D1	Surface Water	14.5	5	x	x	x	x	x
WQ-DC-D1b		14.4	4	x	x	x	x	
DC-03	Groundwater	13.9	3		x		x	x
DC-05		16.5	3	x	x		x	
WQ-DC-U1	Surface Water	14.5	4	x	x	x		x
WQ-DC-U2		13.8	5	x	x	x	x	x
Total			54	15	13	10	9	7
Percentage of Total			100%	13%	12%	9%	8%	6%
Total in Surface Water			36	8	8	8	6	6
Total in Groundwater			18	7	5	2	3	1

Note: Sample locations along Dome Creek sorted from upstream to downstream. HA denotes sample locations near Huestis Adit.
Analytical results are compared to CCME
Yukon CSR standards were not applied as this evaluation is limited to surface water and CSR standards are designed for groundwater.
Total cations are expressed in milliequivalents per litre (meq/L).

Based on the total cation concentrations and the exceedances noted, there is essentially no distinction between the Huestis Adit (HA) samples and upstream or downstream Dome Creek water quality. The total cation concentration in the upstream WQ-DC-DX sample is half that of the downstream samples, but there were a total of five exceedances at this upstream location. Two downstream locations also had five exceedances, but the five HA samples had between three and five exceedances.

Based on these results, there is no indication that Huestis Adit is contributing to the contaminant loading in Dome Creek at a level that would distinguish it from the contribution from the Mill area.

5.5 Design Contingencies and Adaptive Management

One of the key objectives of the MNRP is the maintenance of acceptable surface water quality at compliance points (i.e. most likely CCME fresh water quality guidelines (adjusted as may be appropriate to reflect inputs upstream of the site) at Victoria Creek). The work to date predicts that the current Design Base Case for Option 4 can likely provide and sustain acceptable downstream water quality. However, there is a considerable degree of uncertainty that continues to be associated with this prediction. This uncertainty is outlined by the discussion in Section 5.1.8, and is a product of limitations in the quantitative characterizations and understandings that have been developed for:

- the geochemistry of tailings and PAG waste rock and the associated definitions of modelling source terms;
- the timing and extent of potential tailings acidification;
- the hydrogeological model for the area and the associated understanding of potential groundwater flow paths;
- the pit groundwater balance (i.e. inflows vs. outflows) and its long term influence on maximum post remediation groundwater levels;
- the attenuation of parameters of concern between the backfilled pit containment structure and surface water compliance points;
- the potential influence of climate change on the pit's permafrost regime and hence groundwater flow paths;
- tailings and waste rock settlement behaviours and their influence on the ability of both interim and final covers to limit infiltration and oxygen transfer;
- the flow characteristics of Dome and Victoria Creeks;
- variations (including potential CCME excursions) in surface water quality upstream of the site;
- the impacts of water quality excursions on the ecologies downstream of the site; and
- travel time from contaminant sources to potential monitoring locations or receptors. (i.e. predictions of when the contaminants are expected to appear in Victoria Creek, where the CCME guidelines are to be applied).

The current ranges that apply to these key parameters, and the permutations of potential interactions and inter-relations, mean that reliable predictions of downstream water quality are difficult, to say the least. The significance of this fact is heightened by the consequences of unacceptable water quality degradations. Should these degradations appear and persist, one of the key objectives of the MNRP would not be satisfied.

Efforts to improve the reliability of water quality predictions would require extensive incremental data acquisition and analysis, and it is not at all clear that the outcomes would be sufficiently definitive to mitigate the potential for unexpected post remediation monitoring results. In AMEC/AE's view, it will be more practical and prudent to mitigate uncertainties in water quality predictions via design contingencies and Adaptive Management.

5.5.1 Design Contingencies

Design contingencies are measures that may be added to the Base Case as the design is further developed (i.e. during subsequent stages of design) or in response to conditions observed during construction (i.e. they are measures that would form part of the as-built remedial design). The key design contingency that AMEC/AE believes may be needed as part of the effort to mitigate uncertainties in water quality predictions will be the ability to control and collect waters before they are released to the local hydrogeological/hydrological regime. The following section describes how this capability would be applied in a broader Adaptive Management strategy for water quality maintenance. This control and collection capability is identified as a design contingency rather than an Adaptive Management measure because of the difficulty of retrofitting this capability after the pit has been backfilled (i.e. it must be incorporated during construction, not after monitoring has confirmed its necessity).

A pit water control and collection capability would take the general form described below and shown on Drawing D034 (note: these are concepts that will require additional definition during subsequent stages of design):

- Waste Rock Liner: groundwater flow out of the pit is less than the permeability of the base rock, meaning that some form of hydraulic barrier near the pit base will be necessary to mound flows as needed to facilitate recovery with production wells. This barrier would likely take the form of a thick HDPE geosynthetic constructed within the waste rock bench and configured to mound water without resulting in groundwater levels above the tailings base when collection is not required to maintain downstream water quality.
- Side Wall Drainage: a vertical drainage layer would be placed between the tailings and the pit wall to direct any local, lateral flows to the contained waste rock area at the base of the pit. These drains would likely take the form of granular filter/processed rock layers if tailings are relocated using the controlled placement method, or geonets and geotextiles hung from the top of the pit if tailings are end dumped into the structure. The viability and longevity of this latter method will require additional assessment in subsequent design phases (i.e. it is not clear at present that geonets could be protected sufficiently to withstand the forces that would be applied in an end dumping scenario).

5.5.2 Adaptive Management

If at any time post remediation, the water quality monitoring program identifies parameter excursions, AMEC/AE would envisage a response hierarchy along the following lines:

- confirmation of the integrity and accuracy of the sampling and analytical data set;
- confirming that excursions are not the product of water quality impacts upstream of the site;
- completing a first order assessment of the human health and ecological risks posed by sustained excursions of the order observed;
- reviewing the monitoring and maintenance history for the pit cover to determine if water quality excursions could be related to previously unflagged changes in cover condition or performance;
- if cover integrity has been confirmed and monitoring excursions are expected to continue, undertaking detailed human health and ecological risk assessments if the first order assessments have concluded that higher, site specific water quality standards could be supported and would be appropriate;
- if water quality criteria changes cannot be supported, or are not sufficient to fully mitigate concerns, undertaking predictive assessments of the potential mitigative benefits offered by:
  - upgrades to the pit cover; and
  - production and treatment of pit waters utilizing the control and collection systems incorporated during remediation.
- designing pit cover upgrades and/or a pit water collection and treatment capability based on the monitoring, maintenance and performance data available at the time, and the outcomes of the predictive assessments described above;
- constructing pit cover upgrades and/or the above water collection and treatment capability. The water collection and treatment design would likely include:
  - the installation of production wells at the pit, completed in the contained waste rock zone;
  - pumping, piping and storage systems needed to convey waters from the pit area to the water treatment plant; and
  - constructing, commissioning and operating a water treatment plant. This would either be the original plant constructed to support remediation (Section 5.2), reconfigured and recommissioned as needed for the Adaptive Management design, or a dedicated capability mobilized specifically to respond to the Adaptive Management requirement (presumably this latter approach would be taken if it was determined that decommissioning and salvaging the original plant was more cost effective than mothballing the facility and retaining onsite for potential Adaptive Management requirements).

6 SITE INFRASTRUCTURE DECOMMISSIONING, DEMOLITION AND DISPOSITION PLAN

6.1 Infrastructure Inventory

6.1.1 Mill Area

Overview

The mill complex was constructed in 1968 and received major upgrades in 1998. It comprises several inter-connected steel buildings of varying size and shape, all in fair condition situated on a levelled site.

It is estimated that potentially 80% of the total deconstructed waste steam could be diverted to reuse or recycled to a smelter or crusher; however, the remoteness of site, and availability of a local waste disposition option (i.e. the Open Pit) are expected to limit the potential salvage benefits. Most high value equipment, for example, pumps, motors, conveyor belts and some cabling, has been removed. Building structures, however, are practically intact.

Drawing D035 shows the subdivided location of the mill complex, with the summarized Structural Inventory in Table 6.1 for the areas A to K. Drawing D036 views show selected views representing the character of the mill building complex.

Structural Inventory

A summary of the features and deconstruction aspects of each building area in the Mill is given in Table 6.1.

Electrical Inventory

Heavy cabling in the mill has largely been removed. Residual electrical equipment includes control and instrumentation cabinets (MCC) in buildings B, C, D and E, switchgear and distribution equipment including cable racks and conduits, and light fittings mostly fluorescent units. All these items have low salvage value destined as managed waste, and they are lumped together as ‘Building Content’ for inclusion under the inventory of the main deconstruction contract.

External electrical infrastructure is discussed under Section 6.1.2.

Mechanical Inventory

Mechanical equipment in the Mill complex includes the following:

- conveyor systems without the rubber belts (which have been removed);
- miscellaneous valves and piping, in steel, PVC and HDPE;
- ventilation ducting and fans; and
- crushers in building H (jaw and cone crushers).

These items have salvage value. They are lumped together under ‘building content’ for inclusion in the inventory of the main deconstruction contract.

Table 6.1: Structural Format and Content Inventory – Mill Complex

Area (see Drawing D035)	Structure Format, Materials	Contents – Generic Terms (Non Itemized)	Suggested Deconstruction Procedure[(1)]	Potentially Hazardous Materials
A – Agitator tank room FLOOR AREA: 466 m^2	High profiled building with steel portal framing (painted); sub framing, steel sheet roof and side cladding (galvanized), fibreglass insulation, grated steel walkways and ladders (painted), concrete floor-on-grade with containment curbs around tank; multiple concrete pedestal and plinths foundations for pumps and equipment.	Cable racks galvanized without cabling, closely arranged large and smaller process steel tanks (eroded paint coating), PVC and steel piping, Miscellaneous left-behind components like mixers from partly- stripped process equipment. Most pumps, electric motors and heavy cabling already removed. Electric lights, mostly fluorescent and other. Itemized inventory not available.	Top-down sequence to remove building envelope, expose large tanks for removal. Large open-top agitator tanks have low probability for salvage due to poor condition (dents, damaged paint, bulky format for transport). Foresee insitu destruction of large tanks by flame cutting for recycling to smelter. Smaller open-top and closed tanks could be salvaged by dragging off the foundations for transporting offsite. Concrete retaining wall south side and floors to be crushed and processed with floors and plinths. Crushed concrete to be tested for contaminants before applying as recycled fill onsite.	No potential hazardous substances identified. Concrete floors-on-grade saturated with wet process sludge. Generally very wet environment from sustained groundwater seepage on floor emanating from south embankment; however, no hazardous substances were identified. Open tanks (large agitators) were empty of liquid, with some dry inert sludge residue on bottoms.
B-Chemical dosing, electrolyte heating, cyanide feeding, cyclone feeders, ball mills, ore bins, MCC room, office FLOOR AREA: 478 m^2	Similar to A, add mezzanine floor (3-level) with concrete retaining walls and steps. Heavy concrete pedestal foundations for ball mills. Small wood framed office and MCC room. Exterior covered insulated pipe box structure down south embankment 15 m long.	Similar to A, without large agitator tanks but with several smaller steel vessels. Ball mill mechanicals already removed on upper mezzanine. Two very large wood stave fine ore feed bins in tower section.	Similar to A. Concrete retaining walls which bound the three mezzanines to be crushed and processed with floors and plinths. Crushed concrete to be tested for contaminants before applying as recycled fill. Retaining walls to be demolished after all upper structure, wood stave bins and conveyors have been removed. Remove any pipes embedded in fill behind retaining walls.	Similar to A; however, dry floors on upper mezzanines. Hydrocarbon saturation of concrete of mill foundations and surrounding floor on upper mezzanine.

Area (see Drawing D035)	Structure Format, Materials	Contents – Generic Terms (Non Itemized)	Suggested Deconstruction Procedure[1]	Potentially Hazardous Materials
C-Refinery flux store, labs, office, mechanical workshop, supply stores. FLOOR AREA: 375 m^2	Low-profile steel portal framed and steel cladded building with fibreglass insulation, Interior wood framed partition walls between workshop, stores, office and laboratories. No ceilings. Roof sheeting and some wall cladding damaged by ice build-up. Concrete floors with storey-height concrete retaining wall south side.	Electric distribution boards, cabling and lights, mostly fluorescent and other.	Clear interior content and wood/steel; removing exterior cladding; lift portal framing off foundations; demolish and crush concrete floors, foundations and retaining wall. Deconstruct this section before B. Retaining wall to remain until H, J and K are deconstructed, to prevent possible embankment failure under wet conditions. Severe damage on areas of roof and side steel cladding, operational damage and ice damage.	Potential hydrocarbons in floor concrete at stores.
D-Store for mining pipes and equipment FLOOR AREA: 37 m^2	Similar to C.	Similar to C.	Similar to C.	Similar to C.
E – Electrical distribution room FLOOR AREA: 119 m^2	Similar to C.	Similar to C. Contains substantial electrical control board with instrumentation and heavy cabling.	Similar to C.	Similar to C.
F – Main workshop FLOOR AREA: 301 m^2	Similar to C.	Contains bridge crane and roll-up doors, concrete floor with embedded steel rails. Only building in complex electrically-energized.	Similar to C. Schedule demolition towards the end of the project, for utilization by contractors.	Similar to C.
G – Ore bin & conveyor 4 FLOOR AREA: 88 m^2 excluding conveyors	High profiled building with steel portal framing (painted), sub framing, steel sheet roof and side cladding (galvanized), grated steel walkways and ladders. High concrete foundation pedestals and perimeter walls.	Houses large wood stave bin for coarse ore. Conveyor feed system with wood substructure.	Top-down sequence to remove building envelope, expose large ore bin for piece-meal deconstruction of wood. Can combine with H.	Similar to C.

Area (see Drawing D035)	Structure Format, Materials	Contents – Generic Terms (Non Itemized)	Suggested Deconstruction Procedure[1]	Potentially Hazardous Materials
H – Jaw & Cone crushers FLOOR AREA: 136 m^2	Similar to G.	Contains crusher equipment.	Top down, alternatively collapse by controlled blasting of foundations and pull-over with bulldozer after removal of crushers and conveyors.	Similar to C.
J – Conveyor transfer tower FLOOR AREA: 17 m^2 excluding conveyors	High profiled small footprint building with steel framing (painted), sub framing, steel sheet roof and side cladding (galvanized), grated steel walkways and ladders, high concrete foundation walls. Conveyor bridges on wood trestles.	Conveyor belt mechanisms.	Top down, alternatively collapse by controlled blasting of foundations and pull-over with bulldozer after removal of conveyors.	
K – Fresh water tower FLOOR AREA: 50 m^2	High profiled building with steel framing (painted), sub framing, steel sheet roof and side cladding (galvanized), grated steel walkways and ladders. On stilts. Concrete stair down south embankment, exterior.	Unknown.	Top down, alternatively collapse by controlled blasting of foundations and pull-over with bulldozer after removal of steel tank.	
Fuel Tanks – next to Workshop F FLOOR AREA: 110 m^2	1.2 m high concrete containment walls and floor around tanks.	Two steel tanks for diesel fuel.	Salvage tanks; demolish and crush concrete for recycling as fill onsite, provided without contamination with hydrocarbons.	Potential hydrocarbons
Generator sheds FLOOR AREA: 3x30 m^2	Three steel shipping containers.	Three diesel generators and electrical distribution systems.	Dismantle for reuse or resale. Schedule dismantling towards the end of the project, for utilization by contractors.	

Note (1): All work to conform to the Regulations of the Yukon Workers Health and Safety Compensation Board.

6.1.2 Camp Area and Miscellaneous Small Buildings

Structural Inventory

Overview

The various wooden buildings appear to be older than the Mill complex. They are generally of light wood frame construction of varying size and shape, in poor to reasonable condition. The Bunkhouse was in good condition with recent interior renovations.

It is estimated that 25% of the total deconstructed waste stream could be diverted for recycling, with 0% from small pump stations.

Drawing D037 is a compilation of the miscellaneous buildings showing six wood structures. The Structural Inventory summary with features and deconstruction aspects of each building is given in Table 6.2.

The Victoria Creek Wellhouse is located south of the OIC boundary where Dome and Victoria Creeks meet.

There is a bridge over the diversion ditch where the existing road provides access to the tailings facility.

Electrical Inventory

These buildings contain small electrical distribution boards and cabling for appliances and lighting. In the case of the Seepage Pond Pumphouses and the Electrical Transfer Station the supply is expected to be of a higher rating than the Bunkhouse and Cookhouse.

Mechanical Inventory

Other than domestic plumbing, there is no mechanical component in these buildings, except for pumps and valves in the two Pumphouses which are fitted with a well pump of unknown depth and power rating. A compact water purification system is installed in the Cookhouse.

Electrical and mechanical equipment are typically lumped together under ‘building content’ for inclusion in the inventory of the main deconstruction contract.

Table 6.2: Structural Format and Content Inventory – Camp Area and Miscellaneous Small Buildings

Building Name (see Drawing D036)	Structure Format, Materials & Content	Contents – Generic Terms (Non Itemized)	Deconstruction Aspects	Potentially Hazardous Materials
Bunkhouse FLOOR AREA: m^2	Wood frame, wood sided, pitched steel covered roof, gypsum board partitioned interiors, vinyl covered floors laminated ceiling beams, wood doors and PVC windows, roof ventilator, fluorescent lighting and multiple wall outlets, residential style plumbing with kitchen and washrooms in good condition, concrete foundation walls. Sloping site. Electrically energized.	Kitchen appliances. Bathroom and toilet fittings.	Piece-meal deconstruction. Remove steel roofing, doors, windows and plumbing fittings for recycling. Gypsum walling and vinyl flooring likely to hazardous disposal. Push-over with dozer and dispose of wood in waste pits onsite. Laminated ceiling beams have salvage value. Concrete foundation walls crushed and recycled as fill onsite.	Possible asbestos in floor covering, PCBs in fluorescent lights.
Cookhouse FLOOR AREA: m^2	Wood frame, wood sided, pitched steel covered roof, gypsum board partitioned interiors, vinyl covered floors, wood doors and steel windows, fluorescent lighting and multiple wall outlets, residential style plumbing with kitchen and washrooms in fair condition, large walk-in freezer. Large uncovered wood deck. Concrete foundation walls. Sloping site. Electrically energized.	A compact water purification system is installed. Stainless steel hooded gas burning stoves and stainless steel wash troughs.	Similar to bunkhouse, without laminated beams.	Similar to bunkhouse.
Camp Shed FLOOR AREA: m^2	Simple wood frame, wood sided, pitched asphalt roof, no partition walls, wood doors and window, fluorescent lighting and wall outlets. Concrete floor and foundation walls. Level site. Electrically energized.	Wood shelves.	Piece-meal deconstruction. Remove steel roofing, doors, windows and plumbing fittings for recycling. Push-over with dozer and dispose of wood. Concrete floor and foundations crushed and recycled as fill onsite.	Potential hydrocarbons on floor.

Building Name (see Drawing D036)	Structure Format, Materials & Content	Contents – Generic Terms (Non Itemized)	Deconstruction Aspects	Potentially Hazardous Materials
Septic tanks	No information	Domestic wastewater and sewerage.	Septic tanks are punctured to drain and retrieved if steel, wasted with the mill complex steel waste. Concrete or masonry tanks to be crushed for backfill. Core sheds are demolished, and cores used as fill combined with crushed concrete.	
Core shacks at Cookhouse & Pony Creek Adit	Wood frame, wood sided	Drilling cores	Core sheds are demolished for waste in pits, and cores used as fill combined with crushed concrete.	
Victoria Creek Wellhouse FLOOR AREA: m^2	Wood frame, wood sided, pitched asphalt covered roof, gypsum board partitioned interiors, vinyl covered floors laminated ceiling beams, wood door, fluorescent lighting and multiple wall outlets, concrete foundation walls. Sloping site.	Well pump and pump mountings. Electrical distribution boards.	Piece-meal removal of well pump and electrical fittings including control panels and cabling. Push-over with dozer and dispose of wood, which has no salvage value left. Concrete foundation walls crushed and recycled as fill onsite.	Lead paint, PCBs in fluorescent lights. Hydrocarbons on floor.
Seepage pond pumphouse FLOOR AREA: m^2	Wood frame, wood sided, steel roof, gypsum board partitioned interiors, vinyl covered floors laminated ceiling beams, wood doors and PVC windows, fluorescent lighting and multiple wall outlets, concrete foundation walls. Sloping site.	Electrical boards.	Piece-meal removal of well pump and electrical fittings including control panels and cabling. Push-over with dozer and dispose of wood, which has no salvage value left. Pull away concrete encasement and well pipe.	Similar to Victoria Creek Wellhouse.
Electrical Transfer Station at tailings dam FLOOR AREA: m^2	Wood frame, wood sided, steel roof, gypsum board partitioned interiors, vinyl covered floors laminated ceiling beams, wood doors and PVC windows, fluorescent lighting and multiple wall outlets, concrete foundation walls. Sloping site.	Electrical distribution boards.	Piece-meal removal of electrical fittings including control panels and cabling. Push-over with dozer and dispose of wood, which has no salvage value left.	Similar to Victoria Creek Wellhouse.

6.1.3 Miscellaneous Infrastructure

Electrical Grid

Drawing D038 indicates the greater site layout of electrical grid with estimated quantities, and Drawings D039 and D040 describe the associated overall electrical single line diagram. For additional detail, reference should be made to the Stantec single line diagram and the Arcrite Northern Ltd survey. Primarily, the system consists of three diesel generators supplying power via an overhead feeder line, fitted with pole mounted transformers at branches to the Victoria Creek Wellhouse, the camp site, the mill and a branch to the transfer station for small pump stations. Table 6.3 summarizes the format and content inventory of the site electrical grid.

Table 6.3: Electrical Infrastructure: Format and Content Inventory

Building (see Drawing D038)	Structure Format, Materials & Content	Deconstruction Aspects	Potentially Hazardous Materials
Overhead Electrical Distribution System – Site grid	Overhead 3 phase power line with wood poles and cross arms, a mix of porcelain and resin insulators, galvanized steel hardware, expulsion fuse holders with fuses, surge arrestors and pole mounted transformers. Power line conductors aluminum or ACSR.	Piece-meal removal of transformers for salvage, disconnection of conductors for scrap metal Excavator style removal of poles and remaining hardware Treated timber with metal and porcelain hardware and transformer pill will likely require special disposal.	Although the bulk of the power system was constructed after the phasing out of PCBs as a transformer insulating liquid, there is a possibility that some of the transformers used onsite may have been second-hand and may contain PCBs. The evaluation and testing of these transformers for the presence of PCBs will be included in any supplementary SI scope developed to support subsequent phases of design and/or permitting.
Bunkhouse	Power feed to bunkhouse and cook shed from liquid filled pole mounted transformer. Power distributed to the two buildings is via o/h quadruplex conductor with messenger wiring entering the buildings through roof mounted weather heads. At this location, there is also a tap-off for a power feed to the mess kitchen and the old parking panel. Bunkhouse equipped with 120/208 V 3 phase distribution panel and dire alarm system Electrically energized.	Piece-meal removal of wiring from distribution poles for scrap, and distribution pane, fire alarm panel and light fixtures for salvage. The poles and remaining hardware can be deconstructed with excavator. Remaining electrical equipment in the building can be demolished with the building.	
Cookhouse	Similar to bunkhouse, but also equipped .with a 6 kVA step-up transformer and motor starters.	Similar to Bunkhouse, but transformer and motor starters can also be salvaged.	Similar to Bunkhouse.
Camp Shed	Power feed from bunkhouse via overhead quadruplex with messenger wire on wood poles	Similar to Bunkhouse.	

Building (see Drawing D038)	Structure Format, Materials & Content	Deconstruction Aspects	Potentially Hazardous Materials
Victoria Creek Wellhouse	Power supply from 3 pole mounted transformers via overhead connection with messenger wire to a weather head on the roof. Inside the building is a light fixture, fused disconnects, splitter, 30 kVA dry transformer, distribution panel and pump motor starter. There is also surface mounted Teck cable throughout the building.	Piece-meal removal of pole mounted transformers, dry transformer, fused disconnects, distribution panel, motor starter, splitter and cables. Transformers can be reconditioned for reuse. Distribution panel, splitter, fused disconnects, motor starter, can be reused. Cables should be recycled as scrap metal.	Possible PCBs in pole mounted transformers. The evaluation and testing of these transformers for the presence of PCBs will be included in any supplementary SI scope developed to support subsequent phases of design and/or permitting.
Seepage pond pumphouse	Power supply from 3 pole mounted transformers. This transformer is shared with the Electrical Transfer Station. A disconnect switch is mounted on the transformer pole, from where an underground cable runs to a junction box mounted on a post and another underground Teck cable to the pumphouse Inside the building are receptacles, 30 kVA dry transformer, distribution panel and pump motor starter. There is also surface mounted Teck cable throughout the building.	Piece-meal removal of pole mounted transformers, dry transformer, distribution panel, motor starter and cables. Transformers can be reconditioned for reuse. Distribution panel and motor starter can be reused. Cables should be recycled as scrap metal.	Possible PCBs in pole mounted transformers. The evaluation and testing of these transformers for the presence of PCBs will be included in any supplementary SI scope developed to support subsequent phases of design and/or permitting.
Electrical Transfer Station at Tailings dam	Power supply from 3 pole mounted transformers. This transformer is shared with the Seepage Pond Pumphouse. From the transformer pole, an underground cable runs to the building. Outside the building is a receptacle and light. Inside is a 30 kVA dry transformer, splitter, fused disconnects. Distribution panel and pump motor starters. There is also surface mounted Teck cable throughout the building.	Piece-meal removal of pole mounted transformers, dry transformer, fused disconnections, distribution panel, motor starter, splitter and cables. Transformers can be reconditioned for reuse. Distribution panel, splitter, fused disconnects, motor starter, can be reused. Cables should be recycled as scrap metal.	Possible PCBs in pole mounted transformers. The evaluation and testing of these transformers for the presence of PCBs will be included in any supplementary SI scope developed to support subsequent phases of design and/or permitting.
Mill Building E – Electrical distribution room	Similar to C. Contains generator switchgear and control board with instrumentation and heavy cabling. Also, contains high bay lights fixtures.	Electrical equipment has no salvage and reuse value and should be removed piece meal for disposable waste metal.	

Building (see Drawing D038)	Structure Format, Materials & Content	Deconstruction Aspects	Potentially Hazardous Materials
Generator sheds	Three steel shipping containers. The G1 and G2 containers are equipped with a 175 kW generator each. Each container is also equipped with a distribution panel, lights, power receptacles and space heaters. G3 contains a 175 kW generator, transfer switches, fused disconnects, splitter, distribution panel, a 30 kVA dry transformer and lighting. Underground Teck cables connect the various generator containers.	Dismantle for reuse or resale. Generators for resale. It is also a real possibility that the containerized generators can be reconditioned and sold as complete units, particularly in the Yukon where containerized generator solutions are feasible and popular. In this case, a minimal amount of site preparation will be required for resale. Underground Teck cables can be recycled for scrap metal.	

A buried cable for high current to crushers connected between buildings E and H at the mill could be retrieved and the excavations reinstated. The cable can be recycled for disposable waste metal. No hazmat implications are foreseen.

6.1.4 Underground Piping

No onsite inspections were conducted to characterize underground piping or cabling. Information for a desk study was gathered from an ‘As-built’ sketch by BYG Natural Resources dated April 1998 summarized as follows (note: a portion of this inventory may already have been decommissioned (with underground portions left in place) by the current site operator) :

1. Seven pipelines in the vicinity of the mill complex designated PL-1 to PL-7. Most are presumably water, fresh and other. Only pipe PL-7 is not buried. Materials and potential hazmat content are not available. Coated steel, ductile iron, PVC and HDPE materials could be expected.
2. Line PL-2 is apparently a 4” coated steel drain pipe under the access road coming from the camp site.
3. The origin of the fresh water line PL-1 is unknown (where it traverses west of the camp site). Similarly, the origin of PL-4 along the main access road is unknown.

Decommissioning and remediation of these pipes will likely involve the removal of exposed sections and the in place burial of underground portions.

The salvage value of pipes will depend on hazmat conditions and the pipe material. Clean HDPE and steel pipes will have some salvage value, otherwise expect no value.

6.1.5 Culverts

Six culverts were identified, presumably corrugated pipe. Culvert disposition will be a function of the general site reclamation plan (see Section 7), as follows:

- culverts should remain if the road alignment is not reclaimed back to the natural grade and slope;
- culverts are removed and replaced with cross ditches where required or backfilled together with the remediation of road alignment, according to the selected option under 6.1.7.

6.1.6 Road Bridge over Diversion Channel

The 10 m span steel girder/wood deck bridge resting on concrete lock blocks can be deconstructed efficiently, and salvaged for reuse. The gravel foundation bases under lock blocks can be removed and replaced (the upper 0.6 m, say) with soil, riprap and vegetation to blend with the immediate surroundings. No hazardous material impacts are foreseen.

6.1.7 Roads

Roads are all surfaced with granular soil and gravel. All roads are in fair to good, trafficable condition with little evidence of drainage scouring and erosion damage of the shoulders or local site.

Two options will be considered for remediation:

(a) road alignment is not reclaimed back to the natural grade and slope; however, the surface is scarified to promote revegetation, and local cross-ditching is added where required to facilitate natural drainage and prevent scouring developing in to ditch formations; and

(b) in those limited circumstances where more complete reclamation is required, cut-and fill back to the natural grade with vegetation and riprap scour prevention, including cross-ditching and shaping of natural gullies.

6.2 Contaminated Soil and Hazardous Materials Inventory

6.2.1 Contaminated Soils Volume Estimate

Approximately 155,000 m^3 of contaminated soil remains onsite. Most of this material contains metals concentrations above CSR-PL standards and potentially contains some waste rock. The characteristics of the waste rock were discussed in Section 5.1.4. During the 2013 assessment work, contaminated soils were classified as both potentially acid-generating and metals-leaching (PAG/ML) or non-acid generating and non-metals-leaching (NAG/NML). The waste rock which was found to be NAG/NML was determined to have a low potential to negatively impact human health. For this reason, it has been proposed that the NAG/NML materials remain insitu (i.e. remain onsite). The proposed plan does not include excavation, relocation or treatment of NAG/ML.

This document discusses remediation of the impacted soils (approximately 58,000 m^3), which include PAG/ML waste rock, hydrocarbon-contaminated soil, and nitrogen-contaminated soil. The locations of these materials are identified in Drawings D004 and D006. The estimated volumes are summarized in Tables 6.4, 6.5, 6.6 and 6.7.

Table 6.4: Estimated Volumes of Hydrocarbon Contaminated Soils Below Special Wastes Regulation Standards

Location	Area (m^2)[1]	Depth Start (mbgs)[2]	Depth End (mbgs)	Volume (m^3)[3]
Mill Area				
BH-M-13-01 and BH-M-13-02	698	1.1	1.5	279
BH-M-13-07	6,040	0.0	1.0	6,040
Generator Building	180	0.0	1.0	180
Behind Generator Building	48	0.0	1.5	72
Two Stains in Front of Generator Building	64	0.0	1.5	96
Warehouse	312	0.0	1.0	312
Subtotal				6,979
Ketza Shop				
BH-KZ-13-01+02	407	0.0	1.5	611
TP-KZ-13-03	137	0.0	0.5	69
Staining noted in R104[4] (SE end of Former Ketza Shop Area)	21	0.0	0.5	11
TP-KZ-13-02	24	0.0	0.5	12
Staining noted in R104 (NE end of Former Ketza Shop Area)	45	0.0	0.5	23
TP-KZ-13-01	48	0.0	0.5	24
Subtotal				748
Plant Lay Down Area				
Staining noted in R104 (miscellaneous metal debris)	289	0.0	1.0	289
Staining noted in R104 (south of abandoned vehicle)	135	0.0	1.0	135
Subtotal				424
Roads				
Staining noted in R104 (SAG/Upper Mill)	303	0.0	1.0	303
Staining noted in R104 (Haul Rd, near camp, HR10)	840	0.0	1.0	840
Subtotal Volume				1,143
Total Volume				**9,422**

Notes:

1. *m^2 refers to square metres*
2. *mbgs refers to metres below ground surface*
3. *m^3 refers to cubic metres*
4. *R104 refers to the following report: EBA Consulting Engineers Ltd. (2011). Mount Nansen Hazardous Materials Classification. Prepared for Yukon Government – Assessment and Abandoned Mines.*

Table 6.5: Estimated Volumes of Nitrogen Contaminated Soils Below Special Wastes Regulation Standards

Location	Area (m^2)[1]	Depth Start (mbgs)[2]	Depth End (mbgs)	Volume (m^3)[3]
Explosives Storage Nitrogen	255	0.0	0.5	128
Total Volume	**128**			

Notes:
1. *m^2 refers to square metres*
2. *mbgs refers to metres below ground surface*
3. *m^3 refers to cubic metres*

Table 6.6: Estimated Volumes of PAG Metals Below Special Wastes Regulation Standards

Location	Area (m^2)[1]	Depth Start (mbgs)[2]	Depth End (mbgs)	Volume (m^3)[3]
Main Mill Area	19,500	-	-	12,120
PAGM1	*2,500*	*0.0*	*2.0*	*5,000*
PAGM2	*1,250*	*0.0*	*4.0*	*5,000*
PAGM3	*2,800*	*0.0*	*0.5*	*1,400*
PAGM4	*1,800*	*0.0*	*0.5*	*900*
PAGM5	*3,300*	*0.0*	*1.5*	*4,950*
PAGM6	*5,600*	*0.0*	*0.5*	*2,800*
PAGM7	*2,250*	*0.0*	*0.5*	*1,125*
Landfill	*0*	*0.0*	*0.0*	*0*
Settling Pond 1	1,250	0.0	1.0	1,250
Settling Pond 2	950	0.0	1.0	950
Settling Pond 3	0	0.0	0.0	0
Roads	10,613	0.0	1.5	14,777
Explosives Storage	0	0.0	0.0	0
Ketza Shop	5,070	0.0	0.5	1,787
Total Volume				**30,884**

Notes:
1. *m^2 refers to square metres*
2. *mbgs refers to metres below ground surface*
3. *m^3 refers to cubic metres*

Table 6.7: Estimated Volumes of Metals Above Special Wastes Regulation Standards

Location	Area (m^2)[1]	Depth Start (mbgs)[2]	Depth End (mbgs)	Volume (m^3)[3]
BH-M-13-08	1,513	2.5	3.5	1,513
BH-M-13-04	1,125	0.0	0.5	563
Total Volume				**2,076**

Notes:
1. *m^2 refers to square metres*
2. *mbgs refers to metres below ground surface*
3. *m^3 refers to cubic metres*

Table 6.8: Summary of Hazardous Materials Inventory

Location	Waste Description	Count	Unit	Comment	Sampled	Lab Results	Recommendation
Generator Building	day tanks: diesel	2	tanks	100 Litres (L) & 400 L	No	N/A	Consolidate fuel into drums; destroy tanks.
	gasoline	1	drum	200 L	No	N/A	Dispose of at a permitted facility for this waste.
	oil	1	drum	75 L	No	N/A	Dispose of at a permitted facility for this waste.
	Westchem boiler treatment: nitrite & borate	1	pail	20 L	No	N/A	Dispose of at a permitted facility for this waste.
	lead acid battery	1	battery	20 kilograms (kg)-car battery	No	N/A	Recycle offsite.
	lead acid battery	1	battery	100 kg-generator battery	No	N/A	Recycle offsite.
	oil	4	pail	20 L	No	N/A	Dispose of at a permitted facility for this waste.
	aerosols	Approximately 4	-	-	No	N/A	Dispose of at a permitted facility for this waste.
	paint/grease	3	cans	-	No	N/A	Dispose of at a permitted facility for this waste.
	propane cylinder	40	pounds	-	No	N/A	Recycle offsite.
Maintenance Shop	argon	1	cylinder	5' (feet) x1'	No	N/A	Dispose of at a permitted facility for this waste.
	acetylene	2	cylinders	4'x1'	No	N/A	Dispose of at a permitted facility for this waste.
	batteries	15	batteries	various: dry cell, lead acid, nickel cadmium	No	N/A	Recycle offsite.
	aerosols	10		various	No	N/A	Dispose of at a permitted facility for this waste.
	oil	4	pails	-	No	N/A	Dispose of at a permitted facility for this waste.
	fire extinguishers	1	-	-	No	N/A	Dispose of at a permitted facility for this waste.
	paint	2	cans	-	No	N/A	Dispose of at a permitted facility for this waste.
	lubricants	10	various	small cans to 4 L pails	No	N/A	Dispose of at a permitted facility for this waste.
	propane	1	cylinder	40 pounds	No	N/A	Recycle offsite.
	buffer solution	2	bladders	20 L	No	N/A	Dispose of at a permitted facility for this waste.
	wood preservative	1	can	4 L	No	N/A	Dispose of at a permitted facility for this waste.
	gasoline	1	drum	partial	No	N/A	Dispose of at a permitted facility for this waste.
	Stoddart solvent	1	drum	empty	No	N/A	Dispose of at a permitted facility for this waste.
	lab samples-various bottles	1	box	-	No	N/A	Dispose of at a permitted facility for this waste.
Mill Building-Flux/ Refining Area	silica	1	garbage can	-	No	N/A	Spread out onsite.
	soda ash	2	garbage can	-	No	N/A	Dispose of at a permitted facility for this waste.
	borax	2	garbage can	-	No	N/A	Dispose of at a permitted facility for this waste.
	activated alumina	1	keg	-	No	N/A	Dispose of at a permitted facility for this waste.
	zeolite	1	bag	-	No	N/A	Place in the Open Pit.
	aerosols	2	cans	-	No	N/A	Dispose of at a permitted facility for this waste.
	fire extinguisher	1	-	-	No	N/A	Dispose of at a permitted facility for this waste.

Location	Waste Description	Count	Unit	Comment	Sampled	Lab Results	Recommendation
Mill Building-Ball Mill	lime	12	tote sacks	Bags are overflowing; will need to be some additional packaging done with bobcat.	No	N/A	Use onsite.
	lime	1	loose	Overflowing onto floor; will need to clean up and package.	No	N/A	Use onsite.
	ferric chloride	15	bags	-	No	N/A	Dispose of at a permitted facility for this waste.
	sodium metabisulphite	160	bags	-	No	N/A	Dispose of at a permitted facility for this waste.
	water treatment flocculent	50	bags	-	No	N/A	Dispose of at a permitted facility for this waste.
	gear tack/lime sludge mixture	1	Cubic metre	Loose material under the ball mill saddle; needs to be shovelled into drums	Yes	-	Dispose of at a permitted facility for this waste.
	gear tack (oil/grease)	1	keg	-	No	N/A	Dispose of at a permitted facility for this waste.
	gear tack (oil/grease)	2	pails	-	No	N/A	Dispose of at a permitted facility for this waste.
	fine ore bin	Approximately 10	tonnes	Residue remains in the bin.	Yes	Passed TCLP	Place in the Open Pit.
Mill Building-Mill Process Tanks	Tank 1	1	18,000 L	Sludge and water.	Yes	Passed TCLP	Stabilize and ship to a hazardous waste landfill.
	Tank 2	1	18,000 L	Sludge and water: Impeller is imbedded in the sludge.	Yes	Passed TCLP	Stabilize and ship to a hazardous waste landfill.
	Tank 3	1	18,000 L	Water, possibly sludge under the water.	Yes: water & sludge	Passed TCLP	Treat the water on or offsite and dispose of the sludge in the Open Pit.
	Tank 4	1	36,000 L	Up to four feet of solids/sludge in this tank.	Yes	Passed TCLP	Stabilize and ship to a hazardous waste landfill.
	Tank 5	1	18,000 L	Water and sludge.	Yes	Passed TCLP	Stabilize and ship to a hazardous waste landfill.
	Tank 6	1	18,000 L	Water and sludge.	Yes	Passed TCLP	Stabilize and ship to a hazardous waste landfill.
	Tank 11	1	< 100 kg	Empty: some dried residue on tank bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 12	1	< 100 kg	Empty: some dried residue on tank bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 13	1	< 100 kg	Empty: some dried residue on tank bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 13a	1	< 100 kg	Empty: some dried residue on tank bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 14	1	< 10 kg	Empty: some dried residue on tank bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 14a	1	< 10 kg	Empty: some dried residue on tank bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 15	1	< 10 kg	Empty: some dried residue on tank bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 16	1	< 10 kg	Empty: some dried residue on tank bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.

Location	Waste Description	Count	Unit	Comment	Sampled	Lab Results	Recommendation
Mill Building-Mill Process Tanks (cont'd)	clarifier	1	< 100 kg	Some residue in conical bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 18	1	< 100 kg	Hopper bin – empty.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 19	1	< 10 kg	Empty: some dried residue on tank bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 20	1	< 10 kg	Empty: some dried residue on tank bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 21	1	< 100 kg	Empty: some dried residue on tank bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 22	1	< 100 kg	Empty: some dried residue on tank bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 23	1	<200 L	Empty: some water on the bottom.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 24	1	20,000 kg	Eductor tank-half full of hard solids.	Yes	Passed TCLP	Stabilize and ship to a hazardous waste landfill.
	Tank 25	1	<100 L	Acid tank-empty-trace liquid on bottom.	No	N/A	Neutralize/stabilize
	Tank 33	1	110,000 L	Thickener tank: 4 feet of water, minimal sludge.	Yes: water & sludge	Passed TCLP	Treat the water on or offsite and dispose of the sludge in the Open Pit.
	Tank 33 "crawl space"	TBD	-	Mill process sludge.	Yes	Passed TCLP	Place in the Open Pit.
	Tank 37	TBD	-	Cyanide tank-no access to sample.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 37a	TBD	-	Hopper bin from mill-not able to access.	No	N/A	Stabilize and ship to a hazardous waste landfill.
	Tank 39	1	3,000 L	Trace of water/ice on bottom of tank.	Yes	Passed TCLP	Stabilize and ship to a hazardous waste landfill.
	Rail Car	1	L	Empty	No	N/A	Analyze any residue in the tank, stabilize, remove and destroy the tank.
	berm area for tanks 1-6	TBD	kg	Heavy sludge over run by ground water.	2 samples	Passed TCLP	Stabilize and ship to a hazardous waste landfill.
Mill Building-Lime tank	lime	1	3,000 kg	Dry/powdered lime, on floor and in tank.	No	N/A	Stabilize and ship to a hazardous waste landfill.
Outside Mill-Westside	day tank	2	tanks	Yellow tank and blue tank; trace diesel.	No	N/A	Consolidate fuel, destroy tanks.
	large fuel Tank	1	tank	Trace diesel fuel.	No	N/A	Consolidate fuel, destroy tanks.
	cement bags	Approximately 25	bags	Under tarp; appear to have cured into concrete blocks.	No	N/A	Dispose at a local landfill or in the Open Pit.
	grease/oil/lubricants/soil	11	drums	mixtures of oil, grease, water, debris	No	N/A	Dispose of at a permitted facility for this waste.
	grease/oil/lubricants/soil	1	pallet	1 drum-top half cut off; two pails	No	N/A	Dispose of at a permitted facility for this waste.

Location	Waste Description	Count	Unit	Comment	Sampled	Lab Results	Recommendation
Ketza Shop Area	copper sulphate	5	drums	over pack drums with bulk copper sulphate	No	N/A	Dispose of at a permitted facility for this waste.
	petroleum drums	2	drums	almost empty	Yes		Dispose of at a permitted facility for this waste.
	petroleum pails	9	pails	mixture of solvents, lubricants, rain water	Yes		Dispose of at a permitted facility for this waste.
	lead acid battery	1	battery	lead acid car battery	No	N/A	Recycle offsite.
	poles/piles	1	Approximately 30	treated with wood preservative	No	N/A	Dispose at a local landfill or in the Open Pit.
Bunkhouse	propane bullets	3	bullets	1/2 full	No	N/A	Plumb into cookhouse propane system.
	grease/lubricant/sludge	1	drum	Partially full-very poor condition and requires an over-pack.	No	N/A	Dispose of at a permitted facility for this waste.
	insulation	Approximately 100	bags	Large pile of bagged insulation.	No	N/A	Dispose at a local landfill or in the Open Pit.
	Propane tanks	6	tanks	Not observed during hazardous material survey but reportedly onsite	No	N/A	Recycle offsite
	Gas tank	1	tank	Not observed during hazardous material survey but reportedly onsite	No	N/A	Recycle offsite

Notes:
- *TCLP= Toxicity Characteristic Leaching Procedure*

The remaining contaminated soils at the Site were classified based on the level and type of contamination, as per Government of Yukon's Contaminated Sites Regulation (CSR; YG, 2002). The CSR standards were referenced to designate soil as contaminated and potentially special waste based on concentrations of contaminants, and relevant to land use. Soils at the Mount Nansen Site exceed the applicable guidelines for contaminated soils; the levels are above CSR Parkland Use standards (CSR-PL) and Special Wastes Regulation (SWR) standards (YG, 1995).

Metals were detected in PAG/ML soil at the Mill Area, around Settling Ponds 1 and 2, along the roads, and at the former Ketza Shop. The estimated volume for all these locations combined is 32,959 m^3 (Tables 6.6 and 6.7). Of this total, 2,076 m^3 from the Mill Area is believed to be above the SWR standards (Table 6.7).

Hydrocarbon-contaminated soil was detected at levels exceeding CSR-PL standards but below SWR standards; specifically at the Mill Area, on the haul road, at the former Ketza Shop, and at the plant lay-down area. The estimated volume for all these locations combined is 9,422 m^3. Parts of these areas also contain PAG/ML soils.

Nitrogen-contaminated soil of the above-noted classification (above CSR-PL but below SWR standards) was detected in the former explosives storage area. The estimated volume of this material is 128 m^3, and is separate from the PAG/ML soils.

6.2.2 Hazardous Materials Volume Estimate

A number of materials at the Mount Nansen Site were included in a waste disposal tender issued by the YG in November 2013. It is our understanding that those materials, including cement bags, copper sulphate, day tanks, grease/lubricants, select fuel tanks, and lead acid batteries and pole/piles, are currently being removed offsite.

6.3 Contaminated Soil and Hazardous Materials Disposition

6.3.1 Contaminated Soil Remediation Plan

The Mount Nansen site contains four areas of concern for metals and/or hydrocarbon contaminants in soil: the Mill Area, the former Ketza Shop area, plant lay-down area, and the roads. The site grading plans that have been developed on the basis of the recommendations provided in the section are outlined in Drawings D041 through D044.

Several options to remediate the impacted soil were considered:

1. Shipping it to an existing permitted Land Treatment Facility designed for metals. This was not deemed reasonable because the nearest permitted Land Treatment Facility is in Fort Nelson, BC. Relocating this volume of soil would pose significant risks to the environment and the cost would be significant.
2. Building, permitting and operating a Land Treatment Facility designed for metals (either on or offsite). This was not deemed appropriate as metals contamination will not naturally remediate and the facility would require ongoing maintenance and monitoring.

3. Treating the soil on or offsite using chemical systems. This is relatively expensive and requires significant effort. By-products from this treatment would need to be relocated offsite to a permitted Land Treatment Facility. Relocating this material would pose significant risks to the environment and the cost would be significant.
4. Treating the soil on or offsite using plants. This option is relatively time consuming and its efficiency with respect to the site-specific materials would need to be established. The resulting biotic material would potentially need to be relocated offsite to a permitted Land Treatment Facility.
5. Placing the metals-contaminated soil in the Open Pit, specifically above the expected groundwater level and covered with an engineered cover of non-vegetated, non-erodible gradations. This would have to be done one of two ways:
   a. Prior to placing metals-contaminated soil in the pit, the soil could be treated for hydrocarbon contamination in a Land Treatment Facility (on or offsite). This would require medium-term maintenance and monitoring to place this material (a relatively small volume) below the engineered cover; and
   b. The hydrocarbon-contaminated materials and metals-contaminated materials could both be placed in the Open Pit. This option contains and reduces the potential environmental and human health hazards. It was selected as the most appropriate for the Site.

Considering these options, we recommend that soils above CSR-PL standards (but below SWR standards) be excavated and relocated to the Open Pit. In the pit, these materials should be placed above the expected groundwater level and covered with an engineered cover of non-vegetated, non-erodible gradations. The contaminant source materials are currently distributed across the site. This remediation method will ensure that all material is relocated to one area, where it can be easily and carefully managed.

Regarding the metals-contaminated soil that contains concentrations above SWR standards, disposal onsite poses an elevated potential risk to the environment (and it is, therefore, not recommended). The cost, effort and uncertainty related to treating this contamination are also considerable. For these reasons, we propose that this material be relocated to the nearest permitted Land Treatment Facility (Fort Nelson, BC).

The following two sections discuss the proposed excavation, transport and placement of the contaminated material in more detail.

Contamination Above CSR-PL and Below SWR

To excavate the hydrocarbon-contaminated soils, clean topsoil needs to be first excavated and set aside to allow access to the deeper contaminated soil. The contaminated soil should be excavated to the depth and extent based on previous delineation of the contamination from previous studies and field screening results. During removal of the contaminated soils, field screening should be conducted using a photoionization detector to assess for hydrocarbons in soil vapour.

The same steps should be followed to excavate the metals-contaminated soils. During removal of the contaminated soil, field screening should include using X-ray fluorescence (XRF) tool and/or lab testing to determine sulphide content and neutralization potential capacity.

The contaminated material should be transported to the Open Pit in covered haul trucks. Because the material will not leave the site, no YG Relocation Permit will be required.

For this category of soils, confirmatory samples should be collected at each area post-excavation to confirm the excavation boundaries and to confirm that the PAG/ML waste rock, hydrocarbon-contaminated soil and nitrogen-contaminated soil has been removed successfully. As per CSR Protocol 3, one sample should be collected at every 10 m length and 3 m depth, and a minimum of five samples per site should be tested. As well, one haul sample should be collected for every 10 m^3 of excavated soil, as per CSR Protocol 3 (YG, 2012). The samples should be analyzed in accordance with CSR Protocol 5 (YG, 2011).

Contamination Above CSR-PL and Above SWR

Soils with analytical results above the CSR-PL and SWR standards should be excavated to the necessary depth and extent, based on delineation of the contamination from previous studies and field screening results. Field screening during the removal of the contaminated soil should be completed (potentially screening using an X-ray fluorescence (XRF) meter and/or be completed (potentially screening using an X-ray fluorescence (XRF) meter and/or lab testing to determine sulphide content and neutralization potential capacity.

Contaminated material should be transported to the nearest permitted Land Treatment Facility (for metals, this is currently the Tervita Northern Rockies Land Treatment Facility in Fort Nelson, BC). A Special Waste permit from YG is required prior to relocating this material. In addition, the transport will require a YG Relocation Permit, a spill contingency plan, and, if warranted, a Tervita Waste Manifest or a BC Relocation Agreement/Special Authorization (BC, 2005) in order for the material to be accepted at the Tervita facility.

Confirmatory sampling should be completed as described above, but with confirmatory soil samples collected at every 5 m length and 3 m depth (YG, 2012). As indicated above, one haul sample should be collected for every 10 m^3 of excavated soil (YG, 2002). The samples should be analyzed for the metals found to exceed the CSR-PL.

6.3.2 Hazardous Materials Remediation Plan

A hazardous materials remediation plan should be completed and include: handling, transportation and disposal of hazardous materials in accordance with the Environmental Code of Practice for Aboveground and Underground Storage Tank Systems Containing Petroleum and Allied Petroleum Products (Canadian Council of Ministers of the Environment, 2003).

Hazardous Waste Disposal

The Mount Nansen Site has various chemicals remaining that require disposal. These and the proposed recommendations for hazardous materials disposal are included in Table 6.8. In general, efforts should be made to use or recycle the materials. The last resort is to dispose of the materials at a permitted facility or (for certain specific materials) onsite. Below is a summary of the management measures that are proposed for hazardous materials:

- useable hydrocarbons should be consolidated in drums for future use. The resulting empty tanks should be steam-cleaned and rendered unusable as detailed in Canadian Council of Ministers of the Environment (2003);
- non-useable hydrocarbons should be consolidated in drums for offsite disposal at a hazardous waste landfill;
- batteries found onsite should be taken to a recycling facility;
- non-useable chemicals (including borax, wood preservative, soda ash, activated alumina, argon, lead-based paint, Stoddard solvent, nitrate, borate, buffer solution, ferric chloride, sodium meta-bisulphite, water treatment flocculent gear, and any fire extinguishers onsite) should be relocated offsite to a hazardous waste landfill;
- the lime tank, clarifier, rail car, mill processing tanks, and the berm surrounding Tanks 1 through 6 in the Mill Area should be stabilized prior to transport to a hazardous waste landfill;
- lime remaining onsite should be used to reduce the potential for acid generation; and to adjust pH of water that may need to discharge during tailings relocation; and
- materials that can be disposed onsite in the Open Pit are silica, zeolite, ore (in the ore bin), cement bags, insulation, pokes and piles.

Landfill Materials and Waste Piles

A historical landfill was located at the southeast end of the Mill Area on the Mount Nansen Site. Materials from this landfill, and the materials in the various waste piles that the current site operator has accumulated on the site, should be sorted and transported to an offsite site location (if Special Waste), recycling facility or to the Open Pit for disposal.

6.4 Deconstruction Plans

Drawings D035 through D038 illustrate the building and infrastructure components for deconstruction. In addition, all available Record Drawings of the Mill complex should be included in the tender documents.

6.5 Deconstruction and Demolition Materials Disposition

6.5.1 Buildings

Contractors will be responsible, and should fully allow in contract pricing for the removal from site and disposition of all components, content and materials. Hazardous materials shall only be delivered at authorized or legally accredited receiving agents.

An exception to this requirement is that concrete waste shall be crushed to minus 100 mm and completely separated from the embedded reinforcing steel bars and wire, and processed concrete rubble shall be used for filling onsite as directed. Approximately 2,000 m^3 of concrete rubble is expected.

6.5.2 Electrical Infrastructure

Contractors will be responsible, and should allow fully in contract pricing for the removal from site and disposition of all components and materials.

Hazardous materials shall only be delivered at authorized or legally accredited receiving agents.

7 SITE RECLAMATION PLAN

7.1 Reclamation Objectives and Policy

Site-specific reclamation objectives for the Project are provided in the Mount Nansen Options for Closure report, prepared by LORAX Environmental Services Ltd. (2011). That report outlines the major closure objectives for the Project (LORAX, 2011):

- protect human health and safety;
- protect the environment, including land, air, water, fish and wildlife;
- return the Site to an acceptable state that reflects original use where possible;
- maximize local, Yukon and First Nation benefits; and
- reduce government liability and manage risk.

In addition to these objectives, the Yukon Government has a number of guidelines, policies, general reclamation objectives and best management practices for reclaiming mines in the Yukon. These are outlined in the following paragraphs, and were considered during development of the Mount Nansen conceptual reclamation plan.

The Reclamation and Closure Planning for Mining Projects document prepared by Yukon Energy, Mines and Resources (2013) outlines fundamental reclamation objectives and guidelines for all reclamation projects in the Yukon, as listed in Table 7.1. Detailed objectives for a project need to be site-specific, and defined by factors that include environmental and site conditions, and community expectations (Yukon Energy, Mines and Resources, 2013).

Table 7.1: Fundamental Mine Reclamation and Closure Objectives

Value	Reclamation and Closure Objective
Physical Stability	• All mine-related structures and facilities are physically stable and performing in accordance with designs. • All mine-related structures, facilities and processes can withstand severe climatic and seismic events.
Chemical Stability	• Release of contaminants from mine-related waste materials occurs at rates that do not cause unacceptable exposure in the receiving environment.
Health and Safety	• Reclamation eliminates or minimizes existing hazards to the health and safety of the public, workers and area wildlife by achieving conditions similar to local area features. • Reclamation and closure implementation avoids or minimizes adverse health and safety effects on the public, workers and area wildlife.
Ecological Conditions	• Reclamation and closure activities protect the aquatic, terrestrial and atmospheric environments from mine-related degradation, and restore environments that have been degraded by mine-related activities. • The Site supports a self-sustaining biological community that achieves land use objectives.
Land Use	• Lands affected by mine-related activities (e.g. building sites, chemical and fuel storage sites, roads, sediment ponds, tailings storage facilities, waste rock storage areas, underground workings) are restored to conditions that enable and optimize productive long-term use of land. • Conditions are typical of surrounding areas or provide for other land uses that meet community expectations. • Site access is consistent with community land use expectations.

Value	Reclamation and Closure Objective
Aesthetics	• Restoration outcomes are visually acceptable.
Socio-economic Expectations	• Reclamation and closure implementation avoids or minimizes adverse socio-economic effects on local and Yukon communities, while maximizing socio-economic benefits. • Reclamation and closure activities achieve outcomes that meet community and regulatory expectations.
Long-term Certainty	• The need for long-term operations, maintenance, and monitoring after reclamation activities are complete is minimized.
Financial Considerations	• Outstanding liability and risks after reclamation activities are complete are minimized.

Source: Yukon Energy, Mines and Resources 2013

The Yukon Mineral and Coal Exploration Best Management Practices and Regulatory Guide, prepared by the Yukon Chamber of Mines (2010), specifies best management practices associated with reclamation. The most notable of these for the Mount Nansen site are:

- restoring the landscape to its natural contours or at a maximum a 2:1 slope;
- using native species to revegetate and loosen compacted soils; and
- covering the area with stockpiled topsoil, stumps, bucked-up trees and brush to promote natural revegetation.

In the revegetation component of the Yukon Site and Reclamation Closure Policy (Yukon Government, 2006a), the stated objectives are “to ensure physical stability and to prevent a temporary loss of wildlife habitat utilization from becoming permanent, through the re-establishment of a vegetative mat (food source, hide, etc.) leading to self-sustaining native vegetation.” In practice, this means the following:

- Vegetation should normally be self-sustaining within six years of the last application of cover, seed or fertilization.
- Vegetative cover should be of sufficient density and species diversity to stabilize the surface against effects of long-term erosion.
- The vegetative cover should be capable of self-regeneration without continued dependence on fertilizer or reseeding.

Finally, the guidelines for revegetation in the Handbook of Reclamation Techniques and Mining Land Use also state several objectives (Yukon Government, 2006b). Those relevant to the Mount Nansen Site are as follows:

- Re-establish vegetation to mimic similar, naturally occurring environments in the area.
- Provide an adequate growth medium.
- Avoid introduction of non-invasive species.

7.2 Biophysical Setting

Understanding the surrounding biophysical conditions is a pre-requisite for assessing Site recovery potential and limitations, and for identifying and setting reclamation targets. The following text provides an overview of the biophysical conditions in the Order in Council (OIC) area and vicinity followed by an overview of the disturbance area. Information is provided from available literature and a Site visit completed by Associated Engineering (AE) in September of 2013. For details regarding site physiography, surficial materials, and climate information, refer to the Site Characterization report (AMEC, 2014).

7.2.1 Terrain and Soils

Soil development at the Mount Nansen site is largely controlled by aspect which influences the formation of a shallow permafrost table: cold, north facing slopes have a shallow permafrost table while the warmer north side lacks a shallow permafrost table.

Reconnaissance level soil surveys conducted in October 2013 indicate that soils on south facing, undisturbed slopes within the OIC are comprised of approximately 10 cm of forest duff over 13 cm of tephra (volcanic ash). This is underlain by a thin, buried (2 cm) topsoil layer over 13 cm of dark olive brown sandy clay loam with 10% coarse fragments. These soils grade to weathered bedrock consisting of approximately 70% angular coarse fragments in subsurface soils. Soils are considered moderately well drained.

Soils on north facing slopes are comprised of approximately 20 cm of fibric (poorly decomposed) organic material over sand. A shallow permafrost table was encountered between 30 and 60 cm below ground surface (depending on slope position). This results in a perched water table and poorly drained soils.

7.2.2 Vegetation

Dominant vegetation on the south facing, undisturbed slopes consists of white spruce (*Picea glauca*) in the overstory, willow (*Salix* spp.) and Labrador tea (*Ledum groenlandacum*) in the understory, and crowberry (*Empetrum nigrum*), caribou lichens (*Cladina* spp.), and red-stemmed feather moss (*Pleurozium schreberi*) as the ground cover. Mature trees are based on tree ring counts that indicate trees are approximately 200 years old. The lack of permafrost on these south-facing slopes results in much drier soil conditions.

The dominant vegetation on north-facing slopes consists of dwarf birch (*Betula glandulosa*), willow, sedges (*Carex* sp.) and extensive moss cover. The presence of these hydrophilic species is primarily due to the shallow permafrost table approximately 30 to 60 cm below ground surface.

Vegetation and wildlife data from Ecological Logistics & Research Ltd. (ELR) has been reviewed and incorporated into the conceptual reclamation planning. The available vegetation data includes species lists for the different ecotypes in the landscape surrounding the Site. The surrounding plant communities will be a potential seed source; therefore, the ELR vegetation data will be considered when determining species composition for the recommended seed mixes.

Outside of the OIC, the established vegetation cover on the tops of mountains (exposed) is a mix of species dominated by dryas (*Dryas* spp.), a pioneer species and nitrogen-fixing plant.

7.2.3 Wildlife

Ecological Logistics and Research (ELR) completed a preliminary summary of wildlife data and provided some recommendations for reclamation planning (Drawing D045). The key wildlife species in the OIC are moose and the Klaza herd of woodland caribou (ELR, 2013). Observations of other species in the OIC and in the study area (i.e. a 1 km zone around the OIC boundary) include grizzly and black bears, wolf, lynx, wolverine, porcupine, snowshoe hare and other small mammals. Passerines were observed nesting in the Dome Creek area of the OIC and in exploration trenches. Swans, shorebirds and waterfowl were observed in the tailings pond area (ELR, 2012, 2013).

Wildlife move through the area via river valley corridors, and occasionally use existing roads and exploration trenches in other parts of the mine. Moose and caribou travel through the Dome Creek Valley year-round and on the ridge between Dome Creek and Dry Creek (Drawing 45; ELR, 2013). The Victoria Creek Valley and adjacent ridge are used extensively by wildlife, as these likely provide conduits for movements from the south, specifically from the Nisling Valley into the Victoria Creek watershed and/or to valleys beyond (Drawing 45; ELR, 2013).

The habitat requirements for reclamation planning focus on moose and caribou, the most commonly observed large mammal species in and around the OIC. Moose require horsetail (*Equisetum* spp.), sedges, willow and birch for foraging. Caribou feed primarily on terrestrial and arboreal lichen, and in the summer months on sedges, forbs, horsetail, grasses, young willow and birch. Both species require conifer stands for thermal and safety cover (Wall et al., 2011; Thomas and Gray, 2002; Clark and Waterreus, 2012; Johnson et al., 2004).

7.2.4 Disturbance

Disturbed areas within the OIC include the:

- tailings pond and dam;
- Brown-McDade pit;
- waste rock area;
- exploration trenches;
- mill complex;
- camp area;

- access roads;
- Victoria Creek Wellhouse; and
- transmission line from the wellhouse to Mount Nansen Road.

The degree of disturbance varies across these areas. Generally, however, they are comprised of compacted, coarse, crushed rock with little or no vegetation. Where natural revegetation is present, cover ranges from 2% to a maximum of 20%, averaging about 5% (Appendix H, Photo 1).

Within the OIC, there are also numerous exploration trenches that are visible as long linear features typically clustered around a mineralized zone of interest (LORAX, 2011). During exploration, the topsoils and subsoils were side-cast with depths greater than 1 m below ground surface, exposing the nutrient-poor substrates. Many of the exploration trenches oriented perpendicular to the slope have become preferential paths for water courses, and this has caused the formation of minor erosion rills (Appendix H, Photo 2). Vegetation growth is generally very poor in the trench troughs; however, there is vigorous growth of willow and fireweed on the side-cast material (Appendix H, Photo 3). On the slope to the west above the mill site, side-cast material had been pulled back into the trench at this location and the in-filled trenches show dense willow growth. These observations show that revegetation is feasible where soil material is present.

7.3 Reclamation Concepts

Successful long-term restoration of disturbed sites in northern regions is a more complex and difficult task than it is for sites in more temperate climates (Clark and Hutchinson, 2005). Like many mine sites, post-mining landscapes in the north are generally void of some or all functioning ecosystem components (i.e. soil, flora and fauna; Cooke and Johnson, 2002). Furthermore, remnant soils are often compacted and/or phytotoxic, and lack a seed bank. These characteristics, in combination with cold temperatures, can significantly inhibit or prevent recovery of once-thriving ecosystems.

Compaction, poor water holding capacity, absence of organic matter, in addition to a harsh climate (cold air and soil temperatures, wind exposure and short growing season), all impede vegetation development and ecological succession at the Mount Nansen Site. Ecological succession is defined as the process of change in the species structure of an ecological community over time. Mining disturbances remove the existing vegetation from the landscape thereby re-initiating successional processes (Prach et al., 2013). However, early successional ecosystems, such as those on the Mount Nansen Site, must rely on a greatly reduced soil capital. This lack of soil significantly limits natural successional processes and site recovery.

In order to gain a better understanding of successional processes and treatment options of reclaimed sites in the North, the study team reviewed a number of case studies (field trials) in the Yukon (including trials conducted previously at Mount Nansen) to determine the best approach for reclamation. The following section provides a summary of the approaches to reclamation and the results of these studies.

7.3.1 Northern Reclamation-Case Studies

Detailed case studies are summarized here for seven mines. The case studies demonstrate that despite the challenges of reclamation in the north, select reclamation treatment options have proved more successful than others. The results varied from site to site, but the following were noted consistently:

- Rough and loose surface treatments (i.e. created topographic heterogeneity, described in Appendix I) were incorporated into almost all reclamation designs and generally proved successful in promoting vegetation establishment and growth.
- Agronomic seeds established fairly quickly, but out-competed native species and thereby affected succession.
- Native seeded species were generally successful at becoming established and are desirable.
- Live staking with willow is commonly practiced with positive results if the substrate is prepared using the rough and loose technique and/or horizontal staking.
- In cases where fertilizer was used, it proved essential for initial vegetation establishment and growth.
- Treatment plots with topsoil showed slightly better growth than those with mulch, and plots without mulch or topsoil were less productive.

Faro Mine Complex, Yukon (Carter and Tobler, 2013)
Site Preparation

- Soils were mechanically prepared using three different site preparation techniques that created topographical heterogeneity (micro-rill, planar and rough and loose [described in Appendix I]) on refilled exploration trenches. Results indicated that rough and loose surfaces revegetated well and were most effective for controlling erosion, even in areas with minimal vegetation coverage. Results also indicated that this technique resulted in dense grass growth.

Seeding

- Three seed mixes were used: agronomic, native, and nurse and native. All seed mixes demonstrated increased coverage in the third year after seeding. Alder (*Alnus* sp.) seedlings showed a negative response to fertilizer application, likely due to competition with herbaceous vegetation.

Live Staking

- Live staking with horizontal and vertical stakes. Results showed higher stem counts for horizontal staking.

Fertilizer

- Two fertilizer treatments were used. Monitoring indicated fertilizer was necessary to establish herbaceous vegetation and unfertilized plots had minimal growth.

Colomac Mine, Northwest Territories (Hewitt et al., 2013)

Site Preparation

- Soils were mechanically disturbed to promote natural revegetation using the rough and loose technique. Results indicate that native grasses were most prolific where soils were rough and loose.

Soil Amendment

- Areas that were prepared with salvaged peat and had the rough and loose method demonstrated highest initial success rate for plant survival and coverage, as well as increased biodiversity compared to other sites.

Live Staking

- Planted willow shoots had highest success rate where rough and loose technique was applied to the soil.

Kemess South Mine, Northern B.C. (Lysay et al. 2009)

Site Preparation

- Rough and loose was applied to the tailing dam following closure of the mine. It was proven to be effective in controlling surface snow melt in both the 2009 and 2010 spring melt seasons. Little to no erosion was observed on dam slopes. This technique creates favourable conditions for capturing the wind-borne seeds of desired plant species.

Seeding

- Three one acre plots of purchased native seed mix were spread on the dam face in early 2009. Seed mix included a selection of mid- to high elevation species, including slender wheatgrass, Rocky Mountain fescue (*Festuca saximontana*), alpine bluegrass (*Poa alpina*), alpine timothy (*Phleum alpinum*), spike Trisetum (*Trisetum spicatum*), Canada milkvetch (*Astragalus canadensis*) and fireweed.
- Seeds collected from the site in 2009 were hand broadcast over the surface of the dam. These included arnica (*Arnica* sp.), coltsfoot (*Petasites* sp.), fireweed and Sitka burnet (*Sanguisorba canadensis*).
- Results as of 2010 indicated that native vegetation was colonizing the dam.

Live Staking

- A large willow collection program was completed to use the material for willow staking, willow wattle fences and live pole drains.

Patch Creation

- Created micro-sites or “patches” for establishment of vegetation on the exposed rock slope. Some pockets of vegetation had already established, and the intent was to augment these pockets with additional sites. A lack of suitable growth medium meant soil had to be moved to the site. Overburden from the site was mixed with water to form a slurry. Approximately 7 m^3 of soil was moved to create roughly 150 planting sites. At the time that this report was prepared, the Kemess reclamation project was ongoing and results were not available.

Mount Nansen (EDI 2008)

Seeding

- In mid-October, native grass seed was spread over 0.2 ha at a rate of 25 kg/ha resulting in approximately 5 kg of seed dispersed. Grass seed used included slender wheatgrass (*Elymus trachycaulus*), alpine bluegrass, tufted hairgrass (Deschampsia cespitosa*)*, fringed brome (*Bromus ciliatus*), Rocky Mountain fescue, oatgrass species (*Trisetum* sp.), fowl bluegrass (*Poa palustris*), alkali grass (*Puccinnellia distans*) and awned wheatgrass (*Agropyron subsecundum).* Two separate mixes were used containing varied percentages of each species. Monitoring results were not reported. During the Summit September 2013 Site visit, it was difficult to determine where the seeding application took place.

Live Staking

- Live willow and balsam poplar (*Populus balsamifera*) stakes were harvested from within the general area of the Site and along Mount Nansen access road (less than 15 km from the Site). They were placed vertically in 12 x 12 m grids to a depth of 40 cm on a hill crest and hill slope and diagonally (to avoid permafrost layer). Monitoring results indicate that live staking was unsuccessful for a number of reasons including dry compacted substrate, exposure and erosion issues. The sub-optimal planting schedule also likely contributed to the live staking failure at this site.

Live Pole Drains and Brush Layers

- In late September, additional live stakes were harvested for the Pony Creek area revegetation. In late September to early October, live stakes were planted, live pole drains were installed and a light seeding of native grasses was applied to address short term erosion concerns. Two brush layers were placed at the toe of the slope for stream-side bank stabilization. To prevent erosion, a biodegradable erosion blanket was installed between the two brush layers. Monitoring results have not been reported. During the Summit Site visit in September 2013, growth was observed on approximately 30 to 50% of the cuttings (the number and spread of the initial cuttings was difficult to determine; Appendix H, Photo 4).

Reclamation Practice and Research of Mineral Exploration Properties in the Yukon Territory (Craig et al., 1998):

Reclamation research was carried out by the Yukon Government to guide the development of policy and general operating conditions for the mining industry and government regulators at three separate sites (all old exploration trenches) in the Yukon.

- Red-Ridge (Whitehorse area);
- Nucleus (Carmacks area);and,
- Hawk (Dawson City area).

During research trials, trenches were filled in and recontoured with a small bulldozer and five plots were constructed on each new surface consisting of one control plot and four treated plots. The plots were either seeded or fertilized using a mulch blanket, topsoil blanket and the substrate present (different mixtures of seed and fertilizer).

The results varied from site to site, but they generally showed that:

- vegetation growth rates on back-filled trenches are mostly a function of climate, availability of moisture and substrate grain size;
- fine grained soils are more efficient for retaining moisture at the surface;
- microsites created through mechanical techniques promoted plant growth by trapping soil fines, seed and moisture;
- agronomic species inhibited growth of indigenous species in the first years after seeding;
- growth was not significantly improved with imported topsoil and mulch;
- imported topsoil introduced non-native weed seed in the form of foxtail barley;
- grass seeds promoted rapid vegetation to stabilize slopes;
- native seeds, such as reed grass (*Calamagrostis* sp), bluegrass and fescues, which are considered to be hardy, widespread and nutritious forage species for ungulates are recommended; and
- a single application of inorganic fertilizer helped to stimulate growth.

Based on these results of these case studies, several treatment options and strategies are considered feasible for reclamation at Mount Nansen. For a detailed description of recommended treatments and strategies, rates of seed and fertilizer application (if applicable) and potential source material, refer to Appendix I. Treatment methods, rates and potential material sources are described for the following: rough and loose, seeding (collection and spread), patch planting, fertilizer, mulch, coarse woody debris, live staking and biochar.

7.4 Preliminary Reclamation Plan

This section presents the preliminary reclamation plan for the Mount Nansen Site. The goal of this plan is to restore the natural landform, which will ultimately lead to restoration of natural ecological function. The first step is for the disturbance areas to be shaped to mimic the natural slope contours. After contouring is complete the reclamation prescriptions outlined in this plan can be applied to initiate revegetation of the disturbed areas.

In general, to support natural revegetation, landforms will be made concave where possible to retain water, and surfaces made rough and loose to create micro-sites that will boost revegetation success (based on Polster, 2014 and Sweigard et al., 2007). Patch creation will be applied to select areas to initiate the establishment of a self-sustaining vegetation community. Due to site limitations, especially the lack of salvaged topsoil, the reclamation of the Mount Nansen Site will require a creative approach and patience.

To determine the level of treatment intensity, the landscape at the site was stratified (i.e. classified) into High, Moderate, Low or Null Priority Areas, as described in Section 7.4.3. Prescription concepts are described for the three stratification levels in Sections 4.4 (High), 4.5 (Moderate) and 4.6 (Low). Exploration trenches were considered separately from the remainder of the disturbance and the reclamation plan for the trenches is described in Section 7.4.7.

7.4.1 Assumptions

Development of a final plan requires knowledge about the state of the Site after decommissioning and removal of contaminated material. In other words, the reclamation prescriptions are not absolute; they are concepts that may be modified as closure progresses. Therefore, the prescriptions outlined herein assume the following:

- All contaminated material, including tailings from the tailings pond will be collected and buried in the Brown-McDade pit.
- Material contaminated with metals and considered to be special waste will be transferred from the site to a licensed waste facility.
- All redundant buildings will be demolished and removed. These include the mill complex, the camp area and the Victoria Creek Wellhouse.
- Waste rock, decommissioned buildings and other waste material will be buried in the Brown-McDade pit.
- The pit will be covered with an engineered cap.
- The power line from the Victoria Creek Wellhouse will be removed and all timber poles will be pulled from the ground intact and removed from the site.
- All roads except the Mount Nansen public road will be decommissioned. Decommissioning will consist of full pullback of the road prism for road sections on a side hill (cut/fill constructed) so that they can be made stable for runoff. For roads in fill only situations decommissioning would likely just include making the surface rough and loose. For a more detailed description of road decommissioning, see Appendix J.
- In all decommissioned areas, the landscape will be contoured to blend with the surrounding area.
- The prioritized excavation trenches will be treated as recommended in Section 7.4.7 (Drawing 046). The others will not be treated.
- Approximately 180,000 m^3 of clean sandy material is available within the OIC (from the tailings dam or from sand borrow areas).
- Sourcing of seed from the OIC for collection and subsequent spreading is an option.
- Commercially sourced seed is an option.
- Use of fertilizer and mulch sourced from offsite is an option.
- The Dome Creek area will be returned to grades consistent with upstream and downstream portions of the channel using coarser, non-erodible material over sand.

7.4.2 End Land Use Objectives

The following end land use objectives are based on the major closure objectives outlined in the LORAX report (2011; Section 1.0), input from AAM and the wildlife and vegetation data provided by ELR (2013):

- creation of habitat for caribou and moose;
- restore the natural functioning of Dome Creek by restoring disturbed areas in the watershed; and
- restoration of conditions that reflect the future land use.

The creation of caribou and moose habitat, and wildlife habitat will entail establishing thermal cover, security areas and forage for moose and caribou (willow, grass, forb and sedge growth; ELR, 2013).

In order for Dome Creek to become a naturally functioning hydrologic and ecologic system, erosion and sedimentation must be controlled by promoting rapid establishment of vegetation (especially riparian vegetation), which also serves to enhance and protect terrestrial and aquatic life.

A natural landscape lends to landscape stability, serves to protect the environment and reduces government liability and management of risk. A natural landscape can be achieved through initiating the establishment of a self-sustaining vegetation community. A self-sustaining vegetation community will aid in returning the Site to an acceptable state that reflects original use where possible. This will also maximize local, Yukon and First Nation benefits (LORAX, 2011), and achieve a self-sustaining biological community that achieves land use objectives (Yukon Energy, Mines and Resources, 2013).

7.4.3 Landscape Stratification – High, Moderate and Low Priority Areas

In an optimum reclamation situation, there would be an adequate supply of topsoil to apply to disturbed areas, as recommended in the LORAX report (2011). This is not an option for the Mount Nansen Site. For this reason, treatment intensity will vary through the landscape, based on landscape priority stratification. For all but the exploration trenches, the landscape is stratified to determine reclamation treatment intensity. Areas are ranked from null to high treatment intensity based on end land use objectives, which are equated to the following parameters:

- importance to wildlife;
- potential for negative impacts from erosion or sedimentation; and
- duration of time to become a natural landscape.

If an area met only one of these criteria, it was ranked as low priority; if it met two of these criteria, it was ranked as moderate priority; and if it met all three, it was ranked as high priority. Importance to wildlife is based on the data provided by ELR (ELR, 2013; Figure 2-1).

Results of stratification are listed by category and reclamation prescriptions reflect this stratification (Drawing 046):

- High: Dome Creek Valley;
- Moderate: mill complex and camp area, Brown-McDade pit;
- Low: identified roads and landings; and
- Null: all other disturbance areas.

The exploration trenches that require treatment are identified in Drawing 46. All other exploration trenches are considered low priority and, therefore, do not warrant treatment. Trenches considered as priorities for treatment are those that met the following criteria:

- above average potential for erosion;
- location near to or within wildlife corridors; and
- good access.

The following reclamation prescriptions are a combination of the treatment options identified in Appendix I. These prescriptions are conceptual in design and are subject to modification based on the final Site design plan. Prescriptions are separated into high, moderate, low or null level of reclamation treatment intensity (Drawing 046). The prescriptions are discussed separately for the excavation trenches and Dome Creek Valley.

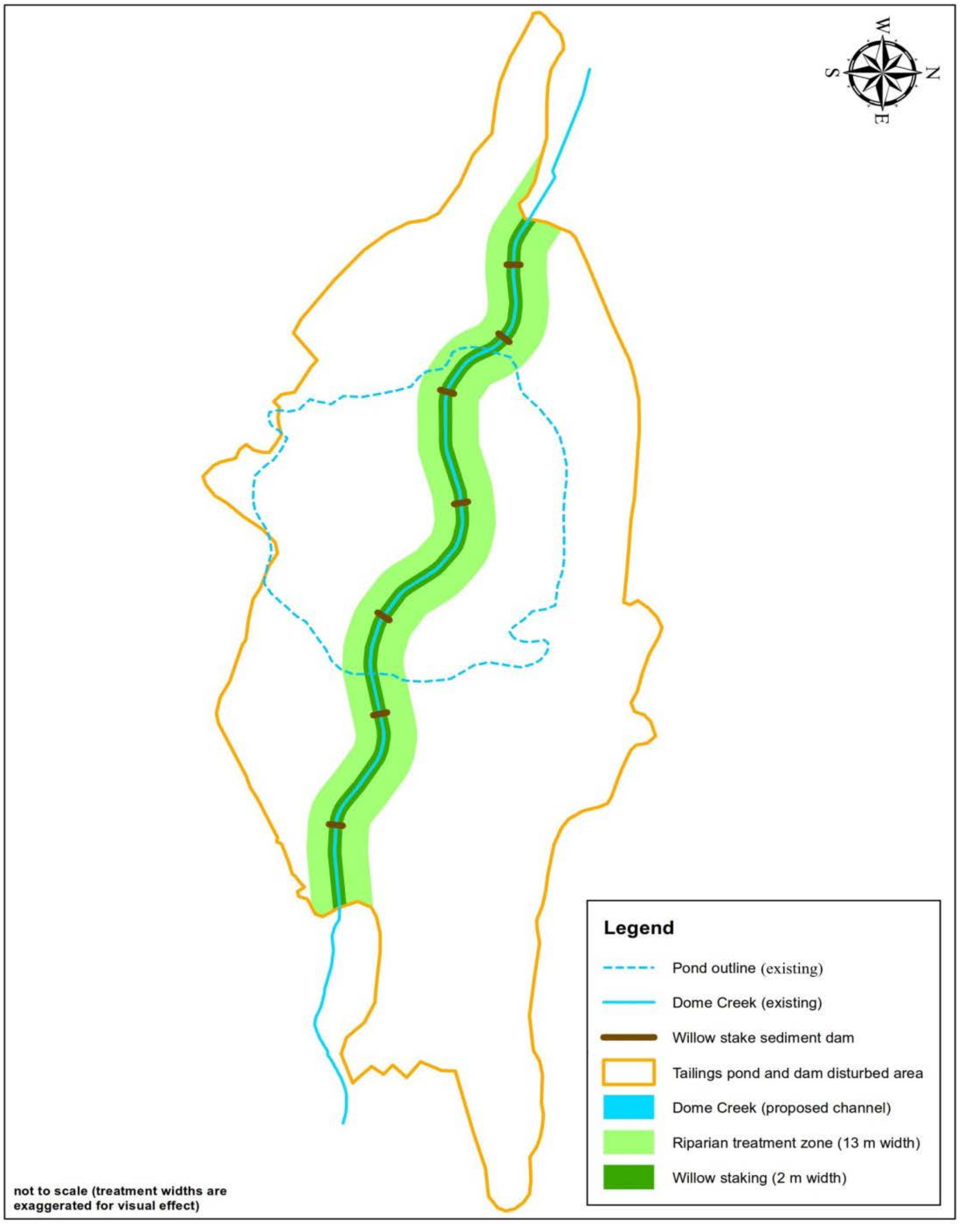
7.4.4 Reclamation of High Priority Areas (Dome Creek Valley and Dome Creek)

Dome Creek and Dome Creek Valley (including the tailings pond and dam sites) were identified as high priority areas for the following reasons:

- They are high-value areas for wildlife and biodiversity (ELR, 2012, 2013).
- They will require careful erosion control to maintain water quality in Dome Creek.
- They make up a large proportion of the disturbed area and will likely take a long time to naturally revegetate.

Dome Creek and Dome Creek Valley total approximately 16.4 ha. The Dome Creek Valley overview showing the Dome Creek riparian area is shown in Figure 42.

Figure 42: Dome Creek Valley Overview



Dome Creek Riparian Area

The reclamation objectives for the Dome Creek riparian area are to prevent erosion and sedimentation, and promote rapid establishment of vegetation to enhance and protect terrestrial and aquatic life. Efforts should be made for 100% treatment for revegetation of a 2 m wide riparian buffer immediately adjacent to the channel top of bank, and 25% treatment for revegetation within the next 13 m of the riparian buffer (from 2 m to 15 m from top of bank). The exact areas for the riparian habitat will be based on the length of the restored stream, to be determined when the channel design is complete. The example prescription is as follows and shown in the creek profile, Figures 43 and 44 (refer to Appendix I for specific treatment methods including rates and potential material sources):

Figure 43: Dome Creek Profile – Reclamation Prescription Example for Riparian Area

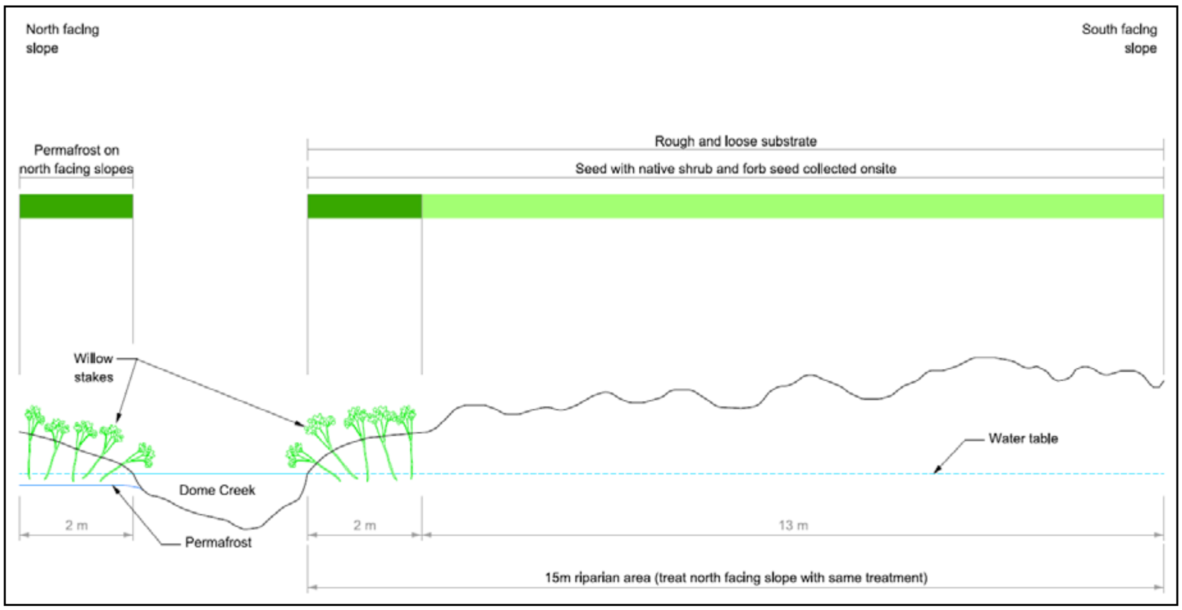
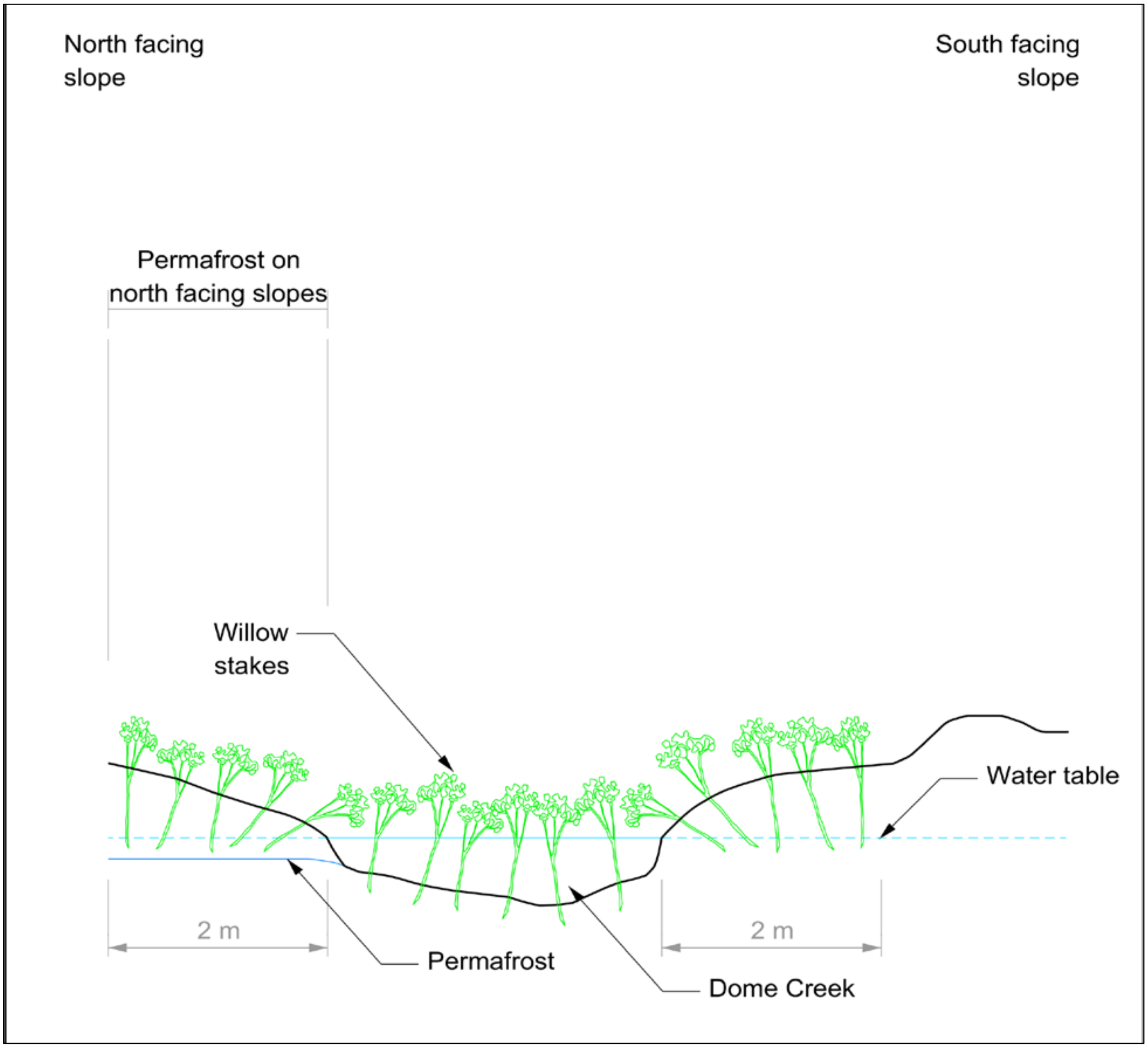


Figure 44: Dome Creek Profile – Live Silt Fence



- Restore Dome Creek by recreating the channel to an acceptable grade blending into the adjacent topography (as per engineered design which is based on hydrological modelling appropriate for Dome Creek).
- Create a channel bed similar to natural sections of Dome Creek using available boulder, cobble and gravel materials, select rounded gravel and cobble, and minimize angular materials. Source the material from contaminant-free areas within the OIC.
- Create live silt fences within the channel (i.e. plant willow stakes from creek bank to creek bank) to slow velocities and protect creek banks from erosion while establishing riparian vegetation (Figure 42). Approximately seven of these should be placed at bends in the creek, however the number and spacing may be revised once the creek design is finalized.

- Within the 2 m riparian area, 100% of the area should be treated with a combination of willow staking, native seed application, placement of transplanted vegetation mats and application of biochar and/or mulch. The total area to be treated will be based on the length of the restored stream, to be determined at a later iteration.
- Within the 13 m riparian buffer, 25% of the area should be treated. Again, the total area will be determined once the restored stream length is determined. A breakdown of possible treatment combinations (prescriptions) to the patches, and application amounts based on the total area of patches is summarized here, which will be revised based on trial outcomes:
- Monitor for erosion (Section 5.3.1).

Treatment	Application Amount[1] and Estimated Total for Unknown ha
Seed with native mix[2]	To be determined
Add fertilizer	To be determined
Add mulch	To be determined[3]
Add coarse woody debris	To be determined
Add biochar	To be determined[4]
Stake willows	To be determined
Plant white spruce and trembling aspen within patches, focussing on mid to lower slope locations	To be determined
Transplant vegetation mats onto patches	As available

1 *Application rates are outlined under treatment descriptions, Appendix I.*
2 *Appropriate seed mixes are outlined in Table 7.2.*
3 *To cover 70% of the patch areas as it can be done in combination with biochar and coarse woody debris application.*
4 *To cover 30% of the patch areas, as this is potentially very costly at the recommended rate and can be done in combination with mulching and coarse woody debris application.*

Dome Creek Valley

The prescription for Dome Creek Valley is to treat the entire area as rough and loose (outside of the 15 m riparian area), and add additional treatment combinations to maximize revegetation as follows (refer to Appendix I for specific treatment methods including rates and potential material sources):

- Restore the tailings pond and dam sites to an acceptable grade that blends into adjacent topography.
- Create micro-site patches, as outlined in Appendix I. These should be scattered across the landscape at a rate of 2.5 patches per ha, or approximately 41 patches covering 10% of the landscape (2 ha). Patch spacing should be 50 m, working outwards from the riparian area (exact locations to be determined). A breakdown of possible treatment combinations (prescription) to the patches, and application amounts based on the total area of patches is summarized here, which will be revised based on trial outcomes:

Revegetation prescription efforts in this area should be approximately 10% of the site.

Treatment	Application Amount	Estimated Total for 16.4 ha (2 ha treated)
Seed with native mix	44 kg/ha	88 kg
Add fertilizer	Site-specific prescription should be completed.	
Add mulch	1 ton/ha	2.8 tons[1]
Add coarse woody debris	30% of the treated areas	To cover 0.6 of a ha
Add biochar	5 tons/ha	3 tons[2]
Stake willows	1 stake/m^2	17,000 stakes[3]
Plant white spruce and trembling aspen within patches, focussing on mid to lower slope locations	1 transplant /m^2	3,000 transplants[3]
Transplant vegetation mats onto patches	As available	

1 *To cover 70% of the patch areas as it can be done in combination with biochar and coarse woody debris application.*
2 *To cover 30% of the patch areas, as this is potentially very costly at the recommended rate and can be done in combination with mulching and coarse woody debris application.*
3 *Staking and transplanting are considered in combination, with the staking is assumed to comprise 85% of effort and transplanting 15% because staking is less labour intensive and material is readily available.*

Recommended Seed Mixes

It is highly recommended to use seed from the regional area, as it is most likely to germinate and become successfully established. The species listed in Tables 7.2 and 7.3 are recommended for riparian and upland areas, respectively.

Table 7.2: Riparian Species Seed Mix

Species – Common Name	Scientific Name
Grasses	
Bluejoint reed grass	*Calamagrostis canadensis*
Aquatic sedge	*Carex aquatalis*
Sheathed sedge	*Carex vaginata*
Tufted hairgrass	Deschampsia cespitosa
Cotton grass spp.	*Eriophorum spp.*
Bluegrass	*Poa spp.*
Forbs	
Dwarf fireweed	*Epilobium latifolium*
Shrubs	
Dwarf birch	*Betula nana*

Table 7.3: Upland Species Seed Mix

Species	Scientific Name
Grasses	
Bluejoint reed grass	*Calamagrostis canadensis*
Sheathed sedge	*Carex vaginata*
Tufted hairgrass	Deschampsia cespitosa
Slender hairgrass	*Deschampsia elongata*
Wildrye species	*Elymus spp.*
Fescue species	*Festuca spp.*
Bluegrass	*Poa spp.*

Species	Scientific Name
Forbs	
Yarrow	*Achillea millefolium*
Arnica species	*Arnica spp.*
Milkvetch species	*Astragalus spp.*
Fireweed	*Epilobium angustifolium*
Alpine sweetvetch	Hedysarum alpinum
Shrubs	
Arctic bearberry	*Arctostaphylos rubra*
Dwarf birch	*Betula nana*
Buffalo berry	*Sheperdia canadensis*

7.4.5 Reclamation of Moderate Priority Areas (Mill, Camp and Pit Areas)

Moderate priority areas total approximately 29.2 ha and are identified in Drawing 46. They include the mill complex (approximately 8.8 ha), camp area (approximately 2.1 ha) and Brown-McDade pit (approximately 18.3 ha). The conceptual reclamation prescriptions for moderate priority consist of a combination of treatments. The initial treatment is to make all of the identified moderate priority disturbance rough and loose, then create patches in 10% of the disturbance, or approximately 3 ha. An example of an appropriate prescription for areas identified as moderate priority for intensive reclamation is as follows:

- Prepare all areas with rough and loose treatment. Avoid compaction of the substrate materials (i.e. do not drive over the treated areas).
- Determine optimum locations for patch creation. Patches should be approximately 50 m from valuable landscape features, such as dense shrub cover and intact forest, and scattered across the landscape.
- Create patches at a rate of 2.5 per ha, or approximately 3 ha in total area.
- A description of possible treatment combinations (prescription) for the patches, and application amounts based on the total area of patches is summarized here. This will be revised based on trial outcomes:

Treatment	Application Amount	Estimated Total for 3 ha
Seed with native mix	44 kg/ha	132 kg
Add fertilizer	Site-specific prescription should be completed.	
Add mulch	1 ton/ha	2.1 tons[1]
Add coarse woody debris	30% of the treated areas	to cover 1 ha
Add biochar	5 tons/ha	4.5 tons[2]
Stake willows	1 stake/m^2	25,500 stakes[3]
Plant white spruce and trembling aspen within patches, focussing on mid to lower slope locations	1 transplant /m^2	4,500 transplants[3]
Transplant vegetation mats onto patches	As available	

1 *To cover 70% of the patch areas as it can be done in combination with biochar and coarse woody debris application.*
2 *To cover 30% of the patch areas, as this is potentially very costly at the recommended rate and can be done in combination with mulching and coarse woody debris application.*
3 *Staking and transplanting are considered in combination, with the staking is assumed to comprise 85% of effort and transplanting 15% because staking is less labour intensive and material is readily available.*

In addition, the following is prescribed for the final cap on the Brown-McDade pit, which will likely be adjusted as the cap design is finalized:

- Apply rough and loose surface treatment over the entire surface.
- Create patches, as outlined above.
- If the surface cannot be made rough and loose, utilize onsite sand to create a final cap.
- Seed all areas where sand is applied.
- Monitor growth and adapt the management of the pit cap as needed.

Recommended Seed Mix

The same upland seed mix as the High and Moderate Priority areas is recommended, as listed above in Table 7.3.

7.4.6 Reclamation of Low Priority Areas (Roads and Landings)

Low priority areas will be subject to rough and loose site preparation after landform engineering is complete (e.g. the roads will be ripped to break up compaction). This will be the extent of treatment for roads and landings (i.e. all low priority areas). Seed will not be spread in these areas (roads and other narrow disturbances are close to propagules from natural vegetation communities; therefore, have natural ingress more quickly, provided the conditions are right).

7.4.7 Exploration Trench Reclamation

Exploration trenches at the Mount Nansen Site vary in depth, length, width and natural revegetation cover. The trenches are grouped by area, as shown in Drawing 046, and have been classified based on priority for reclamation treatment. The total trench area to be treated is approximately 9 ha, and translates to 2,305 m in length in the western area of the Site (west of the mill complex), and 2,175 m in length in the northern area of the Site. The goal of reclamation treatments in these areas is to blend the trenches into the natural topography and to facilitate revegetation using material that is already growing on the side of the trenches. The trench treatment process would likely consist of the following measures:

- The equipment is an excavator, truck and brush saw.
- Moving along the trench, cut the shrubs that are growing on the side-cast material to approximately 6 inches above the moss layer, and stockpile the cut material in a suitable location outside the trench.
- Using the excavator, remove the surface vegetation and moss organic layer (approximately 10 cm to 30 cm deep), and stockpile. As much as possible, remove the surface vegetation as an intact mat.
- Pull the substrate (spoil material) that is currently piled on the sides into the trench and spread to make a more even terrain.

- Use the “dig and drop” method to make the substrate surface rough and loose (Appendix I). No smoothing is required. Avoid compacting the substrate materials (i.e. do not drive over the treated areas).
- Replace the vegetation and mossy layer in patches that are at a minimum 50 m apart.
- Apply woody shrub material in patches at a minimum 4-inch depth.
- Retain an environmental monitor to direct the location and extent of placement of material.

The patches of vegetation and moss organic layer and the woody shrub material will spread over the surface of the former trench areas, enhancing natural revegetation of the surrounding bare areas. Because the removed surface vegetation will be placed in patches, not all of the removed material will be required in the resurfaced trench. The extra revegetation material will be stockpiled, with organic matter separated from woody shrub. This material will be moved and deposited as soon as possible in other disturbed mine areas; specifically the Dome Creek riparian area and Dome Creek Valley (see example prescriptions above).

7.4.8 Invasive Plant Management

An invasive plant management plan will be developed once site contouring is complete. There are minimal invasive species currently at the Site; however, with improved ground preparation and potential vectors for weed seed (vehicles, supplied seed and mulch); invasive species could become an issue in the reclamation areas. Management would include incremental monitoring for presence, followed by preparation of a control plan including mechanical and potentially herbicide treatment.

7.4.9 Recommended Field Trials

For reclamation to be successful, AMEC/AE recommends that a detailed field trial and monitoring plan be developed, and that field trials be undertaken prior to full scale execution. The field trial program is recommended to develop the optimal reclamation procedures for the Mount Nansen Site. Experience at other mines sites in the Yukon and in similar climates has shown that field trials are cost-effective because they increase the potential for the reclamation goals to be met within a reasonable time frame. The monitoring plan is discussed in Section 7.4.10.

The field trials will determine whether the prescriptions provided above are appropriate for the Site. If areas requiring improvement are identified, the reclamation prescriptions will be revised accordingly. The proposed trials would involve setting up a number of plots, all with the rough and loose surface treatment. Replicate plots would then be established with the recommended revegetation methods: i.e. live-staking, applying native seed and transplanting individual specimens (sourced from within the OIC and white spruce sourced commercially). A statistical design will be developed to accomplish a rigorous analysis of results. Treatments to be assessed in the field trials are limited to the following key trials:

- rough and loose surfaces with existing substrate (coarse) material (control);
- rough and loose surfaces with mulch applied to the surface;

- rough and loose surfaces with fertilizer applied; and
- combinations of the above.

A hydroseeding trial should also be completed on a representative rough and loose surface. This would involve applying a mix of seed, mulch, tackifier and fertilizer.

Transplanting of vegetation mats will be trialed as follows:

- lifting mats to depths varying from six inches below the subsoil (coarse material surface) and one foot below the subsoil; and
- placing mats on smooth substrate with no amendments.

Native seed mixes that are sourced from within the OIC will be trialed to determine rate of germination and species with highest success of germination and survival.

7.4.10 Monitoring

Monitoring of reclamation trials and prescription outcomes is used to determine whether objectives are being met and can provide direction for changes to the reclamation approach if objectives are not being met (i.e. allows an adaptive management approach).

A detailed monitoring plan will be required at the initiation of trials and reclamation of the site. The plan will outline (Gonzales, 2013):

- detailed objectives for the trials and reclamation (i.e. what is expected, why is it important and who is involved);
- measurable targets (how much, how many, how to know when a target has been accomplished and what are the units of measurement); and
- timing (relative to treatments and relative to what is realistically possible in a period of time).

Monitoring will be designed to quantify the success or limitations of reclamation programs for Dome Creek, Dome Creek Valley and Brown-McDade pit cover. Regular monitoring of the Site will continue until a self-sustaining vegetation community is determined to have been established in the created patches and riparian area, the Site is stable and the end land-use objectives are on track to be met. The reclamation monitoring program will be done in collaboration with the hydrology discipline’s groundwater, surface water, and water quality monitoring and other Mount Nansen monitoring programs.

7.5 Reclamation Plan Summary

Reclaiming the Mount Nansen Site to a self-sustaining vegetation community is likely to be a challenging task due to a lack of topsoil cover, poor soil nutrient availability, the cold climate, and permafrost issues (i.e. effects of the freeze-thaw cycle, poor drainage in some locations). Due to these limitations, establishing a self-sustaining vegetation community is likely to take longer than in other, more temperate climates.

In general, natural revegetation of abandoned surface mines is a patchy process. This process begins with restoring the natural landform; then preparing the substrate so it is able to support vegetation germination and growth. This is followed by establishing vegetative cover through development of new patches via colonization by propagules from adjacent undisturbed land and/or from treatment application. The next phase is naturally increasing vegetative cover, primarily through expansion of existing patches and secondarily through new patch establishment from propagules. The final phase is coalescence or merging of the patches such that, ultimately, all disturbed ground has vegetation cover.

Overall, landforms will be made concave where possible to retain water and minimize erosion and sedimentation. Surfaces will be left rough and loose to create micro-sites that will promote revegetation success. Other treatment options include combinations of soil amendments (e.g. sand, mulch, biochar), revegetation (e.g. live staking, seeding), coarse woody debris placement (to create protected micro-sites), and fertilization. Fertilizer will likely be needed on all reclamation sites, with site-specific fertilizer prescriptions to be developed after site preparation is complete.

This report provides a preliminary reclamation plan that provides example prescriptions based on research completed at Mount Nansen and other cold climate disturbed sites (i.e. suggested combinations of reclamation treatments) for a stratified landscape, specifically:

1) the High Priority Dome Creek Valley;
2) all disturbance identified as Moderate;
3) all disturbance identified as Low Priority; and
4) exploration trenches.

The prescriptions are conceptual based on assumptions regarding site preparation (also outlined in the report), and the overall goals for the site and end land use objectives. The end land use objective is understood to be wildlife habitat for caribou and moose, restoring the natural functioning of Dome Creek and creation of a natural landscape. A field trial program is recommended to turn the conceptual plan into a detail reclamation plan that includes specific site preparation, soil amendment, revegetation, fertilization, and monitoring prescriptions. Although it will take several years to obtain results, a field trial program is likely to be cost-effective over the long run because it will increase the probability that the plan will result in development of a self-sustaining landscape.

7.6 Dome Creek Reclamation near Tailings Facility

The tailings facility located within the Dome Creek Valley will be an intensive area of activity and reclamation efforts. Activities at the mill will also impact upper Dome Creek as discussed in Section 7.4. In addition, there appear to be tailings that have been transported downstream of the tailings storage facility and seepage pond as there are creek sediments with very high metals concentration which have collected at various locations downstream of the seepage pond (AMEC 2014, EDI, 2006). There is also an area of concern on the south bank of Dome Creek, about 100 m downstream of the seepage pond where an area of blackened vegetation about 150 to 200 m in length is evident. In this area of blackened vegetation, the upper organic material and surficial soils have elevated metals but the underlying soils (C horizon) have low metals concentration (EDI, 2006). To better define the extent of the areas of increased metals concentration and to characterize the area of blackened vegetation, additional collection of sediment samples and near surface soils is required. Given the undisturbed nature of downstream Dome Creek, reclamation of these areas will require discussion with the project partners to ensure that the benefit of reclamation exceeds the disturbance caused.

Currently, the base case is predicated on removing the affected sediments and stabilizing the excavated area. Stabilization measures would be similar to those discussed below for the slopes in the tailings storage area and would consist of placing free draining, erosion resistant granular materials on any exposed slopes. Any uncontaminated organic material removed would be stockpiled and used to encourage regrowth of vegetation. In order to minimize disturbance to Dome Creek, work would be carried out in low flow periods and possibly in the winter so that access is over frozen ground.

7.6.1 General Configuration of Remediated Tailings Storage Area

The reclaimed Dome Creek Valley slopes in the general vicinity of the tailings storage facility will be generally graded to match the original ground topography in the area but, with the exception of the local slopes at the terraces, will be limited to maximum slopes of 5H:1V (11 degrees). The regraded slopes will be covered by a minimum of 1.5 m of free draining, erosion resistant granular material to provide a surcharge load and reduce erosion. This is shown in plans and sections in Drawings D047 through D050. These drawings currently show uniform slopes in Dome Creek however in later design stages, this will be refined and benches added to create topographic diversity for reclamation purposes and to minimize runoff velocities and erosion potential.

From a stability perspective, the ideal conditions are bare free draining slopes. This reduces the water levels in the slopes and allows any water from thawing permafrost to exit the slope, improving stability. An organic mat can improve stability by preserving permafrost; however, in this situation, it is very unlikely that a thick organic mat, capable of significantly affecting permafrost conditions would develop in the short term. Introduction of significant fine grained materials on the slopes would thus most likely only result in hindering seepage and raising water levels, reducing stability and potentially requiring design measure to enhance drainage. However, from a reclamation perspective, exposed granular slopes may not be desirable because revegetation on such slopes would be challenging and the aesthetics may not be acceptable to the project partners.

As outlined in Section 7.4.4, vegetation will be encouraged in local islands and particularly in the valley bottom by placement of any stockpiled uncontaminated fine grained materials from the tailings area and placement of fine grained sand in microsites on the final slopes. These fine grained materials will tend to trap moisture in the microsites where seeds can lodge, seedlings can grow, and roots can penetrate.

The interface between the reclaimed slopes and the undisturbed ground will require special attention to prevent degradation of existing permafrost. Placement of wood chips along the interface would protect the permafrost and should be considered further in subsequent phases of design. In any case, there will be some maintenance required in the form of regrading to manage unavoidable differential settlement and the effects of surface water erosion.

7.6.2 Stability Analyses

The maximum slopes and required surcharge loading have been selected based on the stability assessments that are included in Appendix E. The following scenarios were considered:

- short term stability of surficial materials subjected to thaw based on infinite slope stability assessments;
- stability of slopes in consideration of deeper failure surfaces with deeper thaw caused by ongoing permafrost degradation as a result of warming air temperatures; and
- stability of slopes under earthquake loading.

In support of the stability assessment a typical geologic profile across Dome Creek was developed. As illustrated in the stability sections in Appendix E, the typical geology consists of surficial sandy silt with organics up to 2 m thick underlain by fine to medium sand. In the upper portions of the valley slopes bedrock is relatively near surface. Closer to the valley bottom, the overburden thickness are up to 20 m and greater. Silt to sandy silt several metres deep was encountered at depths of 5 to 15 m in various investigation locations on the valley side slopes. This material appears to be absent in the valley bottom. Although not observed in all investigation locations, it appears that the finer material could represent a unit that was deposited across the valley and then eroded in the valley bottom and thus a silt unit with some continuity has been assumed. There are also certainly random zones of finer grained material within the main sandier unit. One borehole from 1988 intersected a pocket of clay at a depth of 18 m. Underlying the sand unit is a coarser sand and gravel unit and bedrock.

Other than the visual descriptions from the available borehole logs, there is limited data regarding the silt unit largely because it was not encountered frequently in the various investigation programs. There are also cases where boreholes have been carried out by different consultants within close proximity to each other and in one log, the material is described as a silt and in the other, it is described as a sand. The main conclusion from the available information is that the material is likely of relatively low plasticity and variable, particularly with regards to sand content.

Stability Under Thawing Conditions

In order to assess the potential for thaw induced pore pressures, preliminary one-dimensional thermal analyses of a typical subsurface stratigraphic sequence were completed. General details and results of the thermal analyses are included in Appendix F. The results indicate that thaw will progress at a rate of about 20 cm per year with increasing thaw rate predicted in 15 to 20 years if air temperatures continue to rise. If, however, the current climate is maintained, the depth of thaw would begin to slow in about 15 years. This corresponds to a rate of thaw, α, of between 6×10^{-5} and 4×10^{-4} m/s$^{0.5}$.

This maximum value is slightly less than the rate of thaw predicted in support of the original dam design ($6x10^{-4}$ m/s$^{0.5}$, Klohn, 1995) for thaw of the insitu soils under the tailings pond with a minimum temperature of 4^{o}C. At this stage of design, as it was conservative, a rate of thaw of $6x10^{-4}$ m/s$^{0.5}$ was used.

The stability of shallow infinite slope type failures with thaw induced consolidation and a free draining surcharge load was assessed per the method presented in McRoberts (1977). Deeper potential failure surfaces were assessed using limit equilibrium method with the Slope/W software program. For the deeper potential failure surfaces, excess pore pressure induced by thaw were incorporated through use of a pore pressure ratio, r_u, added to the static water levels (r_u = ratio of thaw induced pore pressure to total stress). The pore pressure coefficient was calculated based on the thaw consolidation ratio, R, estimated for the various materials. The conditions of thawing permafrost were considered to be a transient state and, therefore, the target factor of safety is 1.3 per the design criteria (see Appendix A). The key material properties for the various materials are summarized in Table 7.4 below.

Table 7.4: Material Properties for Dome Creek Stability Analyses

Material	Frozen Moisture Content	Bulk Density (kN/m^3)	Thawed Effective Friction Angle ϕ'	c_v (m^2/s)	R (= $^{0.5}$/)(2	r_u
Surficial silt	30-50%	14	25 to 27^o	$1x10^{-6}$	0.3	n/a
Fine silty sand	18%	19	30^o	$1x10^{-4}$	0.03	0.16
Deeper silt – sandy silt	25%	18.5	28^o	$1x10^{-6}$	0.3	n/a
Sand and gravel	15%	19	30^o	$1x10^{-4}$	n/a	n/a

The infinite slope stability calculations show that for slopes of 11 degrees or less, a 1.5 m thick, unsaturated, free draining layer provides sufficient surcharge to result in calculated factors of safety exceeding the design criteria for a thaw depth of 2 m in silt. A 2 m thaw depth in silt was selected because the remediation operations will remove the upper metre of insitu soils and the maximum thickness of surficial silt reported on the valley side slopes was 2 m. Furthermore, it is suggested that if any significant thickness of non-contaminated silt material remains on the exposed slopes. The silt should be excavated and stockpiled for use as a reclamation material. There is essentially no source of fine grained materials to support reclamation so any silt would be valuable to reclamation activities and its removal would improve the stability of the reclaimed slopes. The factors of safety calculated for thawing sand slopes under infinite slope conditions meet or exceed the target factors of safety for depths of thaw in excess of 8 m.

Limit equilibrium slope stability assessments were carried out for deeper potential failure surfaces in thawed silt using the typical geologic profile developed with the original topography from the dam centreline profile. This geometry was selected because it appeared to have the steepest slopes. Groundwater was assumed to be at a depth of 2 m on the valley side slopes. As shown in Appendix E, the minimum calculated factor of safety with thaw induced pore pressures in sidcrete silt layers was 1.7.

Stability Under Earthquake Loading

Stability under earthquake loading had to take into consideration the potential for liquefaction of the silty fine sand deposits in the Dome Creek Valley. The seismic design parameters used for the assessment are discussed in Appendix A. The design earthquake selected for the reclaimed Dome Creek is 1:1,000. This is a lower return period earthquake than used for the design of the backfilled Open Pit in consideration of the lower consequences of failure of the Dome Creek Valley Slopes. The peak ground acceleration (PGA) associated with the design 1:1,000 earthquake is 0.08.

The liquefaction case records which form the basis of the liquefaction screening methods commonly adopted (Idriss and Boulanger, 2008; Youd et al., 2001) do not include any case records in which liquefaction occurred at cyclic stress ratios associated with the design earthquake magnitude and PGA. On this basis alone, it is considered that the fine sands in Dome Creek Valley are not susceptible to earthquake induced liquefaction under the design earthquake. Regardless, a liquefaction screening assessment of the CPT data obtained for the Dam Safety Assessment in 2002 (EBA, 2002) was completed following the procedures in Idriss and Boulanger (2008). The cyclic stress and cyclic resistance ratios were adjusted for the design earthquake magnitude of 6.5 (refer to Appendix A for discussion of the earthquake magnitude). Plots of the relevant CPT parameters including qc1, clean sand qc1, apparent fines content and the calculated factor of safety against liquefaction are included in Appendix K. The calculated factor of safety against liquefaction is greater than 1.1 everywhere with one exception at a depth of 3 m in a zone with high apparent fines content. The thawed deposits in the Dome Creek Valley are, therefore, considered to have a low likelihood of being susceptible to liquefaction. Earthquake stability assessments, therefore, consisted of pseudo static assessments with long term, unliquefied, slope conditions. Analyses of the infinite slope scenario and deeper failure surfaces were completed. For the design earthquake accelerations, the calculated factor of safety exceeds the target factors of safety. Yield accelerations are greater than the design PGA and, therefore, little movement of the slopes is expected in response to the design earthquake loading.

7.6.3 Channel Design

Introduction

The Dome Creek channel will require reconstruction, at the tailings storage facility area (shown on Drawing D051) once the tailings have been relocated to the pit. This can be achieved by making the channel's morphologic structure and fluvial function more consistent with that of the upstream and downstream conditions. After excavation, the tailings facility footprint will be graded and filled with imported material as outlined in the previous section. The channel will be constructed in the imported material and will be lined with a granular material.

The objectives of the restoration design for Dome Creek are:

- restoration of self-sustaining stream functions
- sufficient capacity to carry annual peak flow within bankful depth;
- minimum impact on the upstream and downstream of the restored channel area; and
- erosion protection through armouring of the channel until the channel is self-sustaining.

Design Criteria

The design criteria for Dome Creek restoration is based on annual peak flow, which corresponds to the 1 in 2 year peak flow, which is equivalent to bankful flow rate. The restored channel of Dome Creek will also be designed so as to prevent damages during a larger flood. Although typically closed sites are design to the 1 in 200 year flood, the Mount Nansen Site is design to the 1 in 1,000 year flood.

Design Flow, Channel Sloping, Sizing and Alignment

The main design elements for the restoration of Dome Creek are:

- design flow;
- channel slope (grade);
- channel alignment;
- channel sizing; and
- channel lining material characteristics.

The peak design flows for Mount Nansen Site were estimated using the Hydrological Engineering Center-Hydrological Modelling System (HEC-HMS) watershed model. HEC-HMS is a watershed model developed by the US Army Corp of Engineers (USACE) which has been adapted for use in Yukon. HEC-HMS is designed to simulate the precipitation-runoff processes in the watershed in order to estimate the resulting peak runoff discharge.

The channel slope was estimated from the regraded contours developed for Dome Creek. On average, the slope is about 4% and locally varies from approximately 3% to about 8%.

The results of the model were validated by calibrating the model to measured flood from a historical flow which occurred on August 18, 2010.

The following are the main input parameters of the HEC-HMS model:

- sub-catchment areas;
- lag time;
- curve number;
- design storm; and
- storm type.

These parameters for Mount Nansen and the results are presented in Table 7.5.

Table 7.5: Peak Flow Results and Parameters

		Return Period			2	25	200	500	1,000
		Short Storm (mm)			15.4	26.5	34.6	38.2	40.9
		Area (km^2)	CN	Lag Time (mins)	Flow (m^3/s)				
Pony Creek	At Pit	0.9	80	5.5	0.01	0.09	0.20	0.29	0.37
	At Back Creek	1.38	80	10.2	0.01	0.14	0.30	0.44	0.56
Dome Creek	Downstream Mill	1.21	80	5.4	0.06	0.13	0.31	0.43	0.54
	Upstream TSF	2.32	80	8.9	0.07	0.19	0.55	0.78	0.99
	Downstream TSF	3.56	80	12.7	0.07	0.27	0.81	1.17	1.49
	At the road	4.74	80	18.2	0.08	0.34	0.96	1.46	1.89
	At Victoria Creek	4.86	80	23.7	0.08	0.34	0.98	1.50	1.94

Note: A base flow of 5 L/s/km^2 is assumed.

The peak flow results presented in Table 7.5 are for the 1 in 2 year, 1 in 25 year, 1 in 200 year and 1 in 1,000 year storms. The channel geometry is designed for the 1 in 1,000 year flood for downstream of the TSF peak flow of 1.5 m^3/s.

Dome Creek channel design is presented in Table 7.6. The channel design parameters include bottom slope, width, depth of flow, total channel depth, side slopes velocity of flow.

Table 7.6: Design of the Dome Creek Restoration Channel

Channel Type	**Trapezoidal**
Design Parameter	Value
Flow (m^3/s) (1 in 1,000 peak flow)	1.5
Channel Grade Slope (%)	3-8
Bottom width (m)	1.0
Water depth (m) (1 in 1,000 peak)	0.4
Total depth (m)(includes freeboard)	0.5
Side slopes (horizontal versus vertical)	2 to 1
Maximum flow velocity (m^3/s) (1 in 25 year peak flow)	1.5
D50 of erosion protection (mm)	50-100

The channel bed material (riprap) required for erosion protection was estimated to have a D50 of 50-100 mm. The riprap was sized based on peak flow of 1 in 25 year storm with a maximum velocity of 1.5 m/s. Erosion protection of 1 in 25 year was considered adequate to protect the channel until vegetation is established (similar upstream and downstream) after which the channel will be self sustaining.

8 LIMITATIONS AND CLOSURE

This report was prepared exclusively for Assessment and Abandoned Mines, Energy Mines and Resources by AMEC Environment & Infrastructure, a wholly owned subsidiary of AMEC Americas Limited. The quality of information, conclusions and estimates contained herein is consistent with the level of effort involved in AMEC services and based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions and qualifications set forth in this report. This report is intended to be used by Assessment and Abandoned Mines, Energy Mines and Resources only, subject to the terms and conditions of its contract with AMEC. Any other use of, or reliance on, this report by any third party is at that party's sole risk.

Yours truly,

AMEC Environment & Infrastructure

R. Brian Geddes, P.Eng.
Senior Design Lead

Renata K. Wood, P.Eng.
Project Manager & Geotechnical Lead

Paul Morton, P.Geol.
Water Lead

Bernard C. Aubé, Eng.
Water Treatment Lead

Nicole R. Jacques
Site Characterization Lead

George De Ridder, P.Eng.
Structures Lead

Melanie Piorecky
Reclamation Lead

Reviewed by:

E.C. McRoberts, Ph.D., P.Eng.
Geotechnical

D.J. Emerson, P.Geo.
Water

S.J.N. Sibbick, P.Geo., P.Geol.
Geochemistry

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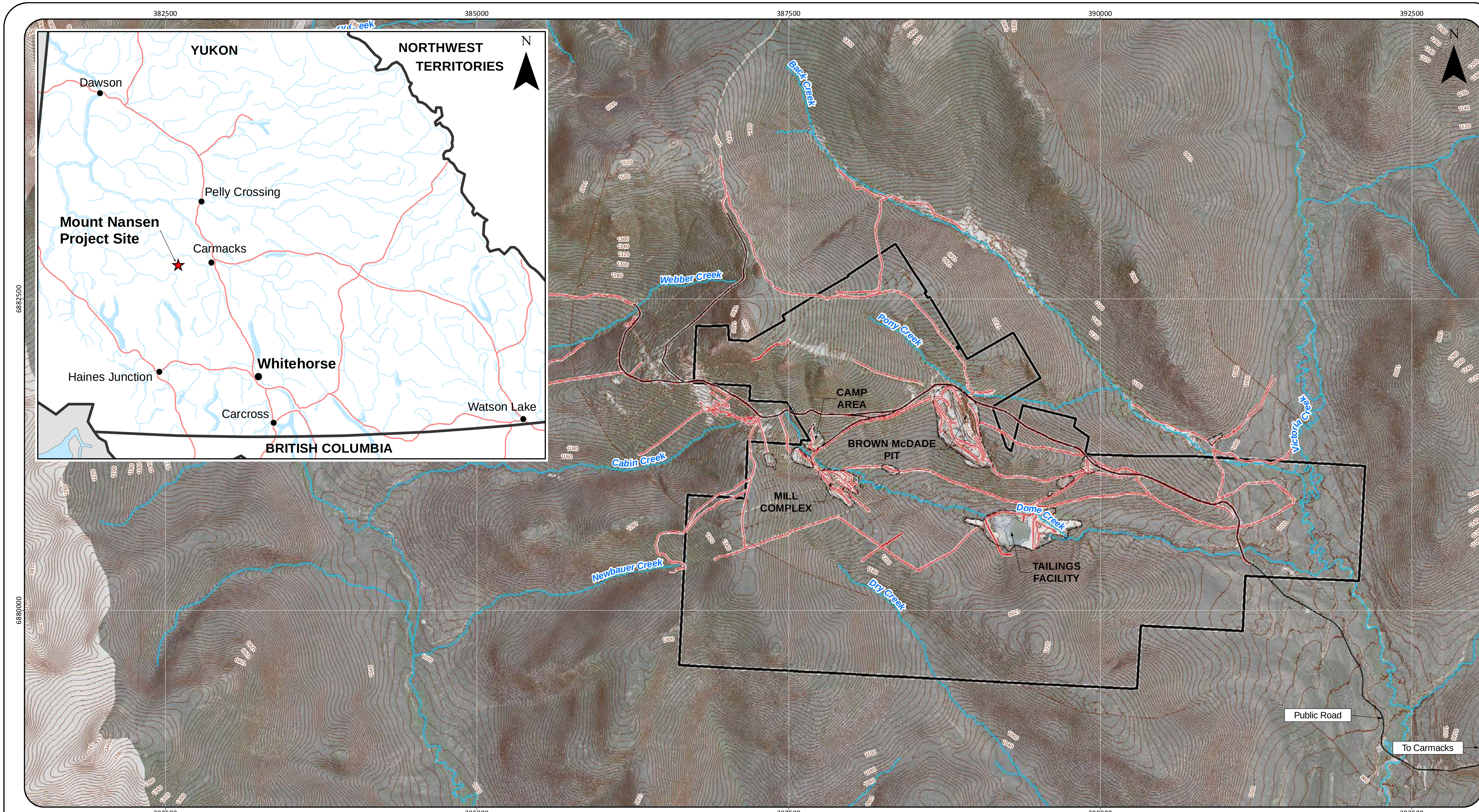
List of Drawings

List of Drawings (cont'd)



Data Source:

Roads, trails, streams, waterbodies, watercourses and infrastructure areas digitized using 2008 Quickbird imagery (courtesy of Yukon Geomatics) and spatial data provided by Yukon government.

Heli LIDAR Data Survey and Imagery, 2012
Pleiades Satellite Imagery, 2013

Datum: NAD 1983 CSRS UTM Zone 8N

Legend

- Order in Council Boundary
- Contour (5 m)
- Disturbed Area
- Roads
- Streams

Associated Engineering — Global Perspective. Local Focus.
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Yukon — Energy, Mines and Resources — Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D001

30% DESIGN PHASE REPORT

KEY MAP AND LOCATION PLAN

Scale 1:30,000
Metres
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March 25, 2014

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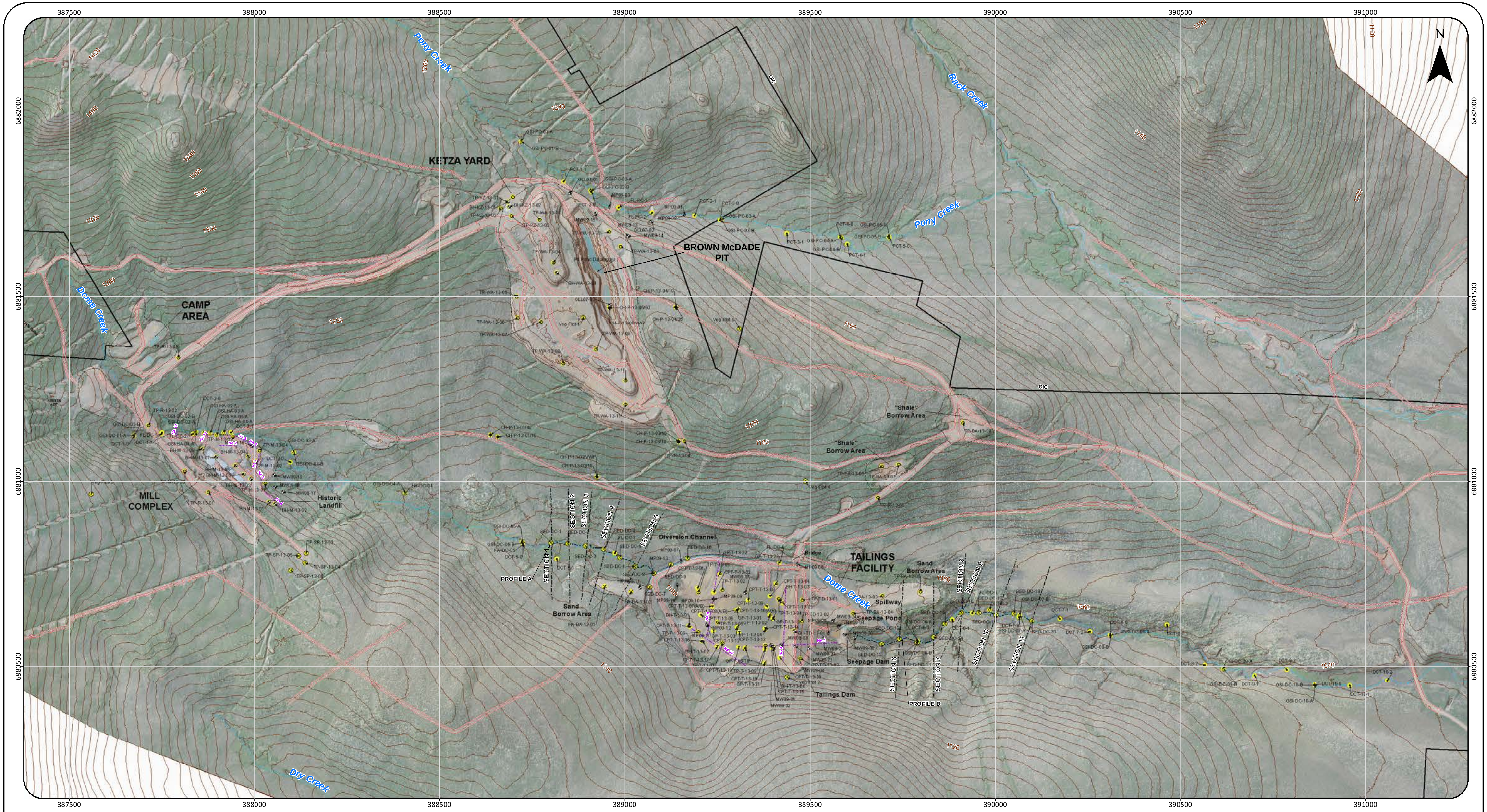

Data Source:

Roads, trails, streams, waterbodies, watercourses and infrastructure areas digitized using 2008 Quickbird imagery (courtesy of Yukon Geomatics) and spatial data provided by Yukon government.

Heli LIDAR Data Survey and Imagery, 2012

Datum: NAD 1983 CSRS UTM Zone 8N

Legend

- Borehole
- Hydrogeological
- CPT
- Geoprobe
- Grab Sample
- Hand Auger
- Mini Piezometer
- Temperature or Flow Measurement
- Test Pit
- 2013 Locations
- Order in Council Boundary
- Geophysics Lines
- Surveyed Sections
- Contour (5 m)
- Disturbed Area
- Roads
- Streams

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MOUNT NANSEN REMEDIATION PROJECT

Drawing D002

30% DESIGN PHASE REPORT

OVERVIEW SITE PLAN

Scale 1:10,000

Metres

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March 25, 2014

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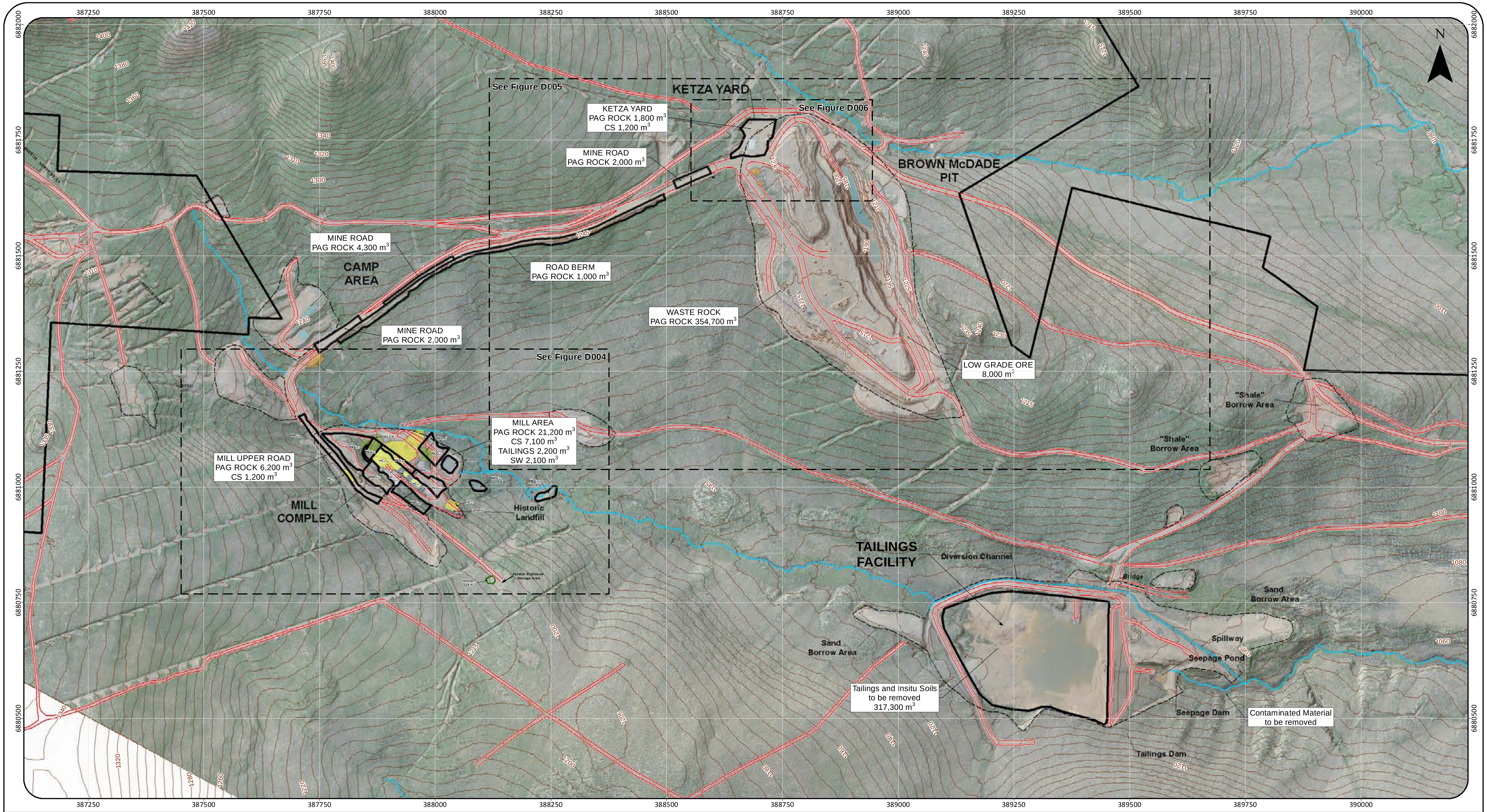

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Roads, trails, streams, waterbodies, watercourses and infrastructure areas digitized using 2008 Quickbird imagery (courtesy of Yukon Geomatics) and spatial data provided by Yukon government.

Heli LIDAR Data Survey and Imagery, 2012

Datum: NAD 1983 UTM Zone 8N

Legend

- Order in Council Boundary
- Contour (5 m)
- Disturbed Area
- Roads
- Streams

Site Characterization

- Landfill
- Observed Surficial Staining
- Hydrocarbon Contamination
- Potential Special Waste
- PAG and Metal Contamination

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

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Yukon Energy, Mines and Resources Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D003

30% DESIGN PHASE REPORT

PAG ROCK AND CONTAMINATED SOILS PLAN LOCATION AND QUANTITIES - OVERVIEW

Scale 1:8,000
Metres
0 200 400

March 25, 2014

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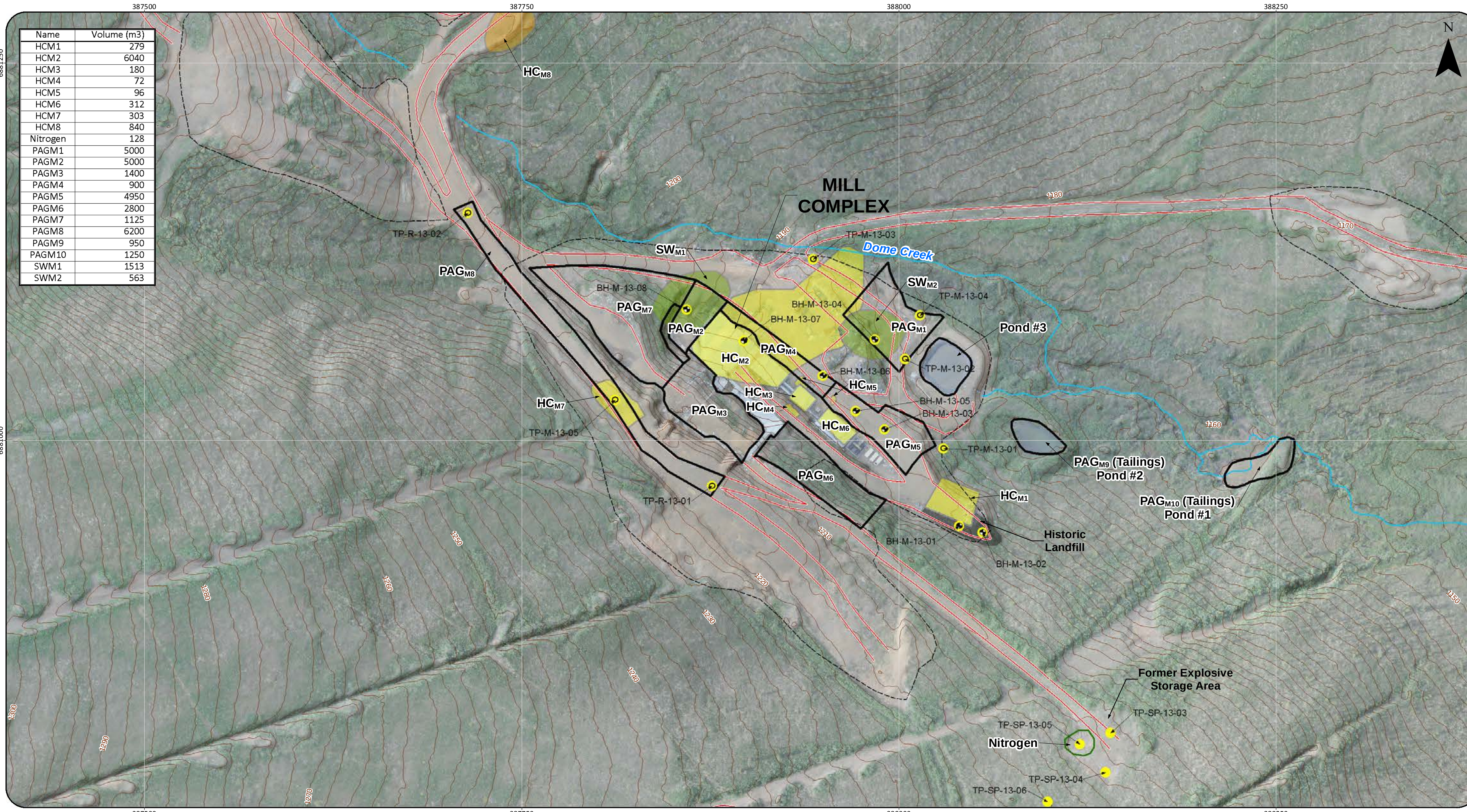
Name	Volume (m3)
HCM1	279
HCM2	6040
HCM3	180
HCM4	72
HCM5	96
HCM6	312
HCM7	303
HCM8	840
Nitrogen	128
PAGM1	5000
PAGM2	5000
PAGM3	1400
PAGM4	900
PAGM5	4950
PAGM6	2800
PAGM7	1125
PAGM8	6200
PAGM9	950
PAGM10	1250
SWM1	1513
SWM2	563



Data Source:

Roads, trails, streams, waterbodies, watercourses and infrastructure areas digitized using 2008 Quickbird imagery (courtesy of Yukon Geomatics) and spatial data provided by Yukon government.

Heli LIDAR Data Survey and Imagery, 2012

Datum: NAD 1983 CSRS UTM Zone 8N

Legend

- Borehole
- Test Pit
- 2013 Locations
- Order in Council Boundary
- Contour (2 m)
- Disturbed Area
- Roads
- Streams

Site Characterization

- Landfill
- Observed Surficial Staining
- Potential Hydrocarbon Contamination
- Potential Special Waste
- PAG and Metal Contamination

Energy, Mines and Resources
Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D004

30% DESIGN PHASE REPORT

PAG ROACK AND CONTAMINATED SOILS PLAN
LOCATION AND QUANTITIES - MILL AREA

Scale 1:2,500
Metres
0 50 100

March 25, 2014

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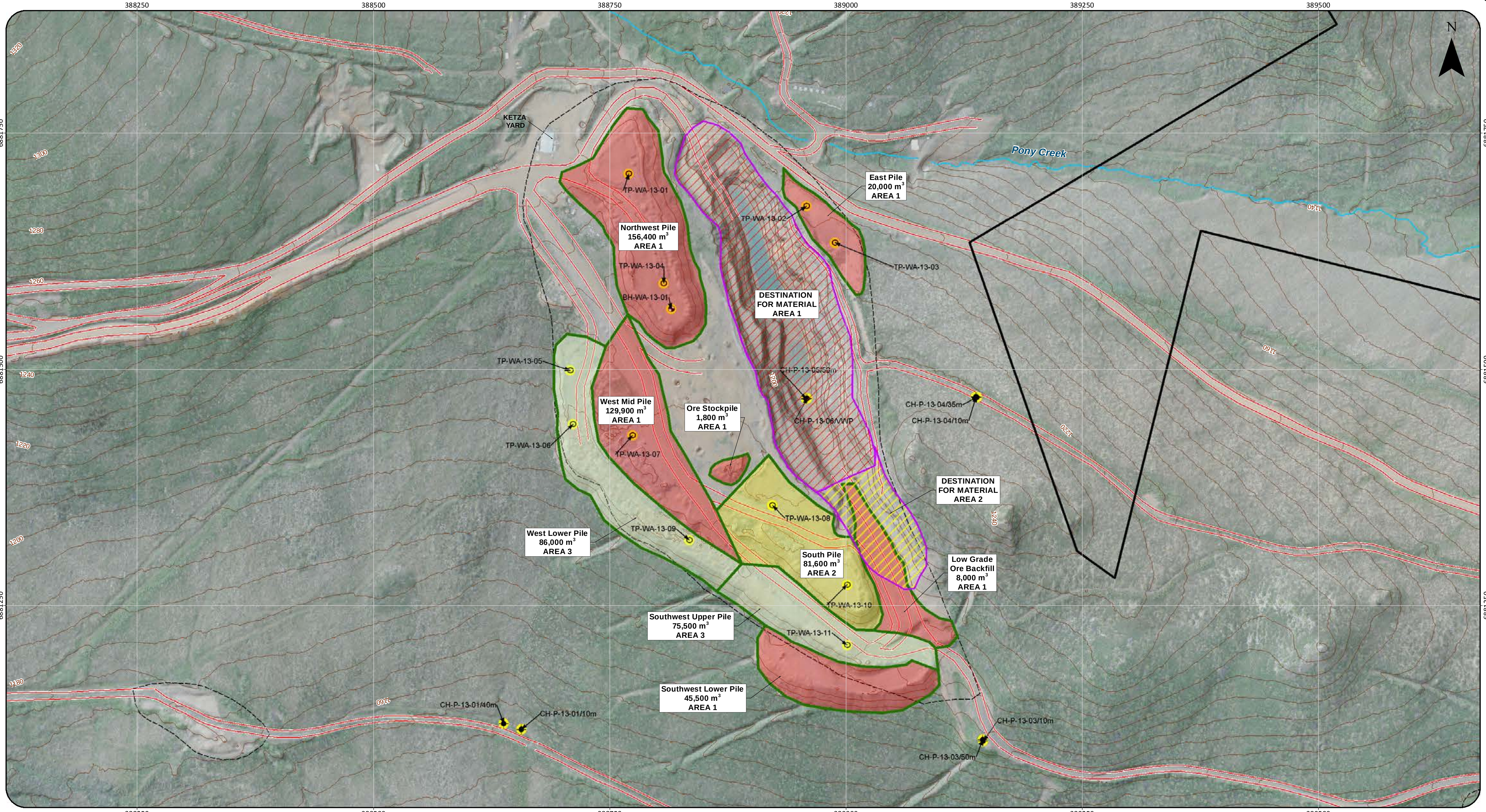

Data Source:

Roads, trails, streams, waterbodies, watercourses and infrastructure areas digitized using 2008 Quickbird imagery (courtesy of Yukon Geomatics) and spatial data provided by Yukon government.

Heli LIDAR Data Survey and Imagery, 2012

Datum: NAD 1983 UTM Zone 8N

Legend

- Borehole
- Hydrogeological
- Test Pit
- 2013 Locations
- Order in Council Boundary
- Contour (5 m)
- Disturbed Area
- Roads
- Streams

Waste Pile Area

- PAG Waste Rock Area 1
- NAG Waste Rock Area 2
- NAG Waste Rock Area 3
- Destination for Material Area 1
- Destination for Material Area 2
- Waste Pile Area

NOTE:
Area 3 material to be placed outside of the backfilled pit.

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

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Yukon Energy, Mines and Resources Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D005

30% DESIGN PHASE REPORT

PAG ROCK AND CONTAMINATED SOILS PLAN
LOCATION AND QUANTITIES
OPEN PIT AND WASTE ROCK AREA

Scale 1:4,000
Metres
0 100 200

March 25, 2014

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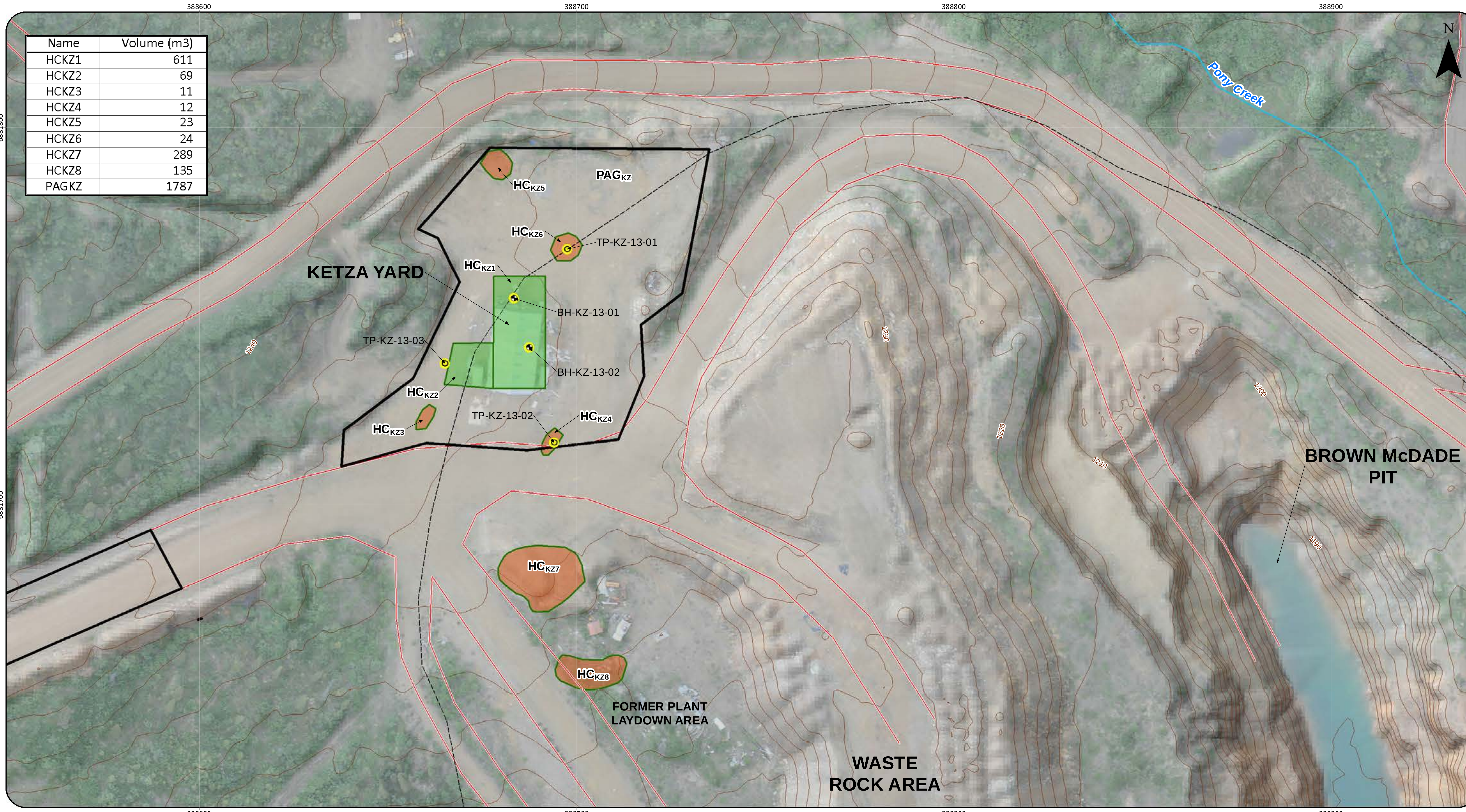

Name	Volume (m3)
HCKZ1	611
HCKZ2	69
HCKZ3	11
HCKZ4	12
HCKZ5	23
HCKZ6	24
HCKZ7	289
HCKZ8	135
PAGKZ	1787

Data Source:

Roads, trails, streams, waterbodies, watercourses and infrastructure areas digitized using 2008 Quickbird imagery (courtesy of Yukon Geomatics) and spatial data provided by Yukon government.

Heli LIDAR Data Survey and Imagery, 2012

Datum: NAD 1983 CSRS UTM Zone 8N

Legend

- Borehole
- Test Pit
- 2013 Locations
- Order in Council Boundary
- Contour (2 m)
- Disturbed Area
- Roads
- Streams

Site Characterization

- Known Contamination
- Observed Surficial Staining
- PAG and Metal Contamination

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

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Yukon Energy, Mines and Resources Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D006

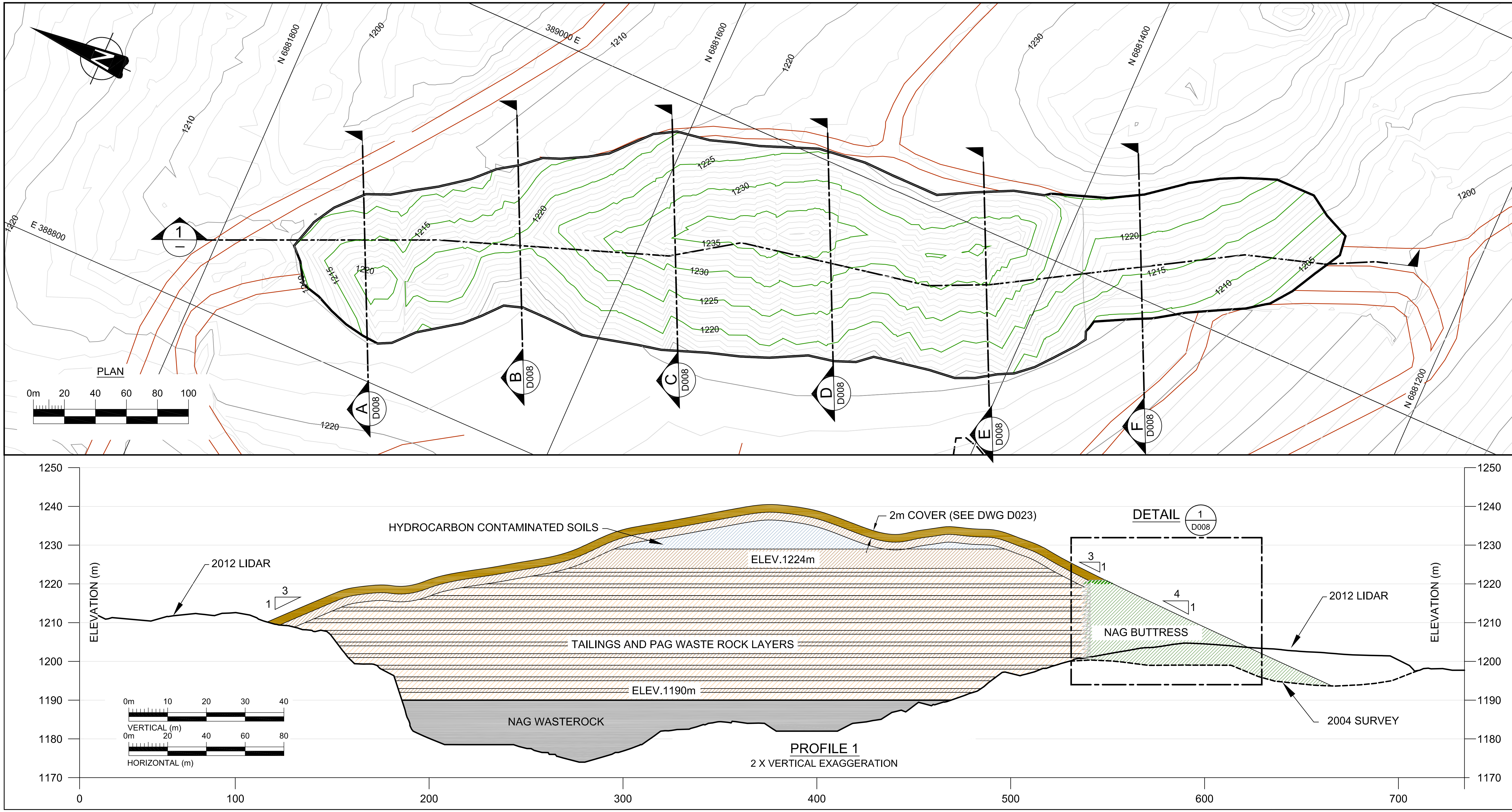
30% DESIGN PHASE REPORT

PAG ROCK AND CONTAMINATED SOILS PLAN LOCATION AND QUANTITIES - KETZA YARD AREA

Scale 1:1,000
Metres
0 25 50

March 25, 2014

S:\PROJECTS\VM00605 - Mount Nansen\GIS\Mapping\VM00605_9013d_11x17_30PctDesignPhaseReport_PAGContamination_KETZA.mxd



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

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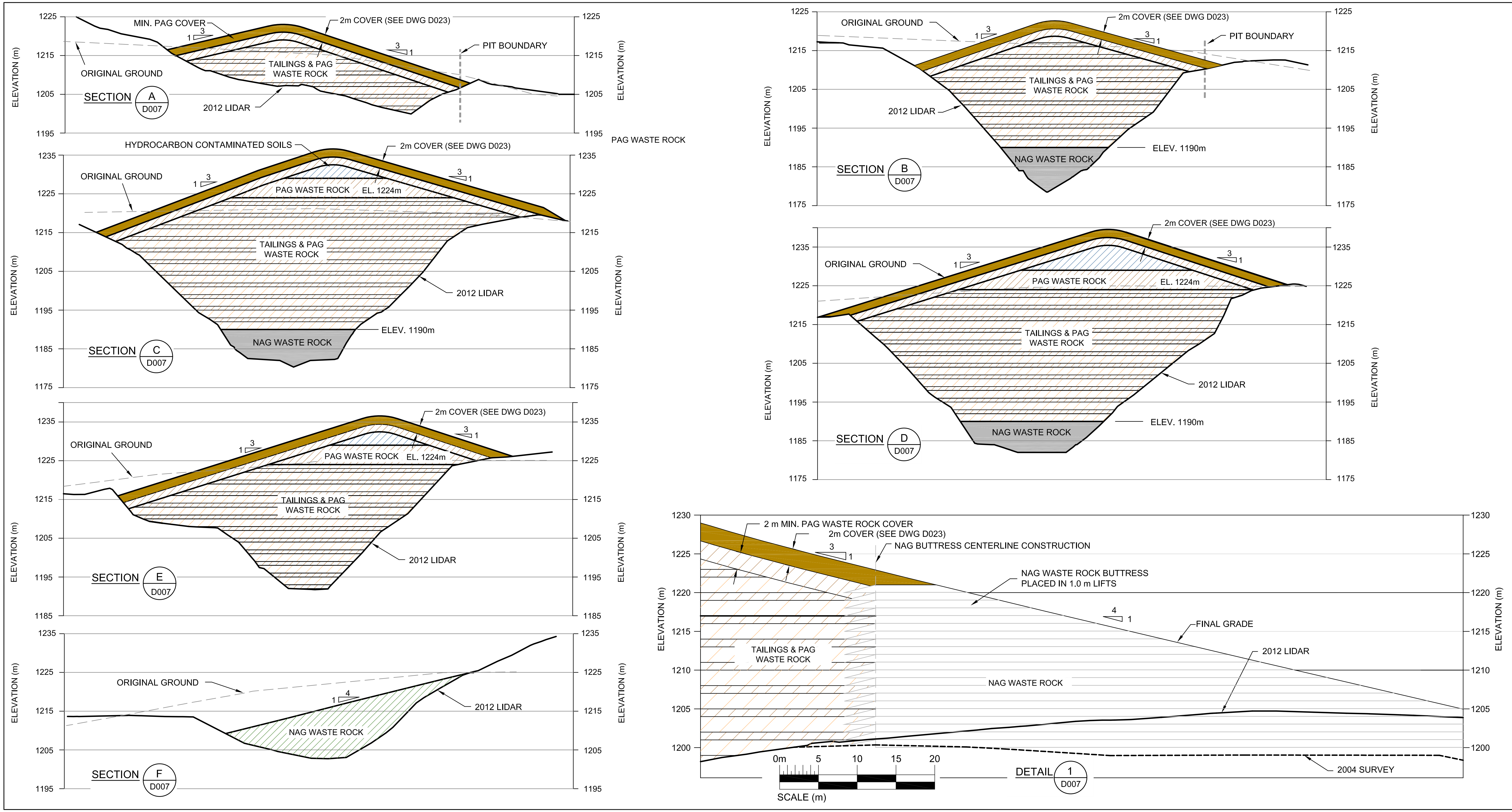
MOUNT NANSEN REMEDIATION PROJECT
Drawing D007

30% DESIGN PHASE REPORT

FINAL OPEN PIT CONFIGURATION
DIRECT PLACEMENT METHOD
PLAN AND PROFILE

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\DC 007,008,0020,D021,D034.dwg – D007 – Mar. 24, 2014 6:28pm – yuan.chen



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

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Yukon Energy, Mines and Resources Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D008

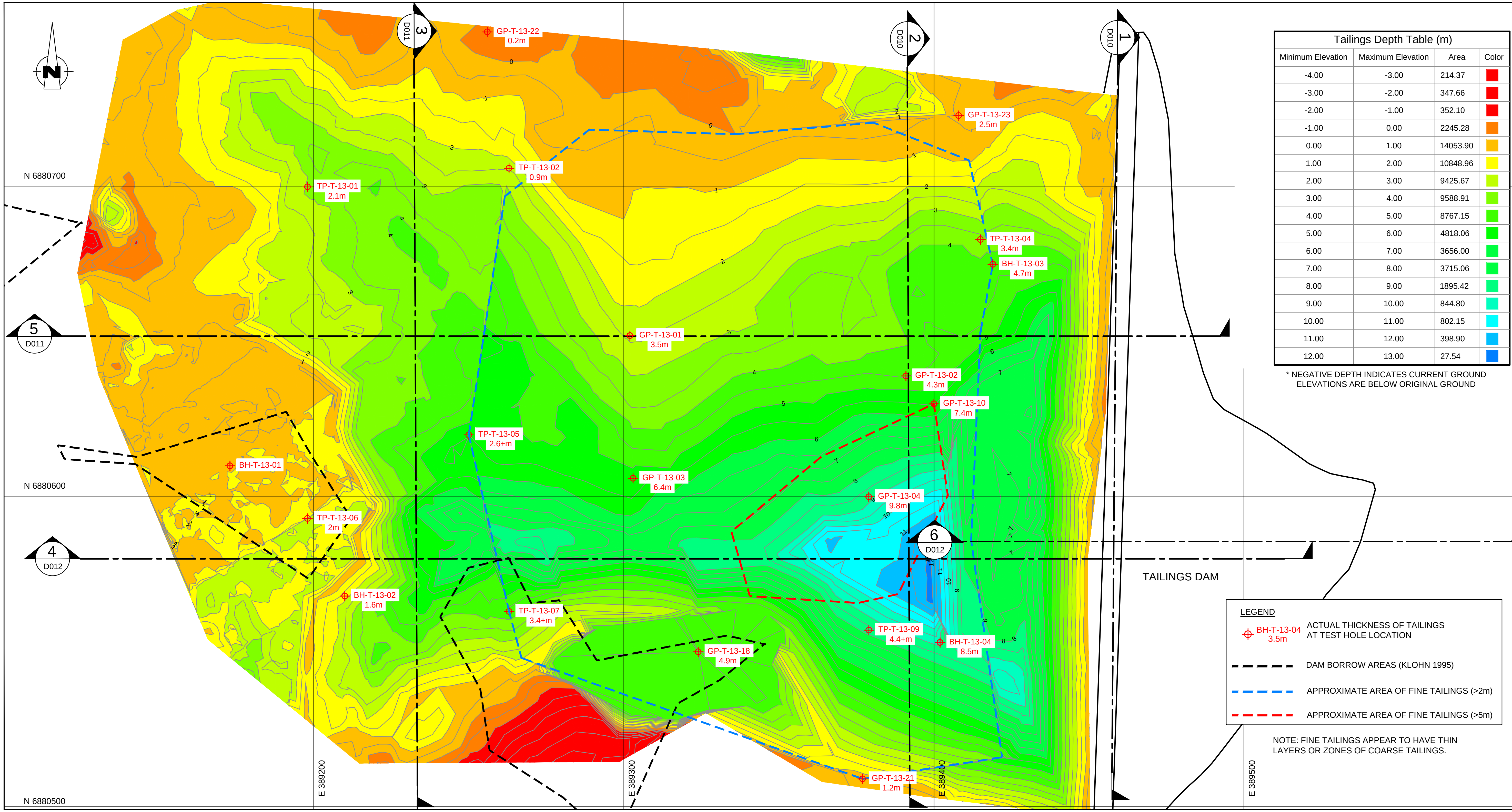
30% DESIGN PHASE REPORT

FINAL OPEN PIT CONFIGURATION
DIRECT PLACEMENT METHOD
SECTIONS AND DETAILS

0m 10 20 30 40
SCALE (m)

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\D 007,008,0020,021,034.dwg – D008 – Mar. 25, 2014 8:28pm – yuan.chen



Tailings Depth Table (m)

Minimum Elevation	Maximum Elevation	Area	Color
-4.00	-3.00	214.37	
-3.00	-2.00	347.66	
-2.00	-1.00	352.10	
-1.00	0.00	2245.28	
0.00	1.00	14053.90	
1.00	2.00	10848.96	
2.00	3.00	9425.67	
3.00	4.00	9588.91	
4.00	5.00	8767.15	
5.00	6.00	4818.06	
6.00	7.00	3656.00	
7.00	8.00	3715.06	
8.00	9.00	1895.42	
9.00	10.00	844.80	
10.00	11.00	802.15	
11.00	12.00	398.90	
12.00	13.00	27.54	

Data Source:

SOPACH IS BASED ON THE ORIGINAL GROUND SURVEY (KLOHN 1996), 2012 LIDAR AND TAILINGS SURFACES INFERRED FROM 2013 TESTHOLES.

Datum: NAD 1983 CSRS UTM Zone 8N

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

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Yukon Energy, Mines and Resources Assessment and Abandoned Mines

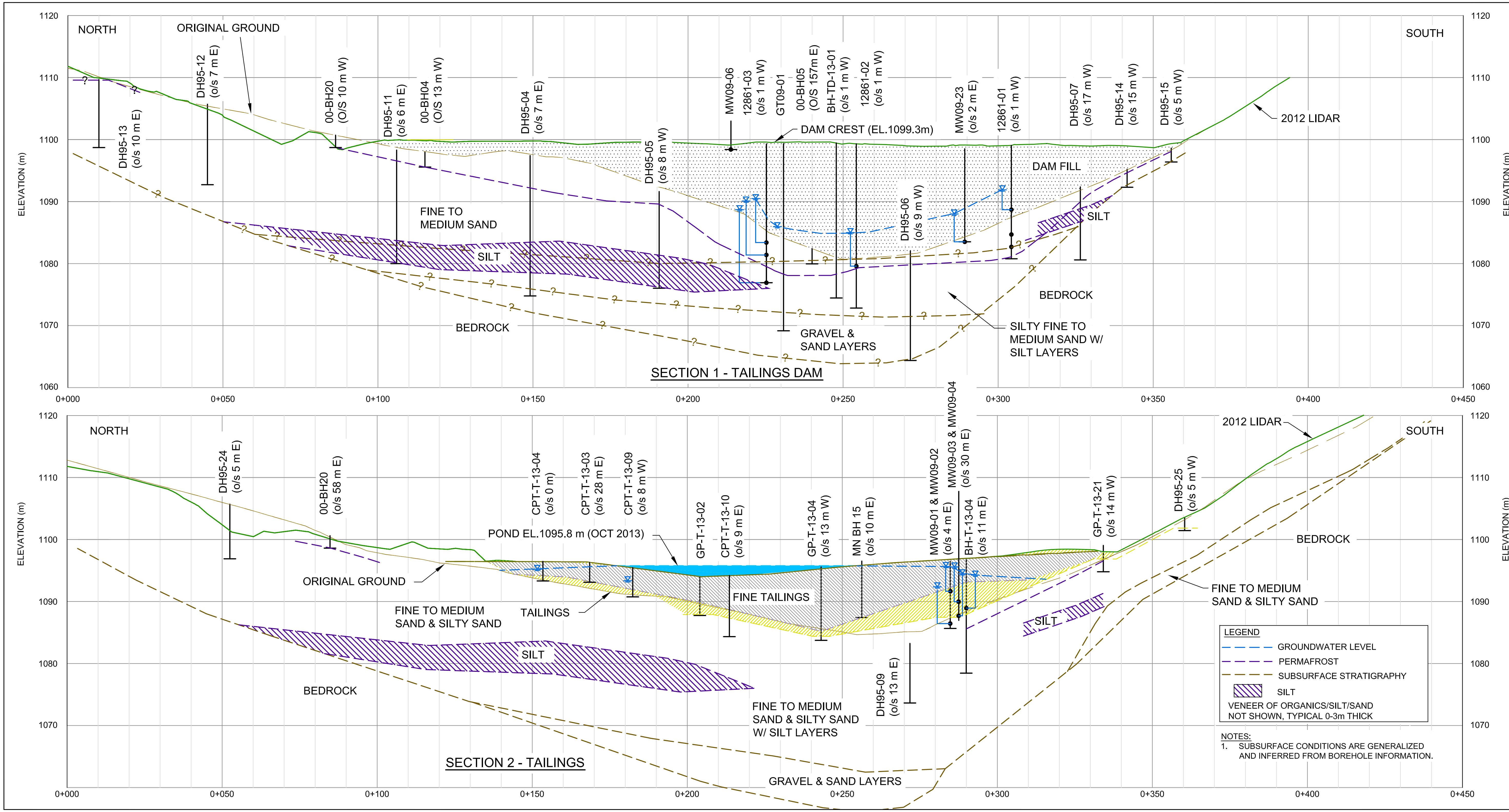
MOUNT NANSEN REMEDIATION PROJECT
Drawing D009

30% DESIGN PHASE REPORT

2013 TAILINGS ISOPACH

0m 10 20 30 40 50
SCALE (m)

MARCH 25, 2014



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

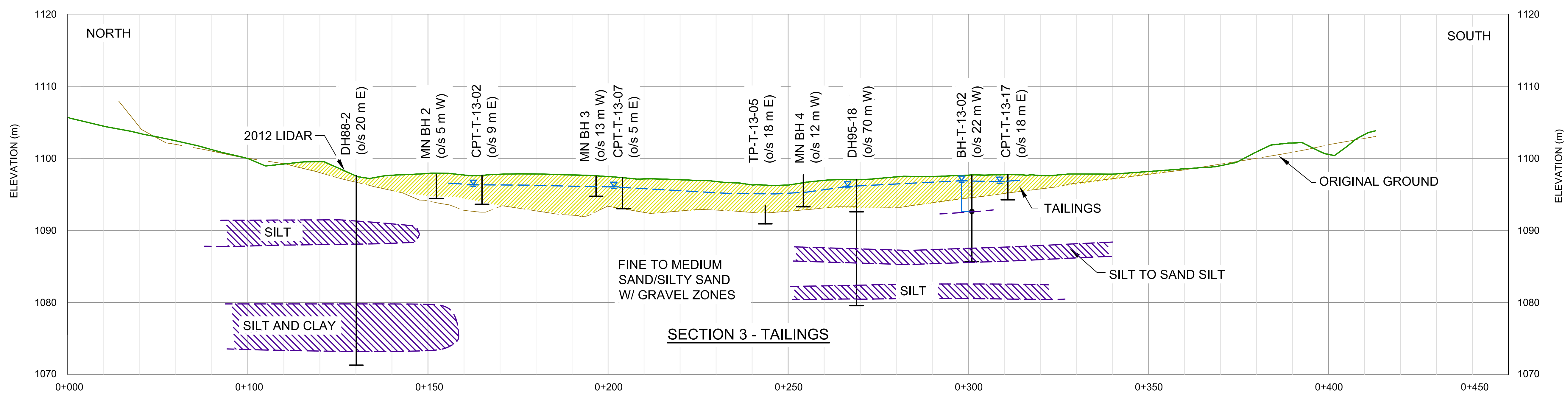
MOUNT NANSEN REMEDIATION PROJECT
Drawing D010

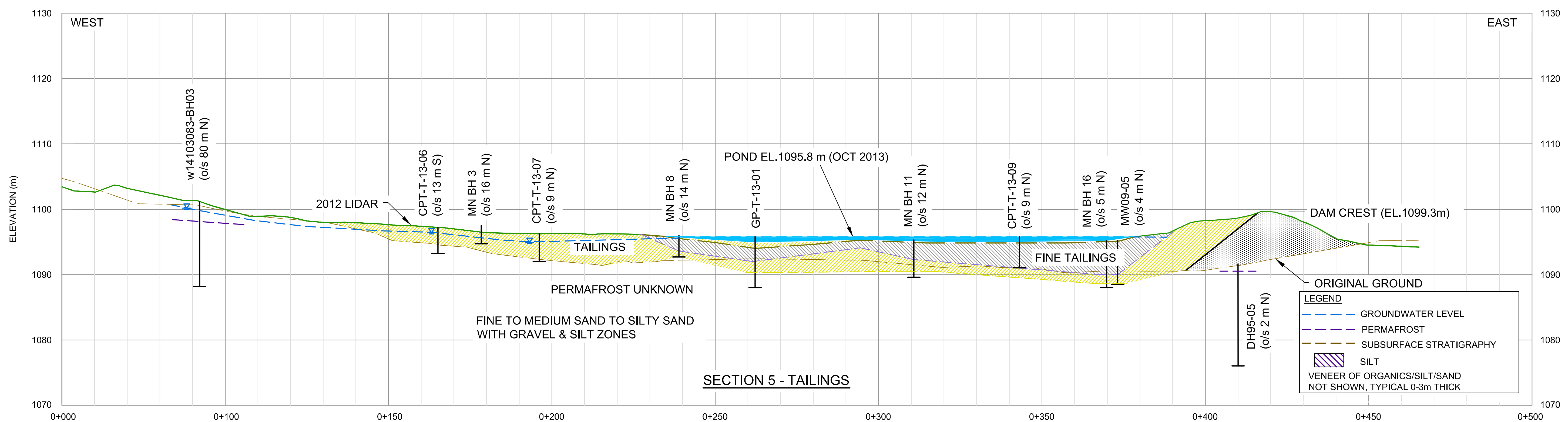
30% DESIGN PHASE REPORT

SECTIONS (SHEET 1 OF 3)

0m 10 20 30 40 50
HORIZONTAL (m)
0m 5 10 15 20 25
VERTICAL (m)

MARCH 25, 2014





NOTES:
1. SUBSURFACE CONDITIONS ARE GENERALIZED AND INFERRED FROM BOREHOLE INFORMATION.

Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.
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MOUNT NANSEN REMEDIATION PROJECT
Drawing D011

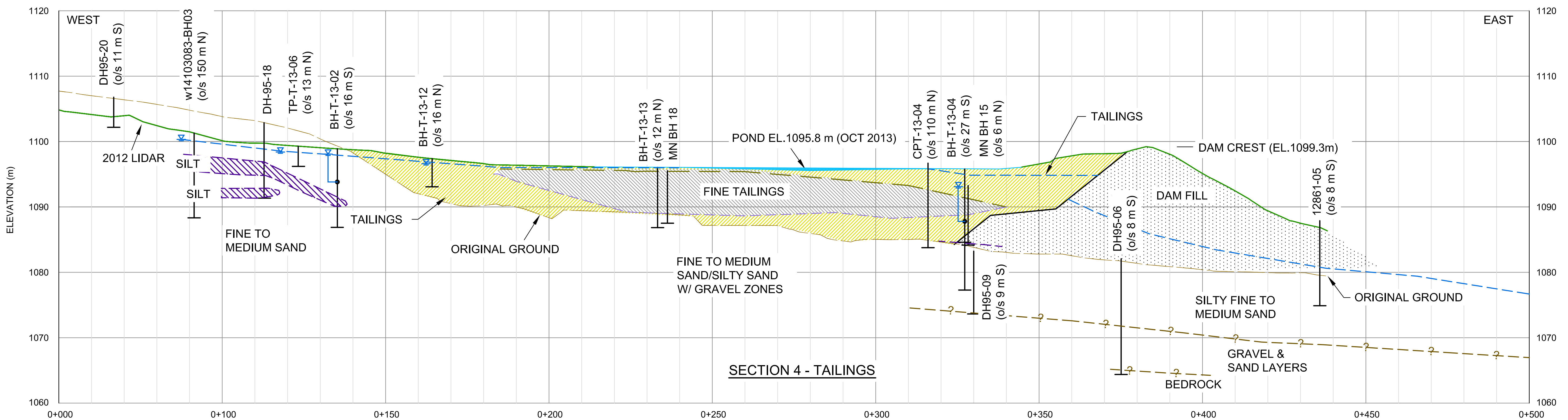
30% DESIGN PHASE REPORT

SECTIONS (SHEET 2 OF 3)

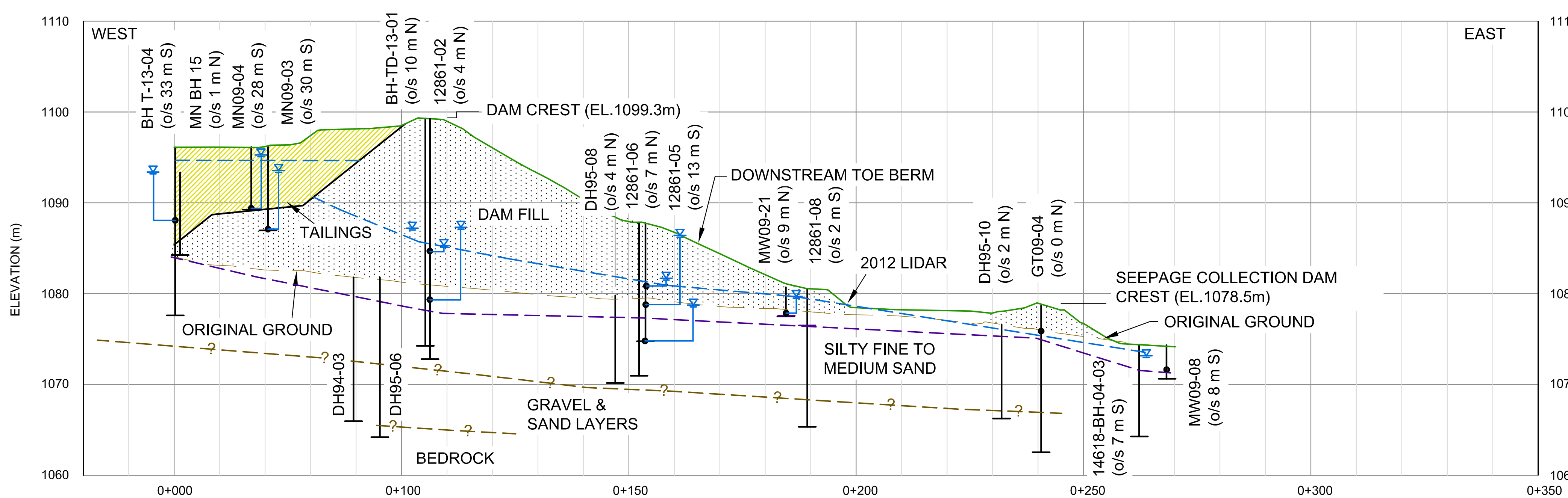
0m 10 20 30 40 50
HORIZONTAL (m)
0m 5 10 15 20 25
VERTICAL (m)

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\DC 010,011,012.dwg – Drawing 11 – Mar. 24, 2014 7:01pm – yuan.chen



SECTION 4 - TAILINGS



SECTION 6 DAM - SEEPAGE DAM SECTION

LEGEND
- GROUNDWATER LEVEL
- PERMAFROST
- SUBSURFACE STRATIGRAPHY
- SILT

VENEER OF ORGANICS/SILT/SAND NOT SHOWN, TYPICAL 0-3m THICK

NOTES:
1. SUBSURFACE CONDITIONS ARE GENERALIZED AND INFERRED FROM BOREHOLE INFORMATION.

Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.
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Yukon Energy, Mines and Resources Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D012

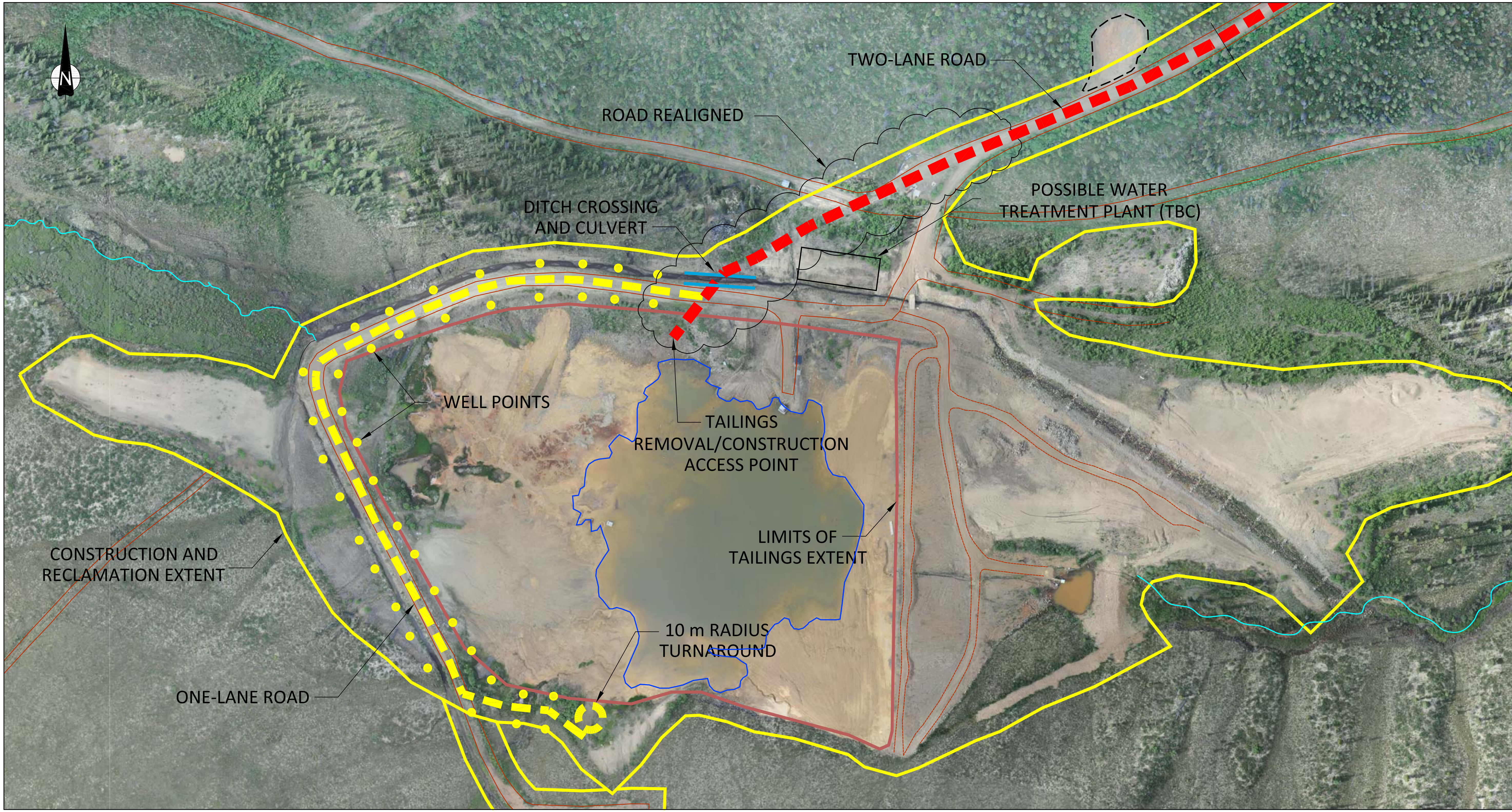
30% DESIGN PHASE REPORT

SECTIONS (SHEET 3 OF 3)

HORIZONTAL (m) 0m 10 20 30 40 50
VERTICAL (m) 0m 5 10 15 20 25

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\D 010,011,012.dwg – Drawing 12 – Apr. 03, 2014 5:34pm – yuan.chen



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

NOTES:
1. THE MINIMUM ROAD WIDTH WAS DETERMINED BASED ON "GUIDELINES FOR MINE HAUL ROAD DESIGN" (TANNANT & REGENSBURG 2001) USING THE FOLLOWING EQUATION: WIDTH OF RUNNING SURFACE (M) = (1.5 X NUMBER OF LANES + 0.5) X VEHICLE WIDTH (M). THIS IS IN ACCORDANCE WITH BOTH SECTION 6.9.1 OF THE MINES ACT AND THE RECOMMENDATIONS OF THE FOREST ROAD ENGINEERING GUIDEBOOK (MOF 2002).
2. ASSUMES ARTICULATED 40 TON TRUCK WITH WIDTH OF 3.5 m.
3. WELL POINT SPACING AND LOCATIONS ARE SCHEMATIC

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MOUNT NANSEN REMEDIATION PROJECT
Drawing D013

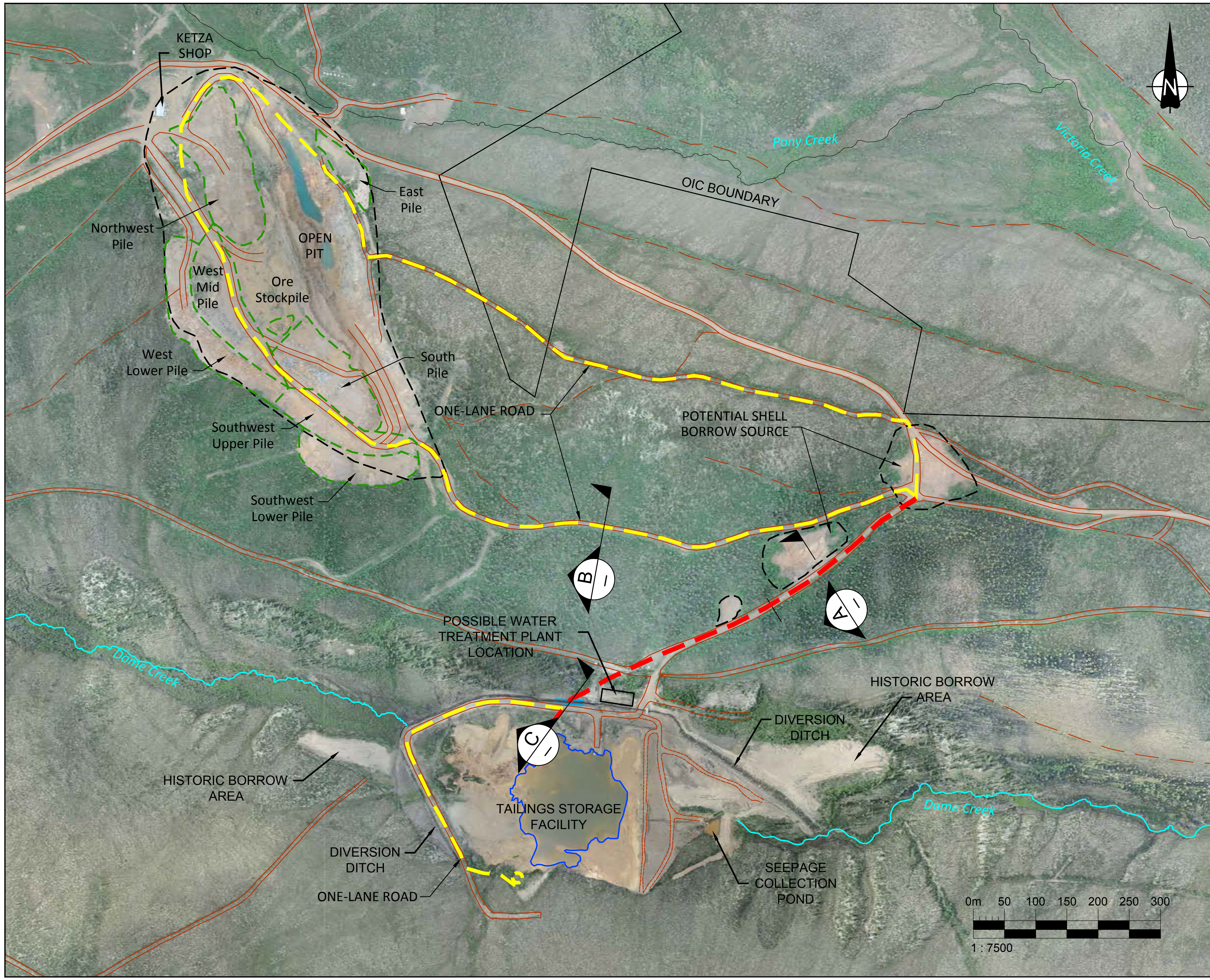
30% DESIGN PHASE REPORT

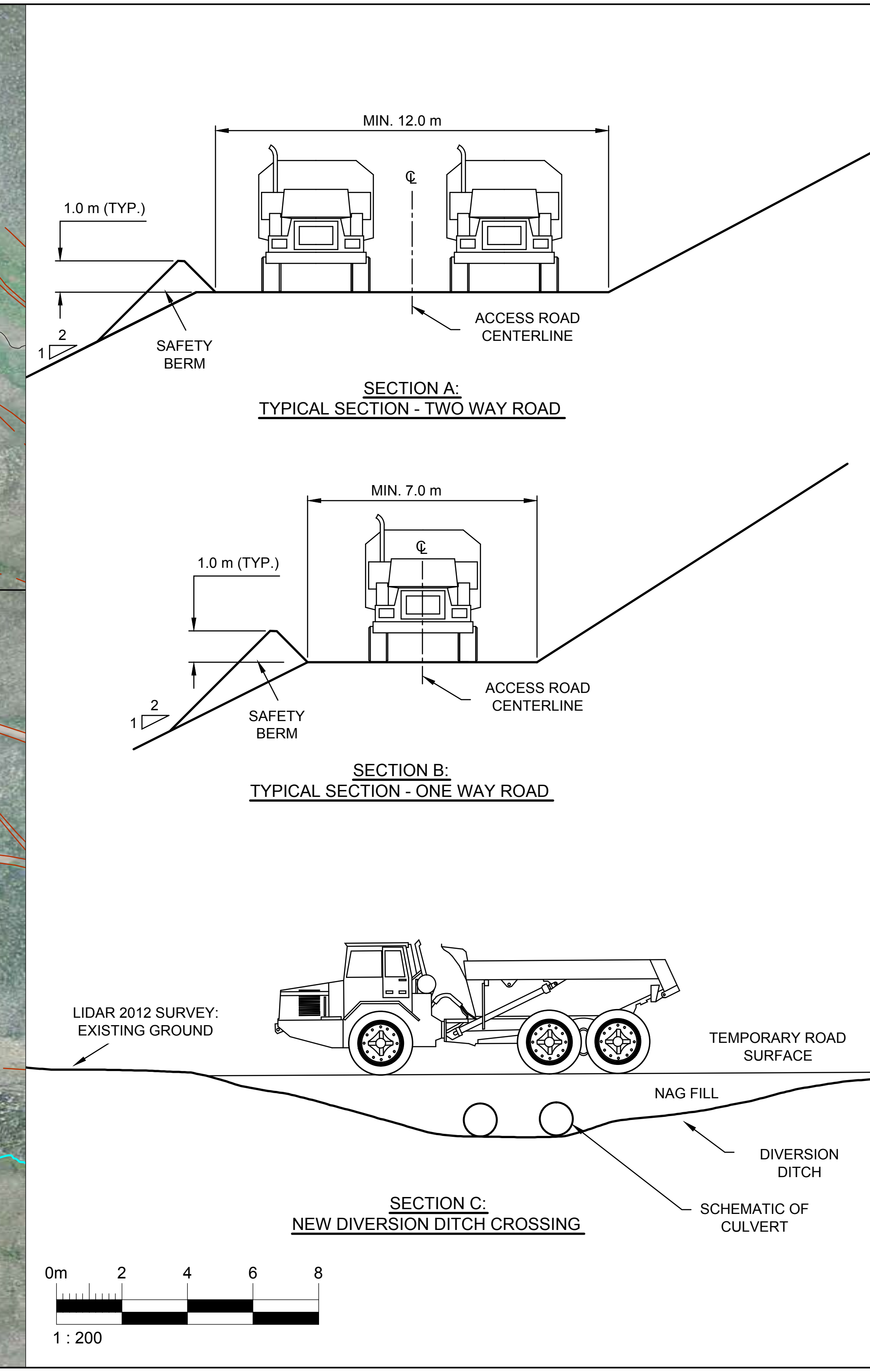
EXTENT OF TAILINGS AREA EXCAVATION AND REMEDIATION

0m 20 40 60 80 100
SCALE (m)

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\DC 013,014.dwg – D013 – Mar. 24, 2014 7:23pm – yuan.chen





Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

NOTES:
1. THE MINIMUM ROAD WIDTH WAS DETERMINED BASED ON "GUIDELINES FOR MINE HAUL ROAD DESIGN" (TANNANT & REGENSBURG 2001) USING THE FOLLOWING EQUATION: WIDTH OF RUNNING SURFACE (M) = (1.5 X NUMBER OF LANES + 0.5) X VEHICLE WIDTH (M). THIS IS IN ACCORDANCE WITH BOTH SECTION 6.9.1 OF THE MINES ACT AND THE RECOMMENDATIONS OF THE FOREST ROAD ENGINEERING GUIDEBOOK (MOF 2002).
2. ASSUMES ARTICULATED 40 TON TRUCK WITH WIDTH OF 3.5 m.

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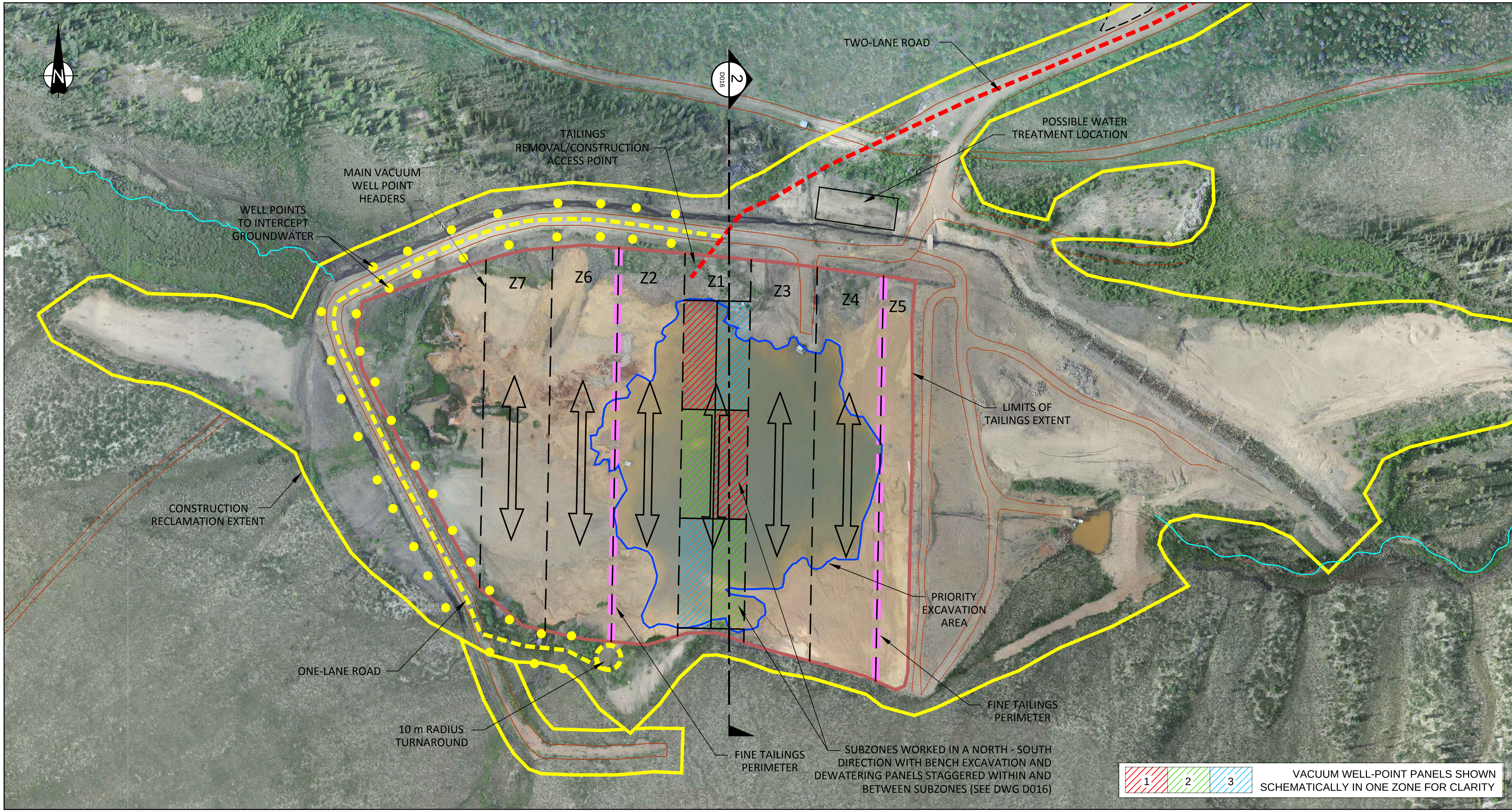
MOUNT NANSEN REMEDIATION PROJECT
Drawing D014

30% DESIGN PHASE REPORT

CONSTRUCTION HAUL ROAD PLAN AND SECTIONS

MARCH 25, 2014

C:\Users\yuan.chen\appdata\local\temp\AcPublish_9328\D 013,014.dwg – D014 – Apr. 03, 2014 6:05pm – yuan.chen



Data Source:

Datum: NAD 1983 CSRS UTM Zone 8N

NOTE:

1. ASSUMES MAXIMUM SIZED TRUCK IS ARTICULATED 40 TON TRUCK WITH WIDTH OF 3.5 m.
2. WELL POINT SPACING AND LOCATIONS ARE SCHEMATIC

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MOUNT NANSEN REMEDIATION PROJECT
Drawing D015

30% DESIGN PHASE REPORT

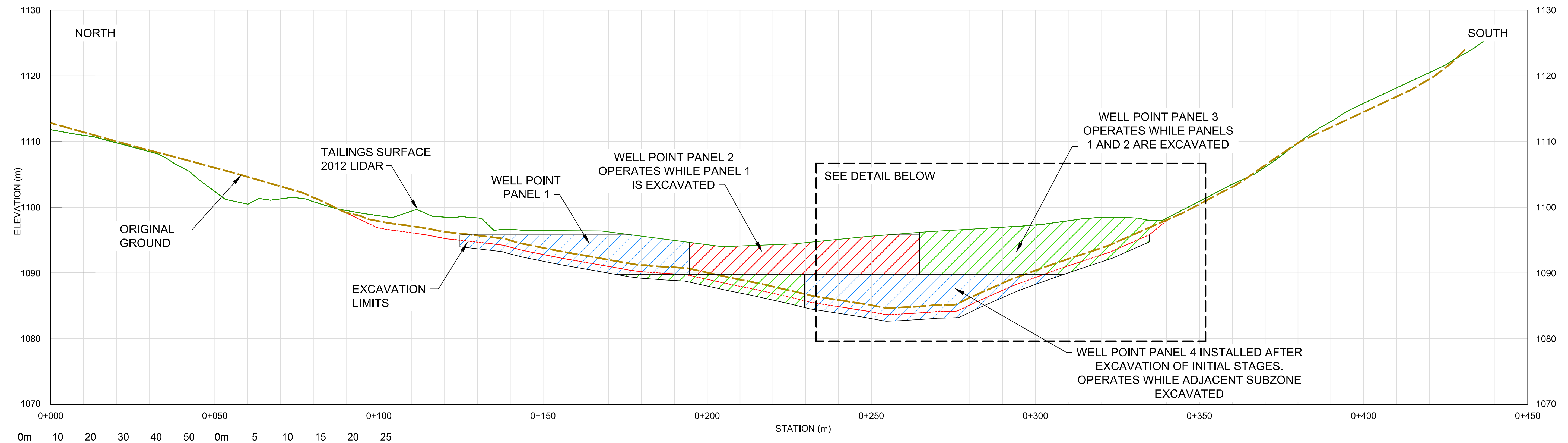
SCHEMATIC TAILINGS EXCAVATION SEQUENCE

0m 20 40 60 80 100

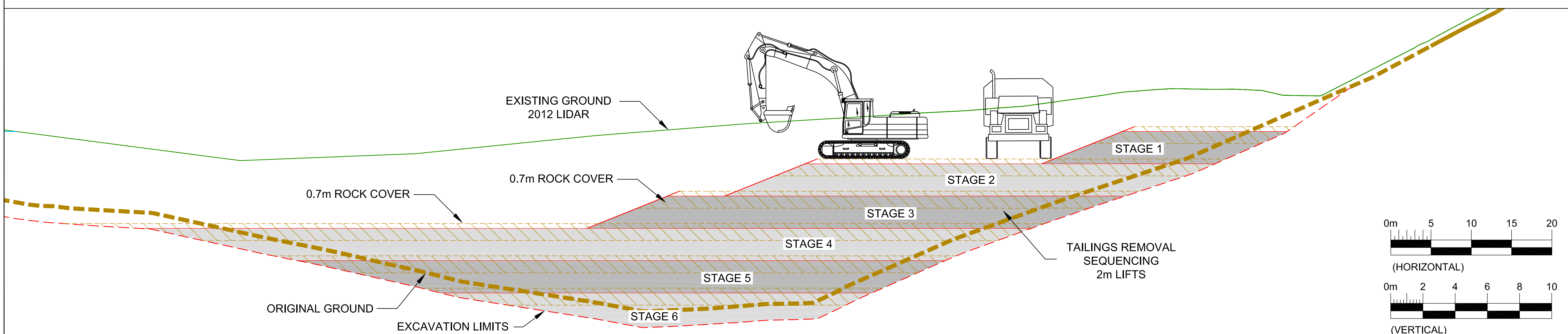
SCALE (m)

MARCH 25, 2014

C:\Users\yuan.chen\appdata\local\temp\AcPublish_3772\D 015.dwg – MM005 – Mar. 26, 2014 11:30am – yuan.chen



SECTION 2 - TAILINGS



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

NOTE:

1. ASSUMES MAXIMUM SIZED TRUCK IS ARTICULATED 40 TON TRUCK WITH WIDTH OF 3.5 m.
2. WELL POINT SPACING AND LOCATIONS ARE SCHEMATIC

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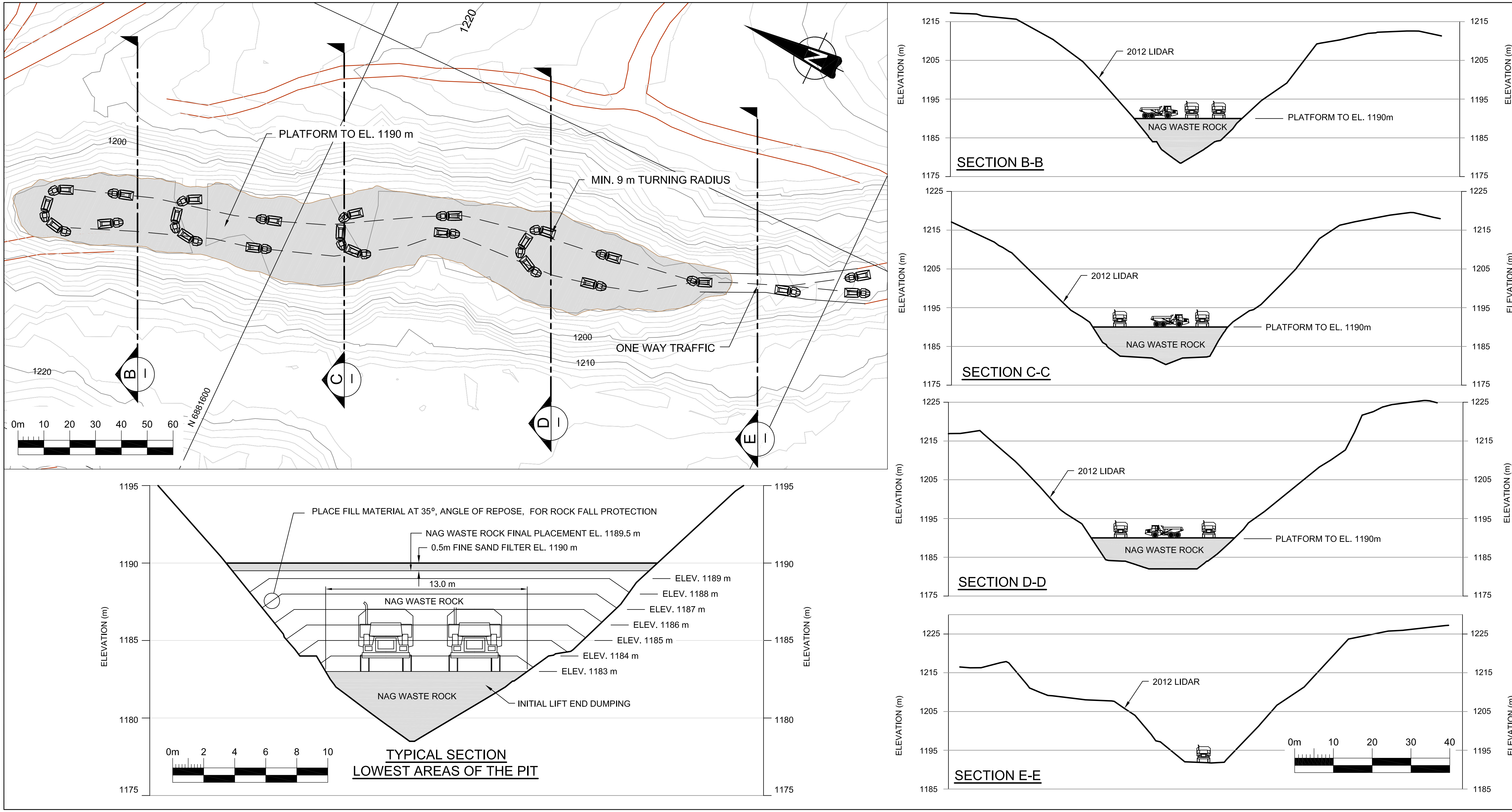
MOUNT NANSEN REMEDIATION PROJECT
Drawing D016

30% DESIGN PHASE REPORT

SCHEMATIC OF TAILINGS EXCAVATION SECTION

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\D 016.dwg – MM005.1 – Mar. 26, 2014 2:04pm – yuan.chen



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

NOTE:
1. ASSUMES MAXIMUM SIZED TRUCK IS ARTICULATED 40 TON TRUCK WITH WIDTH OF 3.5 m.

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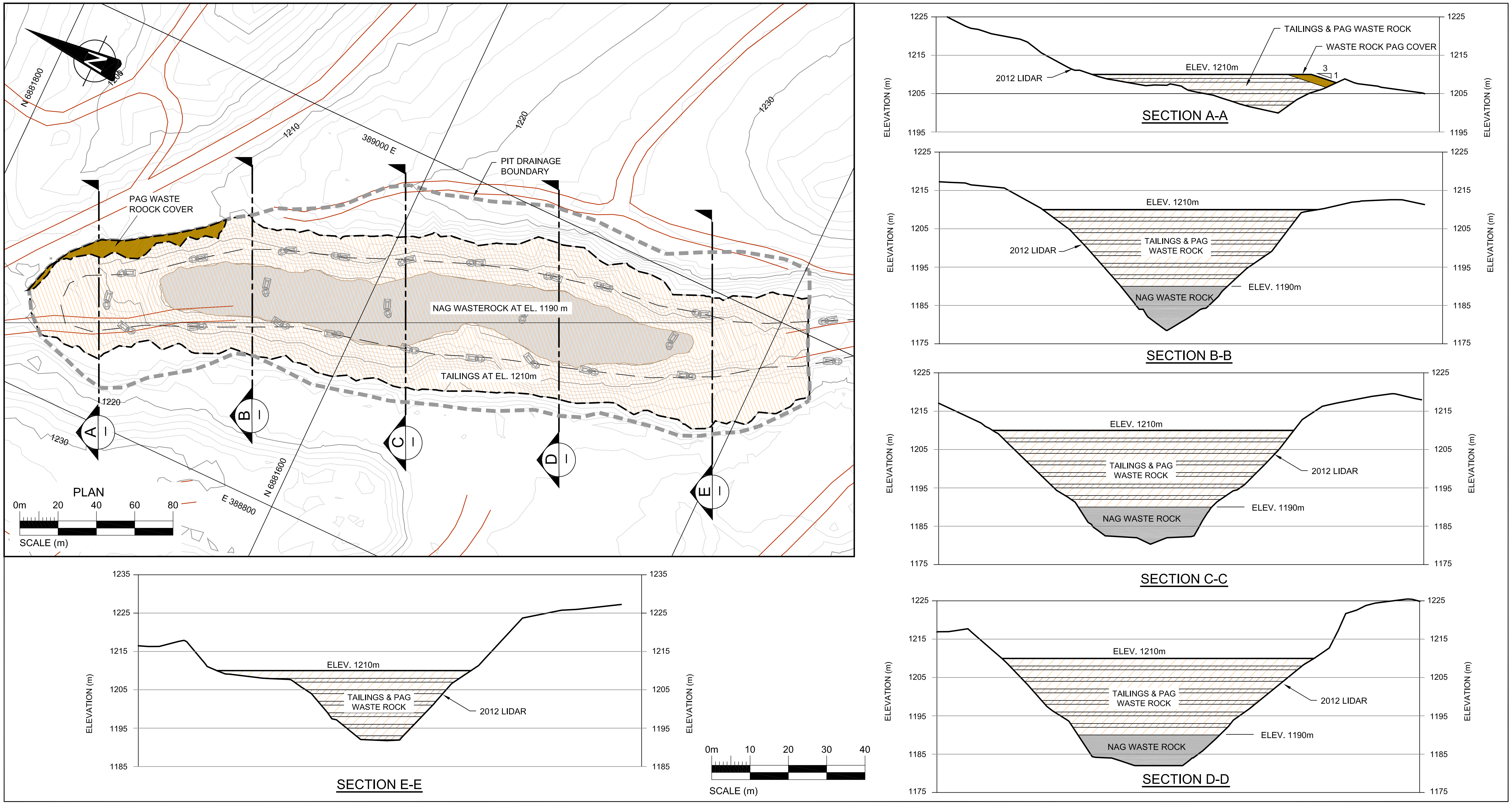
MOUNT NANSEN REMEDIATION PROJECT
Drawing D017

30% DESIGN PHASE REPORT

NAG WASTE ROCK PLATFORM PLAN AND SECTIONS

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\D 017.dwg – MM006 – Mar. 25, 2014 8:41pm – yuan.chen



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

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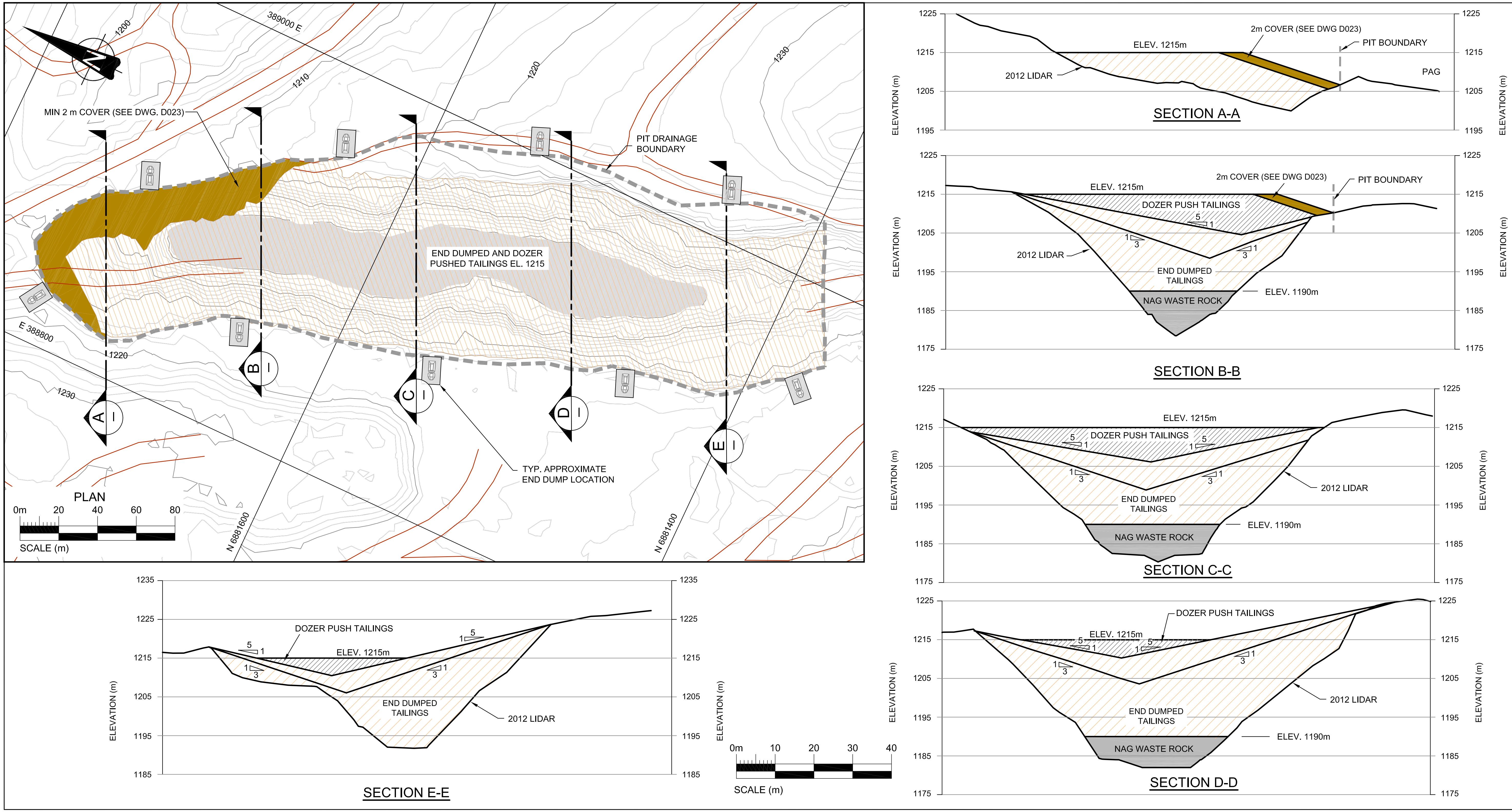
MOUNT NANSEN REMEDIATION PROJECT
Drawing D018

30% DESIGN PHASE REPORT

TAILINGS AND PAG WASTE ROCK DIRECT PLACEMENT METHOD AT EL.1210m PLAN AND SECTIONS

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\D018.dwg – D018 – Mar. 25, 2014 1:14pm – yuan.chen



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

NOTE:
1. SECTIONS SHOWN ARE FOR PLACEMENT OF UNSATURATED TAILINGS WITHIN 5m OF PIT RIM. IF MATERIAL IN THIS ZONE IS SATURATED, STABILIZATION MEASURES ARE REQUIRED.

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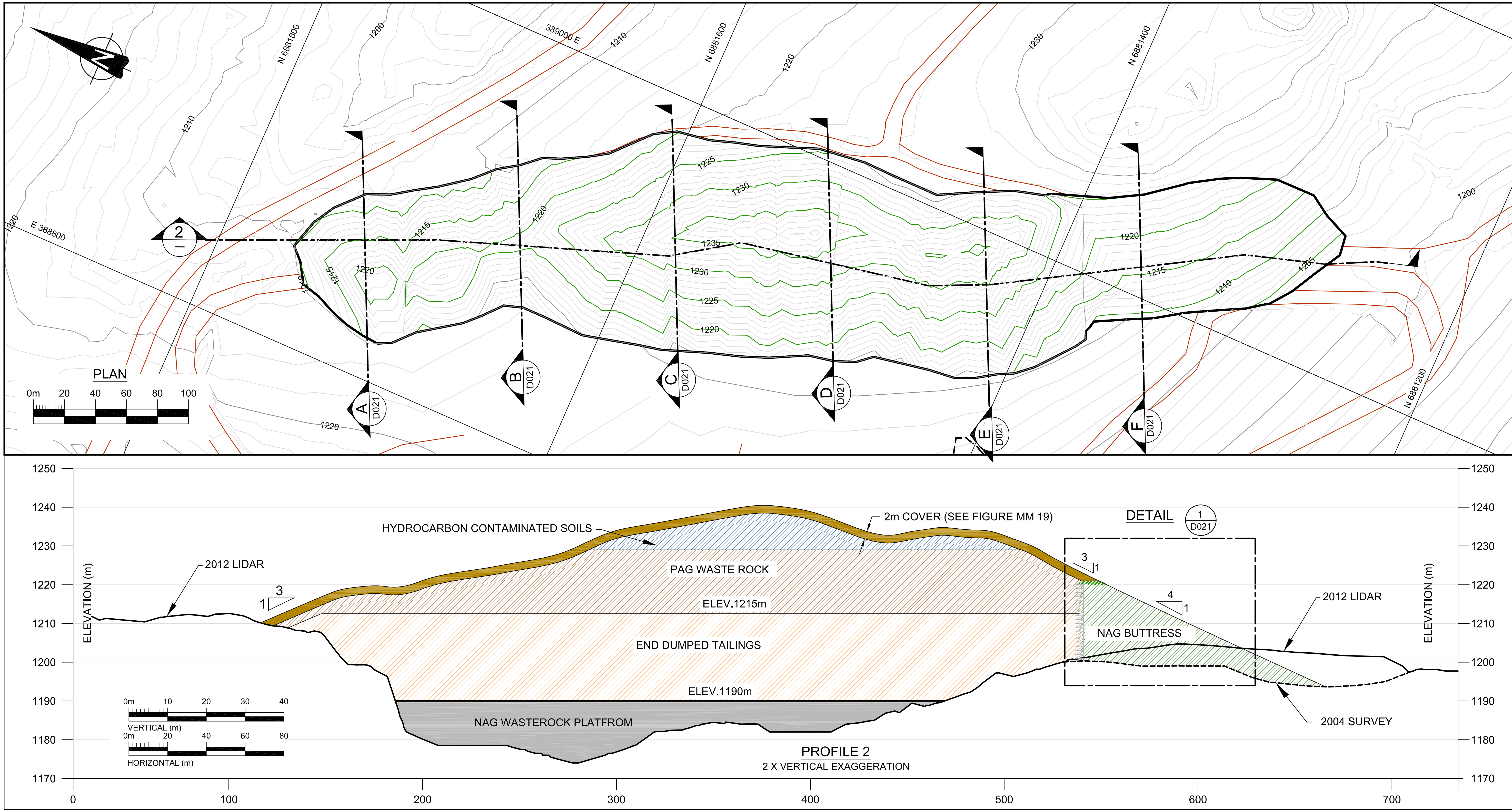
MOUNT NANSEN REMEDIATION PROJECT
Drawing D019

30% DESIGN PHASE REPORT

END DUMP TAILINGS DEPOSITION AT EL.1215m PLAN AND SECTIONS

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\D 019.dwg – MM008 – Mar. 26, 2014 11:21am – yuan.chen



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

NOTES:
1. SECTIONS SHOWN ARE FOR PLACEMENT OF UNSATURATED TAILINGS WITHIN 5m OF PIT RIM IF MATERIAL IN THIS ZONE IS SATURATED, STABILIZATION MEASURES ARE REQUIRED.

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MOUNT NANSEN REMEDIATION PROJECT
Drawing D020

30% DESIGN PHASE REPORT

FINAL OPEN PIT CONFIGURATION
DIRECT PLACEMENT METHOD
PLAN AND PROFILE

MARCH 25, 2014

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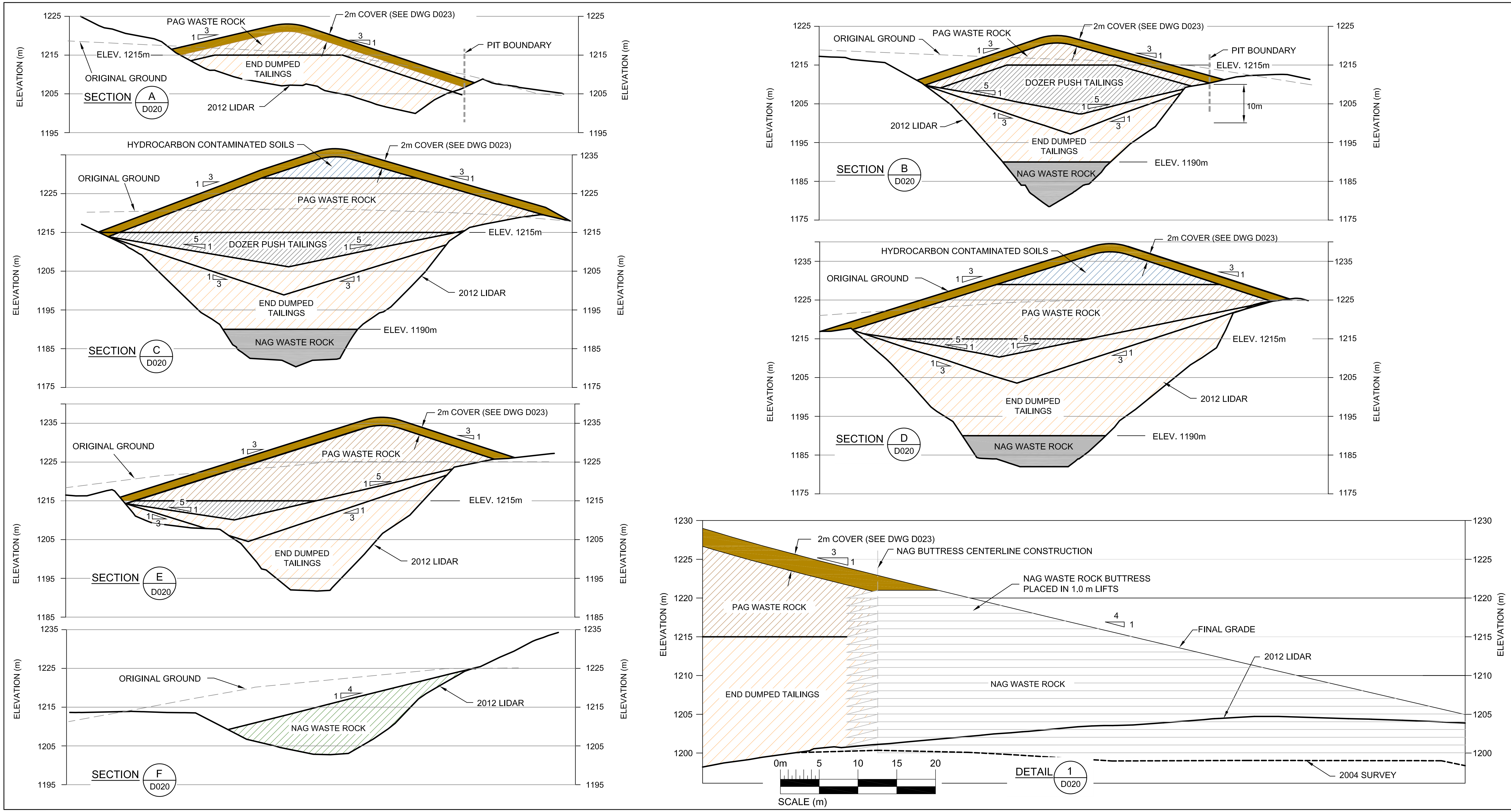

Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

NOTES:
1. SECTIONS SHOWN ARE FOR PLACEMENT OF UNSATURATED TAILINGS WITHIN 5m OF PIT RIM IF MATERIAL IN THIS ZONE IS SATURATED, STABILIZATION MEASURES ARE REQUIRED.

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

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MOUNT NANSEN REMEDIATION PROJECT
Drawing D021

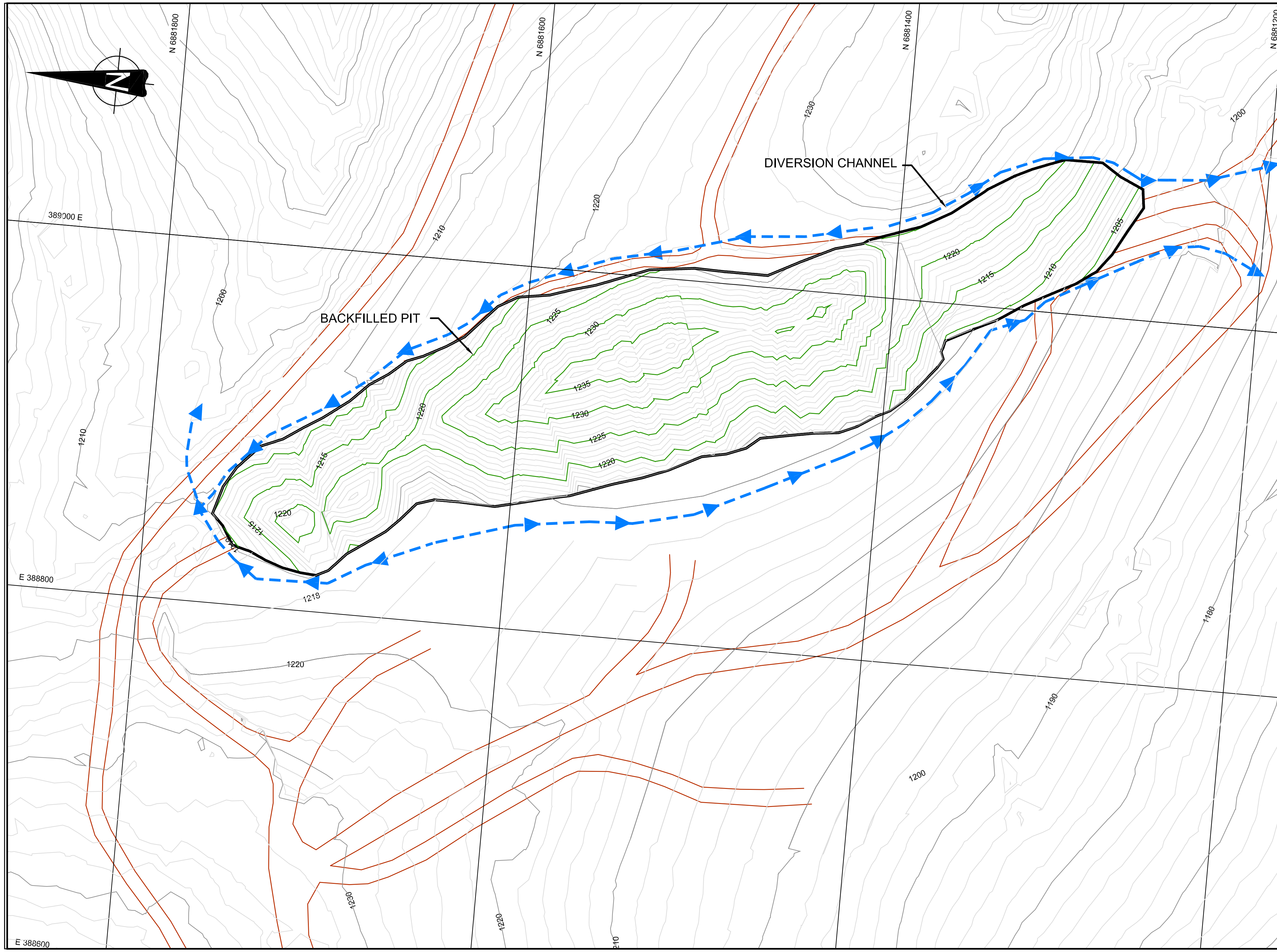
30% DESIGN PHASE REPORT

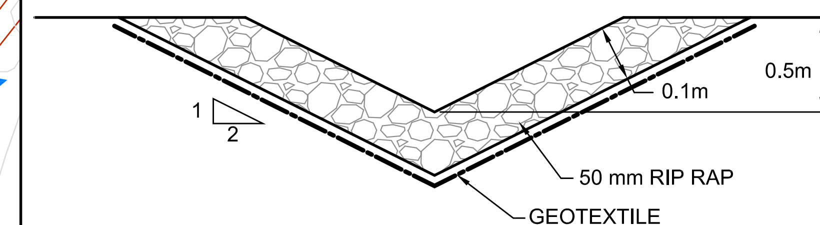
FINAL OPEN PIT CONFIGURATION END DUMP METHOD SECTIONS AND DETAILS

0m 10 20 30 40
SCALE (m)

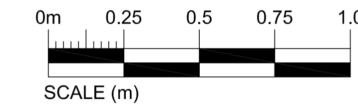
MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\DC 007,008,0020,D021,D034.dwg – D021 REV1 – Mar. 24, 2014 6:51pm – yuan.chen





TYPICAL DIVERSION CHANNEL SECTION



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

NOTES:

1. THE PURPOSE OF A PERIMETER CHANNEL AROUND THE BACKFILLED PIT IS TO ROUTE ANY RUNOFF FROM THE PIT COVER AND SURROUNDING AREAS. THE DIVERSION CHANNEL WILL ALSO PROVIDE A TIE IN BETWEEN THE COVER AND SURROUNDING AREA TO PROTECT THE COVER FROM BEING UNDERMINED.

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

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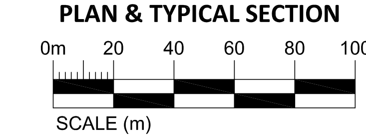
MOUNT NANSEN REMEDIATION PROJECT
Drawing D022

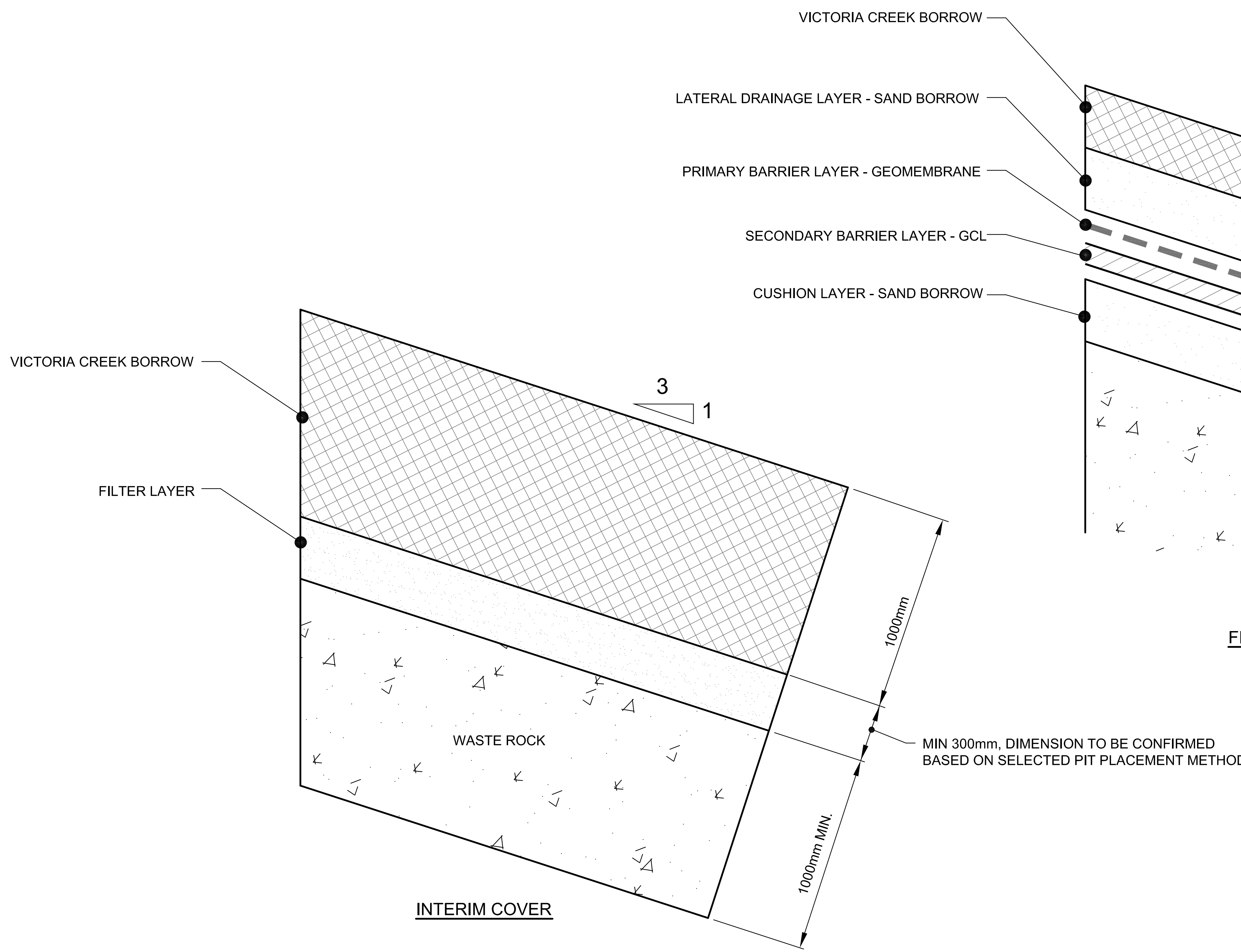
30% DESIGN PHASE REPORT

DIVERSION DITCHES AT OPEN PIT
PLAN & TYPICAL SECTION



MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\D 022.dwg – plan and profile – Mar. 26, 2014 2:46pm – yuan.chen



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MOUNT NANSEN REMEDIATION PROJECT
Drawing D023

30% DESIGN PHASE REPORT

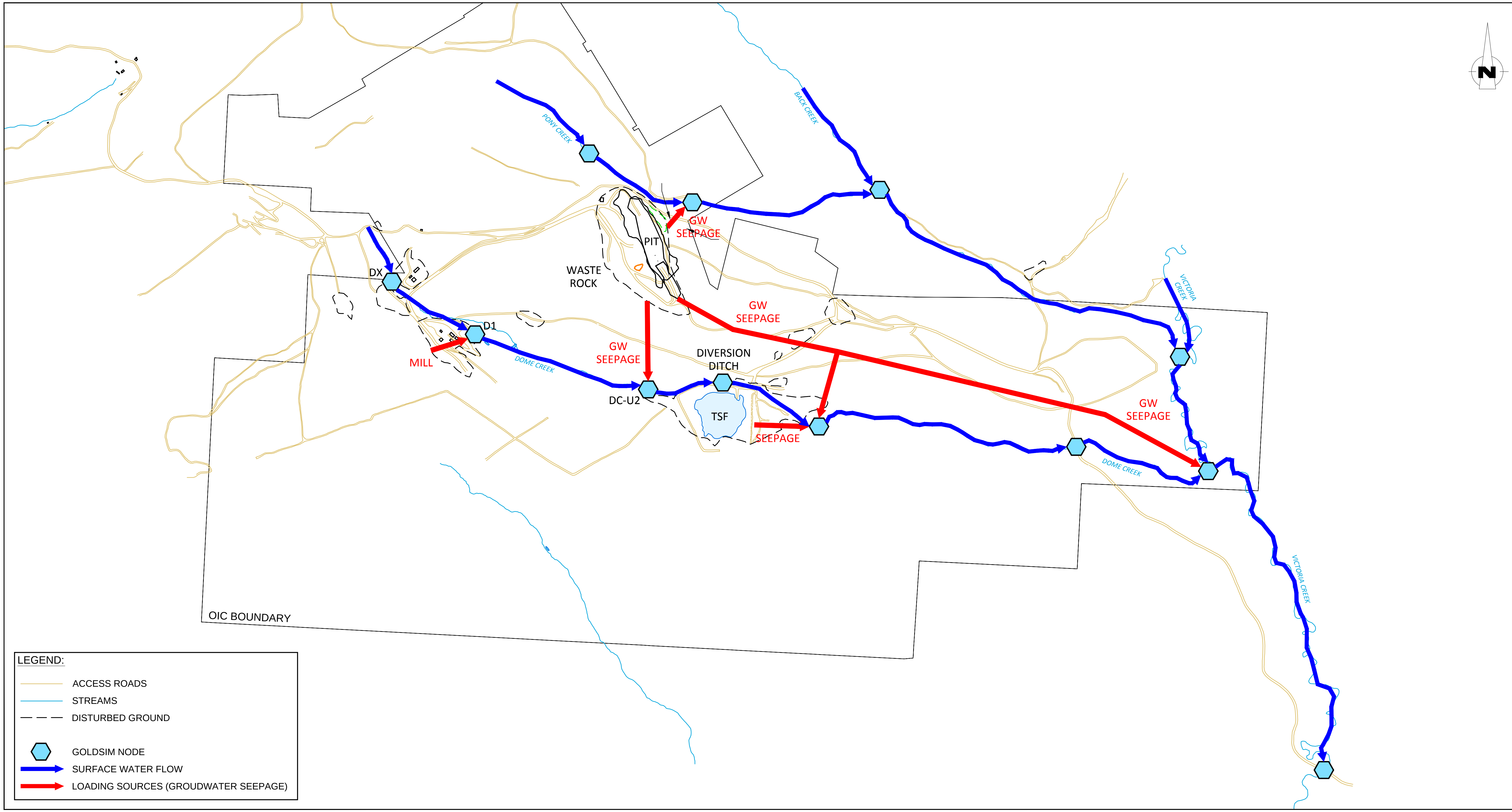
PRINCIPAL COMPONENTS OF INTERIM AND FINAL COVERS

0m 0.25 0.5 0.75 1.0

SCALE (m)

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\D 007,008,0020,021,034.dwg – D023 – Apr. 03, 2014 6:00pm – yuan.chen



Note:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00605F DATED MARCH 2014.

Datum: NAD 1983 CSRS UTM Zone 8N

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MOUNT NANSEN REMEDIATION PROJECT
30% DESIGN PHASE REPORT

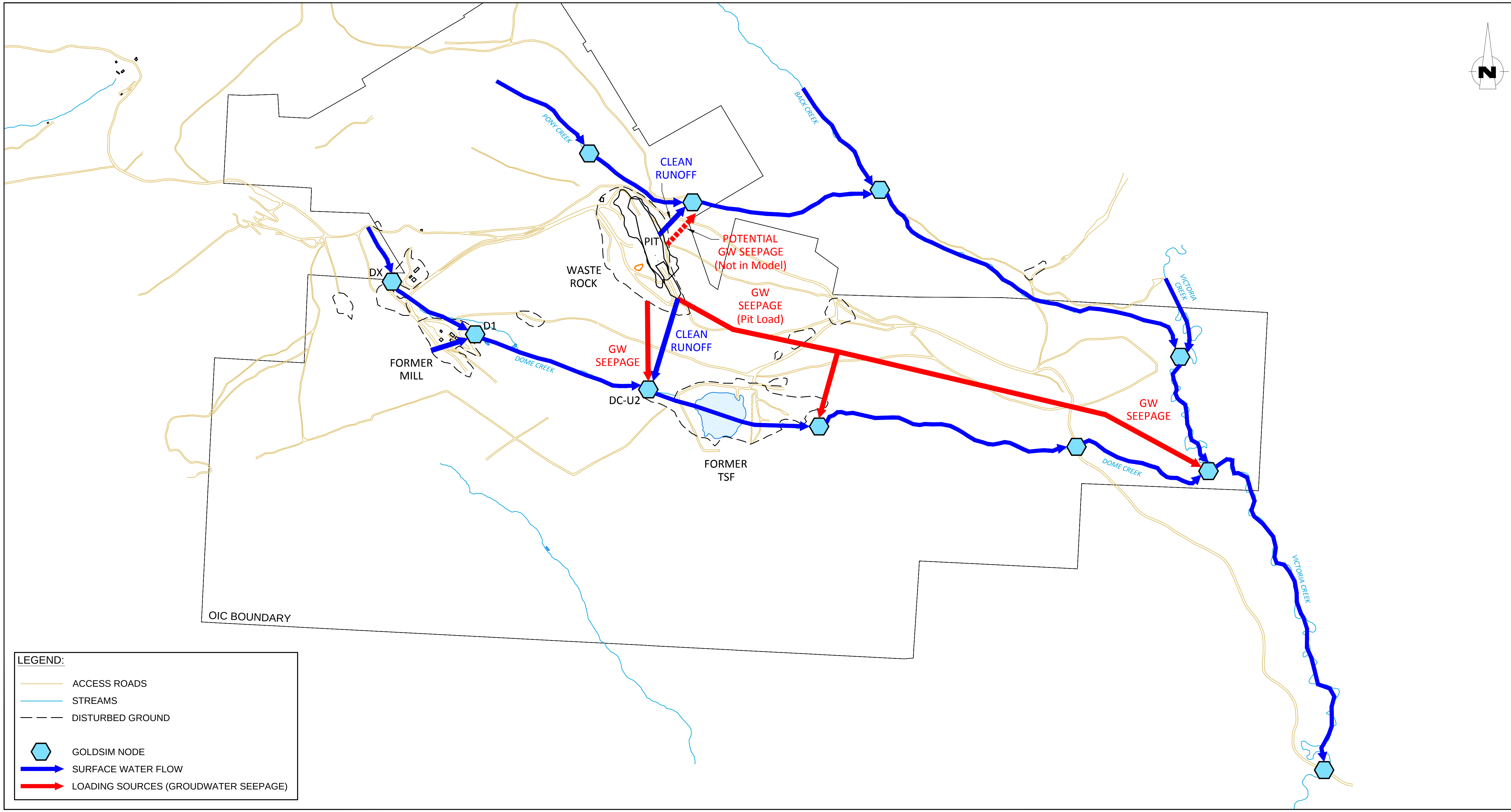
Drawing D024

Conceptual Model
Existing Conditions

0m 200 400 600 800

March 24, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\VM00605–MNRP–GOLDSIM–CONCEPT.dwg – D024 – Mar. 24, 2014 2:01pm – tim.hawker



Note:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00605F DATED MARCH 2014.

Datum: NAD 1983 CSRS UTM Zone 8N

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Yukon Energy, Mines and Resources Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
30% DESIGN PHASE REPORT

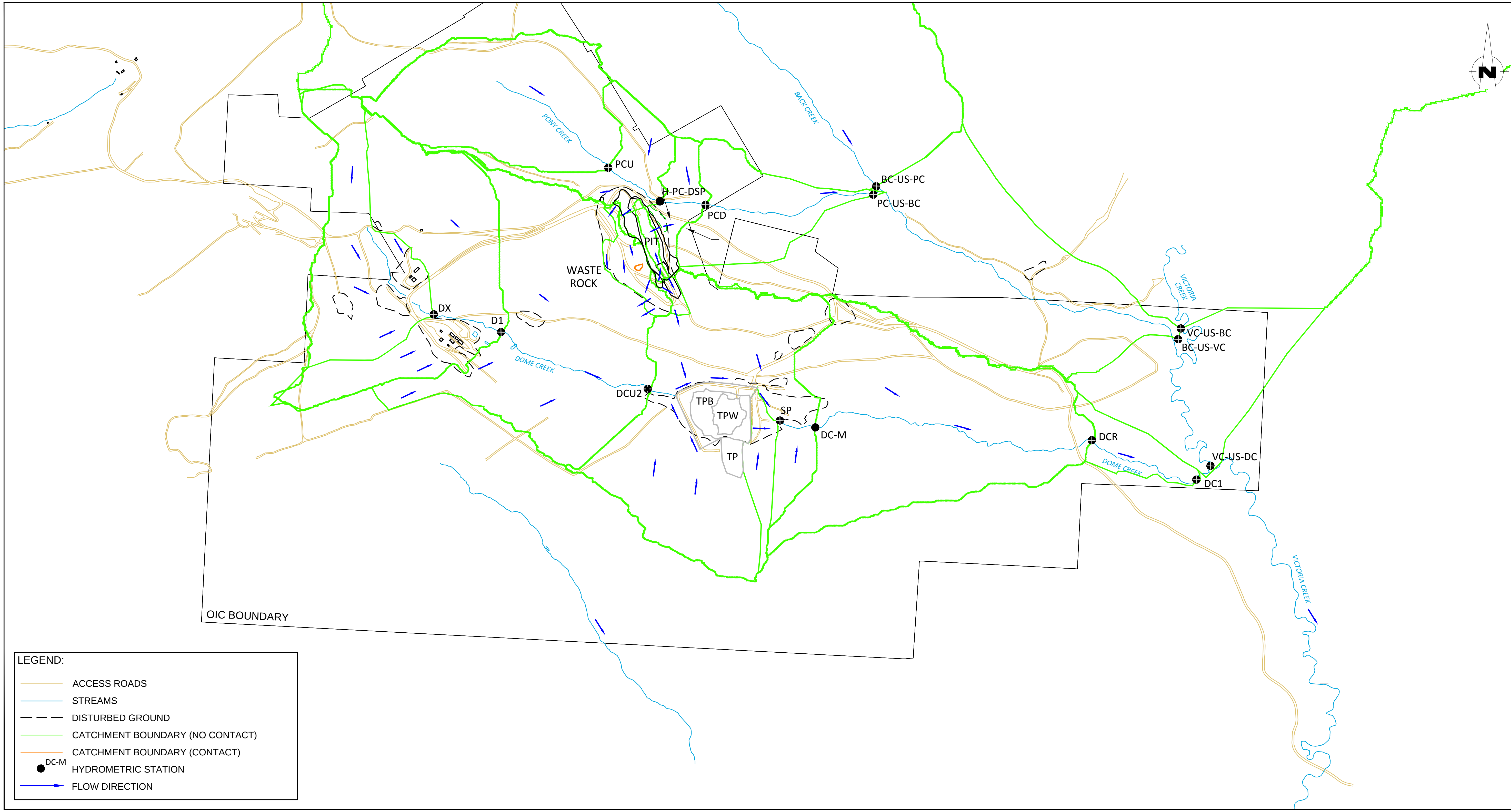
Drawing D025

Conceptual Model
Proposed Option 4 Conditions

0m 200 400 600 800

March 24, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\VM00605–MNRP–GOLDSIM–CONCEPT.dwg – D025 – Mar. 24, 2014 2:01pm – tim.hawker



Note:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC ENVIRONMENT & INFRASTRUCTURE REPORT No. VM00605F DATED MARCH 2014.

Datum: NAD 1983 CSRS UTM Zone 8N

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Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
30% DESIGN PHASE REPORT

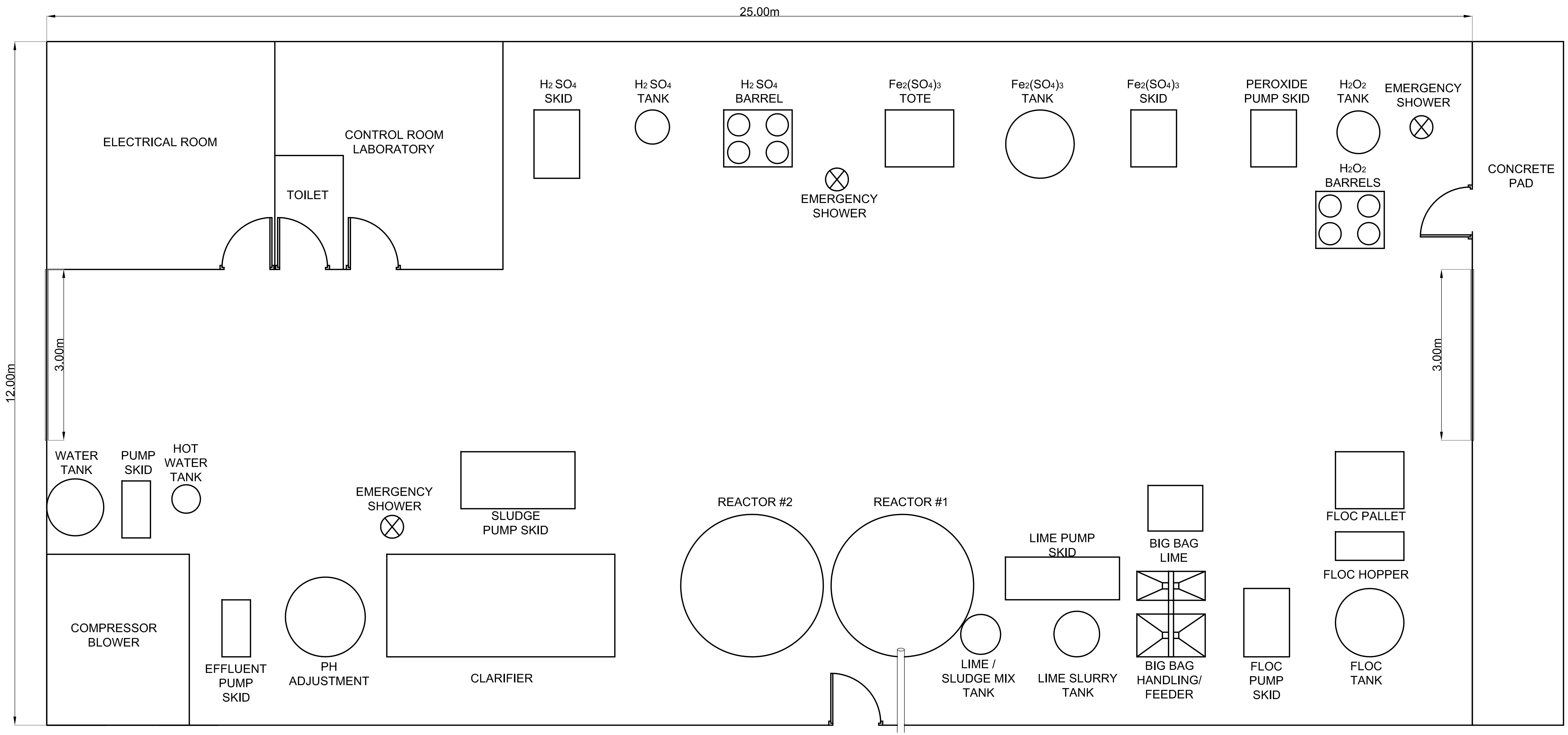
Drawing D026

Mount Nansen Catchment Areas

0m 200 400 600 800

March 24, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\VM00605-MNRP-GOLDSIM-CONCEPT.dwg – D026 – Mar. 24, 2014 2:02pm – tim.hawker



MOUNT NANSEN REMEDIATION PROJECT
Drawing D027

30% DESIGN PHASE REPORT

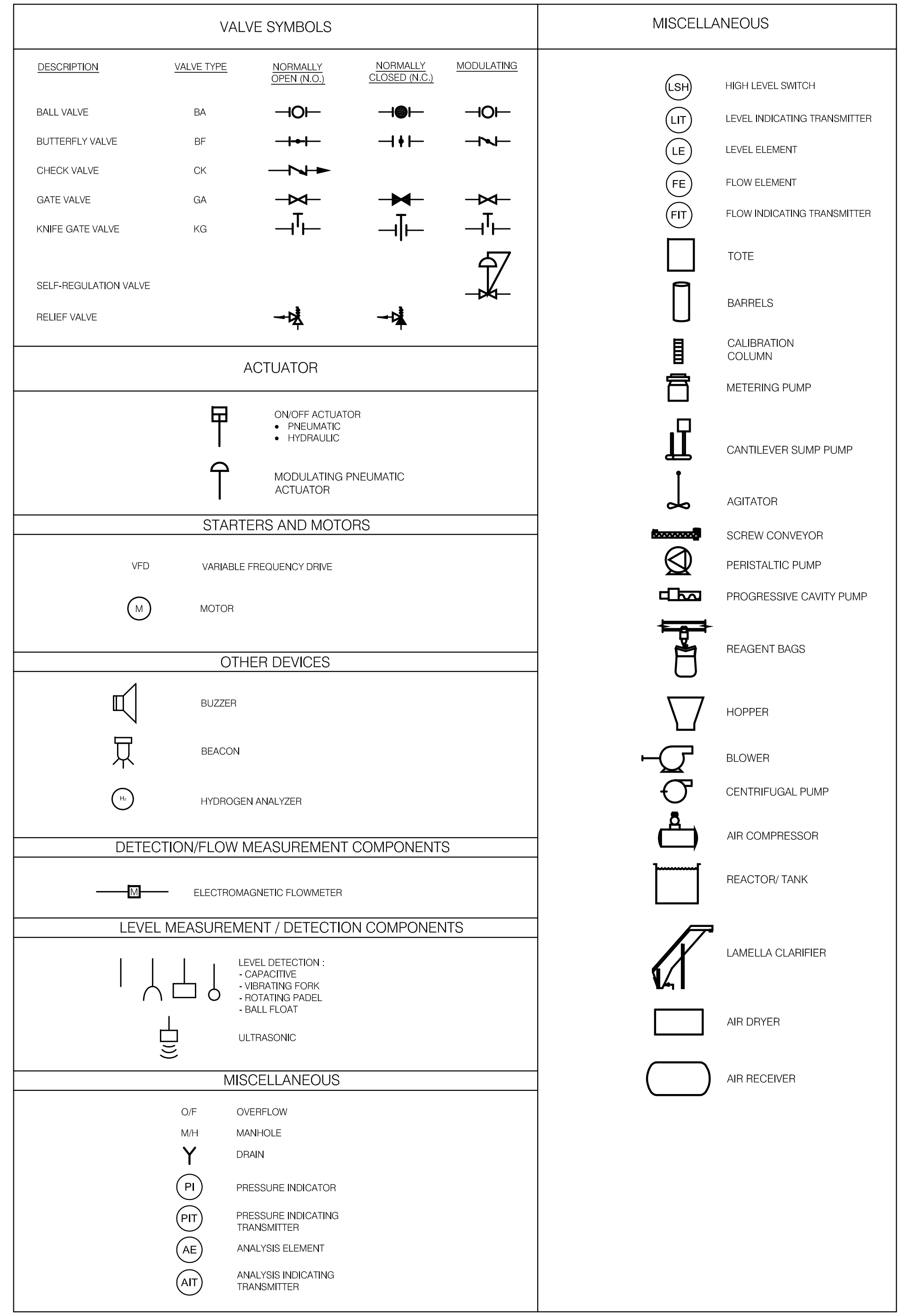
WATER TREATMENT PLANT
CONCEPTUAL GENERAL PLAN VIEW

0m 0.5 1.0 1.5 2.0 2.5 3.0

SCALE (m)

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\Water Treatment Drawings\D 027,28,29,30,31,32,33.dwg – D027 – Mar. 25, 2014 7:22pm – yuan.chen



Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

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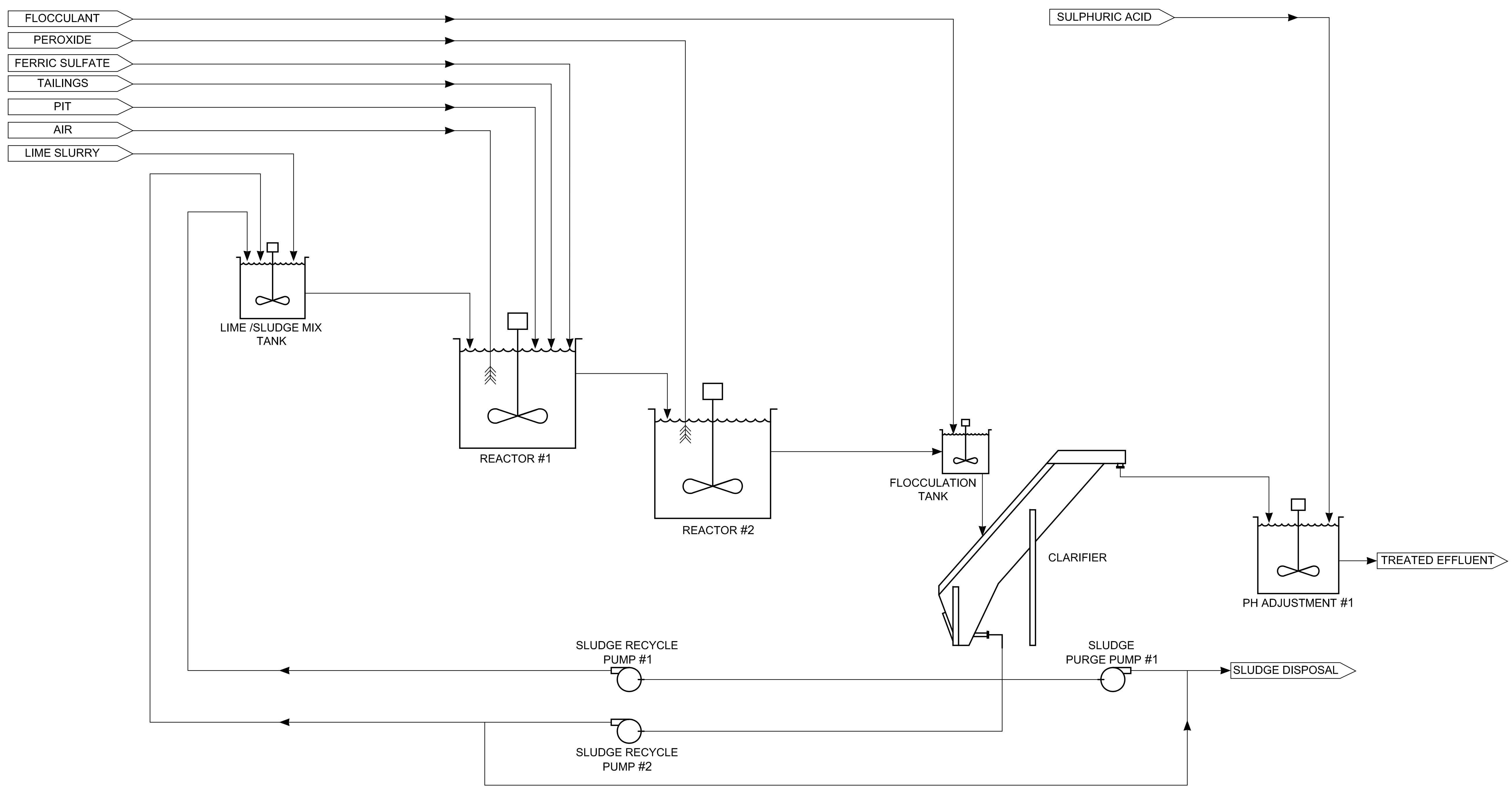
Yukon Energy, Mines and Resources Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D028

30% DESIGN PHASE REPORT

WATER TREATMENT PLANT
THE LEGEND

MARCH 25, 2014



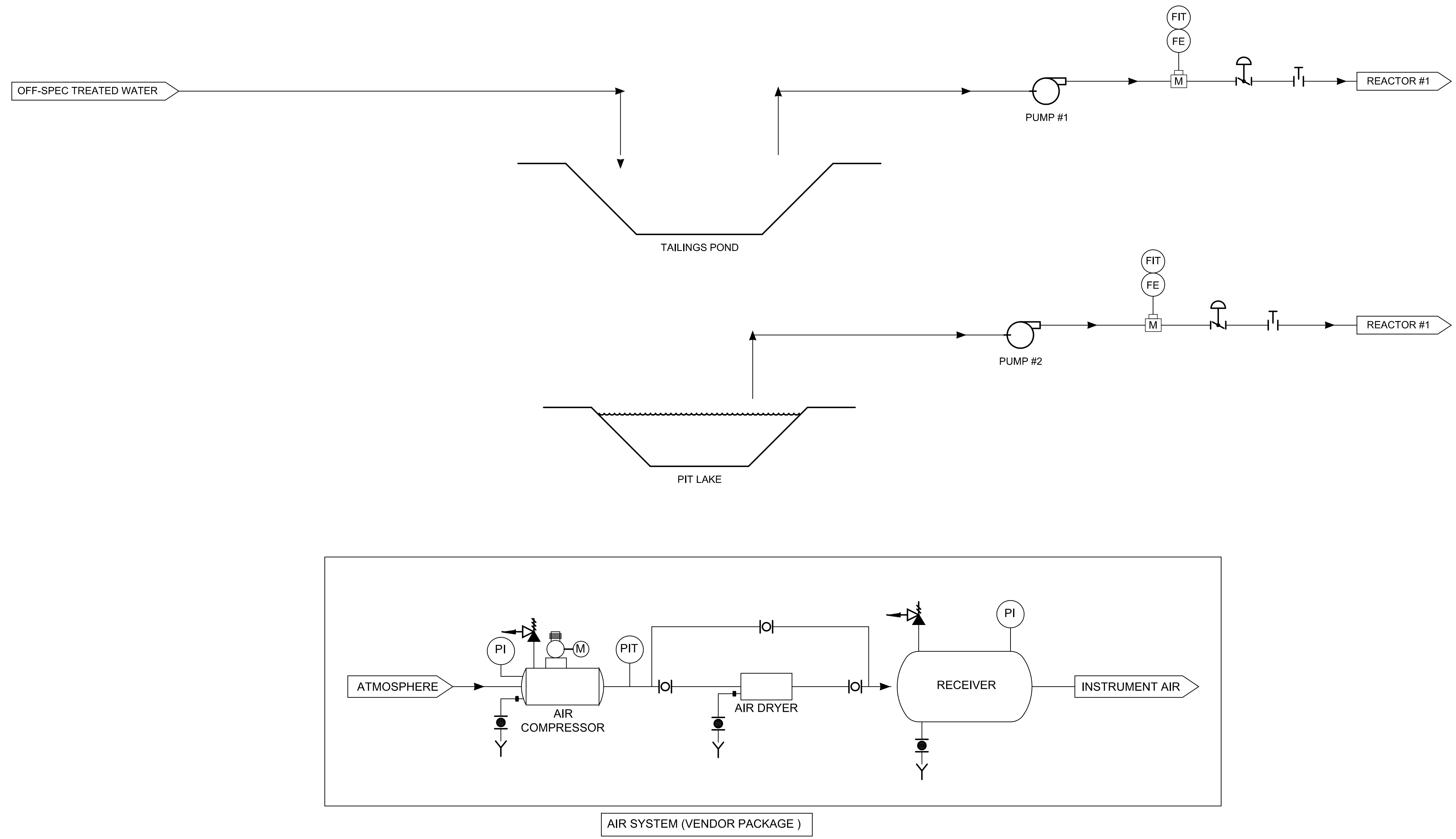
MOUNT NANSEN REMEDIATION PROJECT
Drawing D029

30% DESIGN PHASE REPORT

WATER TREATMENT PLANT
PROCESS FLOW DIAGRAM

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\Water Treatment Drawings\D 027,28,29,30,31,32,33.dwg – D029 – Mar. 25, 2014 7:23pm – yuan.chen



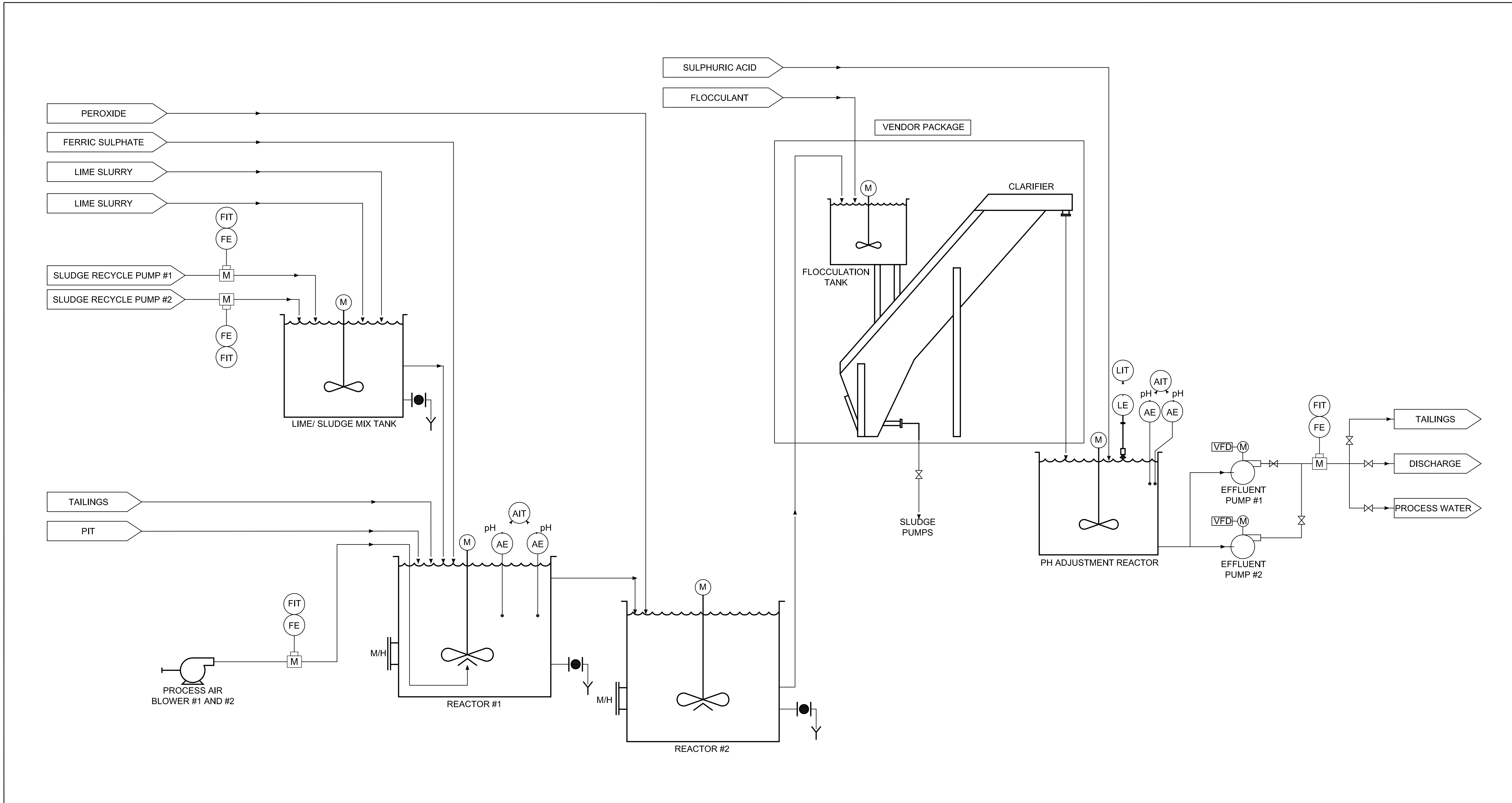
MOUNT NANSEN REMEDIATION PROJECT
Drawing D030

30% DESIGN PHASE REPORT

WATER TREATMENT PLANT
PROCESS AND INSTRUMENTATION DIAGRAM

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\Water Treatment Drawings\D 027,28,29,30,31,32,33.dwg – D030 – Mar. 25, 2014 7:24pm – yuan.chen



MOUNT NANSEN REMEDIATION PROJECT
Drawing D031

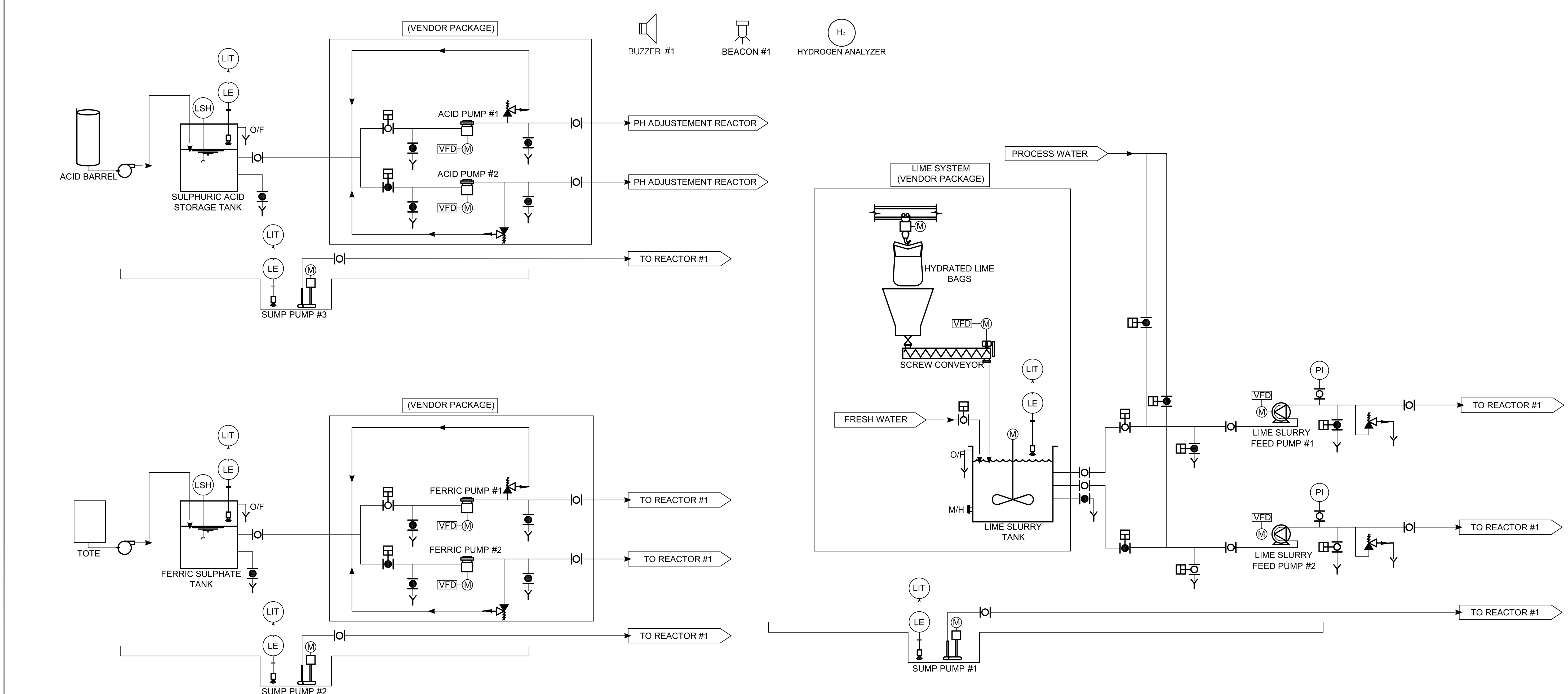
30% DESIGN PHASE REPORT

WATER TREATMENT PLANT PROCESS AND INSTRUMENTATION DIAGRAM

MARCH 25, 2014

Energy, Mines and Resources
Assessment and Abandoned Mines

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\Water Treatment Drawings\D 027,28,29,30,31,32,33.dwg – D031 – Mar. 25, 2014 7:24pm – yuan.chen



MOUNT NANSEN REMEDIATION PROJECT
Drawing D032

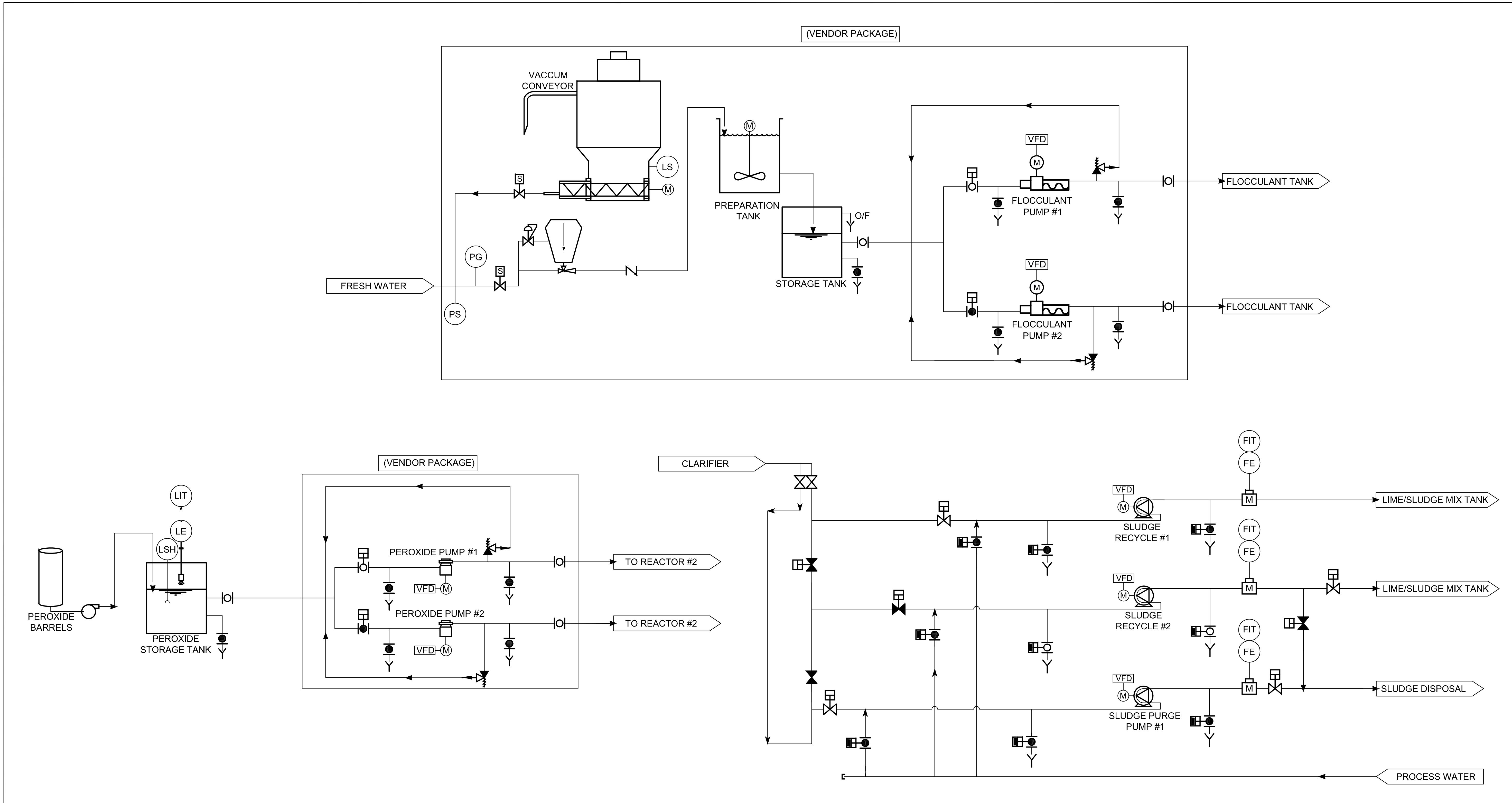
30% DESIGN PHASE REPORT

WATER TREATMENT PLANT
PROCESS AND INSTRUMENTATION DIAGRAM

MARCH 25, 2014

Energy, Mines and Resources
Assessment and Abandoned Mines

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\Water Treatment Drawings\D 027,28,29,30,31,32,33.dwg – D032 – Mar. 25, 2014 7:25pm – yuan.chen



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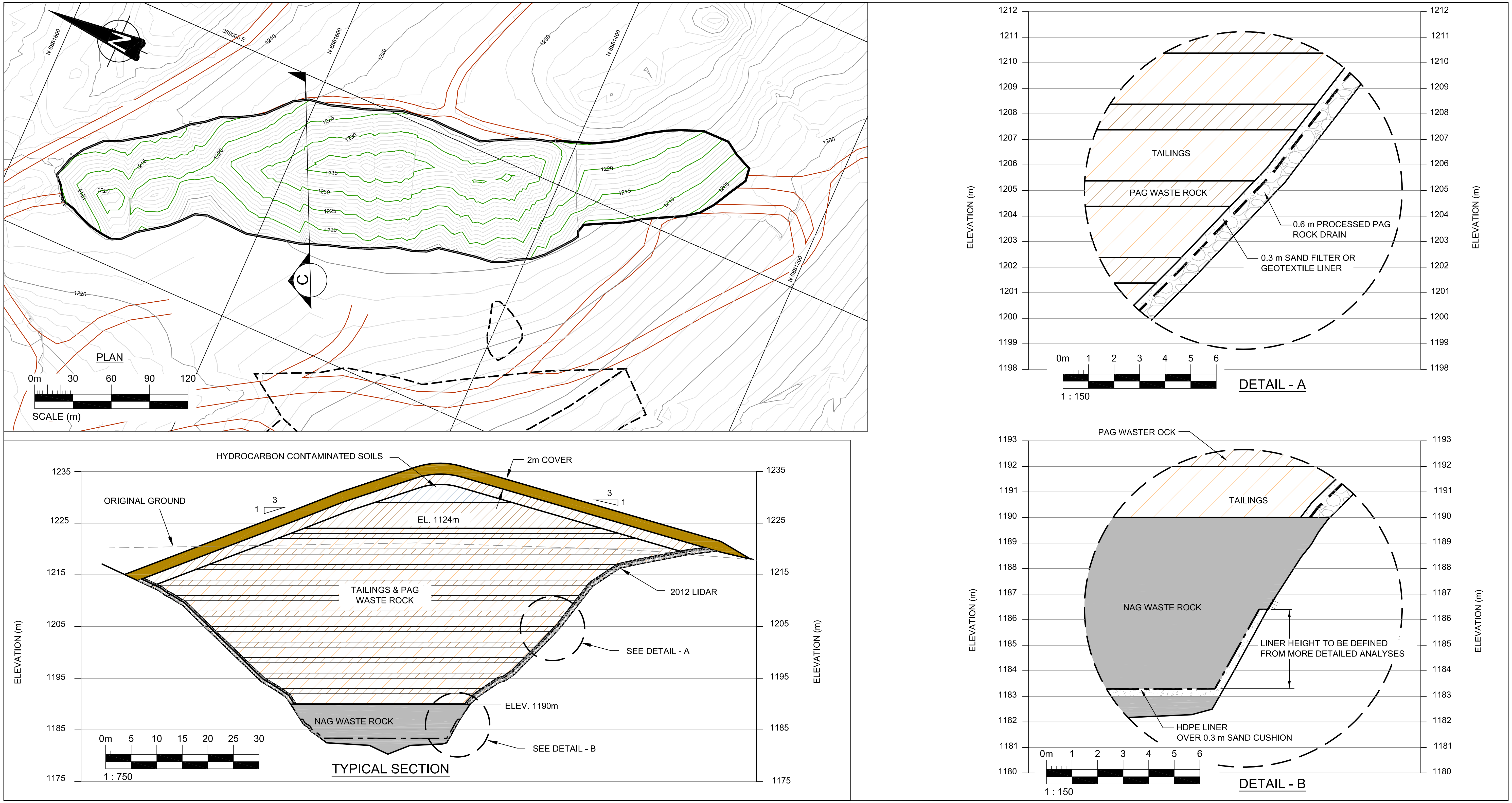
MOUNT NANSEN REMEDIATION PROJECT
Drawing D033

30% DESIGN PHASE REPORT

WATER TREATMENT PLANT PROCESS AND INSTRUMENTATION DIAGRAM

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\Water Treatment Drawings\D 027,28,29,30,31,32,33.dwg – D033 – Mar. 25, 2014 7:26pm – yuan.chen



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

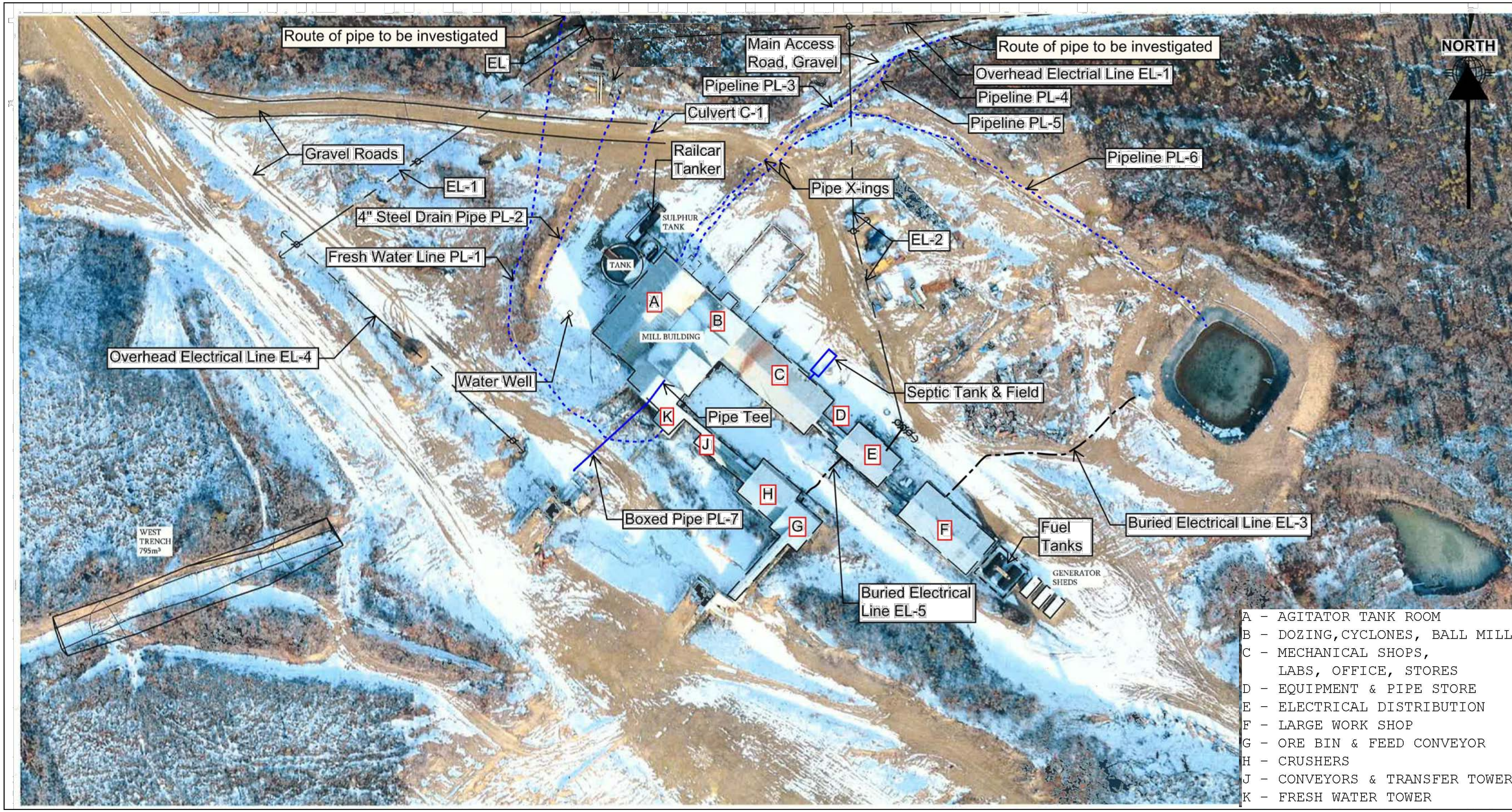
MOUNT NANSEN REMEDIATION PROJECT
Drawing D034

30% DESIGN PHASE REPORT

SCHEMATIC OF PIT COLLECTION DESIGN CONTINGENCIES

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\DC 007,008,0020,D021,D034.dwg – D034 – Mar. 24, 2014 6:26pm – yuan.chen



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

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MOUNT NANSEN REMEDIATION PROJECT
Drawing D035

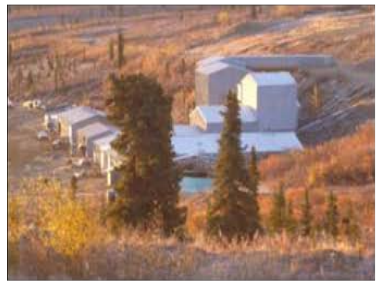
30% DESIGN PHASE REPORT

MISCELLANEOUS INFRASTRUCTURE

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\Infrastructure Drawings\D 033,034,035.dwg – D035 – Mar. 26, 2014 2:37pm – yuan.chen

Mill Complex Random Views



1 - Mill complex looking east

2 - Looking west at Buildings B and C

3 - View of mill looking west at Buildings B, C, and D

4 - Interior Building E MCC

5 - Mill upper terrace, looking west at Buildings J, K, B, and C

6 - Agitator tanks in Building A

7 - Walkways over agitator tanks in Building A

8 - Interior of Building B, ball mill floor

9 - Looking east at Buildings G, H, and J from upper terrace

10 - Cabling and water pipe from Building B and K

11 - South entry to Building K (fresh water tank room)

12 - Wood stave ore bin in Building G

Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

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MOUNT NANSEN REMEDIATION PROJECT
Drawing D036

30% DESIGN PHASE REPORT

MILL COMPLEX RANDOM VIEWS

MARCH 25, 2014

Compilation of Miscellaneous Buildings

11 - Victoria Creek Wellhouse

12 - Victoria Creek Wellhouse Interior

13 - Seepage Pond Pump House

14 - Cookhouse Exterior

15 - Cookhouse Interior

16 - Camp Shed

17 - Bunkhouse

18 - Bunkhouse foundation wall

19 - Electrical Transfer Station (ETS)

20 - Interior of ETS

Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

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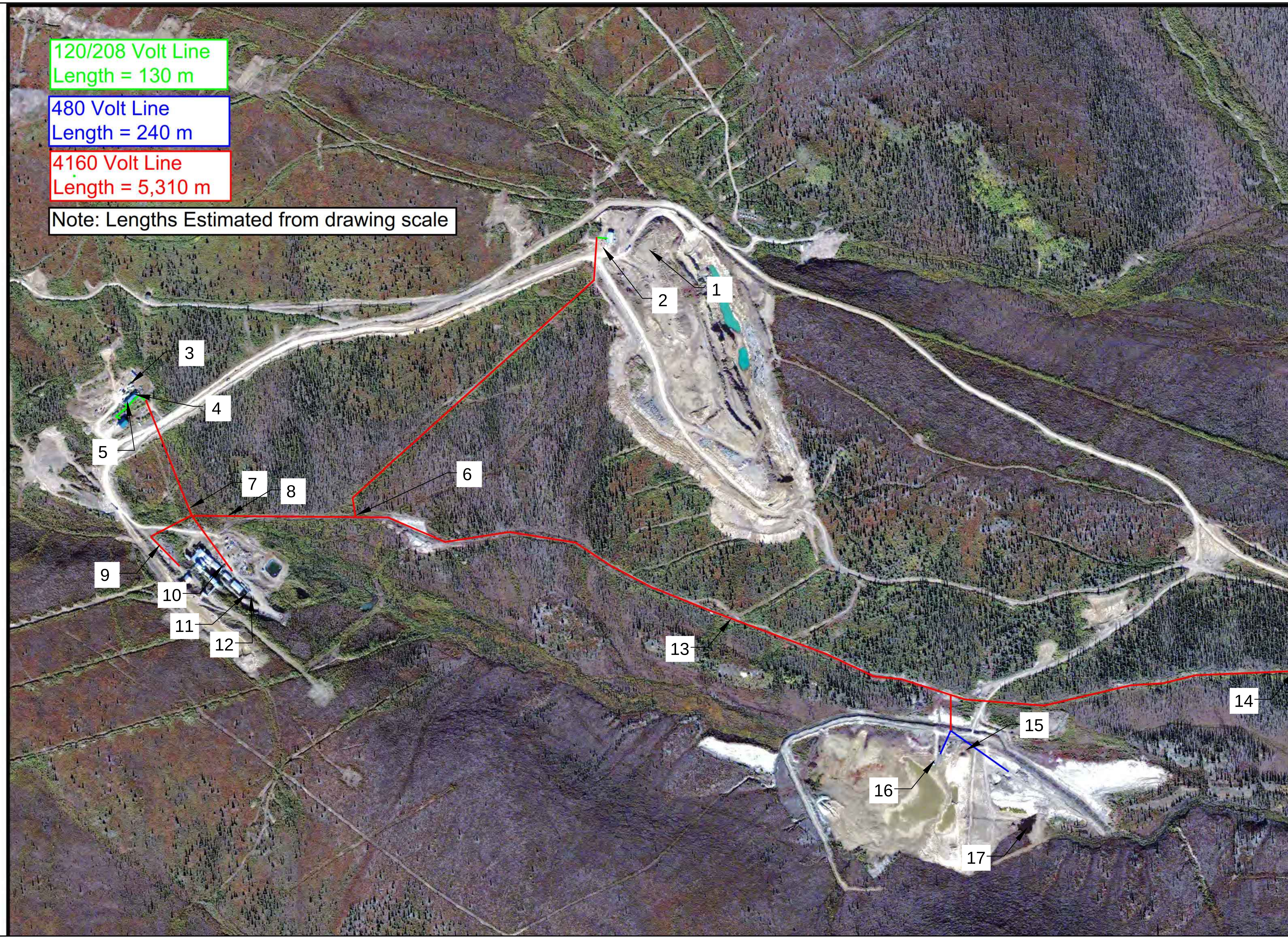
MOUNT NANSEN REMEDIATION PROJECT
Drawing D037

30% DESIGN PHASE REPORT

COMPILATION OF MISCELLANEOUS BUILDINGS

MARCH 25, 2014



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

NOTES:
1. REFER TO DRAWING D040 FOR DESCRIPTIONS

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

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Yukon Energy, Mines and Resources Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D038

30% DESIGN PHASE REPORT

ELECTRICAL POWER DISTRIBUTION

MARCH 25, 2014

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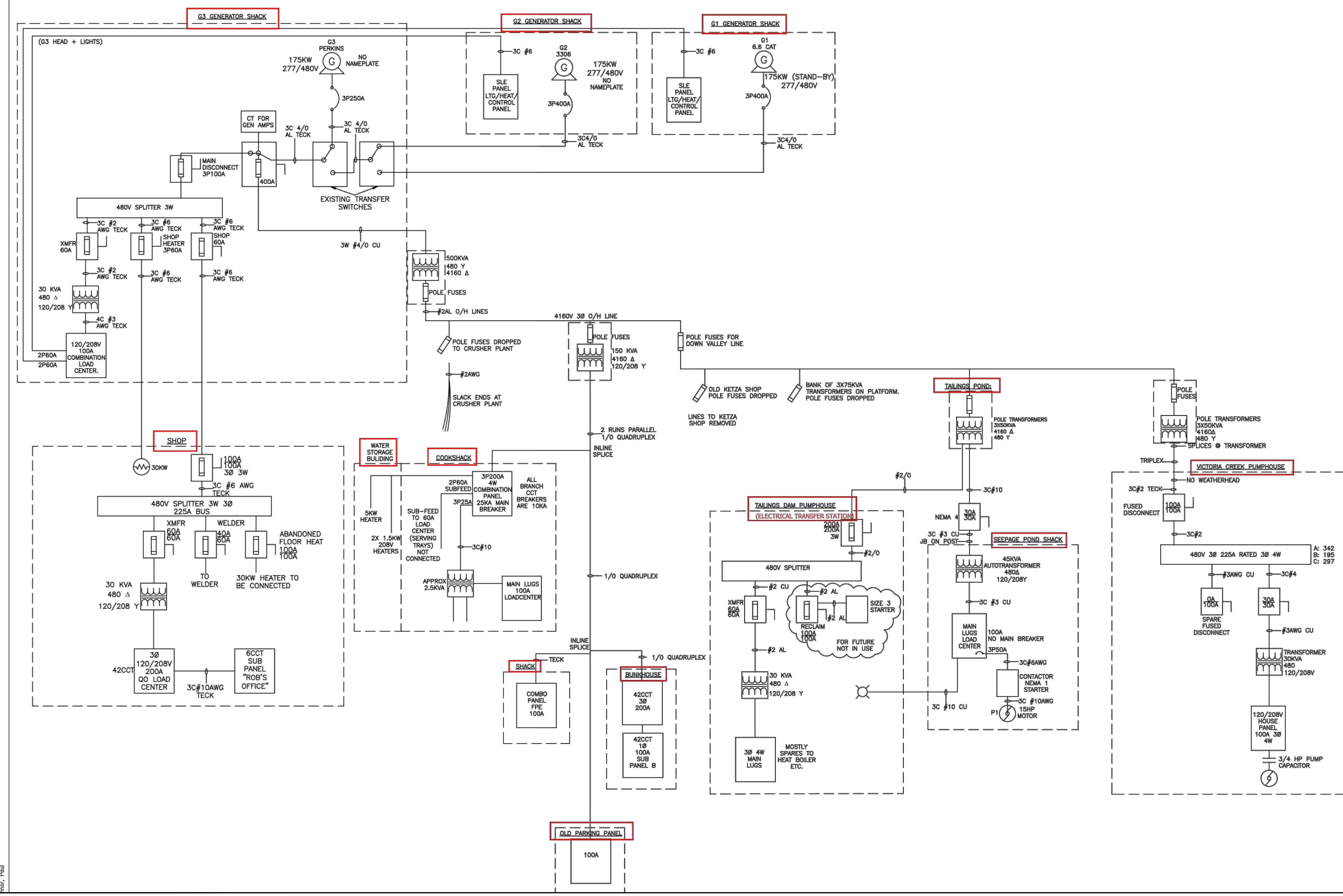

Stantec Architecture Ltd.
107 Main Street, Suite 202
Whitehorse YT Canada
Y1A 2A7
Tel. 867.633.2400
Fax. 867.633.2481
www.stantec.com

Consultants

Legend

Notes

THIS SINGLELINE DIAGRAM REPRESENTS THE STATUS OF THE SITE ELECTRICAL INSTALLATIONS PRIOR TO ANY REVISIONS MADE AS A RESULT OF THE ENGINEERED CHANGES DESIGNED BY STANTEC IN 2012/13. INFORMATION FOR THIS SINGLELINE HAS BEEN OBTAINED FROM A COMBINATION OF ON-SITE REVIEW AND INFORMATION PROVIDED BY A.A.M. AND THEIR CARE AND MAINTENANCE CONTRACTOR, DENISON ENVIRONMENTAL SERVICES.

Revision		By	Appd.	YY.MM.DD
B	ISSUED FOR 100%	PIO	RDS	13.01.09
A	ISSUED FOR REVIEW	PIO	RDS	12.12.06

Issued		By	Appd.	YY.MM.DD
B	ISSUED FOR 100%	PIO	RDS	13.01.09
A	ISSUED FOR REVIEW	PIO	RDS	12.12.06

File Name: Dwn. Chkd. Dsgn. YY.MM.DD

Client/Project

Mt. Nansen Electrical

Whitehorse, YT

Title

EXISTING SINGLE LINE DIAGRAM

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Yukon Energy, Mines and Resources Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D039

30% DESIGN PHASE REPORT

ELECTRICAL SINGLE LINE DIAGRAM

MARCH 25, 2014

Descriptions from Drawing D038

Number	Description
1	**KETZA YARD** Electrical Measurements on Mar. 1st, 2012 238 volts Incoming 14.8A Line A 24.0A Line B 118/238 volts to Panel 14.3A Line A 24.9A Line B At just over four and a half KVA load, this transformer is loaded to approx. 18% of full capacity. Pictures: Page 50, 51 As depicted in the picture, the transformer in the Ketza Shop is a 25KVA, 277 to 120/240 volt transformer.
2	**KETZA YARD** Pictures: Page 46 to 49 The transformer on the pole outside the Ketza Shop is scheduled for disconnection and removal later this year. There were no discernible markings as to the size of this transformer but as depicted in the pictures, it is single phase, 4160 to 277 volts. The transformer has reportedly been removed.
3	**COOKHOUSE** Pictures: Page 21 to 25 As depicted in the pictures, the transformer at the Cook Shack is a 6KVA, 208 to 230 volt step up transformer. The transformer feeds the panel to which only the 3 phase pumps are connected. The pumps were not running the day the measurements were taken. Electrical Measurements on Mar. 1st, 2012 118/204 volts to Panel 28.4A Line A 25.0A Line B 24.5A Line C
4	**COOKHOUSE/BUNKHOUSE** TRANSFORMER Pictures: Page 28 to 30
5	**BUNKHOUSE** Pictures: Page 15 to 19 Electrical Measurements on Mar. 1st, 2012 118/204 volts to Panel 6.6A Line A 37.2A Line B 11.9A Line C
6	High Voltage Branch to **KETZA SHOP** Pictures: Page 52, 53
7	**HIGH VOLTAGE LINE BRANCHES** Picture: Page 41
8	**HIGH VOLTAGE BRANCH LINE DISCONNECT** Picture: Page 44
9	**HIGH VOLTAGE BRANCH LINE DISCONNECT** Picture: Page 45
10	**MAIN TRANSFORMER** Picture: Page 54 As depicted in the picture, the Main transformer is a 500KVA step up transformer.
11	**GENERATORS** 2-175KVA 1-90KVA
12	**GENERATOR SHACK** Pictures: Page 36, 37 Electrical Measurements on Mar. 1st, 2012 480V 124A Line A 107A Line B 114A Line C At an average of 115 amps per line, the generator is loaded to approx. 55% of full capacity.
13	**BOOSTER PUMP STATION** Pictures: Page 5 to 14 The Three 75KVA, 4160 to 480V Transformers have been disconnected from the 4160 Volt High Voltage line by The two transformers pictured in the booster pump station shack have been removed and are being stored inside the main garage next to the generators.
14	**VICTORIA CREEK WELLHOUSE** Pictures: Page 62 to 77 As depicted in the pictures, the transformer at the Victoria Creek Pump house is a 30KVA, 480 to 120/208 volt Electrical Measurements on Mar. 1st, 2012 476 volts Incoming 6.4A Line A 15.5A Line B 16.7A Line C 117/204 volts to Panel 21.8A Line A 17.0A Line B 19.9A Line C Note: Measurements taken without pump running. At close to seven KVA load, this transformer is loaded to approx. 23% of full capacity.
15	Pictures: Page 32 to 35
16	**TAILINGS POND** Picture: Page 61 As depicted in the picture, the transformer at the Tailings Pond Shack is a 30KVA, 480 to 120/208 volt Electrical Measurements on Feb. 29th, 2012... 470 volts Incoming 4.7A Line A 3.0A Line B 3.2A Line C 117/204 volts to Panel 11.9A Line A 10.5A Line B 2.8A Line C At just over sixteen KVA load, this transformer is loaded to approx. 54% of full capacity.
17	**SEEPAGE POND** Pictures: Page 58 to 60 As depicted in the pictures, the transformer at the Seepage Pond Shack is a 45KVA, AUTOTRANSFORMER 480 to 240 volt. The Center Tap of this transformer has been field grounded to provide single phase power to several loads at the seepage pond. Electrical Measurements on Feb. 29th, 2012 465 volts Incoming 12.7A Line A 16.0A Line B 22.3A Line C 134/230 volts to Panel 25.7A Line A 32.5A Line B 40.9A Line C At just over thirteen KVA load, this transformer is loaded to approx. 30% of full capacity.

NOTES:
1. SOURCE: ARCRITE NORTHERN LTD. (2012).
2. REFER TO DRAWING D038 FOR LOCATION OF DESCRIPTIONS.
3. REFER TO ARCRITE NORTHERN LTD. (2012) FOR PICTURES REFERENCED.

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

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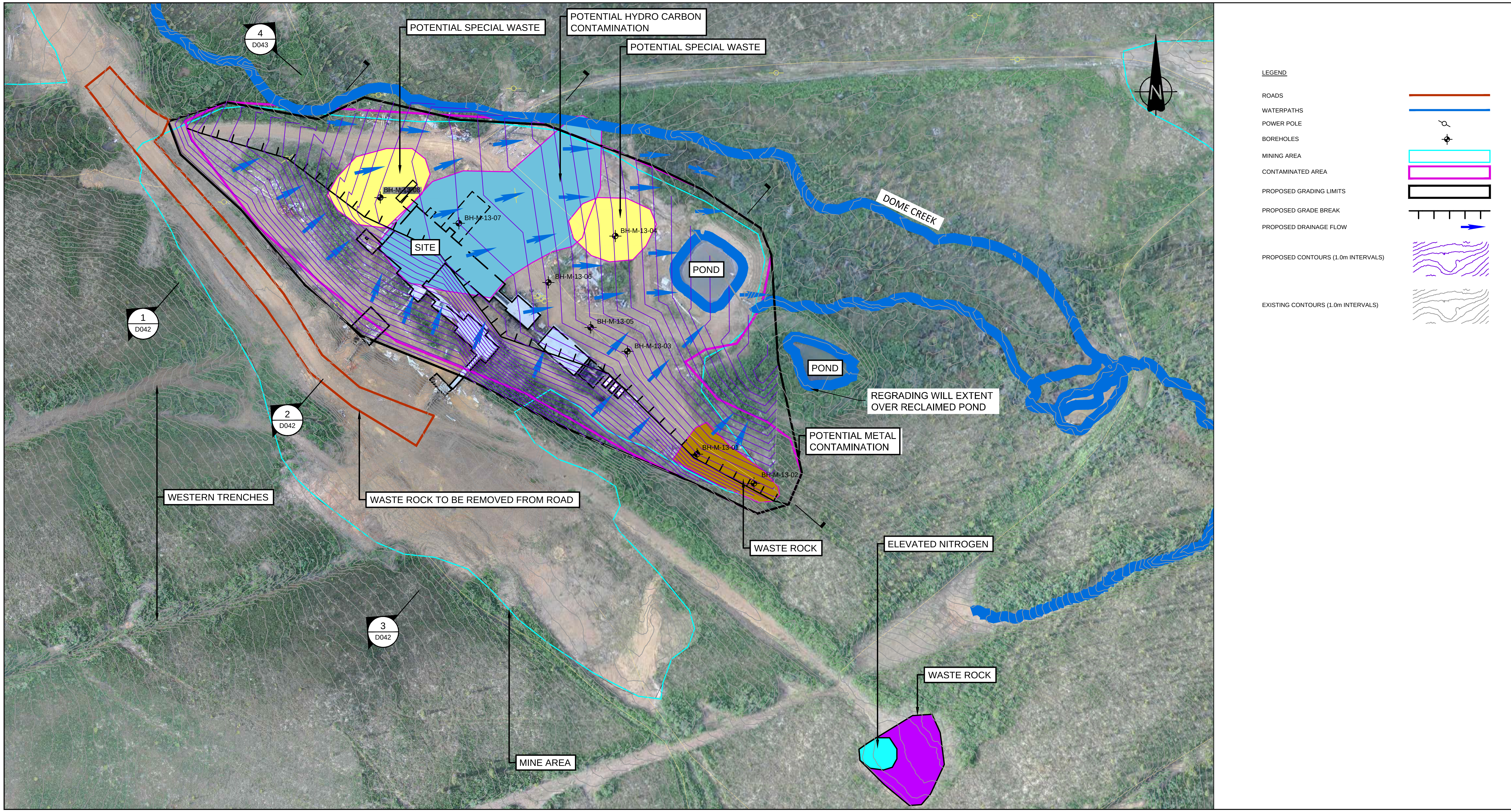
Energy, Mines and Resources
Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D040

30% DESIGN PHASE REPORT

ELECTRICAL POWER DISTRIBUTION DESCRIPTIONS

MARCH 25, 2014



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

Energy, Mines and Resources
Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D041

30% DESIGN PHASE REPORT

SITE GRADING PLAN

0m 20 40 60 80
SCALE (m)

MARCH 25, 2014

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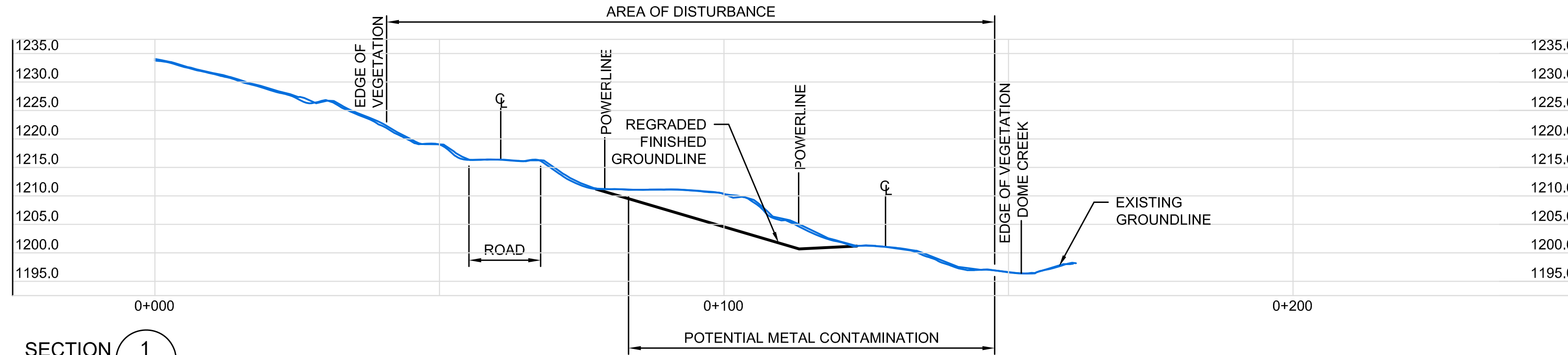
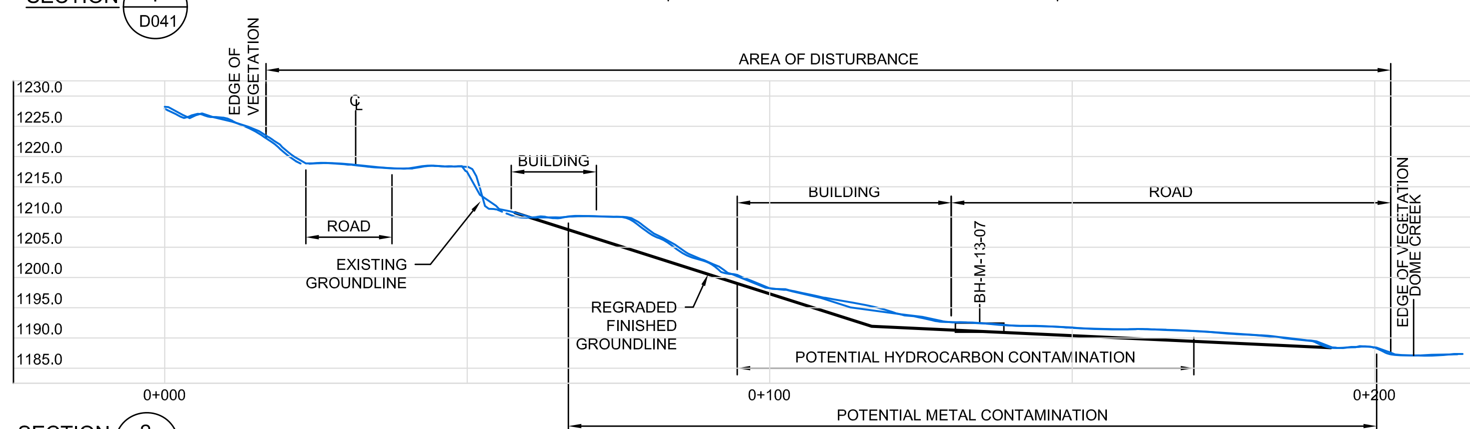
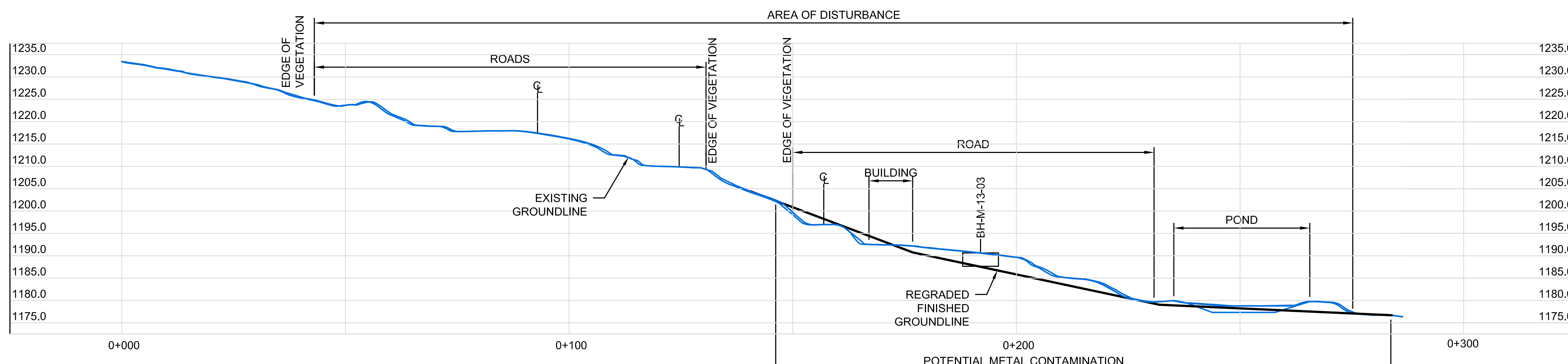


SECTION 1 D041



SECTION 2 D041



SECTION 3 D041

NOTE:
ELEVATIONS AND DISTANCES ARE IN METERS UNLESS OTHERWISE SHOWN

Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

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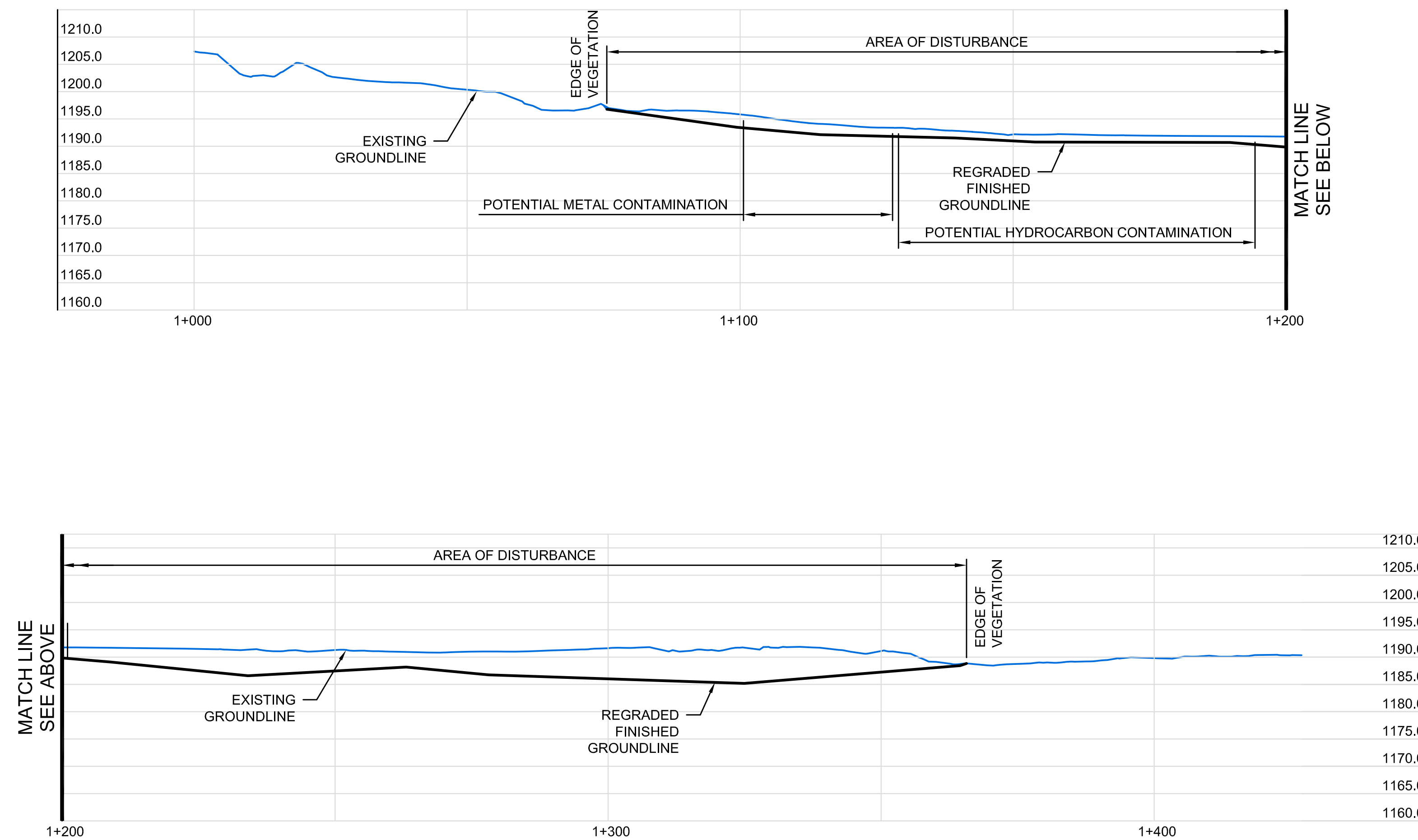
MOUNT NANSEN REMEDIATION PROJECT
Drawing D042

30% DESIGN PHASE REPORT

MILL REGRADING SECTIONS

0m 10 20 30 40 50
SCALE (m)

MARCH 25, 2014



SECTION 4 / D041

NOTE:
ELEVATIONS AND DISTANCES ARE IN METERS UNLESS OTHERWISE SHOWN

Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

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MOUNT NANSEN REMEDIATION PROJECT
Drawing D043

30% DESIGN PHASE REPORT

MILL REGRADING SECTIONS

0m 10 20 30 40 50
SCALE (m)

MARCH 25, 2014

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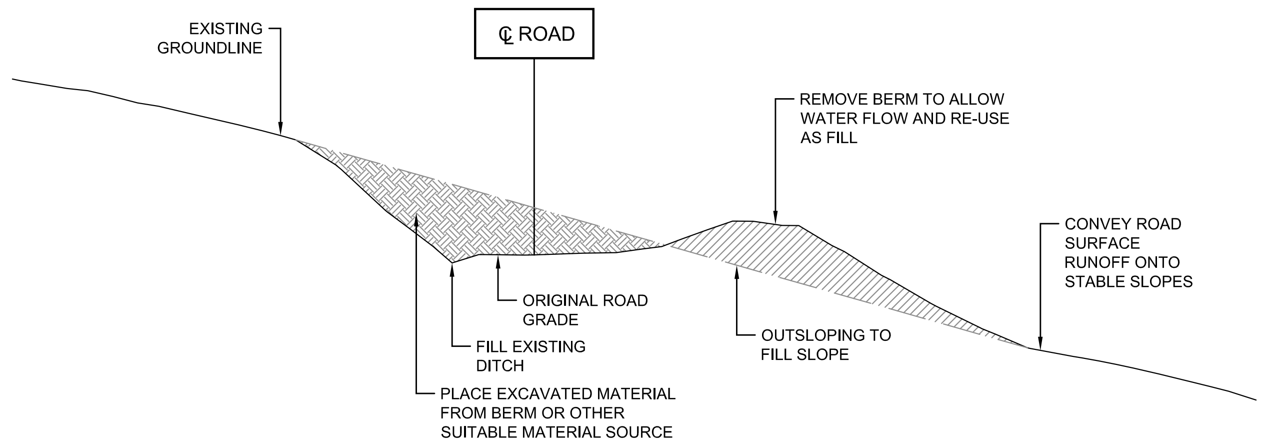
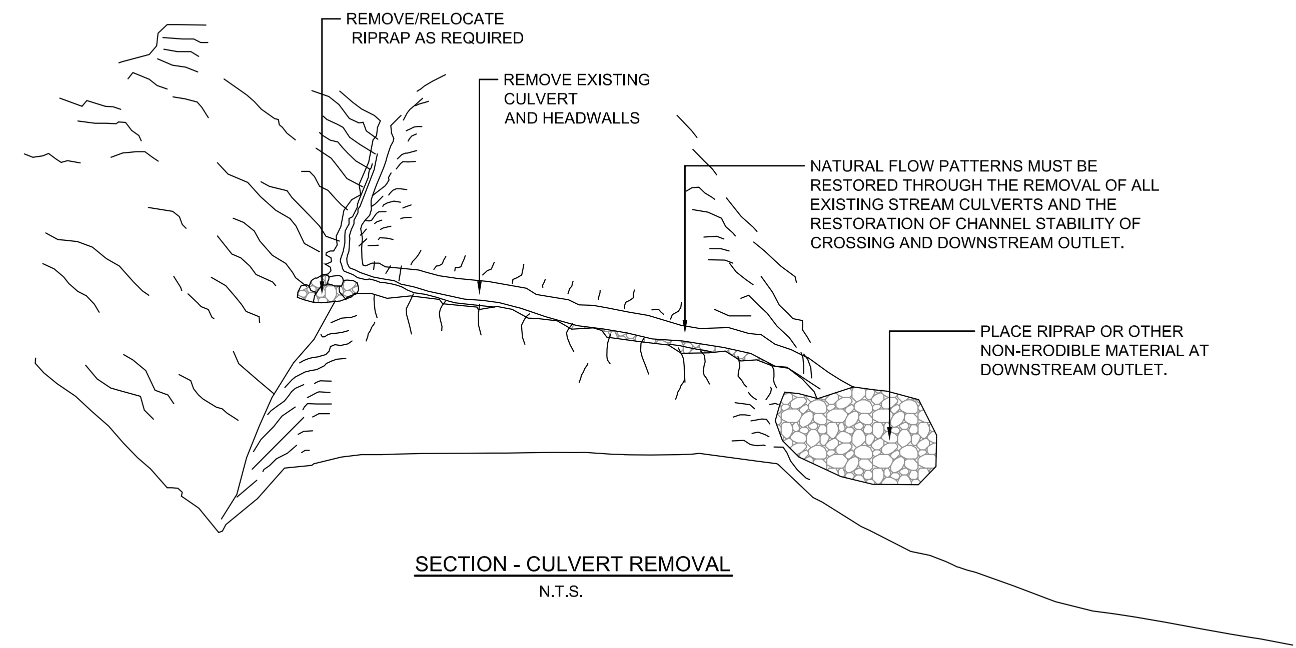


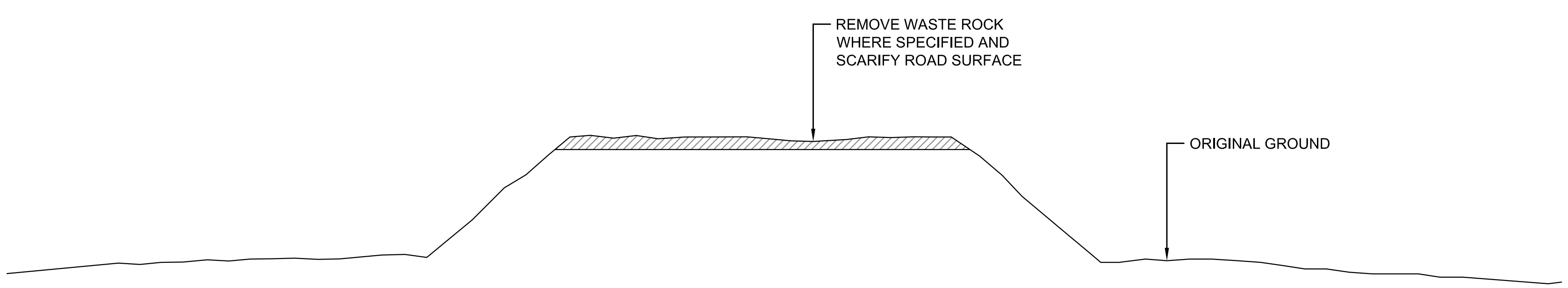
SECTION - ROAD DEACTIVATION OUTSLOPED ROADS

N.T.S.



SECTION - CULVERT REMOVAL

N.T.S.



SECTION - ROAD DEACTIVATION ROADS IN FILL CONDITION

N.T.S.

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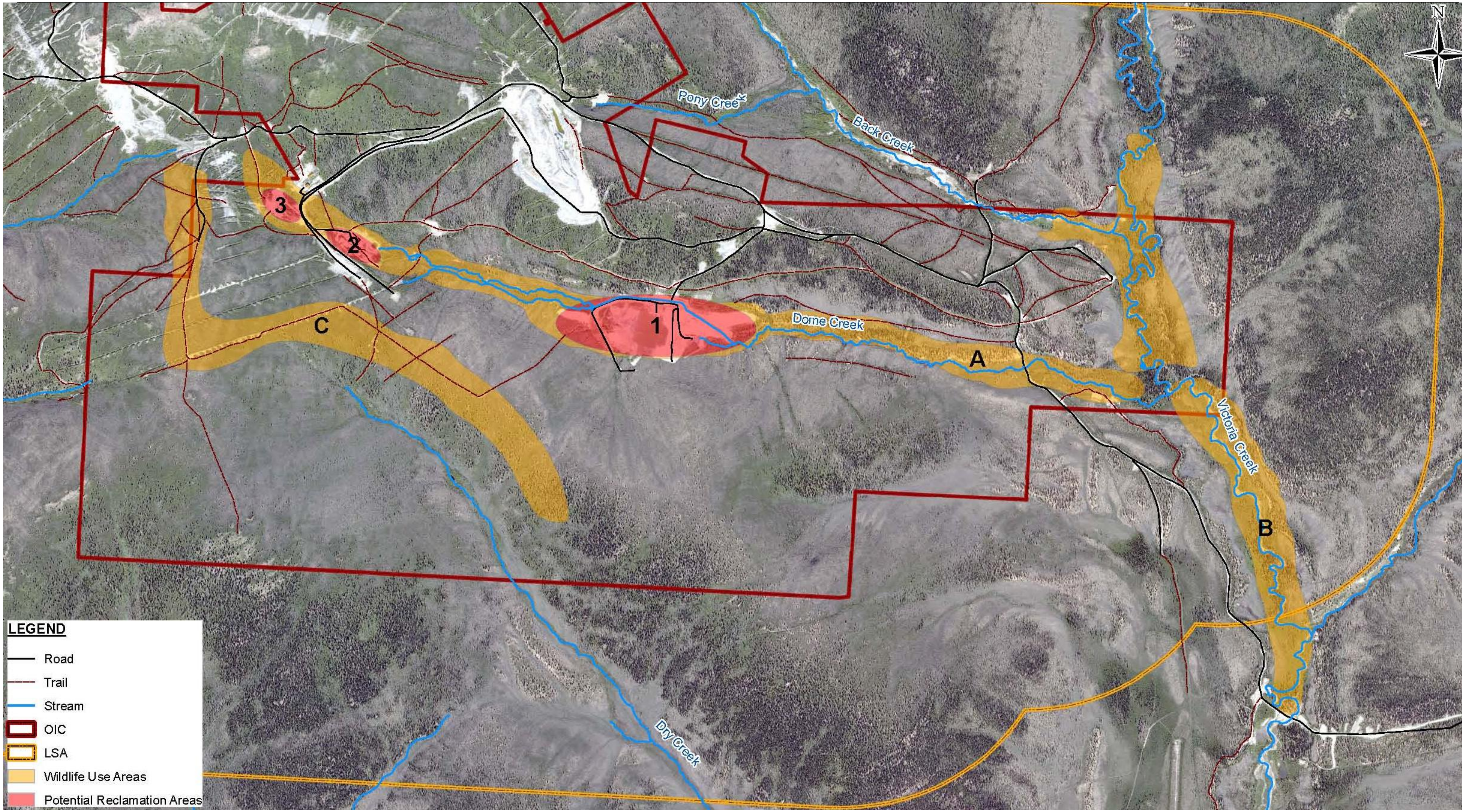
MOUNT NANSEN REMEDIATION PROJECT
Drawing D044

30% DESIGN PHASE REPORT

SITE
TYPICAL ROAD AND CULVERT DEACTIVATION

MARCH 25, 2014



Data Source

1. Map and spatial layers developed by Ecological Logistics and Research Ltd.
2. NTS Mapsheet: 115I03.
3. 2013 Pleiades imagery provided by YG AAM.
4. Roads, trails, streams and infrastructure area digitized using 2008 Quickbird imagery (courtesy of Yukon Geomatics) and spatial data provided by Yukon Government, Assessment and Abandoned Mines Branch (YG AAM).

Datum: NAD 1983 CSRS UTM Zone 8N

Legend

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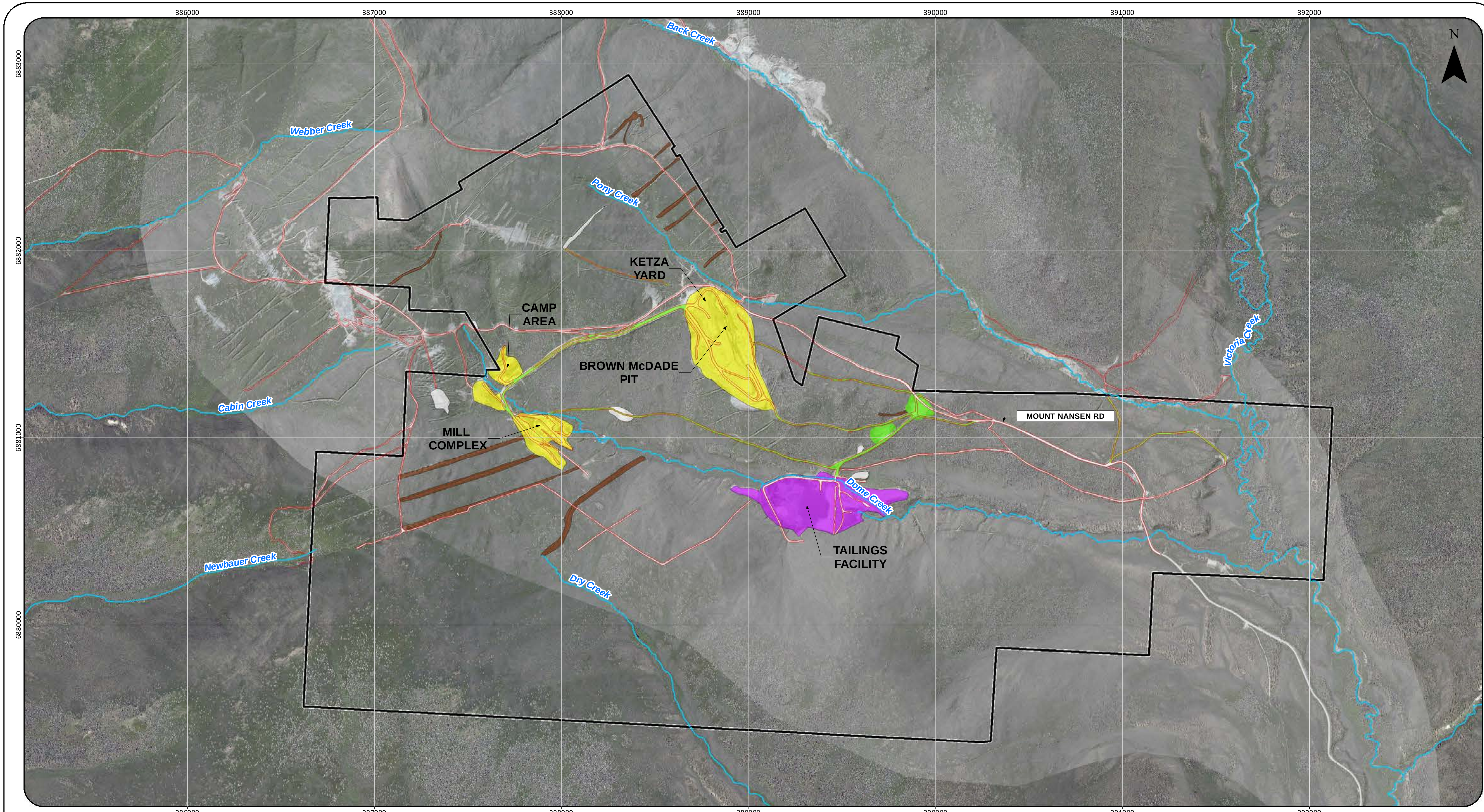
MOUNT NANSEN REMEDIATION PROJECT
Drawing D045

30% Design Phase Report

Wildlife Use Areas

Meters
0 100 200 400 600 800



Data Source:

Roads, trails, streams, waterbodies, watercourses and infrastructure areas digitized using 2008 Quickbird imagery (courtesy of Yukon Geomatics) and spatial data provided by Yukon government.

Heli LIDAR Data Survey and Imagery, 2012
Pleiades Satellite Imagery, 2013

Datum: NAD 1983 CSRS UTM Zone 8N

Legend

Reclamation Treatment Intensity

- Null
- High
- Moderate
- Low
- Trenches Proposed for Treatment

- Order in Council Boundary
- Roads
- Streams

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Yukon Energy, Mines and Resources Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D046

30% DESIGN PHASE REPORT

CONCEPTUAL LANDSCAPE STRATIFICATION FOR RECLAMATION

Scale 1:20,000
Metres
0 500 1,000

March 25, 2014

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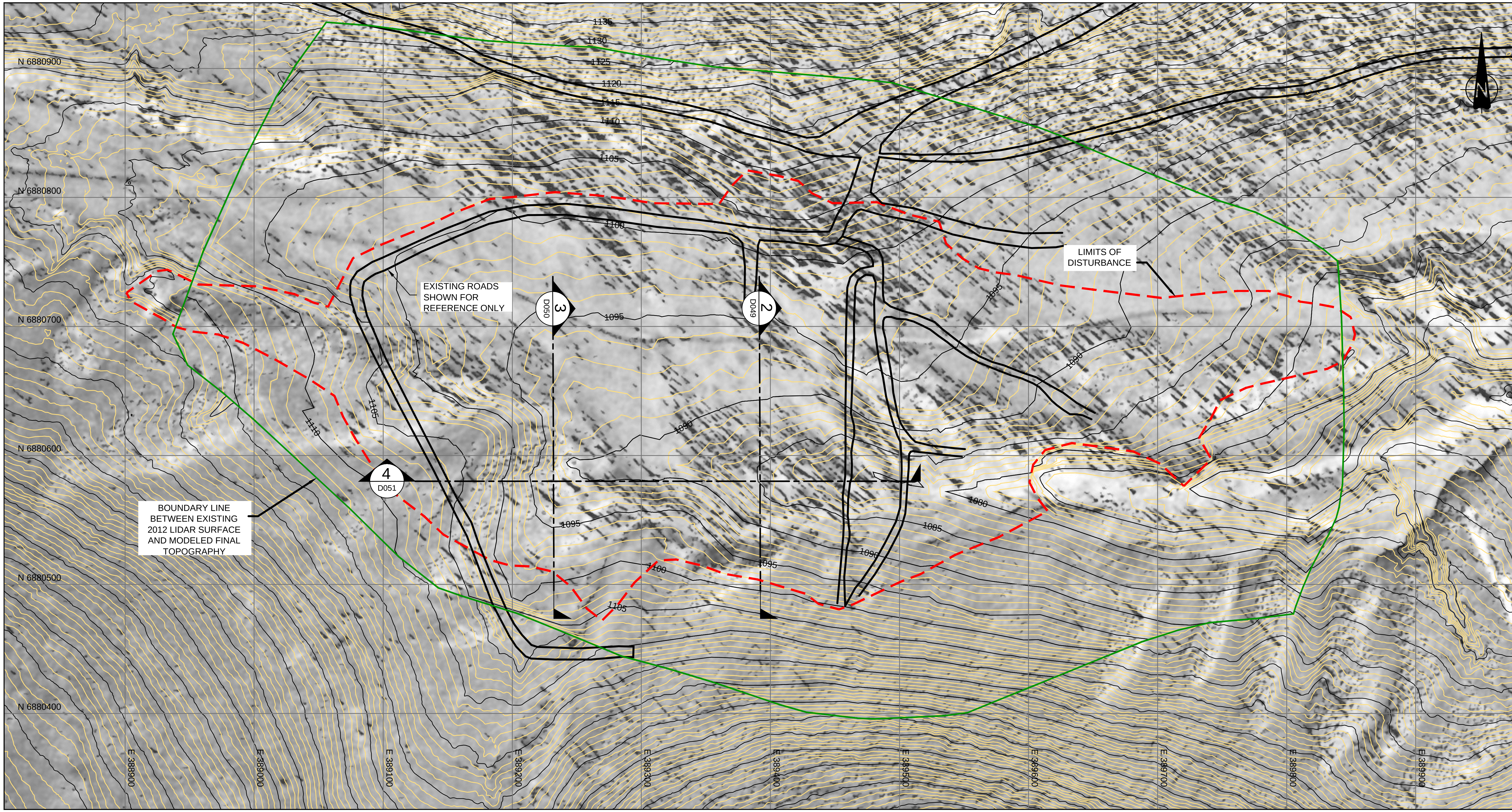

Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

AERIAL IMAGE SOURCE: AIRPHOTO A21285-113 (1969)

MOUNT NANSEN REMEDIATION PROJECT
Drawing D047

30% DESIGN PHASE REPORT

FINAL REGRADING
TAILINGS FACILITY

0m 30 60 90 120
SCALE (m)

MARCH 25, 2014

Yukon Energy, Mines and Resources Assessment and Abandoned Mines

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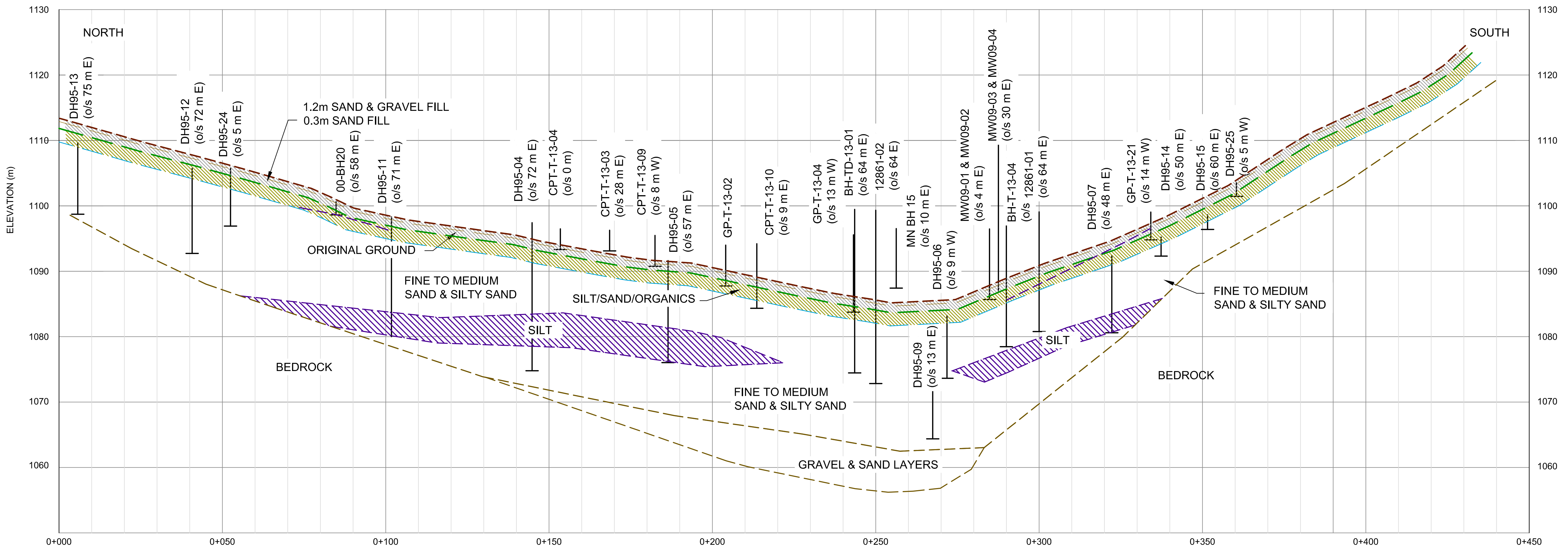

SECTION 2 - TAILINGS

(2 TIMES VERTICAL EXAGGERATION)

NOTES:

1. SUBSURFACE CONDITIONS ARE GENERALIZED FROM BOREHOLE INFORMATION.

LEGEND

- FINAL SURFACE
- PERMAFROST
- ORIGINAL GROUND
- EXCAVATED SURFACE
- BEDROCK SURFACE
- SILT /SAND/ORGANICS
- FREE DRAINING GRANULAR FILL
- SILT

Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

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MOUNT NANSEN REMEDIATION PROJECT
Drawing D048

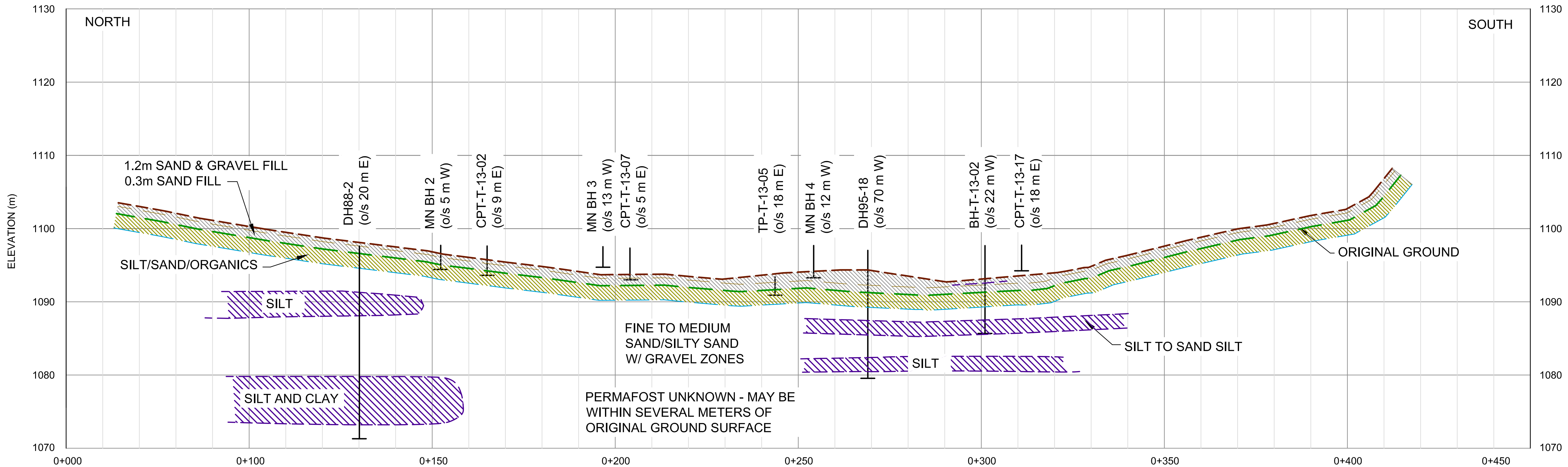
30% DESIGN PHASE REPORT

TAILINGS AREA AFTER TAILINGS REMOVAL AND SLOPE STABILIZATION SECTION 2

0m 10 20 30 40 50
HORIZONTAL (m)
0m 5 10 15 20 25
VERTICAL (m)

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\D 048,049,050.dwg – SECTION 1 & 2 – Mar. 25, 2014 3:46pm – yuan.chen



SECTION 3 - TAILINGS

(2 TIMES VERTICAL EXAGGERATION)

NOTES:

1. SUBSURFACE CONDITIONS ARE GENERALIZED FROM BOREHOLE INFORMATION.

LEGEND

- FINAL SURFACE
- PERMAFROST
- ORIGINAL GROUND
- EXCAVATED SURFACE
- BEDROCK SURFACE
- SILT /SAND/ORGANICS
- FREE DRAINING GRANULAR FILL
- SILT

Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

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MOUNT NANSEN REMEDIATION PROJECT
Drawing D049

30% DESIGN PHASE REPORT

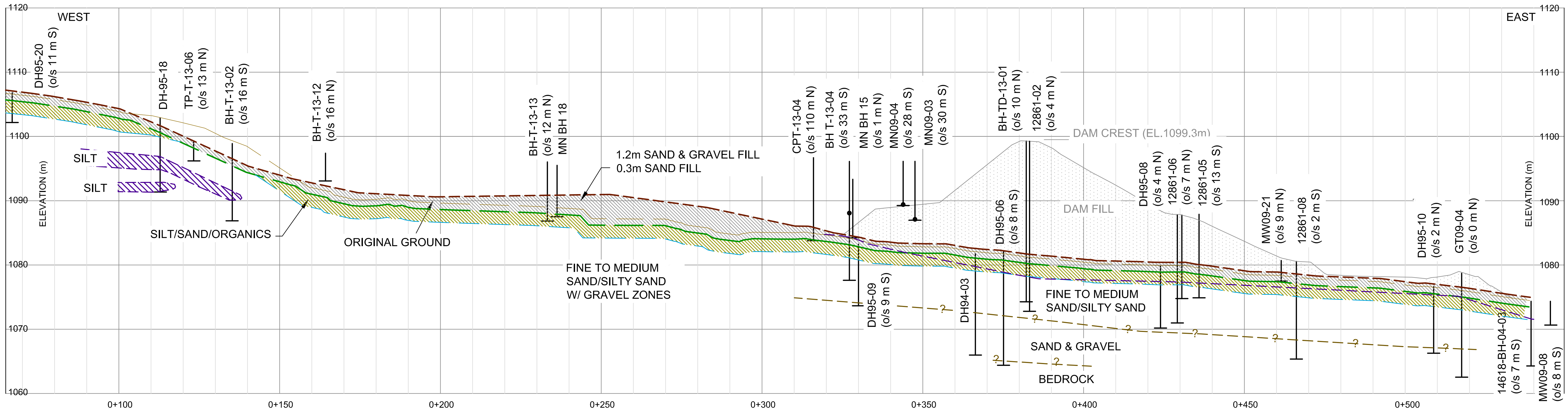
TAILINGS AREA AFTER TAILINGS REMOVAL AND SLOPE STABILIZATION SECTION 3

0m 10 20 30 40 50
HORIZONTAL (m)

0m 5 10 15 20 25
VERTICAL (m)

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\D 048,049,050.dwg – D 049 – Mar. 25, 2014 9:13pm – yuan.chen



SECTION 4 - TAILINGS

(2 TIMES VERTICAL EXAGGERATION)

NOTES:

1. SUBSURFACE CONDITIONS ARE GENERALIZED FROM BOREHOLE INFORMATION.

LEGEND

- FINAL SURFACE
- PERMAFROST
- ORIGINAL GROUND
- EXCAVATED SURFACE
- BEDROCK SURFACE
- SILT /SAND/ORGANICS
- FREE DRAINING GRANULAR FILL
- SILT

Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

amec

Yukon Energy, Mines and Resources Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D050

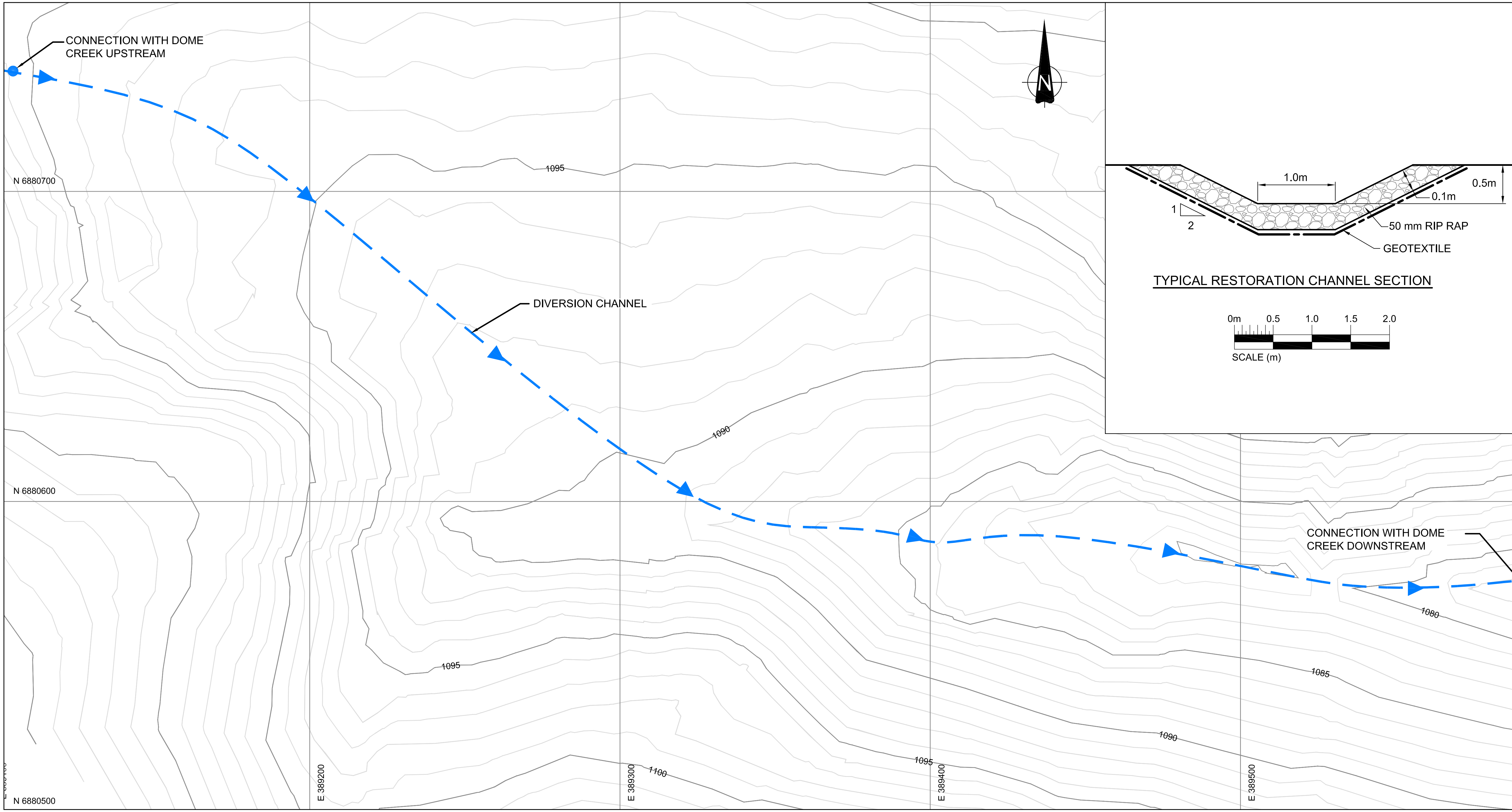
30% DESIGN PHASE REPORT

TAILINGS AREA AFTER TAILINGS REMOVAL AND SLOPE STABILIZATION SECTION 4

0m 10 20 30 40 50
HORIZONTAL (m)

0m 5 10 15 20 25
VERTICAL (m)

MARCH 25, 2014



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

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Yukon Energy, Mines and Resources Assessment and Abandoned Mines

MOUNT NANSEN REMEDIATION PROJECT
Drawing D051

30% DESIGN PHASE REPORT

DOME CREEK CHANNEL RECONSTRUCTION PLAN AND TYPICAL SECTION

0m 10 20 30 40 50
SCALE (m)

MARCH 25, 2014

S:\PROJECTS\VM00605 – Mount Nansen\Drawings\2014 Design Drawings\D 051.dwg – Layout1 – Mar. 26, 2014 12:45pm – yuan.chen

Appendix A – Stability and Seismic Design Criteria for Mount Nansen

Target Factors of Safety

The factors of safety selected for design purposes that are presented in Table A.1 below are consistent with standard geotechnical engineering practice for the analysis methods being used and with recommendations in the Mined Rock Overburden Pile Investigation and Design Manual (Piteau, 1991[1]).

Table A.1: Design Factor of Safety for Stability Analyses

Condition	Analysis Method	Minimum Factor of Safety
Short Term / End of Construction	Limit Equilibrium	1.3
Long Term	Limit Equilibrium	1.5
Earthquake	Liquefaction Triggering per EERI / NCEER methods	1.1
	Pseudo Static	1.1, if <1 requires deformation analyses
	Deformation (closed form, e.g. Bray and Tavasarou)	n/a – limit deformations to tolerable amount based on structure and consequence
Post Earthquake / Static Liquefaction	Limit Equilibrium	1.1

For short term and immediate post closure considerations, the potential for excess pore pressures caused by thawing permafrost are considered in situations where this is a possibility. This short term consideration is not combined with earthquake loading due to the low probability of both events occurring at the same time.

Seismic Design Parameters for Mount Nansen

The selection of seismic design parameters for any project depends on an evaluation of risk, consequence and cost. Only the most critical structures whose failure constitutes an extreme consequence are designed for the maximum credible ground motions, all other situations are designed for lesser ground motions and earthquake magnitudes. The backfilled Open Pit is essentially a waste dump structure. The concept of using consequence to determine the appropriate design criteria and parameters is included in the Mined Rock Overburden Pile Investigation and Design Manual. The guidelines present a method to assess the stability rating of a dump but do not provide a quantitative method for determining the appropriate design earthquake. Guidance for the selection of design earthquake was, therefore, sought in other guideline documents including the Canadian Dam Safety guidelines and the National Building Code of Canada, both of which present design earthquake return periods based on the consequence of failure (refer to the appended table). For the remediated Mount Nansen site, neither the Canadian Dam Safety Guidelines nor the National Building Code are strictly applicable since there are no buildings or dams remaining onsite. However, the guidance provided by these documents can be applied to the site with respect to selecting appropriate seismic parameters.

In the reclaimed Dome Creek Valley, slope movement as a result of earthquake activity will have a low consequence. There will be no contaminated materials so movement of the reclaimed slopes would have a similar consequence as movement of the undisturbed slopes. Consequences would likely include potential changes to the flow or path of Dome Creek and potentially elevated sediment loading or erosion as a result

[1] Piteau Associates Engineer Ltd. 1991, *Mined Rock and Overburden Piles Investigation and Design Manual Interim Guidelines.* Prepared for the British Columbia Mine Dump Committee, British Columbia Mine Waster Rock Pile Research Committee, May 1991.

local slumps. The reclaimed Dome Creek Valley is consistent with low to significant consequence structures which correspond to earthquake return periods of 1 in 500 and 1 in 1000 years respectively. It is, therefore, proposed that the reclaimed slopes in Dome Creek Valley be designed for an earthquake with a return period of 1 in 1,000.

The backfilled Open Pit will form a ridge in the final landscape. Within the ridge there will be soils with elevated metals concentrations stored above ground beneath a low permeability liner. Movement of the slopes would cause cracking and potentially compromise the cover which would increase infiltration and potentially result in reduced water quality. Significant movement could potentially result in some of the materials ending up in Pony Creek affecting water quality. Both of these scenarios can be mitigated through maintenance. Failure of the backfilled Open Pit is considered to be of significant to high consequence which corresponds to earthquake return periods of 1 in 1,000 years and 1 in 2,500 years, respectively. It is, therefore, proposed that the design earthquake for the backfilled Open Pit be designed for a 1 in 2,500 year earthquake event. This value is greater than the typical design earthquake mentioned in the Waste Pile design manual of 1 in 475. In the next phase of design, the manual can be used to assess the stability rating of the backfilled pit and perhaps reduced the design earthquake.

The peak ground accelerations (PGA) associated with these events as calculated using the National Building Code probabilistic hazard assessment tool are summarized in the table below. The PGAs are for a site class "C" which a site in which the upper 30 m of soil has an average shear wave velocity between 360 and 760 m/s (Finn and Wightman, 2003[2]). Cone penetration test results in the Dome Creek valley indicated shear wave velocities of typically in the 250 to 300 m/s range near surface. With depth the material becomes gravelly and frozen with high shear wave velocity. Site Class C is considered appropriate for the Dome Creek Valley. For areas outside the valleys, the overburden thickness is small and conditions would be that of a rock site class B to A. The correction factors that should be applied to PGA for site class are summarized in Table A.3.

Table A.2: PGAs for Mount Nansen Site from the 2010 National Building Code Hazard Assessment

Return Period (years)	2,475	1,000	475	100
PGA (g)	0.11	0.079	0.06	0.034

Source: 2010 National Building Code Seismic Hazard Calculator (http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/ index_2010-eng.php).

[2] Finn and Wightman (2003). Ground Motion Amplification Factors for the Proposed 2005 Edition of the National Building Code of Canada, Canadian Journal of Civil Engineering, Volume 30, pp 272-278.

Table A.3: PGA Factors for Site Class

Site Class	Factor for Peak Ground Acceleration ($PGA=PGA_{SiteClassC} x F_{PGA}$)				
	PGA≤0.1g	PGA≤0.2g	PGA≤0.3g	PGA≤0.4g	PGA≤0.5g
A	0.7	0.7	0.8	0.8	0.8
B	0.8	0.8	0.9	1.0	1.0
C	1.0	1.0	1.0	1.0	1.0
D	1.3	1.2	1.1	1.1	1.0
E	2.1	1.4	1.1	0.9	0.9
F	a	a	a	a	a

Notes:

Use straight line interpolation for intermediate values of PGA, where PGA is the peak ground acceleration obtained from the ground motion maps.

a = Site-specific geotechnical investigation and dynamic site response analyses shall be performed.

Probabilistic analyses are an aggregation of all possible earthquakes that could cause ground motions at the site. It is therefore not associated with a specific earthquake magnitude. An assumption of earthquake magnitude associated with the PGA is required to assess the potential for liquefaction. This can be done through deaggregation assessment; however, given the current design stage and because earthquake induced liquefaction is only a concern for the reclaimed Dome Creek where the consequences of failure are low, it is not considered warranted. Rather an estimate of an appropriate design earthquake magnitude is based on published data and previous analysis done for the site.

In 2000, the maximum design earthquake (MDE) was assessed for Mount Nansen based on both probabilistic and deterministic assessments. The 2002 probabilistic MDE was a PGA of 0.27 g caused by a near field earthquake with a magnitude of 7.5 (EBA, 2002[3]). It was not clear upon what basis the near field earthquake magnitude was selected, but is considered overly conservative, particularly for a closure scenario that does not include a dam. The 2000 deterministic assessment is summarized in Table A.4 below. Given this information, the PGAs presented in Table A.2 must be associated with local earthquakes and the magnitudes of the local earthquakes associated with the lower return periods should have a magnitude less than 7.5. Figure A.1 shows the historical earthquakes near Mount Nansen. The lack of historical seismicity does not, however, indicate that there is no risk of significant earthquakes in the future. Various publications have suggested that minimum earthquake magnitudes of 5 to 6 are applicable for areas with low historic seismicity. For the Mount Nansen site, for the return periods being considered in the current analysis, a near field earthquake magnitude 6.5 is considered to be appropriately conservative.

Based on the above consideration, the seismic parameters summarized in Table A.5 below are proposed for design.

[3] EBA Consulting Engineers Ltd. (EBA) (2002). Dam Safety Assessment, Mount Nansen Tailings Facility near Carmacks, YT, Project number 0201-00-14618, May 2002.

Table A.4: 2002 Deterministic Assessment of Seismic Hazard at Mount Nansen

Fault	Distance to Site (km)	Maximum Magnitude	PGA (g)
Fairweather	254	8.7	0.131
Denali	125	7.3	0.125
Tintina	132	7.3	0.117

Source – Bird, 2002

Table A.5: Seismic Design Parameters for Mount Nansen

Location	Earthquake Return Period	PGA	Site Class Correction Factor	Magnitude
Dome Creek	1:1,000	0.08	C = 1.0	6.5
Ridgetop	1:2,500	0.11	B = 0.8	6.5

Figure A.1: Historic Earthquakes Near Mount Nansen

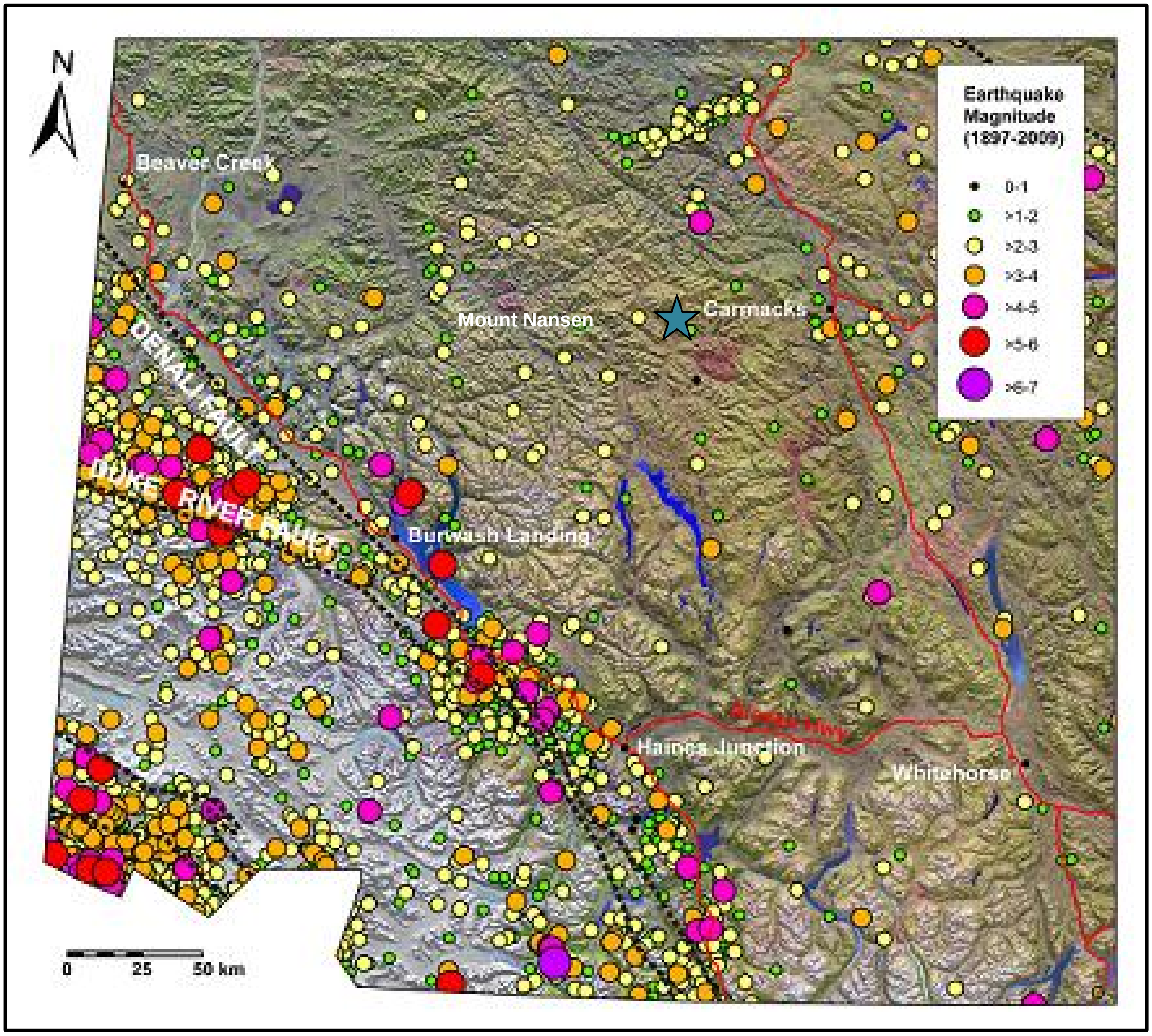

Table A.6: Suggested Design Earthquake Levels from the Canadian Dam Safety Guidelines

Classification	Population at Risk	Loss of Life	Environmental and Cultural Values	Infrastructure and Economics	Earthquake Design Ground Motion
Low	None	0	Minimal short term loss No long-term loss	Low economic losses; area contains limited infrastructure or services	1/500
Significant	Temporary Only	Unspecified	No significant loss or deterioration of fish or wildlife habitat Loss of marginal habitat only Restoration or compensation in kind highly possible	Losses to recreational facilities, seasonal workplaces and infrequently used transportation routes	1/1000
High	Permanent	10 or fewer	Significant loss or deterioration of important fish or wildlife habitat Restoration or compensation in kind highly possible	High economic losses affecting infrastructure and public transportation and commercial facilities	1/,2500
Very high	Permanent	100 or fewer	Significant loss or deterioration of critical fish or wildlife habitat Restoration or compensation in kind possible but impractical	Very high economic losses affecting important infrastructure or services (e.g. highway, industrial facility, storage facilities for dangerous substances)	1/5,000
Extreme	Permanent	More than 100	Major loss of critical fish or wildlife habitat Restoration or compensation in kind impossible	Extreme losses affecting critical infrastructure or services (e.g. hospital, major industrial complex, major storage facilities for dangerous substances)	1/10,000

Source Canadian Dam Safety Guidelines Tables 2-1 and 6-1

Appendix B – Slope Stability of Backfilled Brown McDade Open Pit

MEMO

To Brian Geddes
From Shane Magnusson
Renata Wood
Tel 604-294-3811 **AMEC File No.** VM00605F
Fax 604-294-4664 **cc**
Date 24 February 2014

Subject **Mount Nansen Remediation Project**
Slope Stability of Backfilled Brown McDade Open Pit

Introduction

This memo summarizes the work performed to analyze the geotechnical slope stability of backfilled tailings and waste rock in the Brown McDade Open Pit for the Mount Nansen Remediation Project. The remediation concept entails relocating the tailings from the tailings facility and the waste rock from the nearby waste rock area into the Open Pit. Waste rock would be placed at the bottom of the pit, with tailings above it, and additional waste rock on top of the tailings.

The following sections present the results of the preliminary limit equilibrium stability analyses completed in support of the preliminary design of the pit backfill. Stability analyses were carried out for a variety of geometric configurations and material properties to assess the sensitivity of the parameters and to bracket a wide range of potential conditions. During later stages of design, the likelihood of the various scenarios should be considered in more detail. Stability analyses can then be refined and carried out for additional sections of interest.

Stability Model and Material parameters

General

Two-dimensional limit equilibrium stability analyses were carried out using the software SLOPE/W 2007 (Version 7.23) developed by Geo-Slope International Ltd. The Morgenstern-Price method of slices with a half-sine inter-slice force function solution was used for the stability analyses.

A feature that “optimizes” the traditional circular failure surface to make it linear and convex in shape and thereby locate a more critical failure surface was utilized in the SLOPE/W model. All Factors of Safety (FoS) reported in the following sections are for “optimized” (i.e. critical) slip surface geometries.

A number of sensitivity analyses were run and further explained the proceeding sections. The scenarios are summarized in Table 1. In general, the model is assessing the performance of the backfill and checking a number of scenarios by adjusting the following:

- The geometry, based on the material placed
- Tailings strength parameters, based on handling and dewatering parameters
- Seismic forces, typically applied to the long term condition
- Ground water table (GWT) based on assumed placed conditions and the time frame

Table 1: Summary of Analyses Used

Scenario #	Geometry	Tailings Parameter	Seismic	GWT (m)	Condition
1	A: Flat 1209 m	C/P' = 0.1	no	1209	Short Term
2	B: Flat 1204 m	C/P' = 0.1	no	1204	Short Term
3	C: Shear Key	C/P' = 0.1	no	1209	Short Term
4	C: Shear Key	phi=25	no	1190	Long Term
5	C: Shear Key	phi=25	0.11 g	1190	Long Term with Seismic
6	C: Shear Key	C/P' = 0.1	0.11 g	1209	Short Term with Seismic
7	D: Co-Disposal	phi=27	no	1209	Short Term
8	D: Co-Disposal	phi=27	0.11 g	1209	Short Term with Seismic
9	D: Co-Disposal	phi=27	no	1190	Long Term
10	D: Co-Disposal	phi=27	0.11 g	1190	Long Term with Seismic
11	D: Co-Disposal	phi=25	no	1190	Long Term
12	D: Co-Disposal	phi=25	0.11 g	1190	Long Term with Seismic

Model Geometry

The model geometry consists of the existing Brown McDade Open Pit filled with 4 different tailings backfill arrangements. A single cross-section through the Brown McDade Open Pit was selected for analyses representing the maximum height of backfill, and the lowest pit rim elevation of 1209 m. The following summarizes the geometry common to the 4 tailings backfill arrangements:

- The slopes of the pit are modelled as 1H:1V (horizontal:vertical), typical of the overall slope angle of the pit without intermediate benches.
- The top cap of the backfill is modelled at 3H:1V, to a maximum elevation of 1226 m, reflecting the maximum preliminary design height of 17 m above the pit rim.
- Waste rock is located below Elev. 1190 m

The following 4 backfill arrangements were considered:

A. Geometry A has the simplest geometry consisting of tailings placed as a single mass up to the edge of the pit rim. Waste rock or waste rock and tailings is placed on a flat surface at Elev. 1209 m on top of the tailings, as shown in Figure 1. This is representative of end dumped tailings placed up to the pit rim with direct placement methods employed above this elevation.
B. Geometry B has a similar configuration to Scenario 1, but the tailings are placed up to Elev. 1204 m. This elevation was selected to satisfy the stability requirements if the tailings are placed in a loose saturated state.
C. Geometry C has a waste rock shear key modelled to improve the stability of the backfilled material if placed in a loose saturated state. Above the pit rim, tailings and waste rock are placed using direct placement methods concurrent with placement of an outer PAG shell. The geometry of the waste rock shear key is 27 m wide horizontally from the pit rim, 11 m deep below the pit rim and has slopes of 1H:1V as shown in Figure 2. The geometry of this

shear key was selected to meet the design short term factor of safety target in the worst case scenario of deposition of loose saturated tailings deposition. The width of the PAG shell was based on volume considerations, the minimum width required for stability considerations was not determined.

D. Geometry D has a higher internal elevation of tailings than the above scenarios. The main backfill material modelled in this geometry is co-disposed tailings and waste rock. The material would be deposited in layers and because of the increased volume resulting from inclusion of PAG rock the tailings unit has to rise well above the pit rim with only a relatively thin PAG shell provided on the outer surface. This model is also applicable to unsaturated tailings end dumped into the pit although the volume of tailings required above the pit may be less than shown in this scenario. The layered tailings and waste rock are placed at 3H:1V above the pit rim, with a 3 m vertically thick waste rock shell placed on the top as shown in Figure 3.

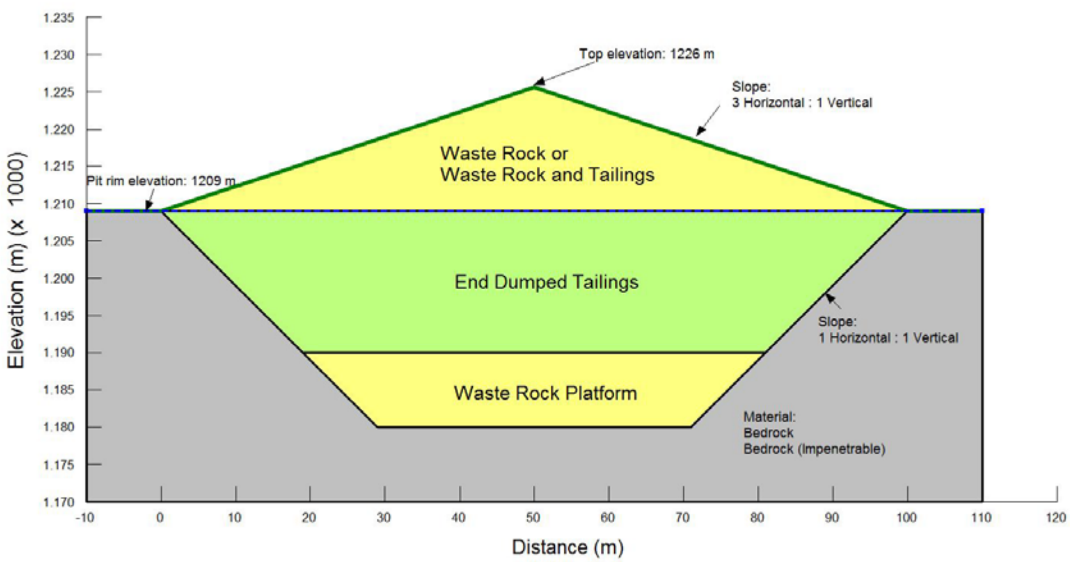

Figure 1: Model geometry A for Scenario 1.

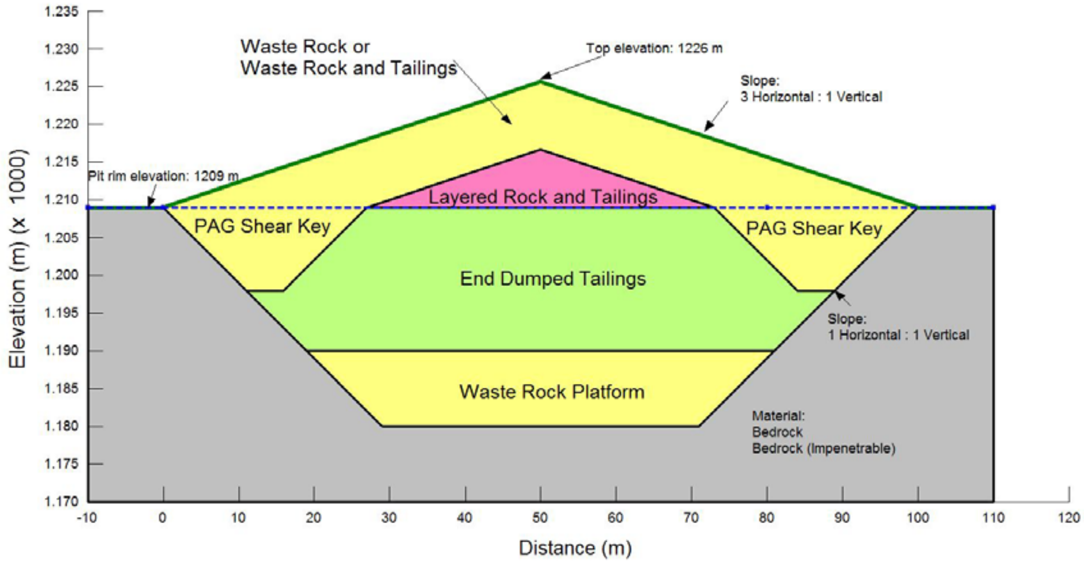

Figure 2: Model geometry C for Scenarios 3 to 6.

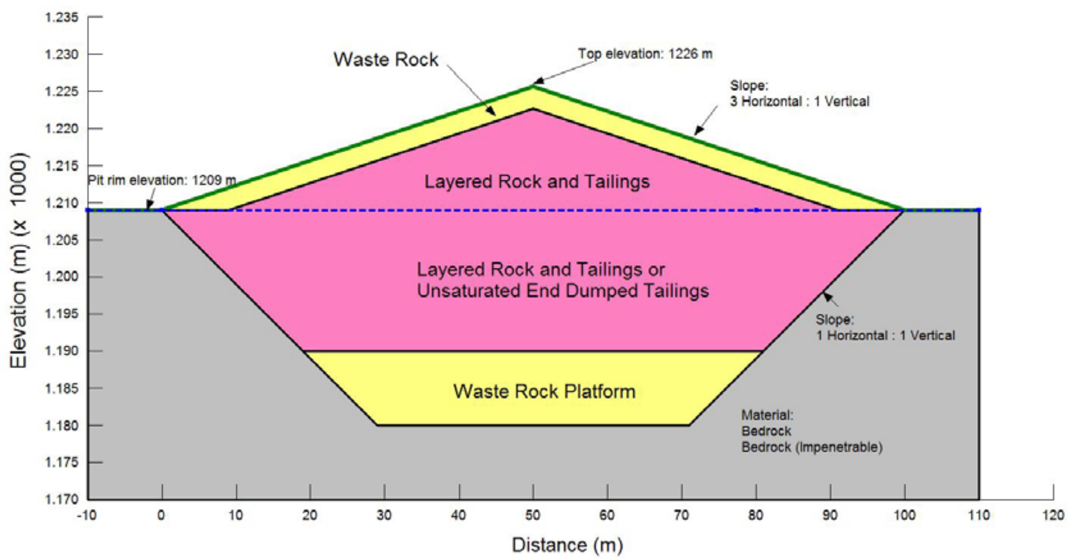

Figure 3: Model geometry D for Scenarios 7 to 12.

Material Strength Parameters

The strength parameters for waste rock and tailings used were based on typical and conservative values from previous experience with tailings design. These parameters are summarized in Table 2.

- Waste rock is the potentially acid generating (PAG) and non potentially acid generating (NAG) rock that is currently located on the periphery of the Brown McDade pit. It generally consists of gravel and sand with some boulders and cobbles, and is generally free draining with a low fines content. A friction angle of 34 degrees has been assigned to this unit.
- Undrained end dumped tailings represent tailings end dumped at high saturation in a loose state or loose tailings that become saturated as a result of poor construction practices, induced pore pressures, or high infiltration or drainage rates. It is considered unlikely that such a condition would develop over the full height of the tailings. If such conditions do develop, it would be a short term condition before the water in the pore space drains. Because loose saturated tailings are subject to static liquefaction as a result of construction loading or progressive failure, a c/p' value of 0.1 has been assigned to this unit.
- Drained or unsaturated end dumped tailings are the same physical tailings as the undrained tailings, but the water in the pore space has drained , or the material was initially placed in an unsaturated state without development of excess pore pressures. In this case, drained behaviour governs the strength of the material. A friction angle of 25° has been assigned to this unit, consistent with loose silty material.
- The co-disposal of waste rock and tailings is envisioned to be a layered deposition of tailings and waste rock. Because of the compaction imposed during construction it is assumed that the material will behave in a dilatant manner . An effective friction angle of 27° has been assigned to allow for increased strength from the PAG waste rock material and increased compactive effort as compared with the end dumped tailings.
- Bedrock is modelled as impenetrable, where no failure surface can penetrate the region.

Table 2: Material Strength Parameters for Stability Analyses

Material	Unit Weight (γ) kN/m^3	Cohesion (c') kPa	Friction Angle (ϕ°)	C/P' (unitless)
Waste Rock	19	0	34	n/a
Tailings - Undrained	18	0	n/a-	0.1
Tailings – Drained	18	0	25	n/a
Co-Disposal Waste rock and tailings	19	0	27	n/a
Bedrock	Impenetrable			

Pore Pressure Conditions

The pore pressure conditions within the backfilled pit were modelled using a piezometric surface as summarized in Table 3, and discussed below:

- Worst case short term conditions (in the order of a few years or less) assume the water table is located at the top of the tailings at Elev. 1209 m. This assumes the tailings are placed in a saturated or nearly saturated state or that the tailings temporarily saturate as drainage from overlying material passes through the unit. A phreatic surface above Elev. 1209 m is considered unlikely because of the layered construction method required above the pit rim, the increased proportion of non tailings material that will be placed in above the rim of the Open Pit and the more free draining placement conditions that exist because there is no pit confinement.
- Long term conditions assumed the water table is located at the bottom of the tailings at Elev. 1190 m. This assumes the pore water in the tailings/waste rock has drained, and the corresponding water level has lowered.
- In subsequent phases of design it may be of value to examine intermediate cases using r_u rather phreatic surfaces.

Seismic Input

Scenarios 5, 6, 8, 10 and 12 have horizontal seismic forces applied to the model to simulate pseudo-static loading. A lateral force (k_h) of 0.11 g (where g = gravitational acceleration constant of 9.81 m/s²) was applied, equal to the design earthquake peak ground acceleration (PGA) selected for the Open Pit landform. Typically the PGA is reduced by a factor of around 0.5 in pseudo static analyses except where extremely brittle materials are present. As a starting point for the preliminary assessment the full PGA was applied and given the high calculated factors of safety with these values, no further refinements were made. A high factor of safety with k_h = PGA indicates small displacements under the design seismic loading event.

Stability Requirements

Minimum Factor of Safety (FOS) criteria for design is as follows per the project design criteria:

- FOS > 1.5 for long-term steady state conditions
- FOS > 1.3 for short-term conditions
- FOS > 1.1 for seismic conditions

Stability Analysis Results

The stability scenarios analyzed are summarized in Table 3, and shown graphically in Figure 4 to Figure 15.

Table 3: Summary of Results

Scenario #	Geometry	Tailings Parameter	Seismic	GWT (m)	Condition Approximated in Model	FoS
1	A: Flat 1209 m	C/P' = 0.1	no	1209	Worst Case saturated end dumped, Short Term	0.7
2	B: Flat 1204 m	C/P' = 0.1	no	1204	Worst Case saturated end dumped with limited elevation for tailings placement, Short Term	1.3
3	C: Shear Key	C/P' = 0.1	no	1209	Worst Case saturated end dumped with stabilization measures, Short Term	1.3
4		phi=25	no	1190	Short term unsaturated end dump and/or Long Term end dump	1.9
5		phi=25	0.11 g	1190	Short term unsaturated end dump and/or Long Term end dump with Seismic	1.6
6		C/P' = 0.1	0.11 g	1209	Worst Case saturated end dumped with limited elevation for tailings placement, Short Term with Seismic	1
7	D: Tailings above pit rim without shear key and thin PAG cover	phi=27	no	1209	Worst case direct placement in layers, Short Term	1.6
8		phi=27	0.11 g	1209	Worst case direct placement in layers, Short Term with Seismic	1.2
9		phi=27	no	1190	Short term unsaturated direct placement and Long Term direct placement	1.7
10		phi=27	0.11 g	1190	Short term unsaturated direct placement and Long Term direct placement with Seismic	1.3
11		phi=25	no	1190	Short term unsaturated end dump and long Term	1.6
12		phi=25	0.11 g	1190	Short term unsaturated end dump and Long Term with Seismic	1.1

- Scenario 1 is not stable. Loose saturated tailings therefore cannot be filled to the pit rim and covered with waste rock.
- To meet the short term factor of safety criteria with backfill rising as shown in the modelled configuration, the maximum elevation of saturated loose tailings is 1204 m (5 m below the pit rim). Limiting the tailings to a depth of 5 m below the pit rim does not provide sufficient capacity for tailings storage however unless increased heights of tailings can be placed elsewhere in the pit which would require buttressing.
- A shear key was added in Scenario 3 to provide a configuration that meets the target short term factor of safety with saturated loose tailings deposition. Tailings can then rise above the pit rim via direct placement methods to increase the available tailings storage. The PAG waste rock shell contributes to the stability of the configuration but its thickness was not determined based on stability requirements. With the end dump deposition the ratio of tailings to PAG in the end dump material is low so that a shell of PAG waste rock must be placed above the tailings to provide adequate storage volume. The influence of the PAG

waste rock shell thickness on stability can be examined in more detail in subsequent design phases to determine a minimum required thickness.

- The shear key configuration provides calculated target factors of safety for the worst case short term conditions of statically liquefied tailings that meet the design criteria. This configuration would only be necessary if there is a threat that loose saturated tailings could exist at the elevations modelled.
- The long term conditions with drained loose tailings below the pit rim and tailings and/or PAG rock rising above the pit rim as modelled meet the design criteria factors of safety and do not require a shear key (i.e. scenarios 11, 12).
- If end dumped tailings are placed in an unsaturated state the calculated factors of safety exceed the factor of safety criteria for all the configurations modelled without the need for a shear key (i.e. scenarios 11, 12).
- The layered tailings and waste rock scenarios provide the most stable geometric configuration, because the blended waste rock and tailings are assumed to form a stronger mass than the tailings alone. The combination of the waste rock layers and increased compactive effort of the placement method are assumed to provide sufficient drainage and/or dilative tendencies that liquefaction is not a concern. The calculated factors of safety exceed the design criteria in all modelled situations.
- The seismic loading is sufficiently small that application of a horizontal seismic loading, $k_{h,}$ equal to the PGA resulted in factors of safety greater than unity. This indicates small displacements under seismic loading and exceeds the design criteria.

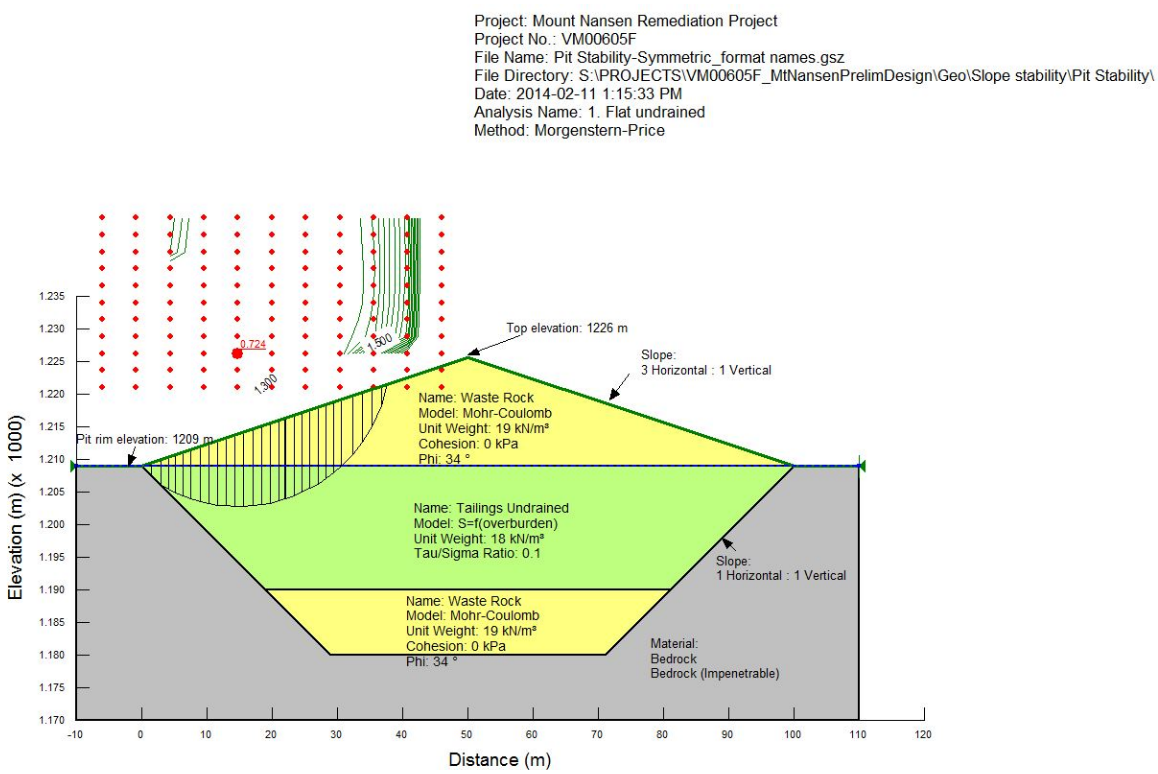

Figure 4: Critical failure surface in Scenario 1

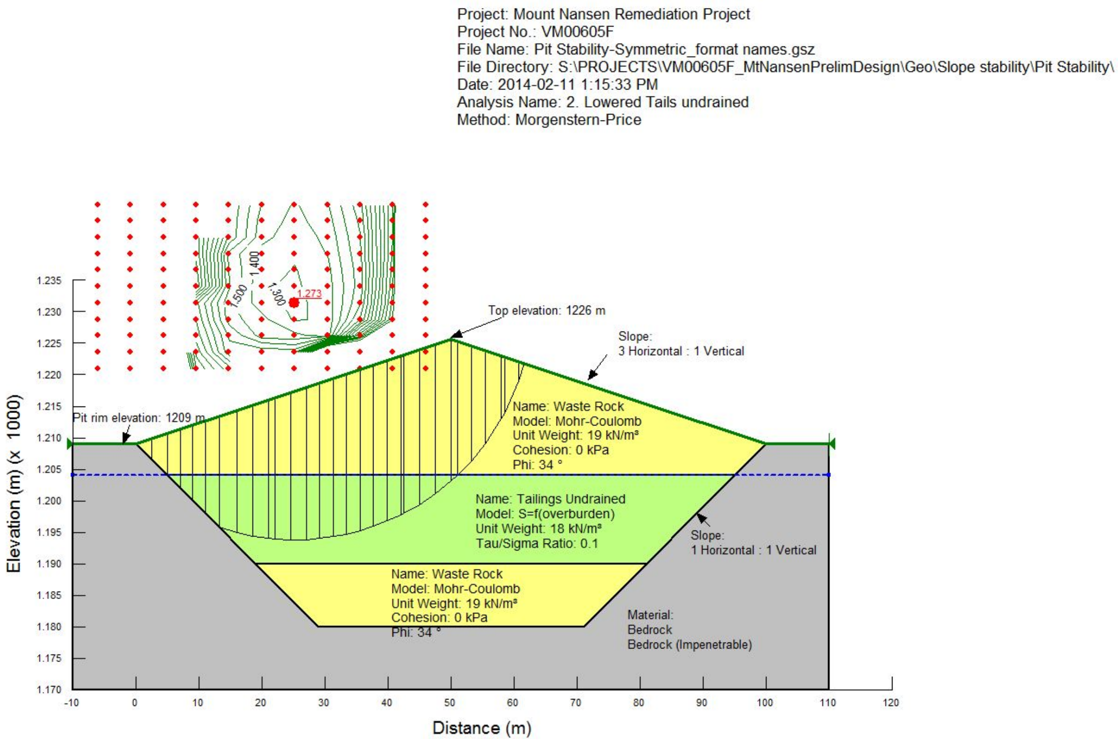

Figure 5: Critical failure surface in Scenario 2

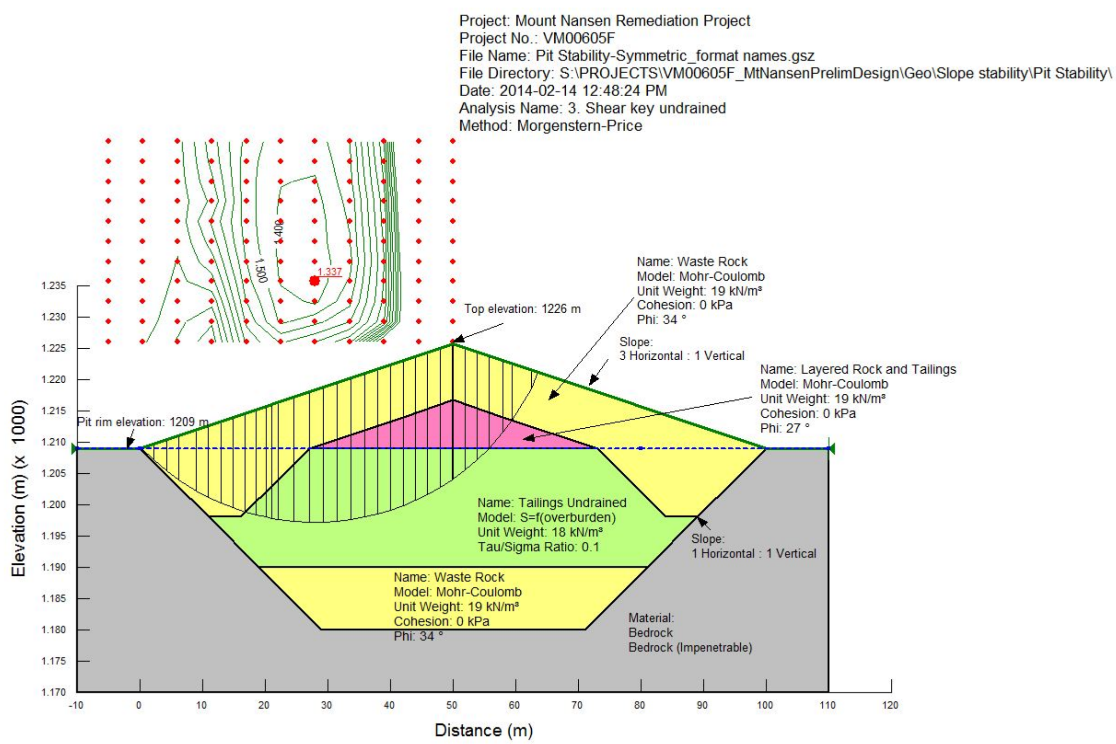

Figure 6: Critical failure surface in Scenario 3

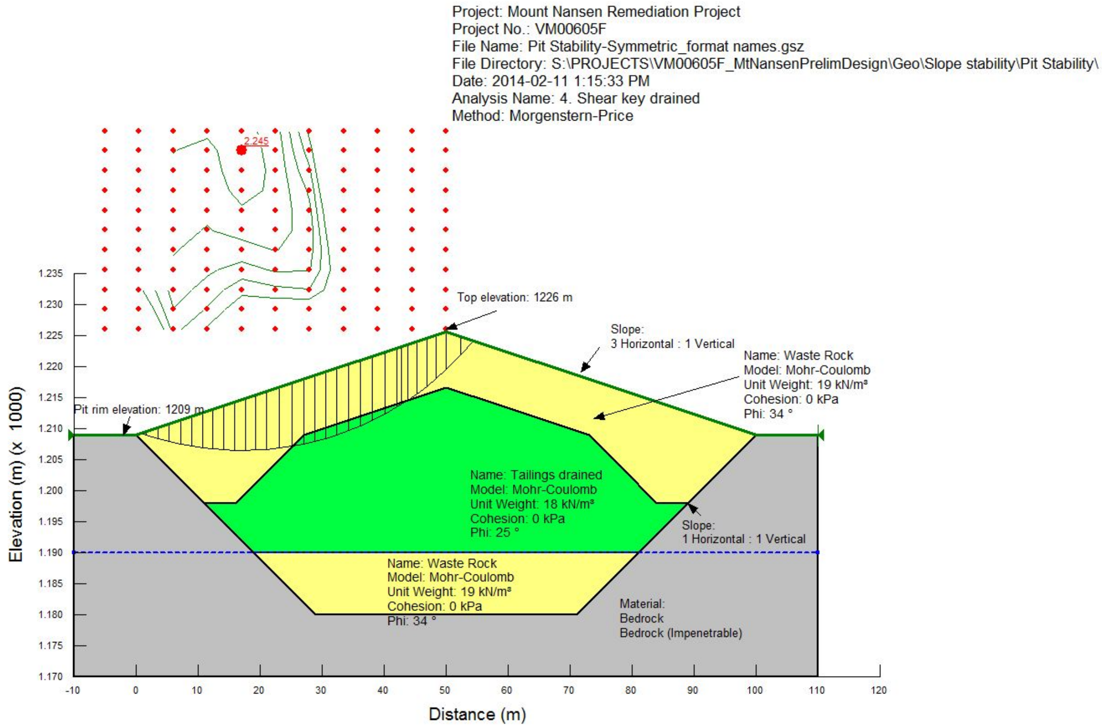

Figure 7: Critical failure surface in Scenario 4

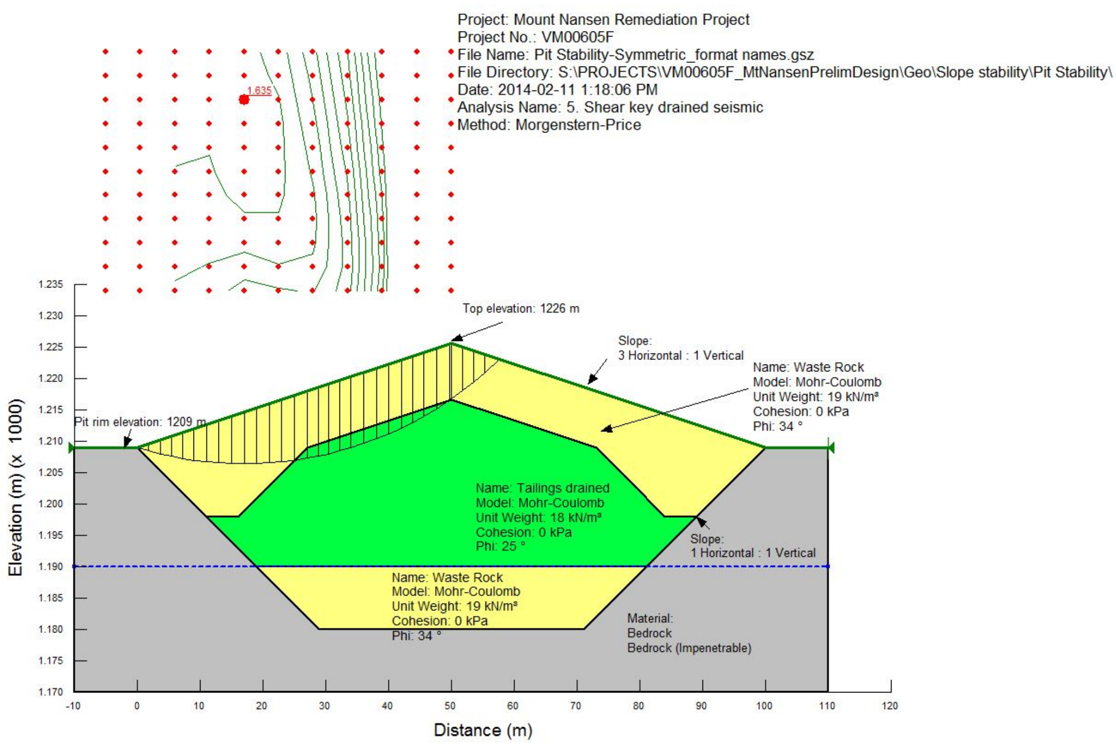

Figure 8: Critical failure surface in Scenario 5

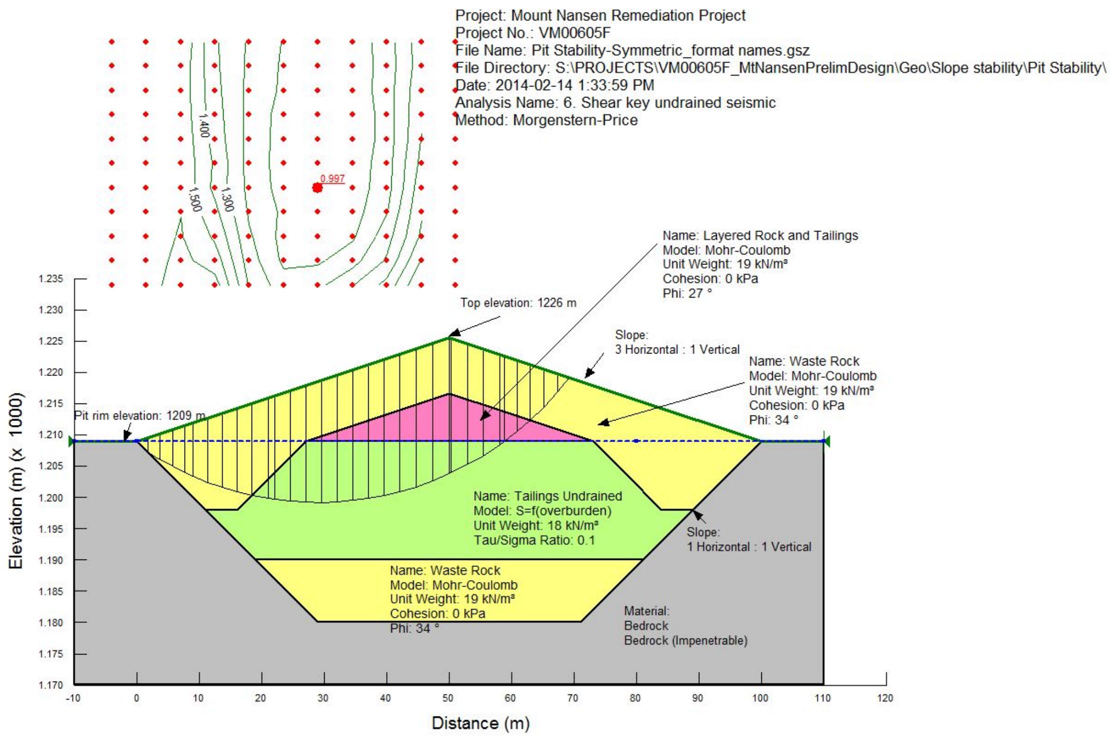

Figure 9: Critical failure surface in Scenario 6

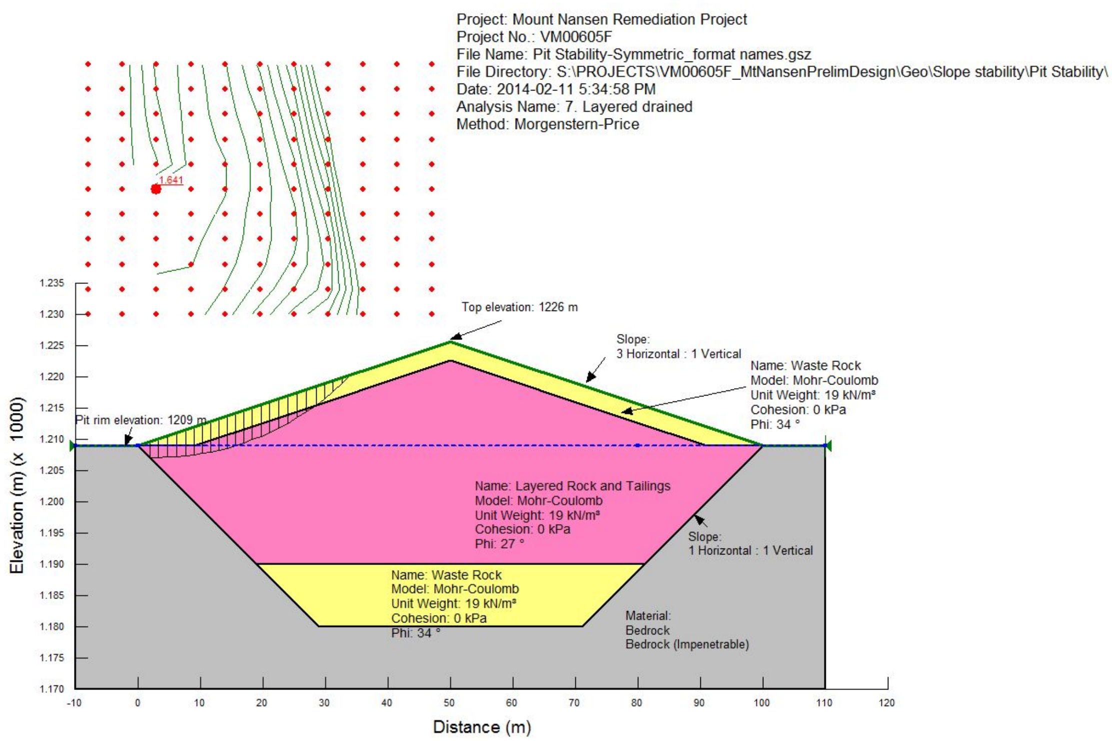

Figure 10: Critical failure surface in Scenario 7

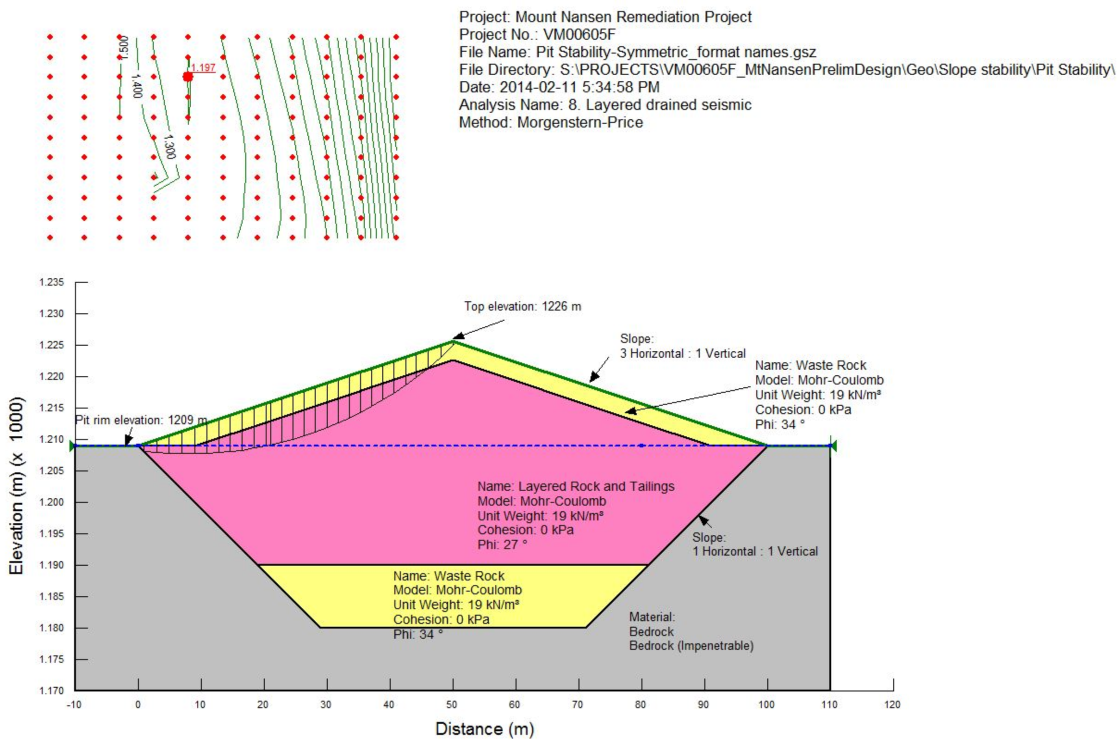

Figure 11: Critical failure surface in Scenario 8

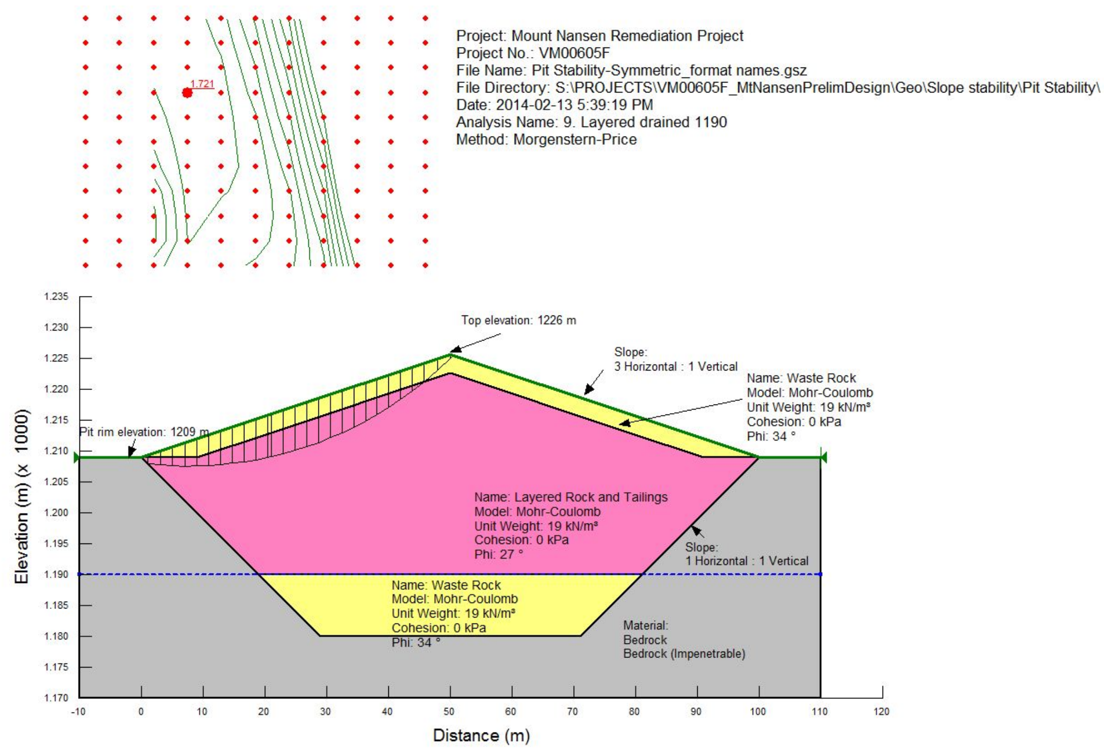

Figure 12: Critical failure surface in Scenario 9

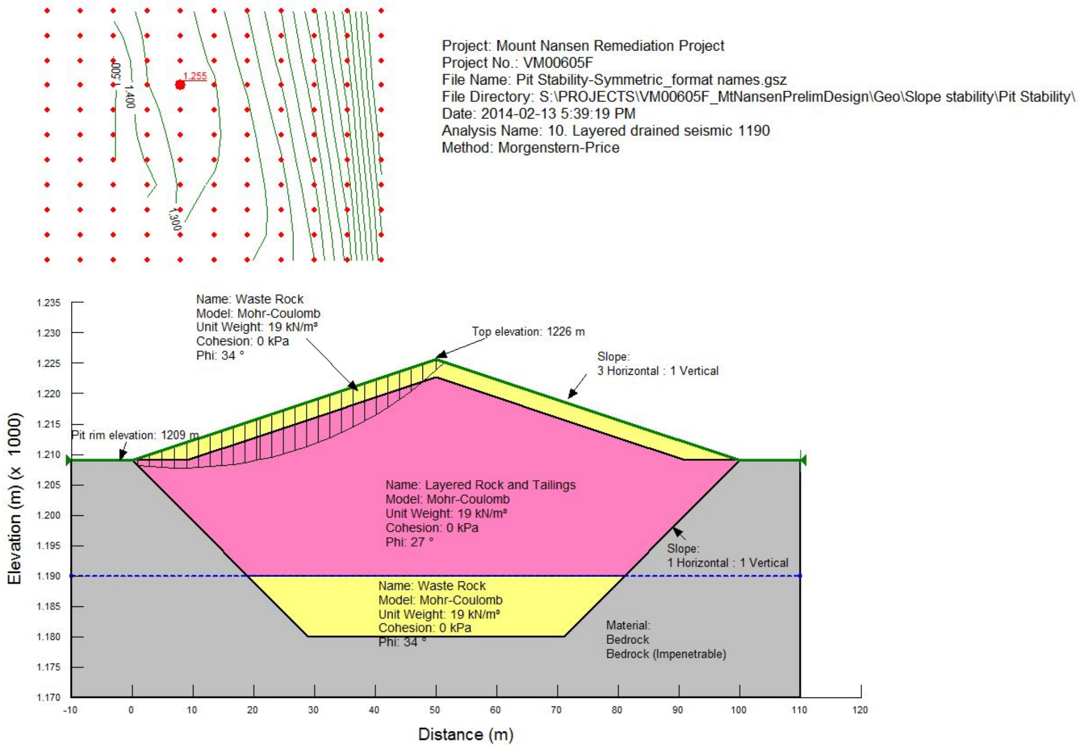

Figure 13: Critical failure surface in Scenario 10

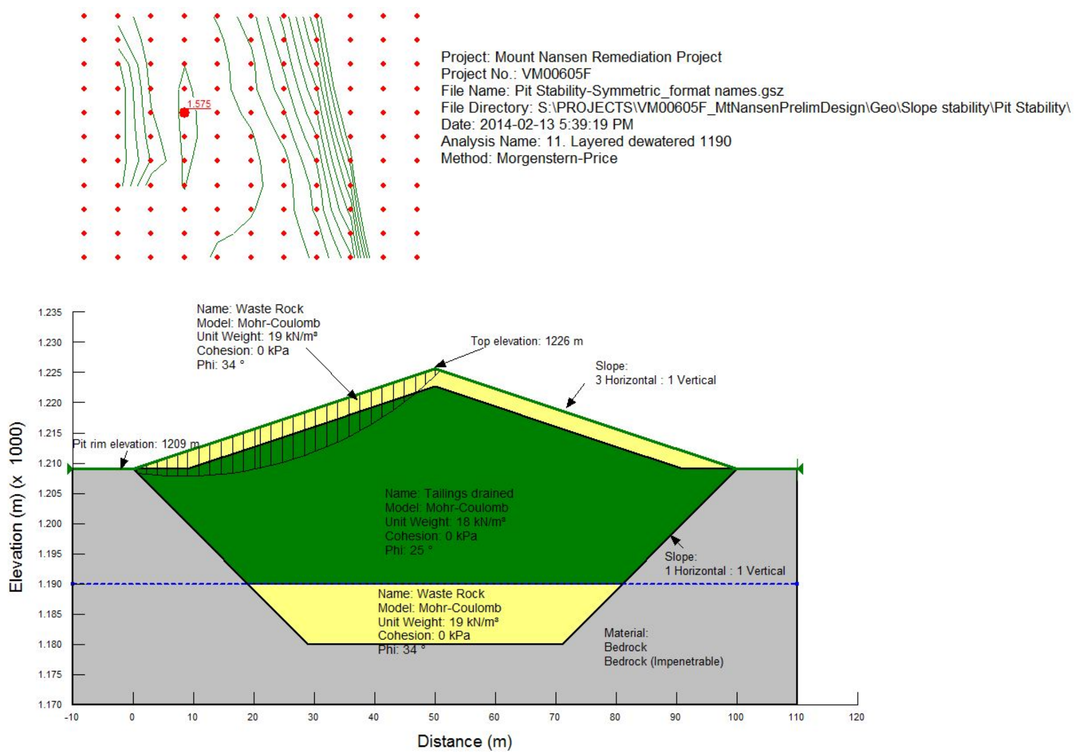

Figure 14: Critical failure surface in Scenario 11

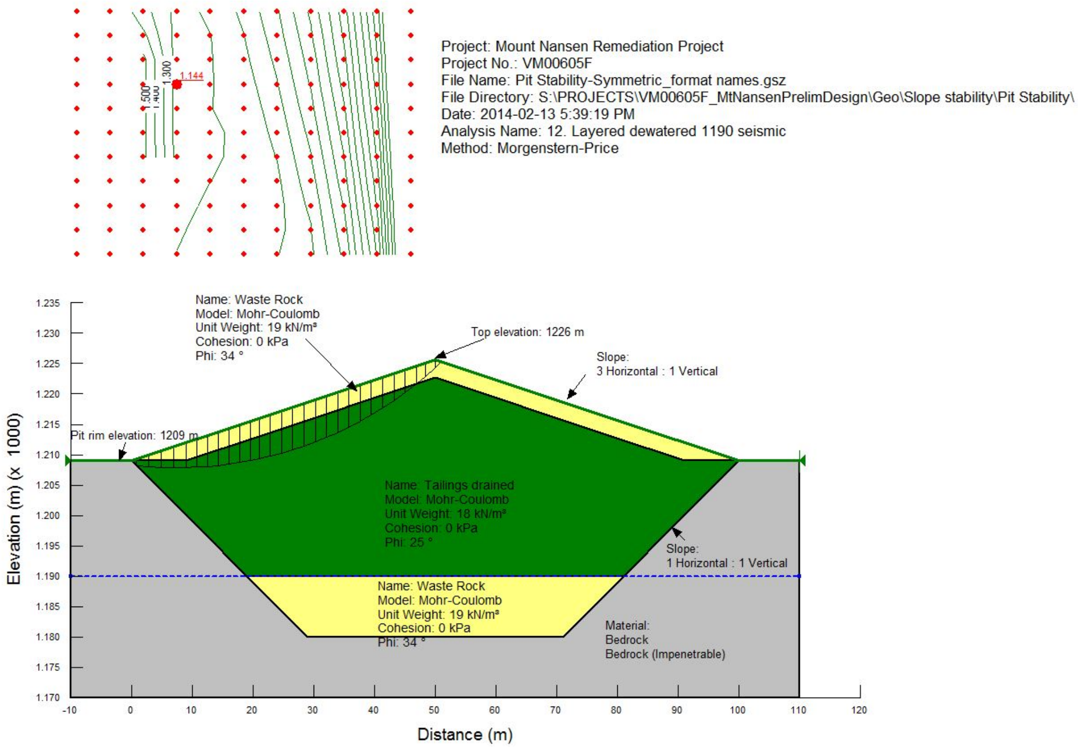

Figure 15: Critical failure surface in Scenario 12

Appendix C – Backfilled Brown McDade Pit Seepage Model

MEMO

To	Brian Geddes		
From	Renata Wood Shane Magnusson		
Tel	604-294-3811	**AMEC File No.**	VM00605F
Fax	604-294-4664	**cc**	
Date	24 February 2014		

Subject **Mount Nansen Remediation Project**
Backfilled Brown McDade Pit Seepage Model

Introduction

Preliminary seepage modelling for the Mount Nansen Brown-McDade Open Pit tailings backfill placement was conducted in January 2013 using the finite element software Seep/W (2007 version, revision 7.23) from Geo-slope International Ltd.

The preliminary tailings relocation plan discussed in this report generally consists of relocating the waste rock and tailings to the Brown-McDade Open Pit. Waste rock is to be placed at the bottom of the pit to an elevation above the long them groundwater level. Tailings and waste rock will then be placed above the lower waste rock platform with a cover to reduce precipitation infiltration.

The purpose of this model is to quantify the potential amount of water draining from a column of tailings and waste rock over time. As such a range of initial tailings saturation conditions were assumed from a worst case scenario of fully saturated tailings to a best case scenario of completely unsaturated tailings. This will be used in conjunction with an understanding of the more regional flow conditions as an input to the water quality modelling effort for the project. A one-dimensional column representative of the maximum height of the tailings is used in the Seep/W model.

Seepage Model Parameters and Analysis Processes

Model Geometry

The one-dimensional geometry is based on the conceptual tailings plan described in this report. Figure 1 shows the layout of the model. The model geometry is 1.0 m wide and 1.0 m deep, resulting in a unit square area of 1.0 m². The main features of the seepage model are:

- Waste rock is placed at the top of the facility from Elev. 1215 to 1209 m. The cover is not specifically included in this analysis however the assumed precipitation infiltration is reflective covers of differing performance.
- Tailings are placed from Elev. 1190 to 1209 m. In the pit backfill model the tailings rise to a height greater than this because the tailings will be mixed with a certain proportion of PAG waste rock. The waste rock however is unsaturated and will not contribute to seepage water. The modelled height of tailings therefore reflects the height that the tailings alone would occupy in the backfilled pit.

- Waste rock is placed at the bottom of the column from Elev. 1190 to 1185 m. Option 4 shows waste rock placed below Elev. 1185 m in some areas, but the zero pressure hydraulic boundary condition at Elev. 1185 m negates the need to extend the column below that level.

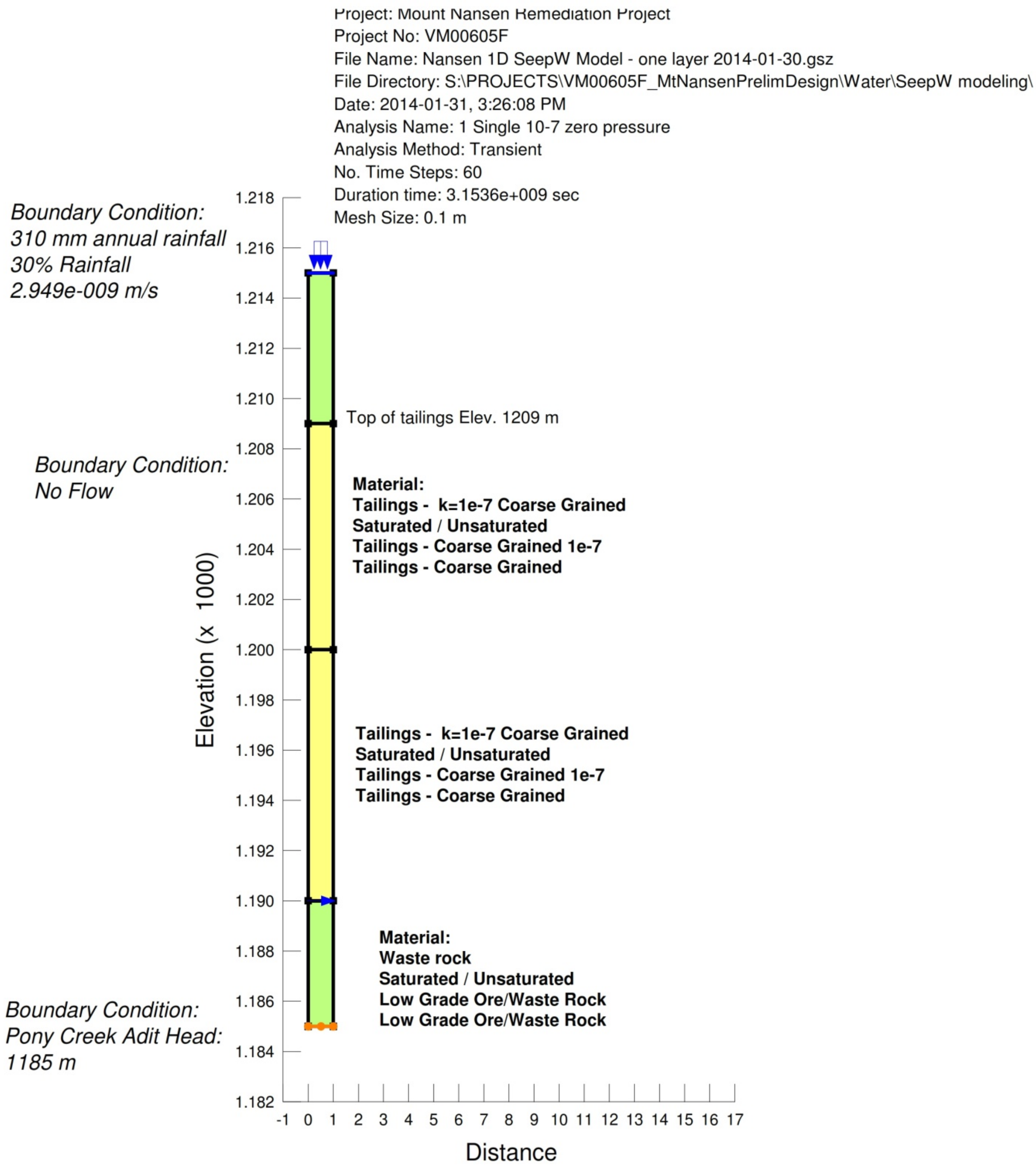

Figure 1: Seepage Model Geometry

Material Properties

Table 1 summarizes the material properties used in the model. Figures 2 and 3 show the hydraulic conductivity and soil water characteristic functions used in the model. It should be noted that the tailings descriptors used in Table 1 are used for modelling purposes only to differentiate between the different hydraulic conductivity values assumed.. The model assumed an isotropic material, where the horizontal and vertical hydraulic conductivities are equal. These parameters were selected to bracket most of the previously reported lab and field tests, although the highest measured hydraulic conductivities have not been included.

Table 1: Material Summary

Material Description	K_{sat} (m/s)	Volumetric Water Content Curve
Waste Rock	1.0E-5	VWCC - Waste Rock
Tailings - Coarse Grained	1.0E-7	VWCC - Tailings – Coarse Grained
Tailings – Medium Grained	1.0E-8	VWCC - Tailings – Coarse Grained
Tailings – Medium Grained	1.0E-8	VWCC - Tailings – Fine Grained
Tailings – Fine Grained	1.0E-9	VWCC – Tailings – Fine Grained

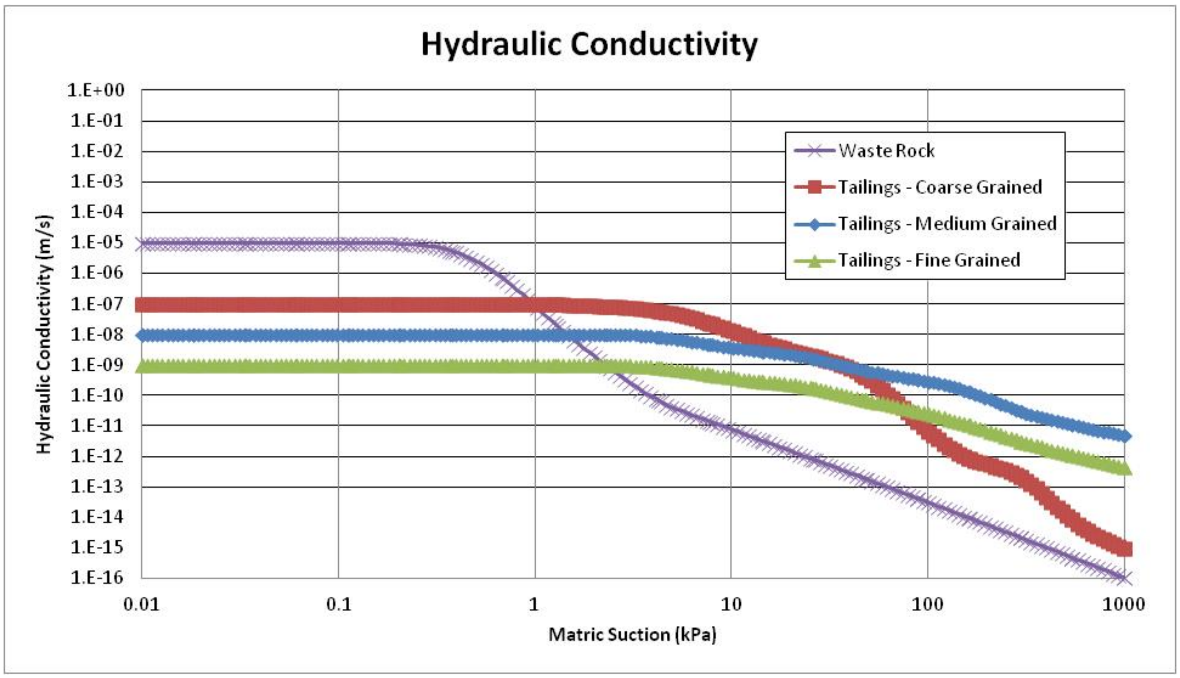

Figure 2: Hydraulic Conductivity parameters used in model

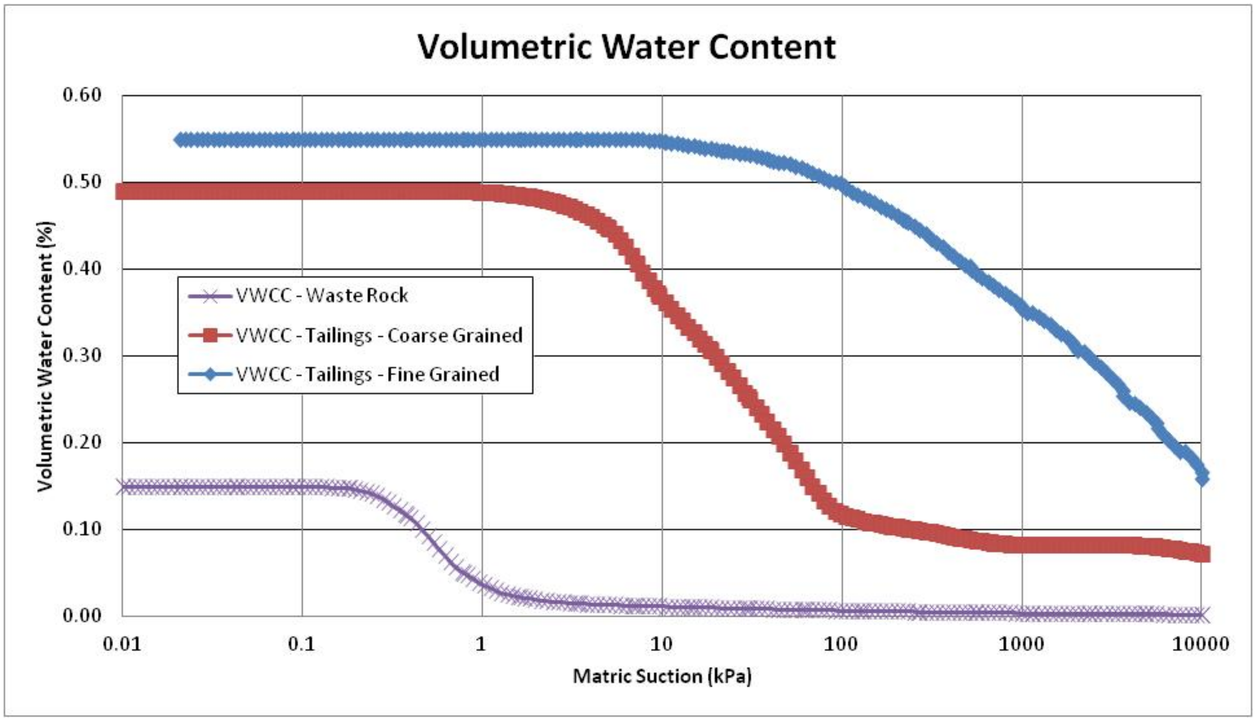

Figure 3: Volumetric water content

Hydraulic Boundary Conditions

Figure 1 also shows the hydraulic boundary conditions used in the model.

- The top surface of the model at Elev. 1215 is assigned a downward flux to simulate infiltration from precipitation. The average annual precipitation of 310 mm[4] has been divided evenly throughout the year for a constant value. A cover over the backfilled pit is envisioned for the design, and the different infiltration rates represent different levels of leakage through the cover, while the remaining balance is assumed to be diverted away via surface runoff. The range in precipitation modelled represents the upper and absolute worst case infiltration scenarios.
- The vertical sides of the model are no-flow boundaries; only 1 dimensional flow vertically is permitted.
- The base of the model at Elev. 1185 is modelled as a zero pressure head boundary. This allows unconstrained flow out of the base of the pit. This is valid provided that the bedrock has the capacity to transmit all of the flow from the tailings or that the waste rock platform has sufficient storage capacity to accommodate the difference between the tailings seepage flow and bedrock flow capacity.

Initial groundwater conditions

A transient groundwater model is employed for this analysis. An initial groundwater condition must be specified at the first time step. Three different scenarios were selected:

[4] AMEC, Associated Engineering, 2013. “Mount Nansen Site Characterization Report.”

1. Ground water table is assumed to be at the top of the tailings (Elev. 1209 m), assuming the tailings are fully saturated. This results in a hydrostatic pressure distribution in the full tailings column.
2. Zero pressure head is assumed everywhere in the tailings. This scenario represents saturated tailings with no construction induced pore pressures. To model this initial condition, a parent steady-state Seep/W analysis is used to develop the starting condition at one second. This starting point is then used as the initial groundwater condition for the transient model.
3. Unsaturated conditions are assumed, consistent with the concept of dewatering the tailings at the tailings facility prior to relocating them to the Open Pit. A suction of 0.5 m pressure head is assigned for the initial condition in the steady state parent steady state model in order to achieve a material that is partly saturated. This results in a lower initial saturation for materials modelled with a “coarse” SWCC than a “fine” SWCC. As above, this starting point is then used as the initial groundwater condition for the transient model after one second.

Analysis Processes

A transient model is selected for the analysis. The following parameters for the time steps are used:

- 60 time steps
- Exponentially increasing time steps, starting at 1 second
- Duration of 3.1536e+09 seconds
- Adaptive time stepping
- Mesh size of 0.1 m square

Results

The instantaneous and cumulative water fluxes at the base of the column were recorded in the transient model. There were two general stages to the instantaneous flux.

- The initial behaviour is the tailings mass losing its water from the pore space (i.e. gravity drainage). This is controlled by the hydraulic conductivity function, SWCC, and initial saturation of the tailings.
- The long-term/steady state behaviour of the tailings stabilizes after the initial water in the tailings pore space equalizes and the flux becomes equal to the infiltration into the model.

The water flux is measured at Elev. 1285 m. Results are presented for the unit 1 m² column from the Seep/W model in Figures 4 and 6. Results are then presented for the overall Brown McDade Pit in Figures 5 and 7, by multiplying the unit area from Seep/W by an area of 16,200 m², the area at the mid elevation of the tailings deposit (Elev. 1200 m).

Sensitivity Analysis

Sensitivity analyses, as summarized in Table 2 were carried out to assess the difference in water draining from the tailings due to variations in:

- Hydraulic conductivity of the tailings
- Layering of the tailings

- Precipitation infiltration passing through the closure cover
- Initial water saturation of the tailings due to dewatering and transporting from the tailings facility to the Open Pit.

The following figures present the results from Seep/W modelling:

- Figure 4 shows the scenarios modelled and the calculated instantaneous unit flux through the model
- Figure 5 shows the calculated cumulative unit flux through the model
- Figure 6 shows the calculated instantaneous pit scale flux through the model
- Figure 7 shows the calculated cumulative pit scale flux through the model

Table 2: Scenarios Modelled

Scenario	Precipitation Infiltration	Tailings Layered	Ksat_1 (m/s)	SWCC_1	Ksat_2 (m/s)	SWCC_2	Saturated	Initial conditions
1	30%	No	1.0E-07	coarse			yes	Zero Pressure
2	30%	No	1.0E-07	coarse			yes	GWT = 1209 m
3	100%	No	1.0E-07	coarse			yes	GWT = 1209 m
4	30%	No	1.0E-08	coarse			yes	GWT = 1209 m
5	30%	No	1.0E-08	fine			yes	GWT = 1209 m
6	100%	No	1.0E-08	fine			yes	GWT = 1209 m
7	30%	No	1.0E-09	fine			yes	GWT = 1209 m
8	30%	No	1.0E-07	coarse			no	unsaturated
9	30%	No	1.0E-08	coarse			no	unsaturated
10	30%	Yes	1.0E-07	coarse	1.0E-08	fine	no	unsat/saturated
11	30%	Yes	1.0E-07	coarse	1.0E-08	fine	yes	GWT = 1209 m

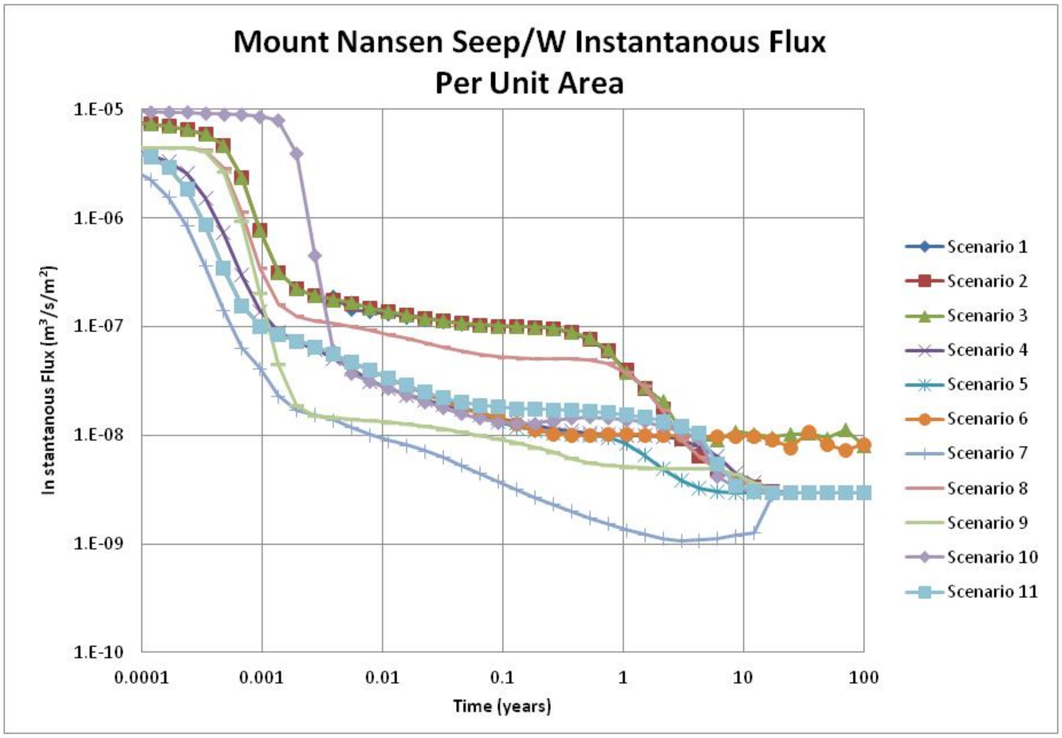

Figure 4: Scenarios and Seep/W Results

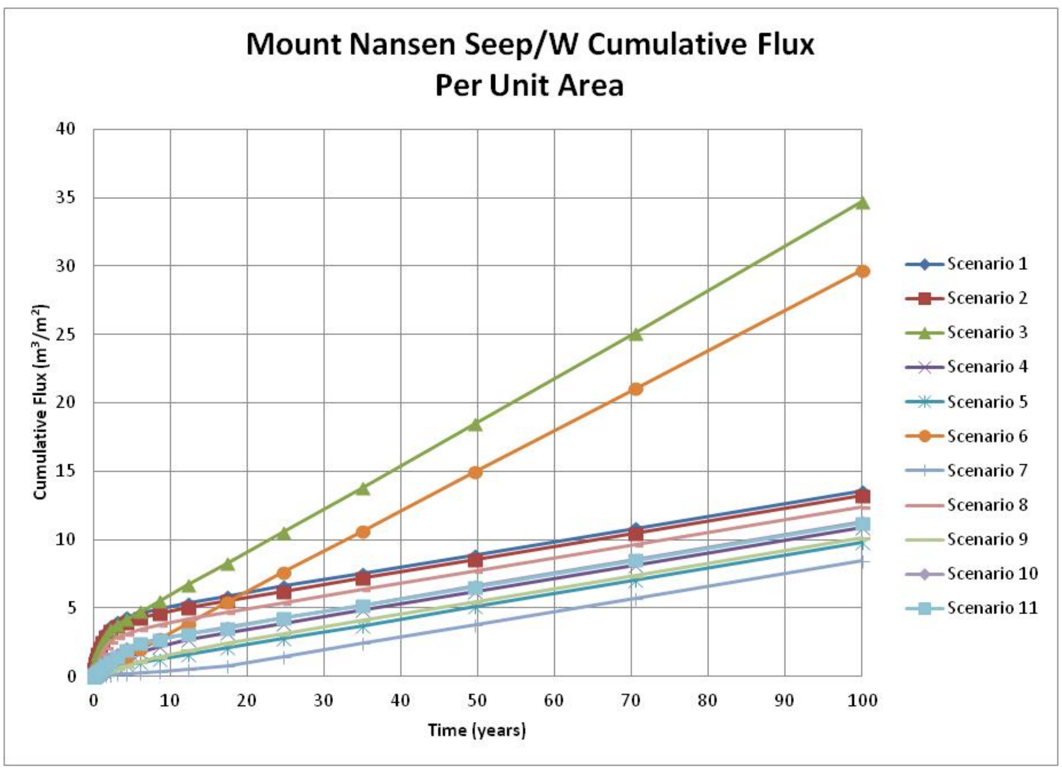

Figure 5: Cumulative water flux per unit area

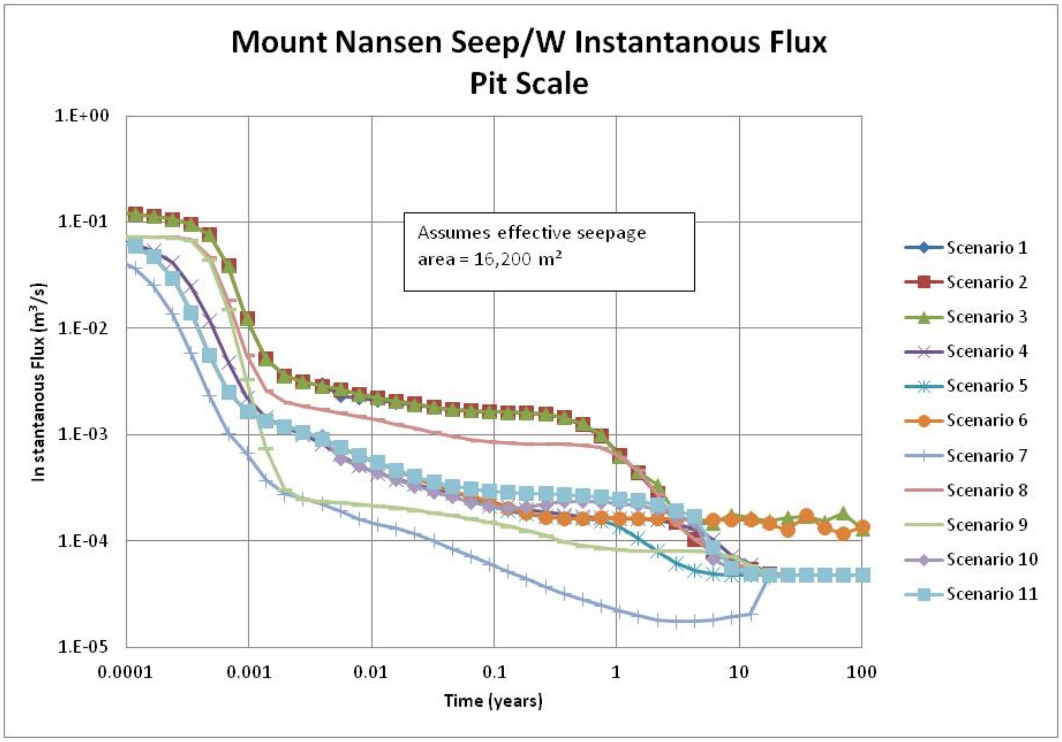

Figure 6: Instantaneous water flux for the pit

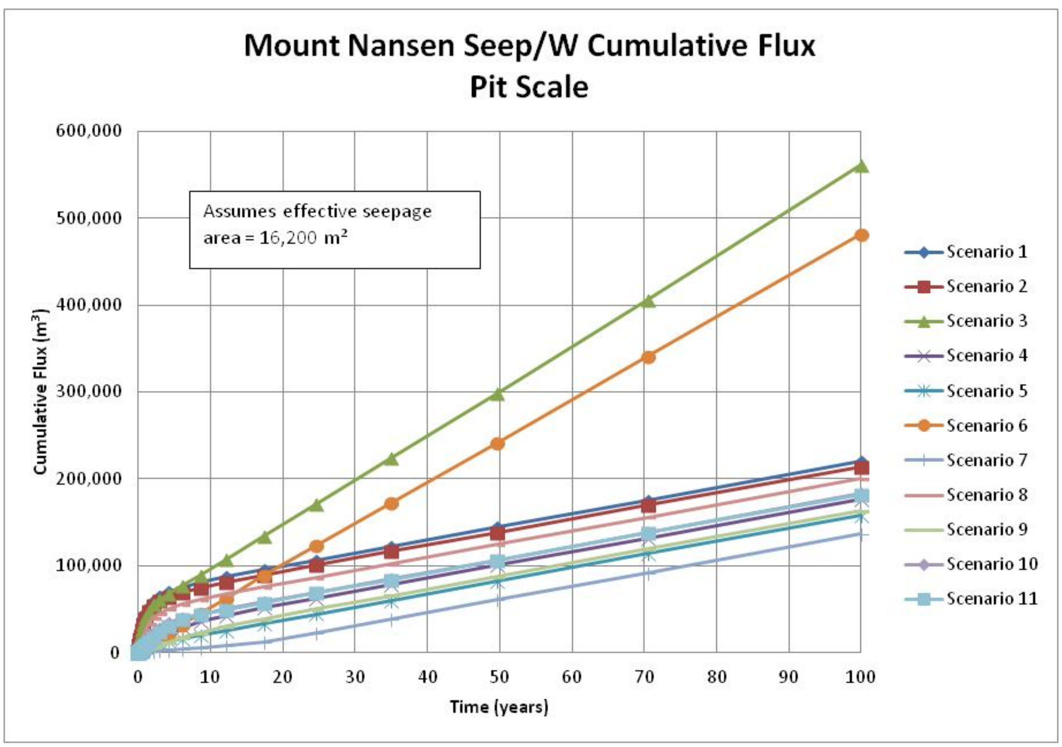

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Figure 7: Cumulative water flux on the pit scale

Sensitivity of Precipitation Infiltration

Precipitation infiltration was modelled at 30% and 100% of the average annual precipitation, indicative of an upper bound infiltration rate from a granular interim cover, and a worst case scenario with no cover and no runoff from the backfilled pit. . In the long term for all scenarios changing tailings properties, placement and saturation, the precipitation infiltration is equal to the long term water flux through the tailings column. In the short term before the water flux stabilizes, the amount of precipitation infiltration does not influence the water flux through the bottom of the column. Additional analyses with lower infiltration rates consistent with final cover performance predictions were therefore not completed. The insensitivity of the initial response of the model to the infiltration is because the infiltration flux is at least an order of magnitude or more less than the predicted seepage due to gravity drainage.

Sensitivity of Hydraulic Conductivity and Soil Water Characteristic Curve

Saturated hydraulic conductivity values were varied from 1E-7 to 1E-9 m/s to assess the potential range in fluxes from the backfilled pit. Given a constant assumed SWCC (steep), tailings with high hydraulic conductivity placed in the facility initially generate more water flowing through the column in the short term compared to tailings with a low hydraulic conductivity (e.g. Scenario 2 vs. 4). This occurs because the higher saturated conductivity allows water to flow more quickly through the tailings. The shape of the SWCC determines the volume of water than can be released by the tailings and thus the total volume of water released or the duration of the elevated flux. The steeper the soil water characteristic curve, the more water that can be released by the tailings (e.g. Scenario 4 vs. 5). As mentioned above, the long term water flux is approximately equal for both soil types and controlled by the precipitation infiltration.

Sensitivity of Initial Hydraulic Conditions

Scenario 1 and 2 compared starting the model with zero hydraulic pressure head throughout the tailings and hydrostatic head from the top of the tailings, respectively. There were a few minor differences at the start of the model as the pressure stabilized, but the end results were very similar for the two scenarios. Subsequent sensitivity analyses based on saturated initial conditions were carried out with a groundwater table at the top of the tailings as this was the easier model to run.

The tailings were also modelled in an unsaturated condition to mimic the results of well-point dewatering. There was a decrease in the short term water flux in the unsaturated tailings as compared to the initially saturated tailings, but the long term results were equal, governed by the precipitation infiltration. Initially unsaturated tailings will have less water to release (starting some distance along the SWCC) and will have a lower hydraulic conductivity. This results in lower instantaneous and cumulative fluxes as compared to the case of saturated tailings (e.g. Scenario 8 vs. 3 and 9 vs. 4).

Sensitivity of Layered Tailings Configuration

Layers were also placed to simulate placing fine grained tailings at the base, and coarse grained tailings on top or to simulate lower void ratio tailings at the bottom of the pit. The lower hydraulic conductivity at the base was the limiting factor with regards to the magnitude of the instantaneous flux. The combined effects of the SWCC controlled the duration of water flux through the column.

The magnitude of the instantaneous drainage flux for Scenario 11, which was a saturated layered system with a saturated hydraulic conductivity of 0^{-7}m/s on top and 10^{-8}m/s at the bottom, is similar to the other scenarios with 10^{-8} m/s tailings. The duration of the drainage fluxes is longer than scenario 5 however because of the 10^{-7}m/s tailings with the coarse SWCC in the upper part of the model.

Conclusions and Recommendations

The following conclusions can be derived from the above modelling:

- In the long term, for the range of conditions modelled, water flow though the tailings is equal to the rainfall infiltration, and is not determined by the material properties of the tailings or placement scheme.
- The amount of precipitation infiltration does not influence the water seepage in the short term.
- Tailings with a steeper SWCC release more water than tailings with a shallow SWCC. Fine tailings may therefore not drain significantly in the pit and could maintain significant saturation. This would have implications with regards to stability if there are significant quantities of fine grained tailings located above the rim of the pit.
- AMEC's best estimate with regards to potential tailings seepage is a layered system with saturated tailings with lower hydraulic conductivity in the bottom of the pit and partly saturated conditions in the top of the pit. The upper bound estimate is an intermediate case between fully saturated and unsaturated coarse tailings (i.e. between Scenarios 8 and 2). A fully saturated coarse scenario is considered overly conservative because coarse tailings will dewater well and should also experience some drainage during placement therefore it is unlikely that a coarse SWCC scenario could also be fully saturated upon infilling. The lower bound estimate corresponds to unsaturated tailings with relatively low hydraulic conductivity or saturated tailings with very low hydraulic conductivity (i.e. Scenarios 9 and 7). Table 3 summarizes the flux amounts and durations for the best estimate, lower bound and upper bound estimates. The flux components into the waste rock platform and pit walls are a function of how the water quality model is set up and assumes vertical flow. The flux into the waste rock platform is calculated as the SeepW calculated flux multiplied by the area of the waste rock platform (10,000 m^2). The flux into the pit wall is the remaining flux, calculated based on the effective area as described previously. This value is then divided by the annulus of the pit area outside the waste rock platform to provide a flow per square metre.

Table 3: Summary of Results

Scenario	SeepW flux ($m^3/s/m^2$)	Total Flux into pit (m^3/s)	Flux into waste rock platform		Flux into pit walls		Duration
			Total (m^3/s)	per m2 ($m^3/s/m^2$)	Total (m^3/s)	per m2 ($m^3/s/m^2$)	
Best Estimate 10	1.27E-08	2.06E-04	1.27E-04	1.27E-08	7.92E-05	3.02E-09	5 years
Lower Bound	5.36E-09	8.71E-05	5.36E-05	5.36E-09	3.35E-05	1.27E-09	5 years
Upper bound	7.13E-08	1.16E-03	7.13E-04	7.13E-08	4.45E-04	1.69E-08	1 year

Appendix D – Pit Cover Seepage Modelling

Project : 3:1

Description

Model : HELP
An US EPA model for predicting landfill hydrologic processes and testing of effectiveness of landfill designs

Author : Environmental Engineer Karen Fairweather

Client : Title Key contact person

Location : Mount Nansen

11/02/2014

1. Profile. EPA profile1

Model Settings

[HELP] Case Settings

Parameter	Value	Units
Runoff Method	Model calculated	(-)
Initial Moisture Settings	User specified	(-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area	100	(%%)
Initial Surface Water	0	(m)
Vegetation Class	Bare soil	(-)

Profile Structure

Layer	Top (m)	Bottom (m)	Thickness (m)
Victoria Creek material topsoil	0.0000	-0.3000	0.3000
Sand Borrow drainage layer	-0.3000	-0.6000	0.3000
Low Density Polyethylene (LDPE)	-0.6000	-0.6010	0.0010
Bentonite	-0.6010	-0.6060	0.0050
Sand Cushion	-0.6060	-0.9060	0.3000
Victoria Creek Material	-0.9060	-1.8560	0.9500
Victoria Creek Bottom	-1.8560	-1.9060	0.0500

1.1. Layer. Victoria Creek material topsoil

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.43	(vol/vol)
field capacity	0.31	(vol/vol)
wilting point	0.16	(vol/vol)
sat.hydr.conductivity	0.003	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.31	(vol/vol)

1.2. Layer. Sand Borrow drainage layer

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.457	(vol/vol)
field capacity	0.083	(vol/vol)
wilting point	0.033	(vol/vol)
sat.hydr.conductivity	0.0031	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.083	(vol/vol)

1.3. Layer. Low Density Polyethylene (LDPE)

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Geomembrane Liner Parameters

Parameter	Value	Units
sat.hydr.conductivity	0.000000000000400	(cm/sec)
pinhole density	7.000	(#/ha)
installation defects	4.000	(#/ha)
placement quality	4	(-)
geotextile transmissivity	0	(cm2/sec)

1.4. Layer. Bentonite

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.75	(vol/vol)
field capacity	0.747	(vol/vol)
wilting point	0.4	(vol/vol)
sat.hydr.conductivity	3E-8	(cm/sec)
subsurface inflow	0	(mm/year)

1.5. Layer. Sand Cushion

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.457	(vol/vol)
field capacity	0.131	(vol/vol)
wilting point	0.058	(vol/vol)
sat.hydr.conductivity	0.001	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.131	(vol/vol)

1.6. Layer. Victoria Creek Material

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.43	(vol/vol)
field capacity	0.31	(vol/vol)
wilting point	0.16	(vol/vol)
sat.hydr.conductivity	0.003	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.31	(vol/vol)

1.7. Layer. Victoria Creek Bottom

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.43	(vol/vol)
field capacity	0.31	(vol/vol)
wilting point	0.16	(vol/vol)
sat.hydr.conductivity	0.003	(cm/sec)
subsurface inflow	0.0000	(cm/day)

Annual Totals rate (m)

	Year-1 (m)	Year-2 (m)	Year-3 (m)	Year-4 (m)
Precipitation (m)	3.1034E-01	3.1034E-01	3.1034E-01	3.1034E-01
Runoff (m)	2.3137E-02	2.6764E-02	2.6837E-02	2.6879E-02
Evapotranspiration (m)	2.2056E-01	2.1586E-01	2.1668E-01	2.1566E-01
Change in water storage (m)	-1.2776E-03	6.0069E-06	1.3057E-06	-2.6759E-04
Water budget balance (m)	-4.6608E-09	-4.6608E-09	-4.6608E-09	-4.6608E-09
Soil water (m)	4.5484E-01	4.5485E-01	4.5485E-01	4.5485E-01
Snow water (m)	2.0829E-02	2.0829E-02	2.0829E-02	2.0562E-02
Lateral drainage collected from Layer 2 (m)	6.7908E-02	6.7693E-02	6.6799E-02	6.8056E-02
Percolation or leakance through Layer 4 (m)	1.7755E-05	1.7545E-05	1.7189E-05	1.7658E-05
Percolation or leakance through Layer 7 (m)	1.7755E-05	1.7545E-05	1.7189E-05	1.7658E-05
Average head on top of Layer 3 (m)	5.8831E-03	5.8637E-03	5.7861E-03	5.8963E-03
Average head on top of Layer 7 (m)	4.1481E-08	3.9924E-08	4.2478E-08	4.4013E-08

(continued)

	Year-5 (m)	Year-6 (m)	Total (m)
Precipitation (m)	3.1034E-01	5.2235E-01	2.0740E+00
Runoff (m)	2.5973E-02	6.4118E-02	1.9371E-01
Evapotranspiration (m)	2.1754E-01	2.7426E-01	1.3606E+00
Change in water storage (m)	2.6793E-04	2.1925E-02	2.0655E-02
Water budget balance (m)	-4.6608E-09	-7.8449E-09	-3.1149E-08
Soil water (m)	4.5485E-01	4.5580E-01	2.7300E+00
Snow water (m)	2.0829E-02	4.1800E-02	1.4568E-01
Lateral drainage collected from Layer 2 (m)	6.6538E-02	1.6201E-01	4.9901E-01
Percolation or leakance through Layer 4 (m)	1.7094E-05	3.7010E-05	1.2425E-04
Percolation or leakance through Layer 7 (m)	1.7094E-05	3.7010E-05	1.2425E-04
Average head on top of Layer 3 (m)	5.7634E-03	1.3912E-02	
Average head on top of Layer 7 (m)	3.9513E-08	9.1442E-08	

Accumulated rate (m)

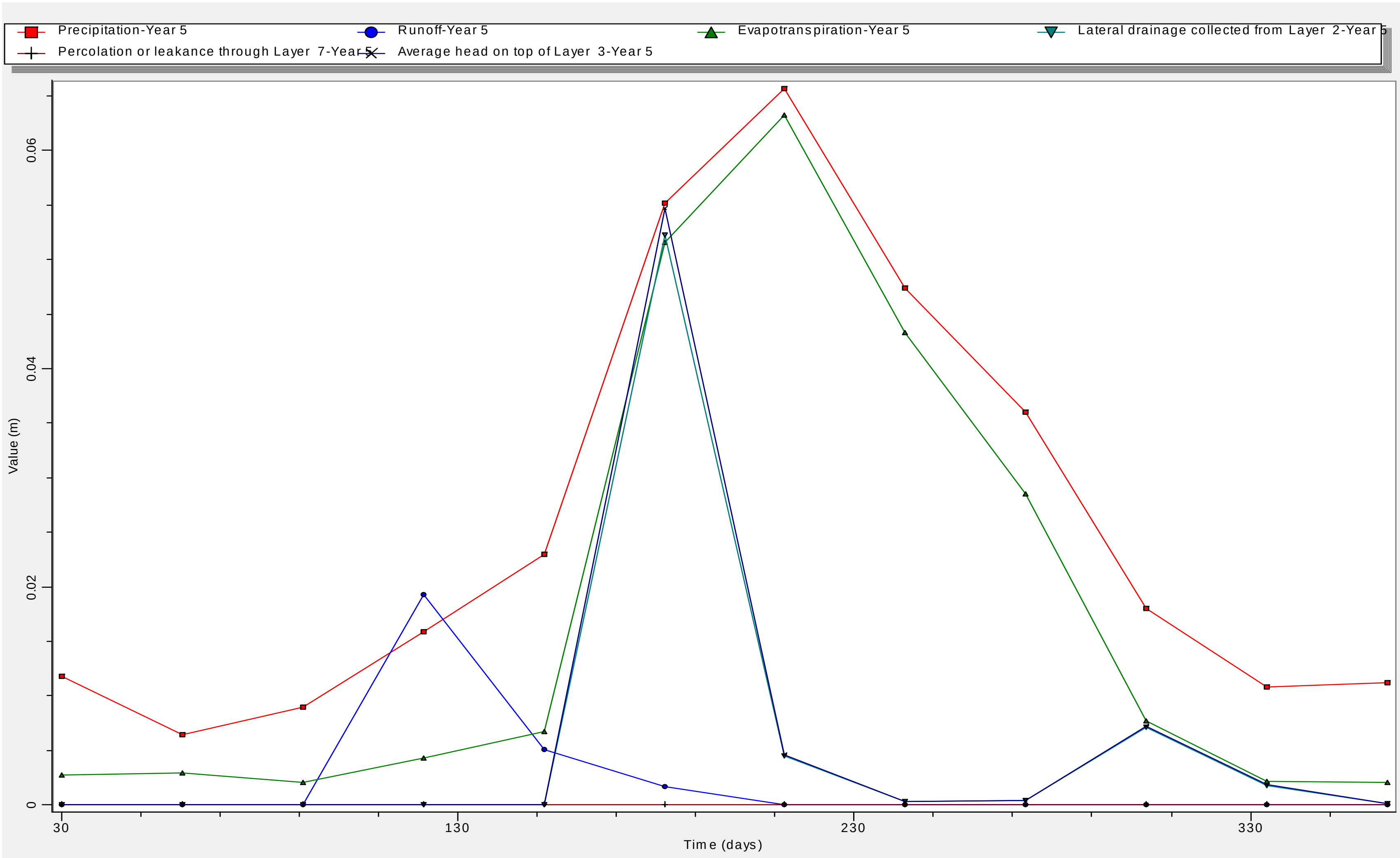
	Year-1 (m)	Year-2 (m)	Year-3 (m)	Year-4 (m)
Precipitation (m)	3.1034E-01	6.2068E-01	9.3102E-01	1.2414E+00
Runoff (m)	2.3137E-02	4.9901E-02	7.6739E-02	1.0362E-01
Evapotranspiration (m)	2.2056E-01	4.3641E-01	6.5310E-01	8.6875E-01
Lateral drainage collected from Layer 2 (m)	6.7908E-02	1.3560E-01	2.0240E-01	2.7046E-01
Percolation or leakance through Layer 4 (m)	1.7755E-05	3.5300E-05	5.2489E-05	7.0147E-05
Percolation or leakance through Layer 7 (m)	1.7755E-05	3.5300E-05	5.2489E-05	7.0147E-05

(continued)

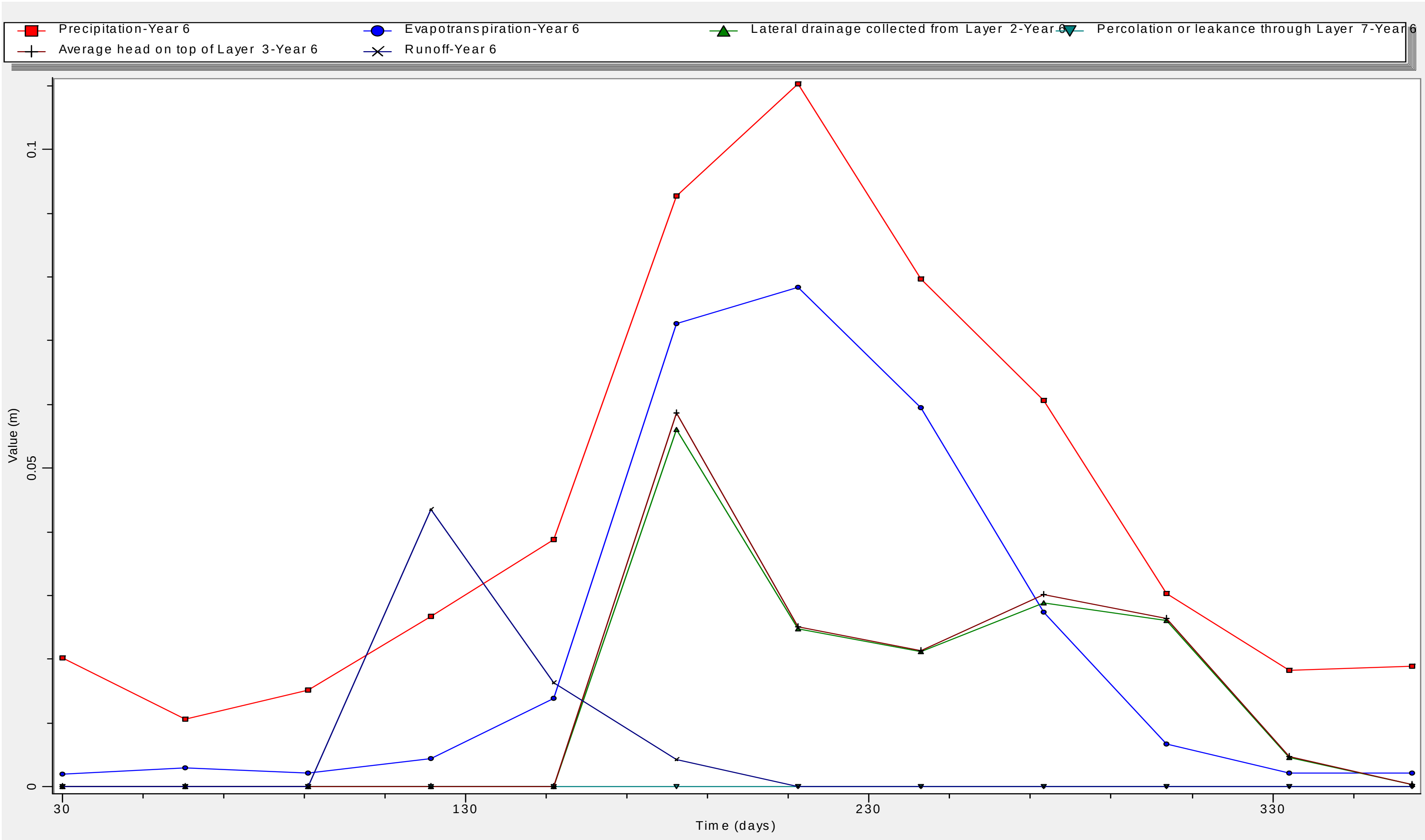
	Year-5 (m)	Year-6 (m)
Precipitation (m)	1.5517E+00	2.0740E+00
Runoff (m)	1.2959E-01	1.9371E-01
Evapotranspiration (m)	1.0863E+00	1.3606E+00
Lateral drainage collected from Layer 2 (m)	3.3699E-01	4.9901E-01
Percolation or leakance through Layer 4 (m)	8.7241E-05	1.2425E-04
Percolation or leakance through Layer 7 (m)	8.7241E-05	1.2425E-04

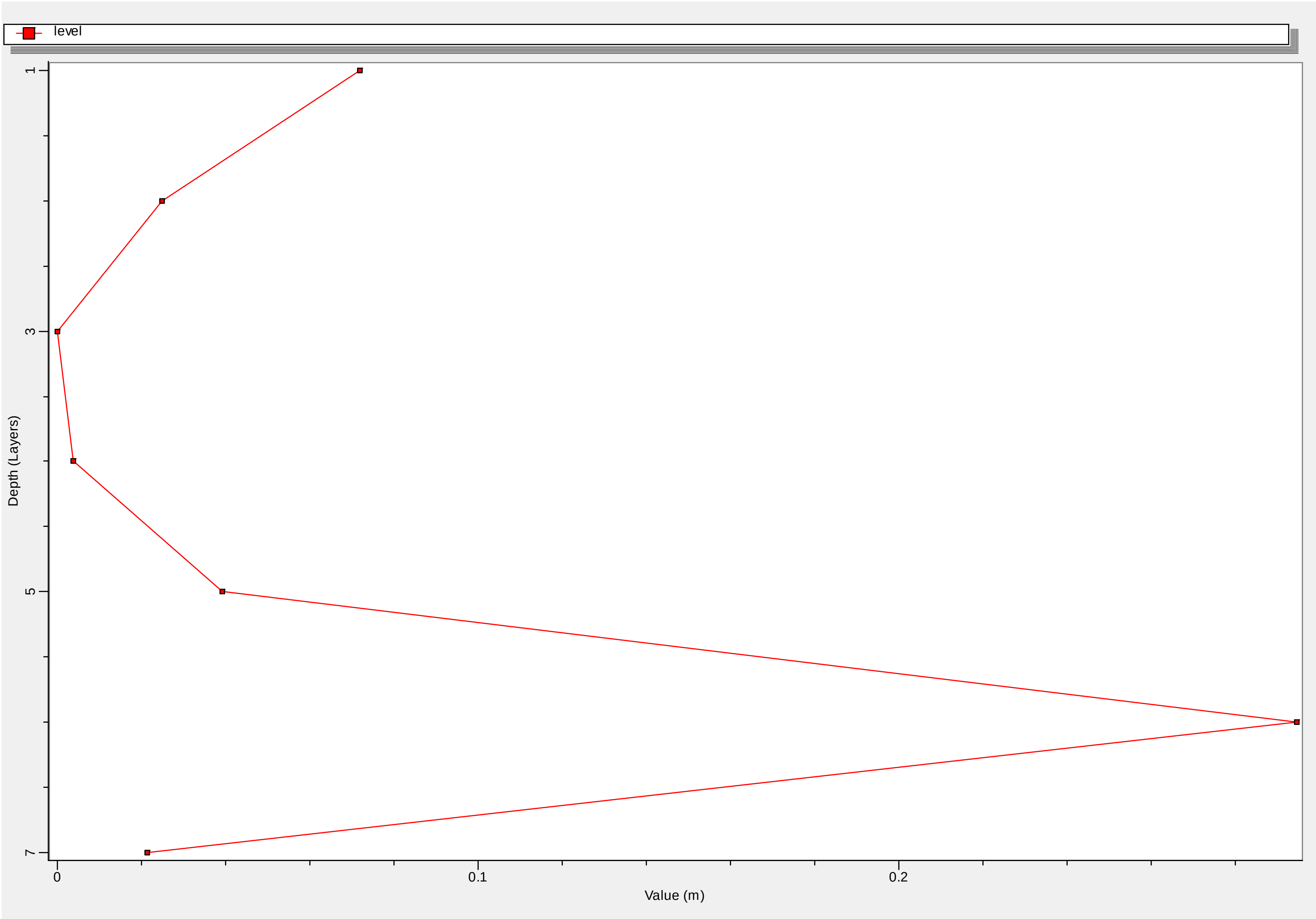
Peak daily values

	Rate (m)	Volume (m3)	Day	Year
Precipitation	3.5600E-03	1.2816E+02	182	6
Runoff	9.5666E-03	3.4440E+02	109	6
Lateral drainage collected from Layer 2	4.5677E-03	1.6444E+02	154	1
Percolation or leakance through Layer 4	1.6139E-06	5.8099E-02	154	1
Percolation or leakance through Layer 7	1.9251E-06	6.9302E-02	154	1
Snow water	6.3630E-02	2.2907E+03	98	6



Precipitation-Year 5
Runoff-Year 5
Evapotranspiration-Year 5
Lateral drainage collected from Layer 2-Year 5
Percolation or leakance through Layer 7-Year 5
Average head on top of Layer 3-Year 5
Value (m)
0.06
0.04
0.02
0
30
130
230
330
Time (days)


Precipitation-Year 6
Evapotranspiration-Year 6
Lateral drainage collected from Layer 2-Year 6
Percolation or leakance through Layer 7-Year 6
Average head on top of Layer 3-Year 6
Runoff-Year 6
Value (m)
0.1
0.05
0
30
130
230
330
Time (days)



level
Depth (Layers)
1
3
5
7
0
0.1
0.2
Value (m)

Project : 3:1 worst case condition

Description

Model : HELP
An US EPA model for predicting landfill hydrologic processes and testing of effectiveness of landfill designs

Author : Environmental Engineer Karen Fairweather

Client : Title Key contact person

Location : Mount Nansen

11/02/2014

1. Profile. EPA profile1

Model Settings

[HELP] Case Settings

Parameter	Value	Units
Runoff Method	Model calculated	(-)
Initial Moisture Settings	User specified	(-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area	100	(%%)
Initial Surface Water	0	(m)
Vegetation Class	Bare soil	(-)

Profile Structure

Layer	Top (m)	Bottom (m)	Thickness (m)
Victoria Creek material topsoil	0.0000	-0.3000	0.3000
Borrow Sand Drainage Layer	-0.3000	-0.6000	0.3000
Low Density Polyethylene (LDPE)	-0.6000	-0.6010	0.0010
Bentonite	-0.6010	-0.6060	0.0050
Sand Cushion	-0.6060	-0.9060	0.3000
Victoria Creek material	-0.9060	-1.8560	0.9500
Victoria Creek Bottom	-1.8560	-1.9060	0.0500

1.1. Layer. Victoria Creek material topsoil

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.43	(vol/vol)
field capacity	0.31	(vol/vol)
wilting point	0.16	(vol/vol)
sat.hydr.conductivity	0.003	(cm/sec)
subsurface inflow	0.0000	(cm/day)
Initial moisture content	0.31	(vol/vol)

1.2. Layer. Borrow Sand Drainage Layer

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.457	(vol/vol)
field capacity	0.131	(vol/vol)
wilting point	0.058	(vol/vol)
sat.hydr.conductivity	0.001	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.131	(vol/vol)

1.3. Layer. Low Density Polyethylene (LDPE)

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Geomembrane Liner Parameters

Parameter	Value	Units
sat.hydr.conductivity	0.000000000000400	(cm/sec)
pinhole density	2.000	(#/ha)
installation defects	6.000	(#/ha)
placement quality	4	(-)
geotextile transmissivity	0	(cm2/sec)

1.4. Layer. Bentonite

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.75	(vol/vol)
field capacity	0.747	(vol/vol)
wilting point	0.4	(vol/vol)
sat.hydr.conductivity	3E-5	(cm/sec)
subsurface inflow	0	(mm/year)

1.5. Layer. Sand Cushion

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.457	(vol/vol)
field capacity	0.131	(vol/vol)
wilting point	0.058	(vol/vol)
sat.hydr.conductivity	0.001	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.131	(vol/vol)

1.6. Layer. Victoria Creek material

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.43	(vol/vol)
field capacity	0.31	(vol/vol)
wilting point	0.16	(vol/vol)
sat.hydr.conductivity	0.003	(cm/sec)
subsurface inflow	0	(mm/year)
Initial moisture content	0.31	(vol/vol)

1.7. Layer. Victoria Creek Bottom

Top Slope Length: 50.0000
Bottom Slope Length: 50.0000
Top Slope: 33.0000
Bottom Slope : 33.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.43	(vol/vol)
field capacity	0.31	(vol/vol)
wilting point	0.16	(vol/vol)
sat.hydr.conductivity	0.003	(cm/sec)
subsurface inflow	0	(mm/year)

Annual Totals rate (cm)

	Year-1 (cm)	Year-2 (cm)	Year-3 (cm)	Year-4 (cm)
Precipitation (cm)	3.1034E+01	3.1034E+01	3.1034E+01	3.1034E+01
Runoff (cm)	2.3380E+00	2.6979E+00	2.7054E+00	2.7097E+00
Evapotranspiration (cm)	2.2035E+01	2.1576E+01	2.2191E+01	2.1729E+01
Change in water storage (cm)	6.8895E-01	6.9489E-02	-1.9317E-02	-1.6615E-02
Water budget balance (cm)	-4.6608E-07	-4.6608E-07	-4.6608E-07	-4.6608E-07
Soil water (cm)	4.7741E+01	4.7810E+01	4.7791E+01	4.7801E+01
Snow water (cm)	2.0829E+00	2.0829E+00	2.0829E+00	2.0562E+00
Lateral drainage collected from Layer 2 (cm)	5.5244E+00	5.5508E+00	5.0800E+00	5.4480E+00
Percolation or leakance through Layer 4 (cm)	1.2155E+00	1.2067E+00	1.0583E+00	1.1753E+00
Percolation or leakance through Layer 7 (cm)	4.4758E-01	1.1394E+00	1.0772E+00	1.1637E+00
Average head on top of Layer 3 (cm)	1.4750E+00	1.4819E+00	1.3561E+00	1.4548E+00
Average head on top of Layer 7 (cm)	1.0601E-03	2.8332E-03	2.6638E-03	2.8349E-03

(continued)

	Year-5 (cm)	Year-6 (cm)	Total (cm)
Precipitation (cm)	3.1034E+01	5.2235E+01	2.0740E+02
Runoff (cm)	2.6188E+00	6.4495E+00	1.9519E+01
Evapotranspiration (cm)	2.1667E+01	2.7588E+01	1.3679E+02
Change in water storage (cm)	3.4751E-02	2.7582E+00	3.5154E+00
Water budget balance (cm)	-4.6608E-07	-7.8449E-07	-3.1149E-06
Soil water (cm)	4.7809E+01	4.8470E+01	2.8742E+02
Snow water (cm)	2.0829E+00	4.1800E+00	1.4568E+01
Lateral drainage collected from Layer 2 (cm)	5.5201E+00	1.3042E+01	4.0166E+01
Percolation or leakance through Layer 4 (cm)	1.2000E+00	2.8332E+00	8.6890E+00
Percolation or leakance through Layer 7 (cm)	1.1939E+00	2.3974E+00	7.4191E+00
Average head on top of Layer 3 (cm)	1.4738E+00	3.4641E+00	
Average head on top of Layer 7 (cm)	2.9402E-03	5.9980E-03	

Accumulated rate (cm)

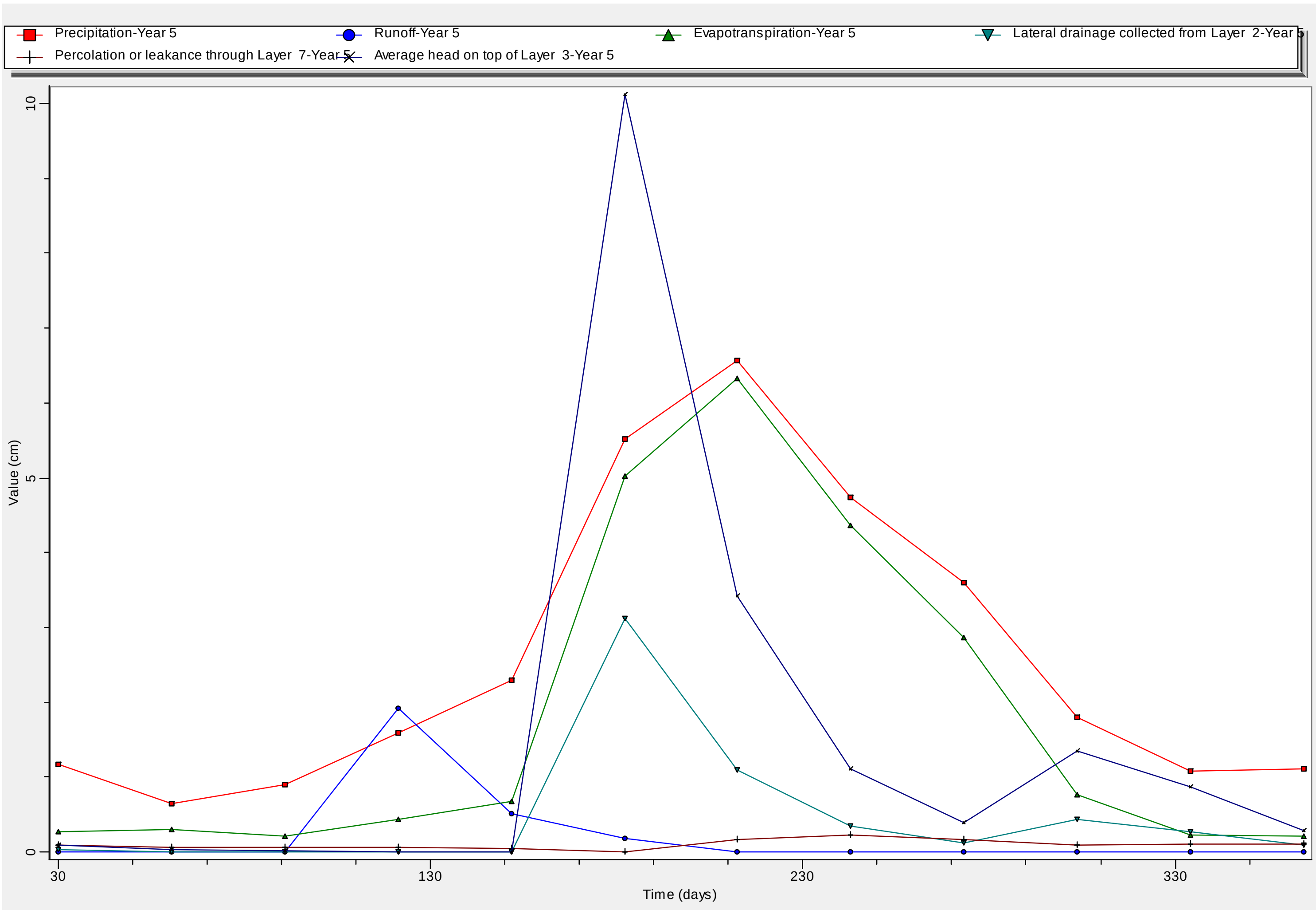
	Year-1 (cm)	Year-2 (cm)	Year-3 (cm)	Year-4 (cm)
Precipitation (cm)	3.1034E+01	6.2068E+01	9.3102E+01	1.2414E+02
Runoff (cm)	2.3380E+00	5.0359E+00	7.7413E+00	1.0451E+01
Evapotranspiration (cm)	2.2035E+01	4.3612E+01	6.5802E+01	8.7531E+01
Lateral drainage collected from Layer 2 (cm)	5.5244E+00	1.1075E+01	1.6155E+01	2.1603E+01
Percolation or leakance through Layer 4 (cm)	1.2155E+00	2.4222E+00	3.4805E+00	4.6559E+00
Percolation or leakance through Layer 7 (cm)	4.4758E-01	1.5870E+00	2.6641E+00	3.8278E+00

(continued)

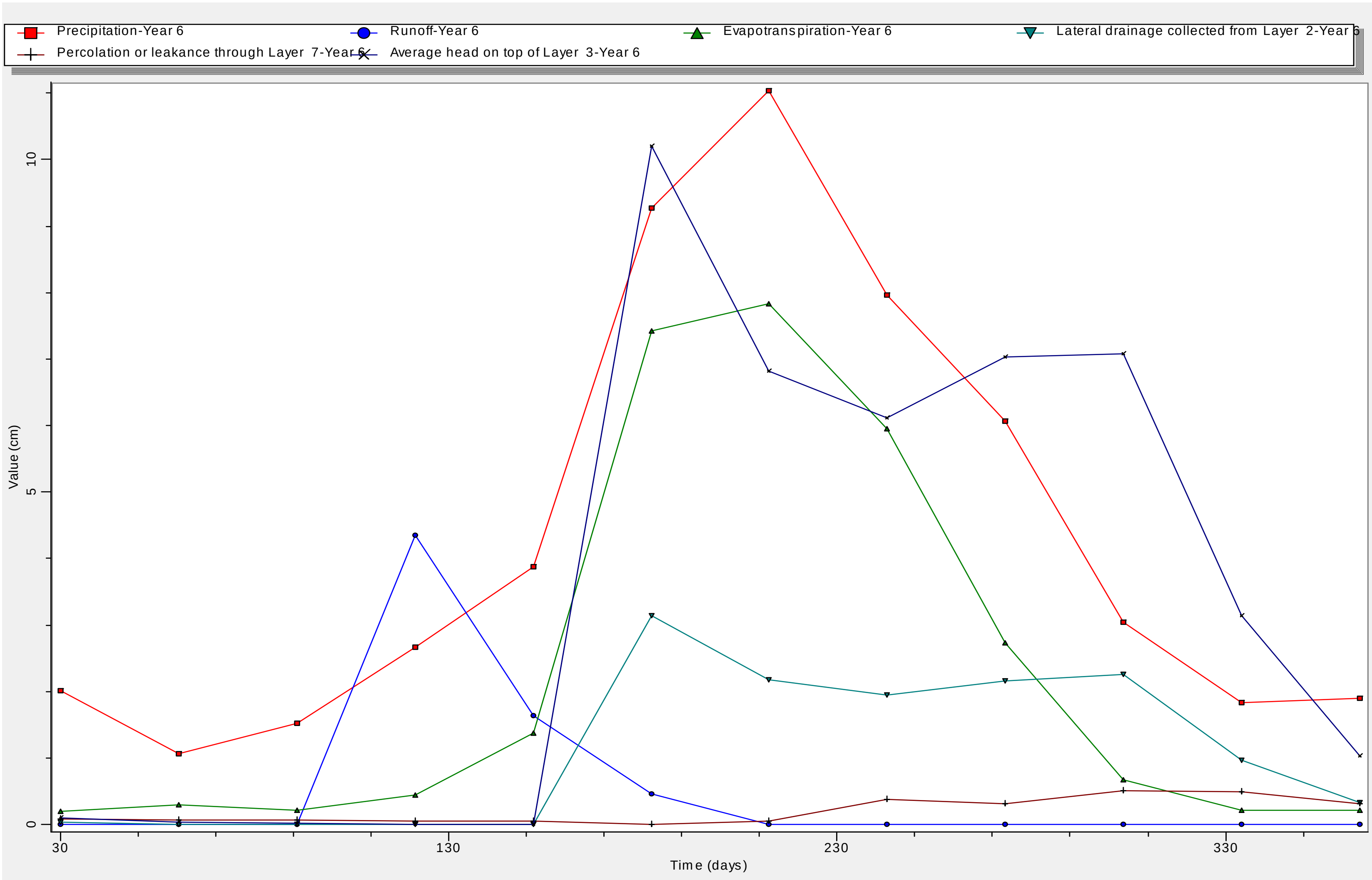
	Year-5 (cm)	Year-6 (cm)
Precipitation (cm)	1.5517E+02	2.0740E+02
Runoff (cm)	1.3070E+01	1.9519E+01
Evapotranspiration (cm)	1.0920E+02	1.3679E+02
Lateral drainage collected from Layer 2 (cm)	2.7123E+01	4.0166E+01
Percolation or leakance through Layer 4 (cm)	5.8559E+00	8.6890E+00
Percolation or leakance through Layer 7 (cm)	5.0217E+00	7.4191E+00

Peak daily values

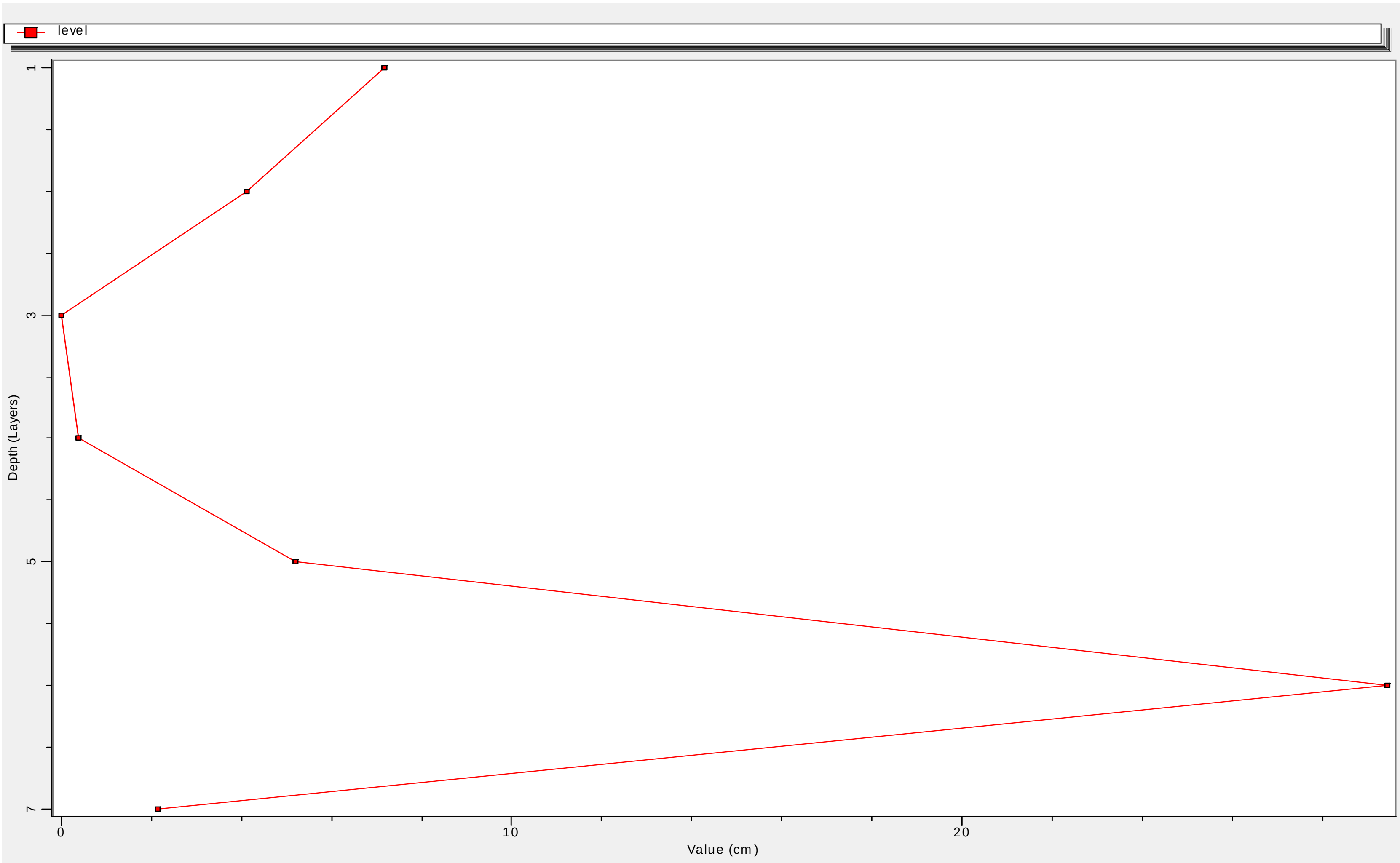
	Rate (cm)	Volume (m3)	Day	Year
Precipitation	3.5600E-01	1.2816E+02	182	6
Runoff	9.5666E-01	3.4440E+02	109	6
Lateral drainage collected from Layer 2	1.7709E-01	6.3753E+01	154	1
Percolation or leakance through Layer 4	5.8612E-02	2.1100E+01	154	1
Percolation or leakance through Layer 7	2.3719E-02	8.5389E+00	306	6
Snow water	6.3630E+00	2.2907E+03	98	6



Precipitation-Year 5
Runoff-Year 5
Evapotranspiration-Year 5
Lateral drainage collected from Layer 2-Year 5
Percolation or leakance through Layer 7-Year 5
Average head on top of Layer 3-Year 5
Value (cm)
10
5
0
30
130
230
330
Time (days)



Precipitation-Year 6
Runoff-Year 6
Evapotranspiration-Year 6
Lateral drainage collected from Layer 2-Year 6
Percolation or leakance through Layer 7-Year 6
Average head on top of Layer 3-Year 6
Value (cm)
0
5
10
30
130
230
330
Time (days)



level
Depth (Layers)
1
3
5
7
0
10
20
Value (cm)

Appendix E – Stability Analyses for Reclaimed Dome Creek

INTRODUCTION

This appendix summarizes the work performed to assess the stability of the Mount Nansen Tailings Storage Facility area (TSF) upon remediation. In general, remediation of the TSF includes removal of all tailings, dam fill and a depth of original ground soils underlying the tailings within the impoundment area. Due to the permafrost conditions of the site, the stripped area will be replaced with a cover of granular fill to help stabilize the exposed slopes.

The following presents the results of limit equilibrium stability analyses completed in support of the preliminary design of the Dome Creek Valley slopes after remediation. Stability analyses were undertaken to assess the existing slopes in the TSF and the proposed final slopes for remediation, given the foundation conditions as interpreted mainly from the 1995 design report[5] and the 2013 site investigation program[6], although other available data was incorporated where relevant. Of particular concern is the stability of the slopes under conditions of thawing permafrost, caused either by exposure of frozen material or warming air temperatures.

ANALYSES PARAMETERS

General

Two-dimensional limit equilibrium stability analyses were carried out by the following methods:

- Infinite Slopes - Thawing foundation per McRoberts 1977[7] and under earthquake loading.
- Method of Slices for deeper seated failures - Slope/W 2007 software.

Material Parameters

The geologic materials and typical geologic section assumed for the Dome Creek Valley are discussed below and the parameters used in the analyses are summarized in Table 1. Consistent with the regional geology, the subsurface deposits in Dome Creek valley are dominated by sands, silty sands and sand and gravels.

Historic investigation data was reviewed and compiled to develop an understanding of the geology in Dome Creek valley (Klohn, 1988, 1995, EBA, AECOM, EBA, 2012). As illustrated in the stability section shown in Figure 5, the typical geology consists of surficial sandy silt with organics up to 3 m thick underlain by fine to medium sand. In the upper portions of the valley slopes on the south side of the tailings impoundment, bedrock was indicated on the borehole logs at depths of several metres. Overburden thickness increases towards the bottom of the valley reaching thicknesses of greater than 20 m. Overburden deposits are thicker on the north side of the valley where there is a fluvial terrace than on the south side.

Silt to sandy silt several metres deep was encountered at depths of 5 to 15 m in various investigation locations on the valley side slopes. This material appears to be absent in the valley bottom. Although not observed in all investigation locations, it appears that the finer material could represent a unit that was

5 Klohn-Crippen (1995). "Mt. Nansen Gold Project, Tailings Impoundment Final Design Report". August 1995.
6 AMEC Environment & Infrastructure (2013). "Mount Nansen Remediation Project, 2013 Site Investigation Data Report DRAFT". December 2013.
7 McRoberts 1977, Extensions to Thawing Slope Stability Theory, Proceedings of the Second International Symposium on Cold Regions Engineering, 12-14 August 1977, p 262 - 276.

deposited across the valley and then eroded in the valley bottom. Underlying this unit is a coarser sand and gravel unit and then bedrock.

The surficial silt to silty sand with organics is a highly variable unit. It ranges in thickness from 0 to 2 or 3 m although there may be local areas where there are more significant thicknesses, particularly in the valley bottoms. It has variable water content up to 50 percent but is typically in the range of 15 to 30%. The surficial silt was assigned a thawed friction angle of 25 degrees consistent with typical values for loose silt.

Other than the visual descriptions from the available borehole logs there is limited data regarding the deeper silt unit largely because it was not encountered frequently in the various investigation programs. There are cases where boreholes have been carried out by different consultants within close proximity to each other and in one log the material is described as a silt and in the other it is described as a sand. The main conclusion from the available data is that the material is likely of relatively low plasticity and variable, particularly with regards to sand content.

The insitu sand to silty sand is generally a fine to medium grained material and when encountered in a frozen state typically has no visible ice. Core samples obtained during drilling retain their shape upon thaw with no excess water visible. There were several ice lenses encountered during drilling with a maximum thickness of 70 cm. These occurred in the valley bottom and were at depth of greater than 5 m below original ground. They did not appear to be at a constant elevation or indicative of a widespread unit.

The underlying sand and gravel unit has not been extensively investigated because it has typically resulted in refusal during drilling. Base on this it is considered to be a competent unit that will not negatively influence stability.

Upon reclamation the slopes will be covered with granular fill consisting of a lower layer of sand and an upper layer of gravel and sand rockfill. This material will be placed in an unsaturated state and is assumed to remain unsaturated.

Table E.1: Summary of Material Parameters

Material	Bulk Unit Weight (kN/m^3)	Friction Angle (Φ)	Cohesion (kPa)	Cv (m2/s) [5]
Insitu sand / silty sand	19[1]	**30-32º[3]**	0	1x10-4
Near surface silt & organics	14[1]	25-27º[4]	0	1x10-6
Deeper silt to sandy silt	18.5[1]	28º[3]	0	1x10-6
Granular fill	16[2]	35º[4]	0	n/a

Note:

1. Bulk unit weights are based on lab testing of insitu soils from Klohn-Crippen (1995).
2. A conservative value was selected for gravel fill because the surcharge provided increases strength and resistance
3. Consistent with values used previously for dam assessment
4. Based on typical values for loose silt and gravel respectively
5. Based on values reported in Klohn, 1995

Ground Slope Angles

Slope angles of the original ground surface were determined based on original topographic data for various locations within and surrounding the TSF area. Typically average slopes varied between 6 and 11 degrees on the side slopes with flatter slopes present in the bottom of the valley. A slope angle (θ) of 11º was selected as the base case for infinite slope sensitivity analyses.

Pore Pressure Assumptions

For the infinite slope conditions which are representative mainly of shallow thaw depths which would occur soon after remediation, it was assumed that the phreatic surface was coincident with the surface of the insitu soils. The granular fill material placed above the insitu soils was assumed to remain unsaturated. Thaw induced pore pressures were then superimposed on the assumed phreatic surface.

For deeper failures, a phreatic surface consistent steady state conditions after tailings removal was estimated based on conditions outside of the current tailings storage facility. This was done because thaw of the deeper silt unit would occur sometime after remediation. The phreatic surface was assumed to generally parallel the ground surface although located slightly deeper in the upper valley slopes and shallower near the valley bottom. On the south slope, the phreatic surface was assumed to be at a depth of 1 to 2 m while on the north slope the phreatic surface on the upper slopes was located at a depth of 4 m.

In addition to the phreatic surface, a pore pressure ratio (r_u) was assigned to the deeper silt unit to account for thaw induced pore pressures. This was based on the equations derived from Morganstern and Nixon (1971) which express the pore pressure generated by a thawing soil settling under self weight as shown in Equation 1.

$$\frac{u}{\gamma' d} = \frac{1}{1 + \frac{1}{2R^2}}$$

where γ' = buoyant unit weight Equation 1
d = depth of interest

$$R = \frac{\alpha}{2\sqrt{c_v}}$$

α = rate of thaw, m/yr$^{0.5}$
C_v = coefficient of consolidation m^2/yr

Since $r_u = \frac{u}{\gamma d}$ multiplying equation (1) above by $\frac{\gamma'}{\gamma}$ results in an r_u value.

The rate of thaw was assumed to be 6.2x10^{-4} m/s$^{0.5}$ per previous design documentation. A rate of thaw has been estimated for the Dome Creek valley and those analyses are presented under separate cover. The analyses resulted in a lower estimated rate of thaw and, therefore, since the assumption above is conservative, the stability analyses were not updated. Based on the rate of thaw and the material parameters presented in Table E.1, the estimated r_u for thawing silt is 0.08. If however the γ'/γ term is ignored to allow for the full weight of the overlying soils, a value of 0.16 is calculated. This value is consistent with previous design work and increases the pore pressures in the silt unit above the hydrostatic condition imposed by the phreatic surface by 16% of the total vertical pressure.

Minimum Factor of Safety Criteria

Minimum Factor of Safety (FOS) criteria for design were as follows per the project design criteria:

- FOS > 1.5 for long-term steady state conditions
- FOS >1.3 for short term conditions
- FOS > 1.1 for seismic conditions

It can be argued that thaw, particularly in the shallow infinite slope case is a short term condition and therefore a target factor of safety of 1.3 is considered appropriate.

SLOPE STABILITY ANALYSIS FOR THAWING FOUNDATION

To access the stability of the slopes within the Dome Creek valley during and post remediation activities, infinite slope stability analysis was performed. The insitu soils are assumed to be subjected to thaw and therefore must account for excess pore pressures caused by thawing conditions. The method used in this analysis is based on the derived relationships for slope stability in a layered system in McRoberts and Nixon, 1977[8] as shown in Equation 2 below.

The factor of safety equation used is as follows:

$$FOS = \frac{1 + \gamma'/\gamma \; d/H}{1 + d/H} \left\{ \frac{d/H + k_2/k_1}{(1 + 2R^2)(d/H + k_2/k_1)} \right\} \tan\Phi'/\tan\theta$$

Equation (2)

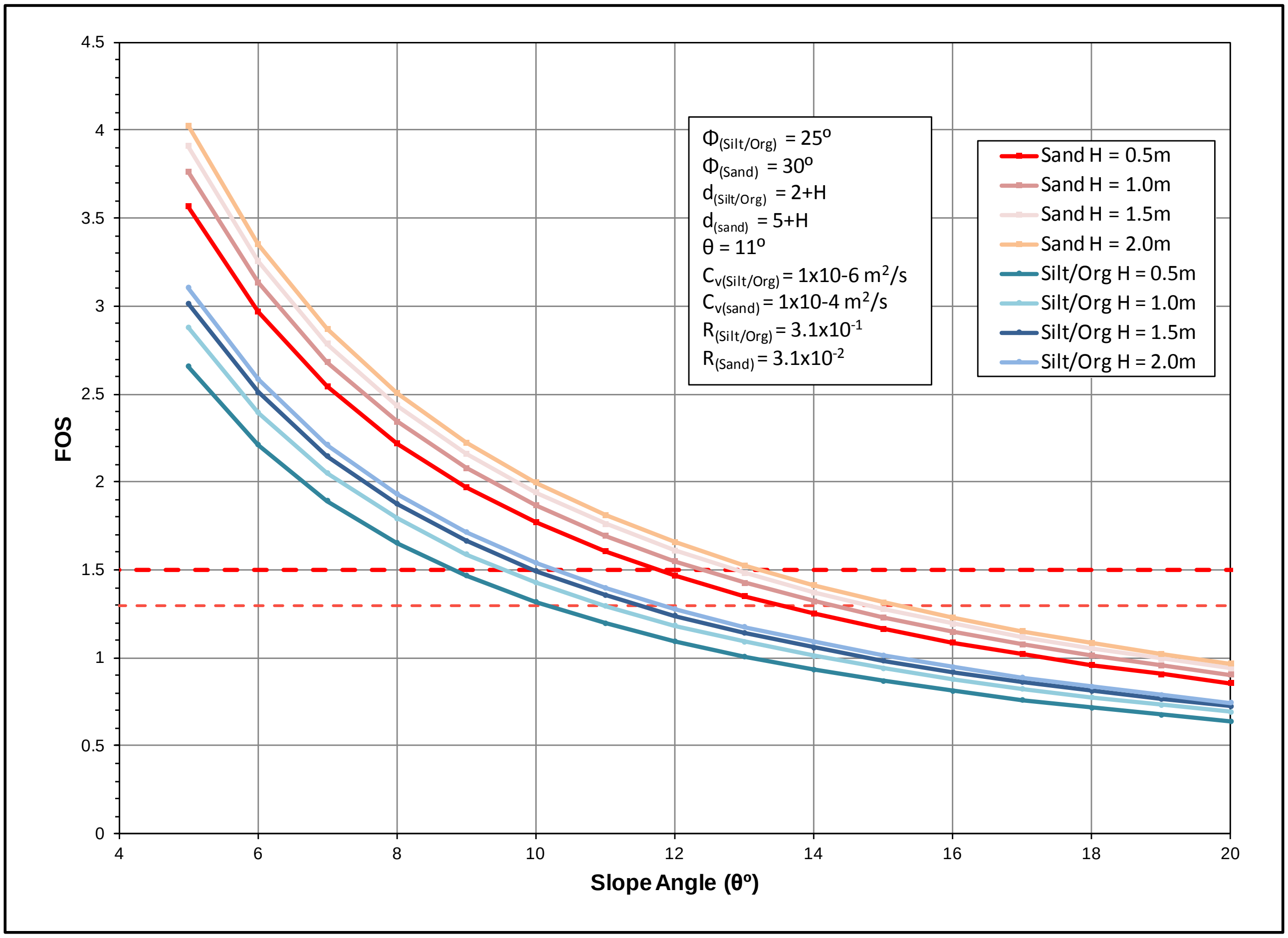
Where:

$k_2/k_1 = 0.67$	Typical ratio for thermal conductivity of underlying layer to surface layer (unfrozen)[1]
H = varies	Thickness of Cover
d = varies	Depth of thaw including cover thickness
$\alpha = 6.2 \times 10\text{-}4$	Rate of thaw in $m/s^{0.5}$ [1]
$C_v = 1.0 \times 10\text{-}6$ (Org/Silt)	Coefficient of consolidation in m^2/s [1]
$C_v = 1.0 \times 10\text{-}6$ (Sand)	
$R = 3.1 \times 10\text{-}1$ (Org/Silt)	Thaw consolidation ratio, $\alpha/(2\sqrt{C_v})$
$R = 3.1 \times 10\text{-}1$ (Sand)	
$\gamma'/\gamma = 0.5$	Ratio of effective to total unit weight[3]
$\theta = 11^{o}$	Angle of ground slope
$\Phi' = 25\text{-}27^{o}$	Friction angle of insitu soil (Silt/organics)
$\Phi' = 30\text{-}32^{o}$	Friction angle of insitu soil (Sand)

8 E.C. McRoberts and J.F. Nixon, (1977). "Extensions to Thawing Slope Stability Theory". May 1977.

The analysis was performed assuming a gravel cover overlying two different insitu soil conditions: 1) Silt with organics and 2) Sand. The slope angle, thickness of cover and depth of thawed foundation soil was varied to access the sensitivity of the factor of safety to these conditions. Results of the analysis are shown in Figures E.1, E.2 and E.3.

Figure E.1: Factor of Safety vs. Slope Angle



Based on the results presented in Figure E.1, the maximum slope angles that can be achieved for the thaw depth and fill height configurations indicated while meeting the factor of safety criteria for short term stability of 1.3 are approximately 14° and 11° for slopes consisting of sand and silt/organics, respectively.

Further sensitivity analysis was completed using a slope angle of 11° varying the thickness of cover and the depth of thawed foundation. The results are shown in Figures E.2 and E.3.

Figure E.2: Factor of Safety vs. Thickness of Cover

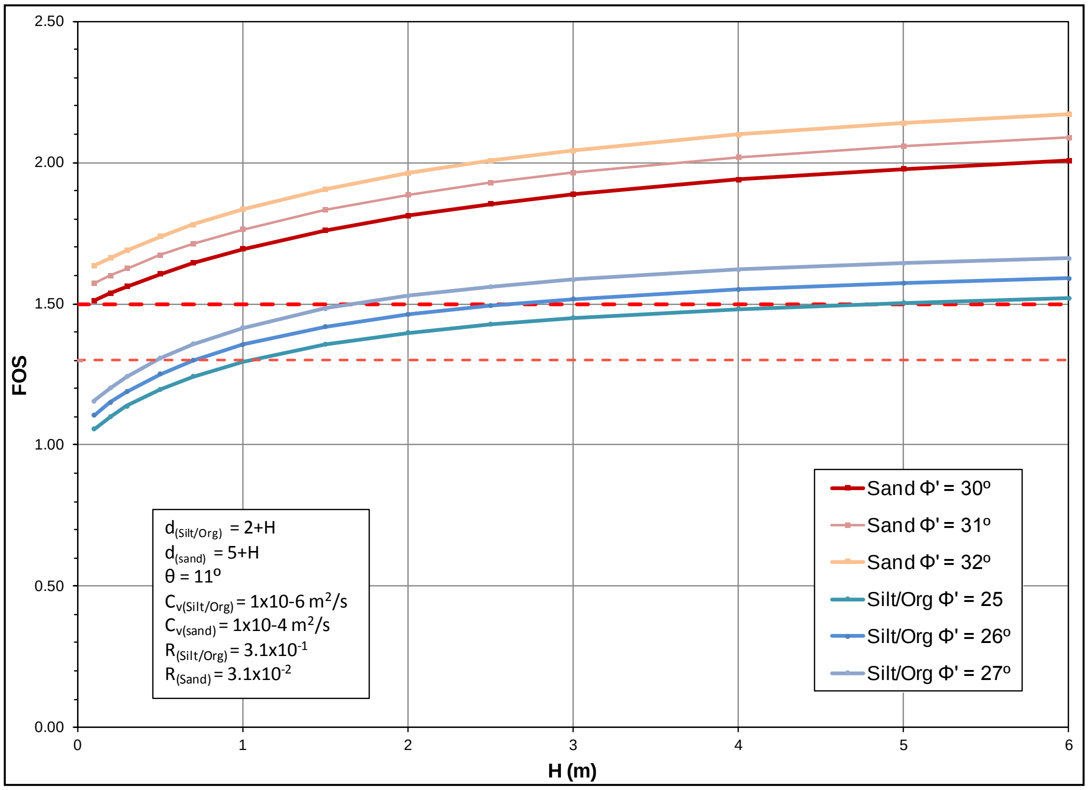
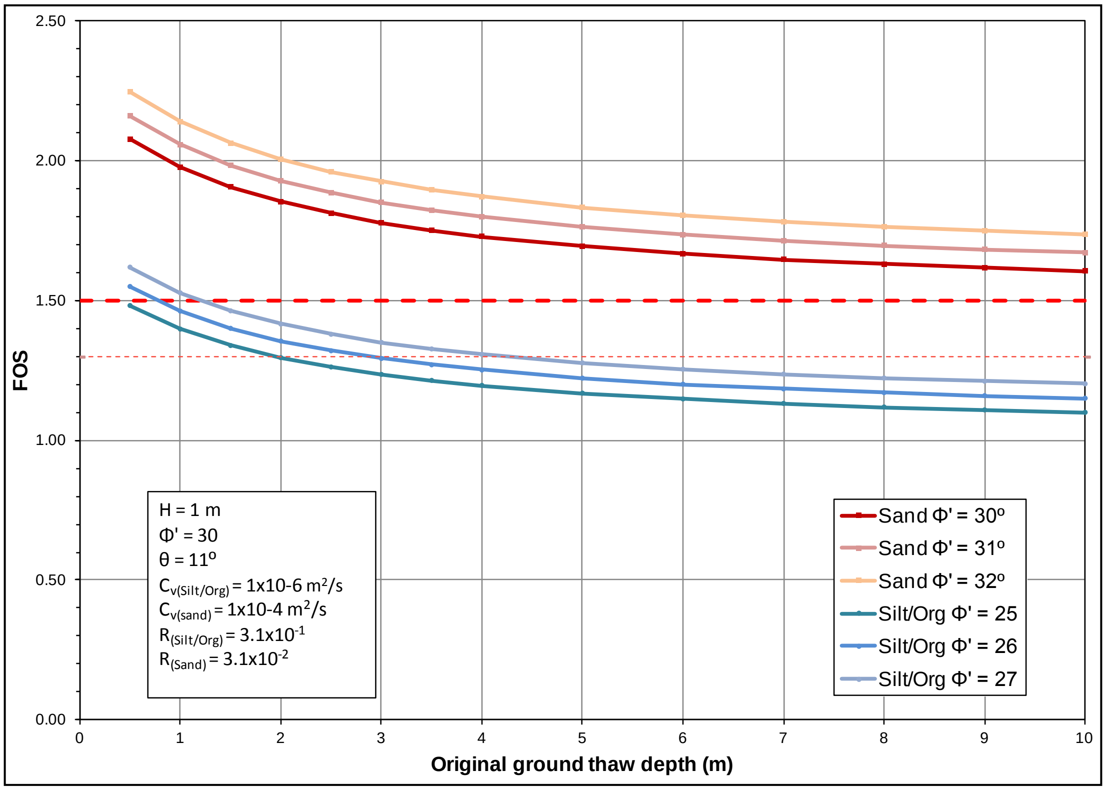


Figure 3: Factor of Safety vs. Original Ground Thaw Depth



Assuming a slope angle of 11º, the factor of safety values shown above for sands is well above the design factor of safety for thaw depths in excess of 10 m even with minimal fill placement. Thus, based on the assumed parameters, if the foundation consists of sands the slope will remain stable regardless of cover thickness and thaw depth of the original ground.

If the slopes have a surficial layer of silt and organics up to 2 m thick then in order to meet the design short term factor of safety criteria a minimum cover thickness of between 0.5 and 1.1 m is required depending on the assumed friction angle of the material. If the silt unit is thicker a greater thickness of cover will be required.

From Figure E.3, it can be seen that once thaw depths reach about 3 to 4 m there is little further reduction in the factor of safety as a result of the deepening thaw. Figure E.2 indicates that the maximum benefit from a cover layer is achieved at thicknesses of about 1 to 2 m. Thicknesses in excess of this result in relatively small increases in the calculated factor of safety. In consideration of these findings the following has been selected to mitigate against shallow slope failure during and post reclamation in Dome Creek:

- Minimum 1.5 m thick free draining granular cover
- Slopes regraded to match original topography but with maximum slopes of 11 degrees (5H:1V)

2D LIMIT EQUILIBRIUM ANALYSES OF THAWING CONDITIONS

General

Two-dimensional limit equilibrium stability analyses were carried out with GEO-SLOPE International Ltd.'s SLOPE/W 2007 software (version 7.17), using the Morgenstern-Price method of slices solution with a sine inter slice force function. The material parameters, and porewater parameters used in the analyses were summarized in previous sections.

Slope stability analyses were carried out for section A through the tailings facility area as illustrated in plan view in Figure E.4 and in section view in Figure E.5. The section was selected as the critical section because it has the steepest natural slopes. The stability analyses were performed to assess the slope stability under two conditions:

- Thawing conditions superimposed on long term steady state pore pressure conditions.
- Earthquake conditions under steady state pore pressure (no excess thaw induced pore pressure)

For the deeper failure surfaces the granular cover and shallow silt unit have no significant impact on the calculated factor of safety and therefore they have not been included in the model. The critical potential failure mode was considered to be failure along a continuous silt layer. The depth of the silt layer was selected based on the shallower (but not surficial) silt units recorded in the borehole logs.

Thawing Stability Results

The stability analysis section and results for the critical slope section are shown in Figures E.6 and E.7. The factor of safety values shown are for the most critical slip surface geometry as generated by grid search routines within Slope/W. A more block type failure mode through the silt unit was also assessed however the factor of safety for those failure surfaces was less critical.

Figure E.6 presents the geometry of the critical failure surface on the north slope using the base case parameters. The results indicate a factor of safety value of 1.9 which exceeds the long term factor of safety criteria of 1.5.

Figure E.7 presents the geometry of the critical failure surface on the south slope using the base case parameters. The calculated factor of safety of 1.7 also exceeds the long term factor of safety criteria.

Figure E.4: Stability Analysis – Critical Section Plan View

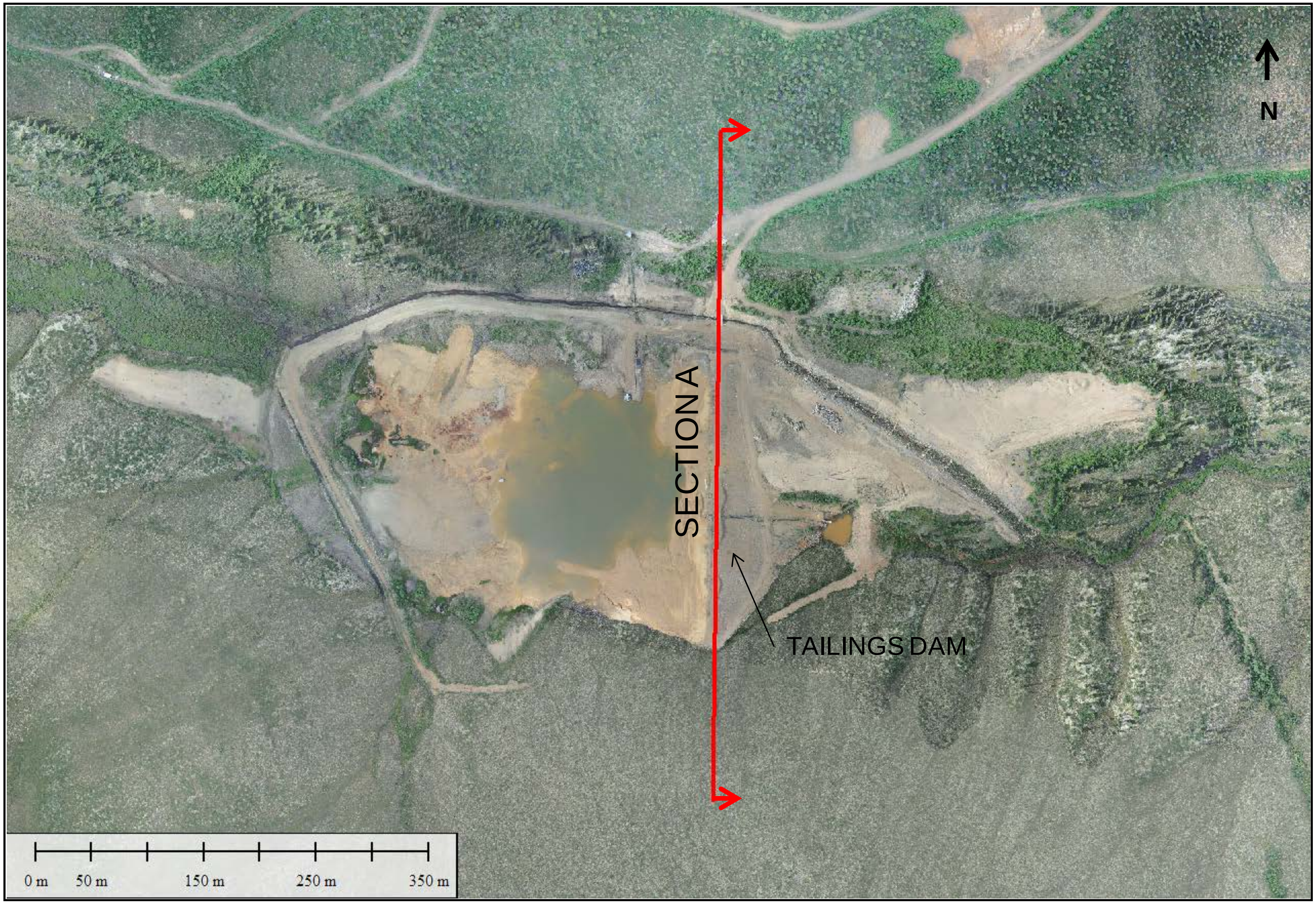


Figure E.5: Stability Analysis – Model Setup and Base Parameters

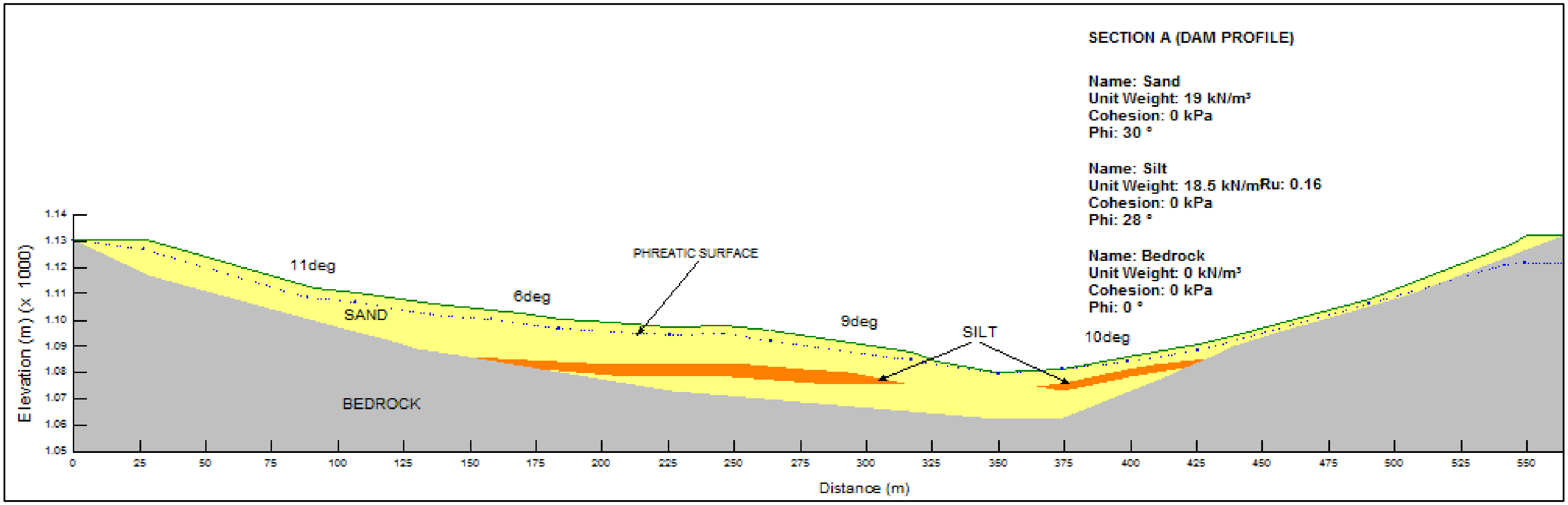


Figure E.6: Stability Analysis – Long Term Steady State (Failure Surface Left to Right)

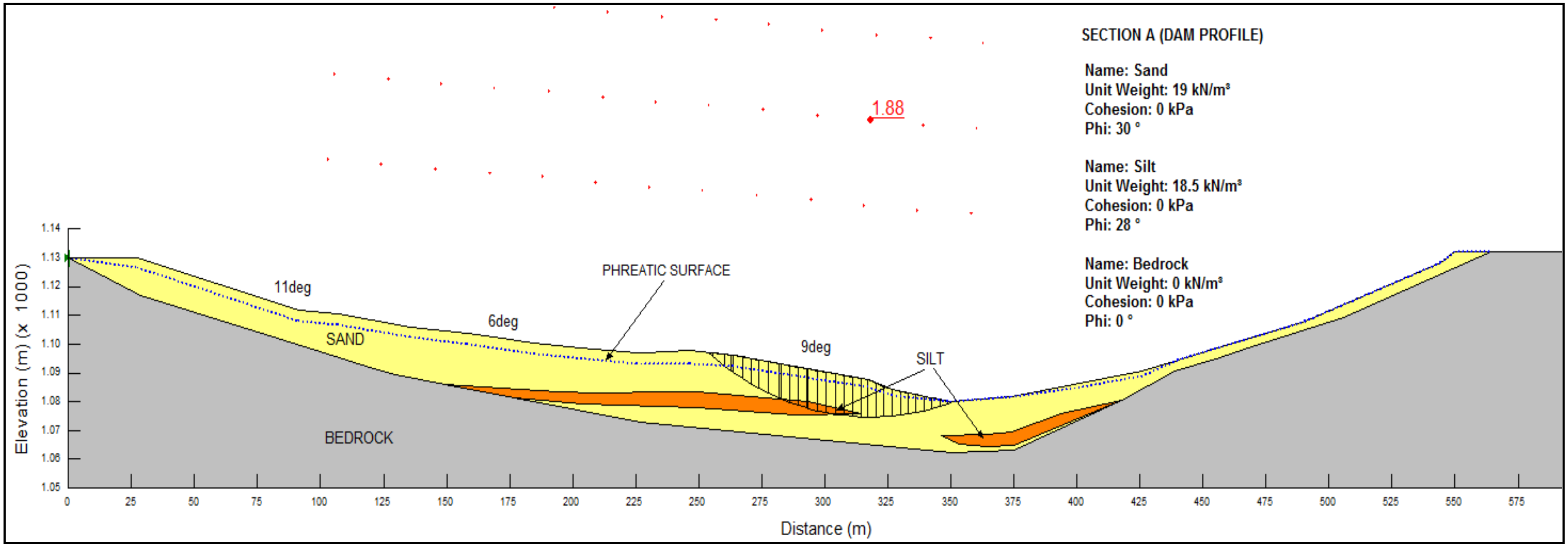
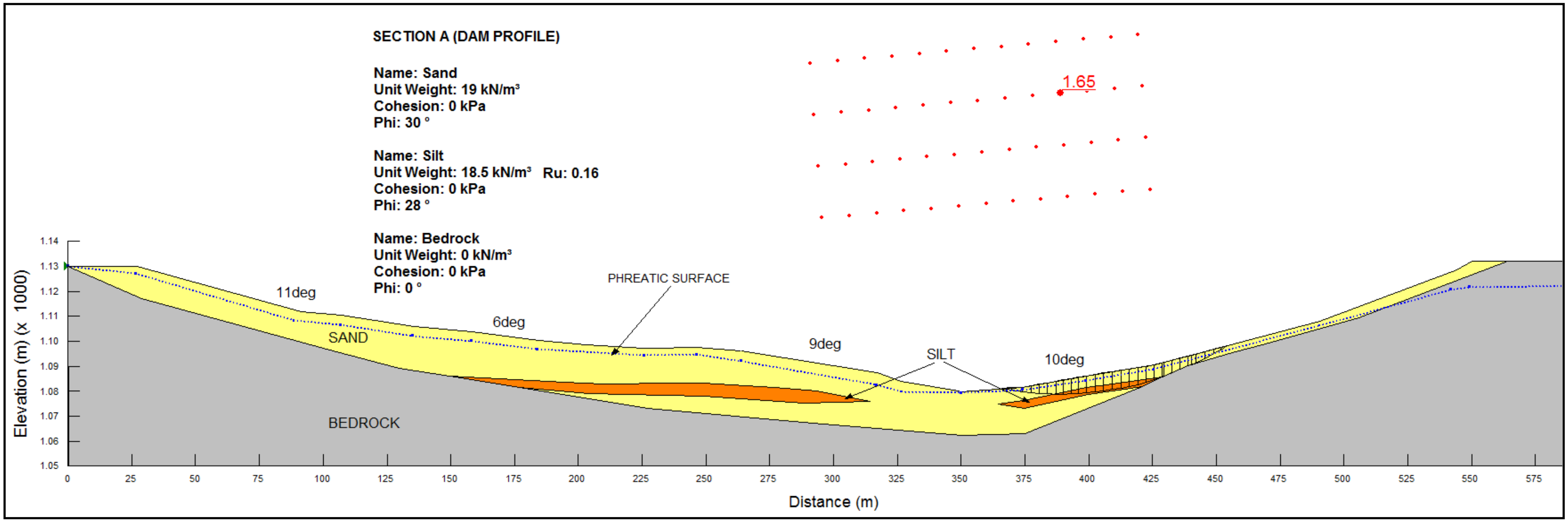


Figure E.7: Stability Analysis – Long Term Steady State (Failure Surface Right to Left)



ASSESSMENT OF STABILITY UNDER EARTHQUAKE LOADING

General

There are a variety of means by which the earthquake stability of infinite slopes can be considered and analyzed. These range from simple pseudo-static analyses, wherein the earthquake loading is factored into a limit equilibrium stability analysis via a seismic coefficient commensurate with the design earthquake loading, to simplified deformation analysis methods that incorporate pseudo-static analyses as a step, to complex finite element (or finite difference) numerical seismic dynamic analyses with earthquake time-histories incorporated to simulate an actual earthquake.

As reported under separate cover, screening assessments suggest that for the design earthquake event (1:1,000) the insitu soils within and surrounding the TSF have low liquefaction potential. As such, liquefaction does not need to be considered in the stability analyses and simplified analyses are considered to be sufficient to evaluate stability under the design earthquake loading.

Pseudo Static Stability Analyses

A pseudo-static analysis, where a horizontal equivalent acceleration is applied to the failure surface, has been performed to determine the yield acceleration k_y. The yield acceleration k_y corresponds to the seismic coefficient needed to achieve a factor of safety of unity for the limit equilibrium analysis. The analysis was performed using three different methods: 1) two dimensional pseudo static assessment using Slope/W assuming thawed conditions, 2) Infinite slope equations that consider the passive resistance of the toe of the slope and a horizontally applied earthquake load; and 3) Infinite slope equations which consider an earthquake force parallel to the slope.

The two dimensional analyses were carried out using the same sections as presented previously with the same long term phreatic surface. Because of the low likelihood of an earthquake occurring at the same moment as thaw is occurring in the silt, no excess thaw induced consolidation pore pressures were considered.

The infinite slope equations used in methods 2) and 3) are as follows and assume the absence of any seepage:

2) Infinite Slope with passive resistance[9]

$$FOS = \frac{\tan \Phi \,(1 - k_h \tan \theta) + (c/\gamma H) \cos^2\theta}{k_h + \tan \theta}$$

3) Infinite Slope with earthquake force parallel to the slope[10]

$$FOS = \frac{(1 - \gamma'/\gamma) - k_h\,(\sin \alpha/\cos \theta)}{\tan \theta + k_h\,(\cos \alpha/\cos \theta)} \tan \Phi$$

9 Based on Hadj-Hamou, T., and Kavazanjian Jr., E. (1985) and Matasovic, N. (1991) presented in Hoe I. Ling, and Dov Leshchinsky (1997). "Seismic stability and Permanent Displacement of Landfill Cover Systems." *J. Geotech. Engrg.*, 123(2), 113-122.

10 Chang, C., Chen, W., & Yao, J. 1984. "Seismic Displacements in Slopes by Limit Analysis." J. Geotech. Engrg., 110(7), 860–874.

Assuming $\alpha = \theta$ (worst case);

$$FOS = \frac{(1 - \gamma_w/\gamma) - k_h (\tan\theta)}{\tan\theta + k_h} \tan\Phi$$

Where;

k_h = horizontal seismic coefficient
$c = 0$ (cohesion)
H = Thickness of Cover
$\gamma'/\gamma = 0.5$ (Ratio of effective to total unit weight)
$\theta = 11^o$ (Angle of ground slope)
α = Angle of horizontal seismic force
$\Phi = 35^o$ Friction angle of Cover (Gravel)

The k_y values corresponding to the critical failure surface are presented in Table E.3.

Table E.3: Summary of Resulting k_y values

Method of Analysis	Equivalent Force Direction	Seismic Coefficient Required for FoS = 1 k_y (g)
1) Original ground (SlopeW) Left-Right Failure	Horizontal	0.18
Right-Left Failure	Horizontal	0.17
2) Infinite Slope with Passive resistance	Horizontal	0.59
3) Infinite Slope with earthquake force parallel to slope	Parallel to slope	0.27

The results indicate that unlike for the static case, the deeper failure surfaces are more critical for earthquake loading than the shallower infinite slope type failures. In all cases, however, the yield acceleration is significantly greater than the design PGA. The design criteria are, therefore, met and deformations during the design earthquake event would be expected to be small.

Appendix F – Thermal Analyses for Dome Creek

INTRODUCTION

In support of the remediation design for Dome Creek Valley, one dimensional thermal analyses were completed to predict ground temperatures in the vicinity of the tailings storage facility following remediation. The analyses were completed primarily to assess the potential for thaw of the remediated slopes as input to stability considerations. Of particular interest was the rate of thaw, α, as it is used to estimate thaw induced pore pressures.

Analysis Method and Inputs

The geothermal modelling software SIMPTEMP, developed in-house by AMEC was used to complete the modelling exercise. The program has one-dimensional, two-dimensional, and three-dimensional versions and was designed for predicting temperature and thaw/frost depth in various materials due to either environmental changes or construction activities. The comprehensive formulation makes it possible to analyze both simple and complex geothermal problems. The software is applicable for a simulation with conductive heat transfer, convective heat transfer, or both, and also can simultaneously incorporate a seepage subroutine; however, this was not used at this time. The algorithms used in the SIMPTEMP model were published by Chekhovskiy and Zenova (1989[11]). The results of their calculations were verified with well-known analytical solutions of the heat transfer problem and compared to numerical solutions produced by other commercial and non-commercial geothermal software. AMEC has used the SIMPTEMP program successfully for a variety of geothermal applications in Canada, and internationally, for more than 10 years.

GEOLOGIC SECTION

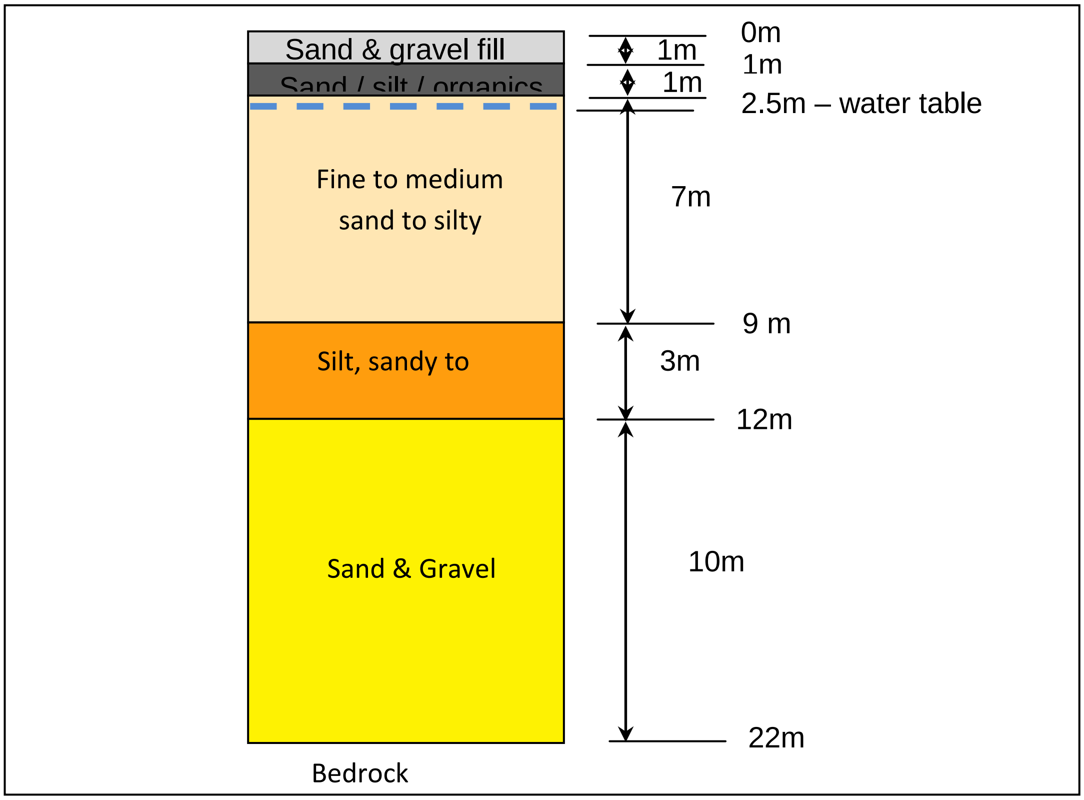
A typical geologic section was developed for reclaimed Dome Creek based on the subsurface information available from various drilling programs (refer to the discussion in the slope stability analysis of Dome Creek and AMEC 2014[12]). The typical stratigraphic section is summarized schematically in Figure F.1 and represents the remediated conditions with a granular layer placed on the surface to stabilize exposed slopes. A section with the same subsurface geology but without the sand and gravel fill and with vegetation was also assessed to represent undisturbed areas and examine the difference between the predicted temperatures in the remediated tailings area and the adjacent undisturbed areas. The properties associated with the various units are summarized in Table F.1.

[11] Chekhovskiy and Zenova, 1989, Nomographs of Soil Annual Average Temperature, Frost in Geotechnical Engineering Volume 1, International Symposium, Saariselka, Finland, 13-15 March, 1989.
[12] AMEC 2014, Mount Nansen Remediation Design Project, Site Characterization Report, January 2014.

Table F.1: Soil Properties

Depth Interval m	Soil Type	Dry Density kN/m^3	Moisture Content %	Thermal Cond., $W/m/^oC$		Heat Capacity, $kJ/m^3/^oC$		Latent Heat, kJ/m^3
				unfrozen	frozen	unfrozen	frozen	
0 -1	Sand and gravel	20	10	2.73	2.91	2680	2260	67,000
1-2	Silty sand	18	15	1.69	1.80	2500	2260	90,500
2-9	Fine silty sand	18	20	2.68	2.85	3200	2400	108,500
9-12	Silt	16	25	1.80	1.92	3140	2350	118,000
12-24	Sand and gravel	18	25	2.68	2.85	3200	2400	151,000
24 and deeper	Bedrock	28	2	2.90	2.90	2600	2600	Negligible

Figure F.1: Schematic of Typical Geologic Section for Thermal Assessment in Dome Creek Valley



Scenarios Analyzed

A total of six scenarios were analyzed comprised of three different ground conditions and two different future air temperature conditions as outlined below:

- Ground conditions scenarios:
  - Reclaimed ground, no vegetation
  - Reclaimed ground with vegetation gradually becoming established
  - Undisturbed ground with vegetation

- Air temperature scenarios:
  - Present air temperatures assumed to continue into the future
  - Warming air temperatures assumed into the future

Inputs for the different scenarios are summarized in Table F.4 below, with a brief discussion in the following relevant sections. The analyses were run for 36 years, from 2014 to 2050.

Air Temperatures

An assessment of the air temperature data gathered at the Mount Nansen site supplemented by interpretation of longer term data available from Carmacks and Dawson City has been completed and was included in AMEC (2014). The thermal analyses were completed for two different air temperature scenarios:

- current 2013 air temperatures remained constant into the future; and
- warming air temperatures (see discussion in AMEC, 2014).

The current temperature conditions at Mount Nansen are summarized in Table F.2 and the temperatures predicted for 2050 are summarized in Table F.3. The freezing and thawing indices for 2013 were calculated to be equal 70°C-months and 45.5°C-months, respectively. The freezing and thawing indexes for 2050 were calculated to be equal 55.5°C-months and 54.5°C-months, respectively.

Table F.2: Current Mean Monthly Air Temperatures for Mount Nansen (2013)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
-17.5	-7.8	-9.4	-1.0	6.9	12.2	12.1	11.4	2.8	-3.2	-8.8	-16.2	-1.5

Table F.3: Predicted Mean Monthly Air Temperatures for Mount Nansen for 2050

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
-16.3	-6.6	-8.1	0.3	8.2	14.2	14.1	13.4	4.1	-1.9	-7.5	-15.0	-0.1

Ground Vegetation

Moss vegetation provides considerable insulating effect to the ground temperature during the summer months. For the models in which vegetation was present, it was assumed that the vegetation had a thermal resistance consistent with that of sphagnum moss, 0.45 m^2 °C/W, per values published in Tchekhovski et al. (1983[13]).

13 Tchekhovski, A., Tchernyadiev, V., et al, 1983, "Prediction of Permafrost Parameters for Developing Arctic Regions", in Russian.

Table F.4: Summary of Scenarios and Model Conditions

Scenario No	Air Temperature	Ground Vegetation	Snow	Initial Ground Temperatures
1	Mean monthly air temperatures for present climate (2013, Table F.2) were applied for the simulation time from 2014 to 2050. An n-factor of 1.2 was introduced for summer months.	No ground vegetation	Average for winter snow resistance of 1.04 m^2 °C/W was applied for simulation time from 2014 to 2050.	• 0 m to 6 m depth: +3°C • 6 m to 9 m depth: Temperature gradually decreased from 0°C to -0.35°C • 9 m to 24 m depth: Temperature was -0.6°C • 24 m and deeper: Temperature gradually increased following to the geothermal gradient of 0.02°C/m.
2	Mean monthly air temperatures for present climate (2013, Table F.2) were applied for the simulation time from 2014 to 2050. An n-factor of 1.2 was introduced for summer months.	Thermal resistance of the ground vegetation was gradually increased from 0 (first year) to 0.45 m^2 °C/W in year 2050.	Average for winter snow resistance of 1.04 m^2 °C/W was applied for simulation time from 2014 to 2050.	• 0 m to 6 m depth: +3°C • 6 m to 9 m depth: Temperature gradually decreased from -0.5°C to -0.8 °C • 9 m to 24 m depth: Temperature was -0.6°C • 24 m and deeper: Temperature gradually increased following to the geothermal gradient of 0.02°C/m
3	Mean monthly air temperatures were gradually increased from the present climate (2013, Table F.2) to the predicted 2050 climate (Table F.3). An n-factor of 1.2 was introduced for summer months.	No ground vegetation	Average for winter snow resistance of 1.04 m^2 °C/W was applied for simulation time from 2014 to 2050.	• 0 m to 6 m depth: +3°C • 6 m to 9 m depth: Temperature gradually decreased from 0°C to -0.35°C • 9 m to 24 m depth: Temperature was -0.6°C • 24 m and deeper: Temperature gradually increased following to the geothermal gradient of 0.02°C/m
4	Mean monthly air temperatures were gradually increased from the present climate (2013, Table F.10) to the predicted 2050 climate (Table F.3). An n-factor of 1.2 was introduced for summer months.	Thermal resistance of the ground vegetation was gradually increased from 0 (first year) to 0.45 m^2 °C/W in year 2050.	Average for winter snow resistance of 1.04 m^2 °C/W was applied for simulation time from 2014 to 2050.	• 0 m to 6 m depth: +3°C • 6 m to 9 m depth: Temperature gradually decreased from -0.5°C to -0.8°C • 9 m to 24 m depth: Temperature was -0.6°C • 24 m and deeper: Temperature gradually increased following to the geothermal gradient of 0.02°C/m
5	Mean monthly air temperatures for present climate (2013, Table F.2) were applied for the simulation time from 2014 to 2050. An n-factor of 1.2 was introduced for summer months.	Thermal resistance of the ground vegetation was constant (0.45 m^2 °C/W) from year 2014 to 2050.	Average for winter snow resistance of 1.04 m^2 °C/W was applied for simulation time from 2014 to 2050.	• 0 m to 2 m depth: +3°C • 2 m to 9 m depth. Temperature gradually decreased from 0°C to -0.35°C • 9 m to 24 m depth: Temperature was -0.6°C. • 24 m and deeper: Temperature gradually increased following to the geothermal gradient of 0.02°C/m
6	Mean monthly air temperatures were gradually increased from the present climate (2013, Table F.10) to the predicted 2050 climate (Table F.3). An n-factor of 1.2 was introduced for summer months.	Thermal resistance of the ground vegetation was constant (0.45 m^2 °C/W) from year 2014 to 2050.	Average for winter snow resistance of 1.04 m^2 °C/W was applied for simulation time from 2014 to 2050.	• 0 m to 2 m depth: +3°C; • 2 m to 9 m depth: Temperature gradually decreased from 0°C to -0.35°C • 9 m to 24 m depth: Temperature was -0.6°C • 24 m and deeper: Temperature gradually increased following to the geothermal gradient of 0.02°C/m

Snow Conditions

A snow cover provides considerable insulating effect to the ground temperature in winter time. The insulating effect of a snow cover was applied in the model for prediction of the mean annual ground temperature as a thermal resistance.

Snow cover data from the Carmacks and Dawson City weather stations indicate negligible change in snow thickness over the past 40 years and 100 years, respectively (AMEC, 2014). Snow thickness has thus been assumed to remain constant into the future. The thermal resistance of the snow for a given thickness does, however, change with air temperature. Snow resistance values were calculated according to Tchekhovski et al. (1983)[14] based on the assumed snow thickness and air temperatures. For a 66 cm snow thickness with 2013 air temperatures, a snow resistance of 1.04 m^2 $^oC/2$ was calculated. The rising air temperatures predicted for 2050 would cause the snow resistance to decrease by 20%.

Initial Ground Temperatures

The initial ground temperatures summarized in Table F.4 were based on an assessment of the recent thermistor data gathered in the vicinity of the tailings facility at Mount Nansen.

RESULTS

The predicted ground temperature profiles at five year intervals are shown for each modelled scenario in Figures F.2 through F.7. Note that the scenarios titled “Tailings” are the models for the remediated areas within the footprint of the current tailings facility.

All of the models show warming ground temperatures with the no ground vegetation scenarios showing the warmest temperatures. It appears that with the predicted climate, undisturbed areas will experience significant permafrost degradation (Scenario 6). Since the disturbed tailings area has such a deep initial thaw depth, the thaw deepening for the tailings area with vegetation established is less severe than for the undisturbed case which initially has very shallow permafrost. It appears that there may be a limiting depth to which thaw will proceed if vegetation is established as both Scenario 6 and Scenario 4 have similar thaw depths in 2050.

The depth of thaw with time is shown in Figure F.8. The rate of thaw parameter, α, is the slope of the thaw depth vs. root time curve as shown in Figure F.9. In the short term, values range from 6 to $8x10^{-4}m/s^{0.5}$ while in the longer term, values increase to 2 to $5x10^{-4}m/s^{0.5}$.

Figure F.2: Predicted Ground Temperatures for Scenario 1

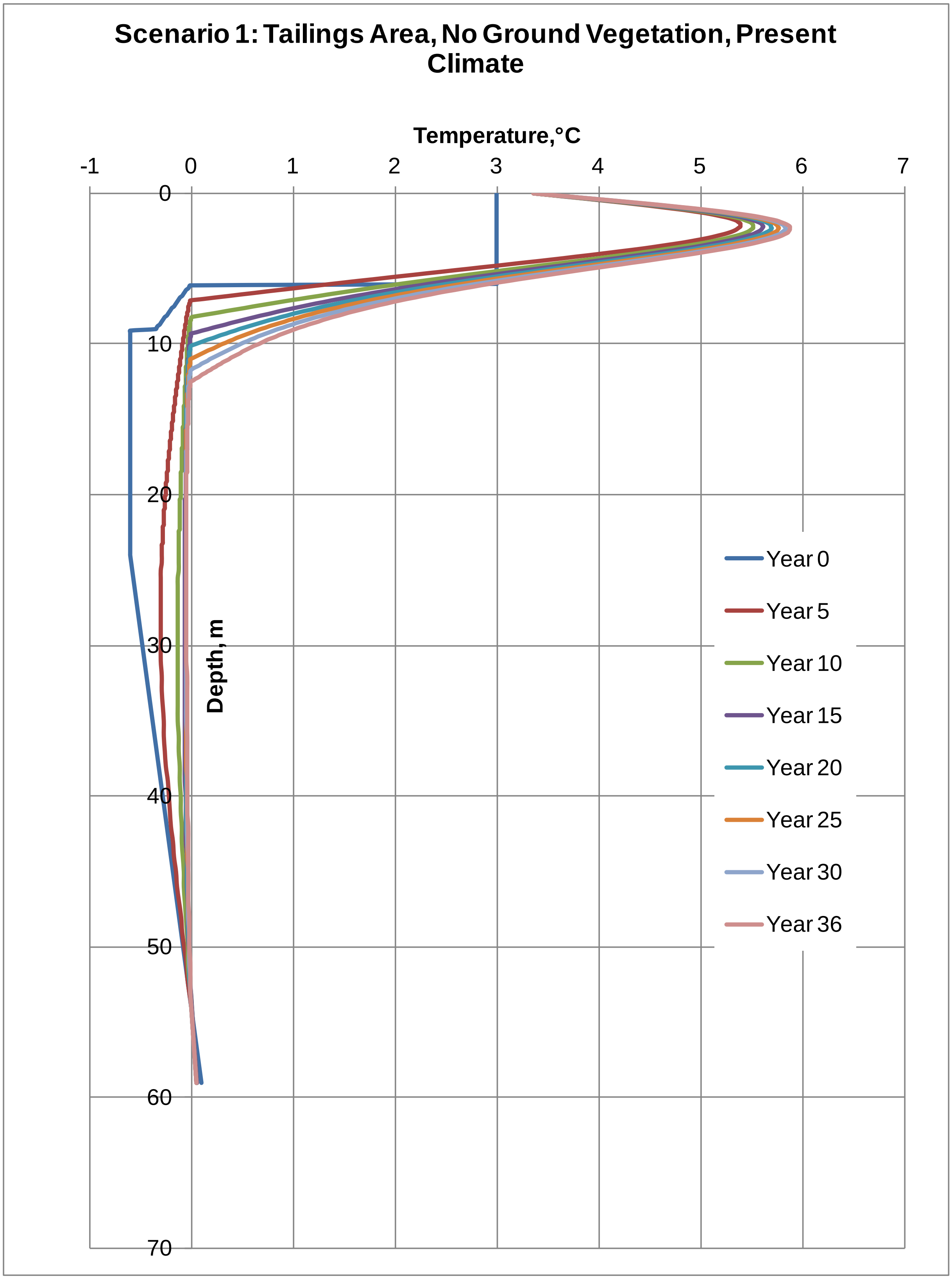


Figure F.3: Predicted Ground Temperatures for Scenario 2

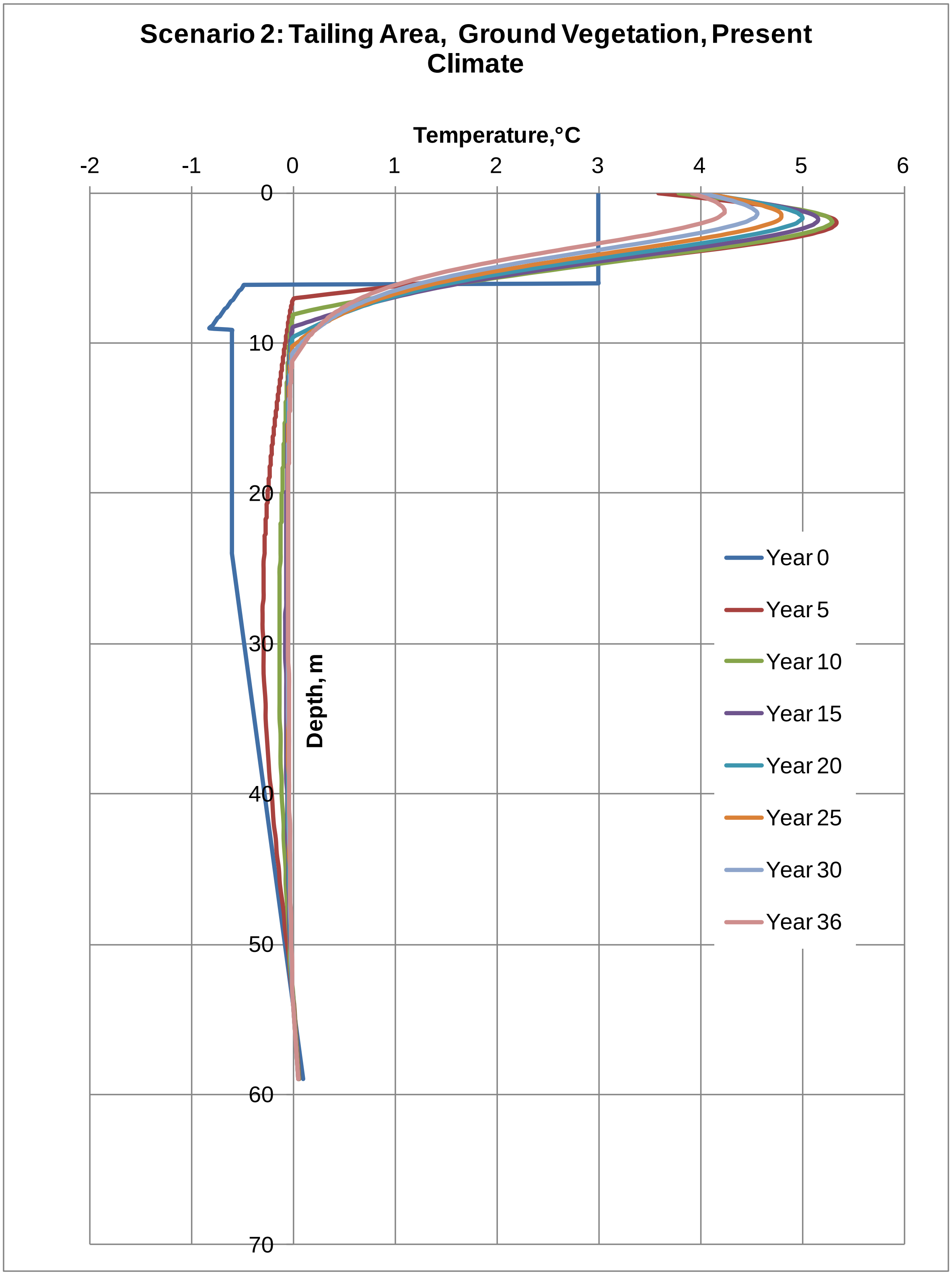


Figure F.4: **Predicted Ground Temperatures for Scenario 3**

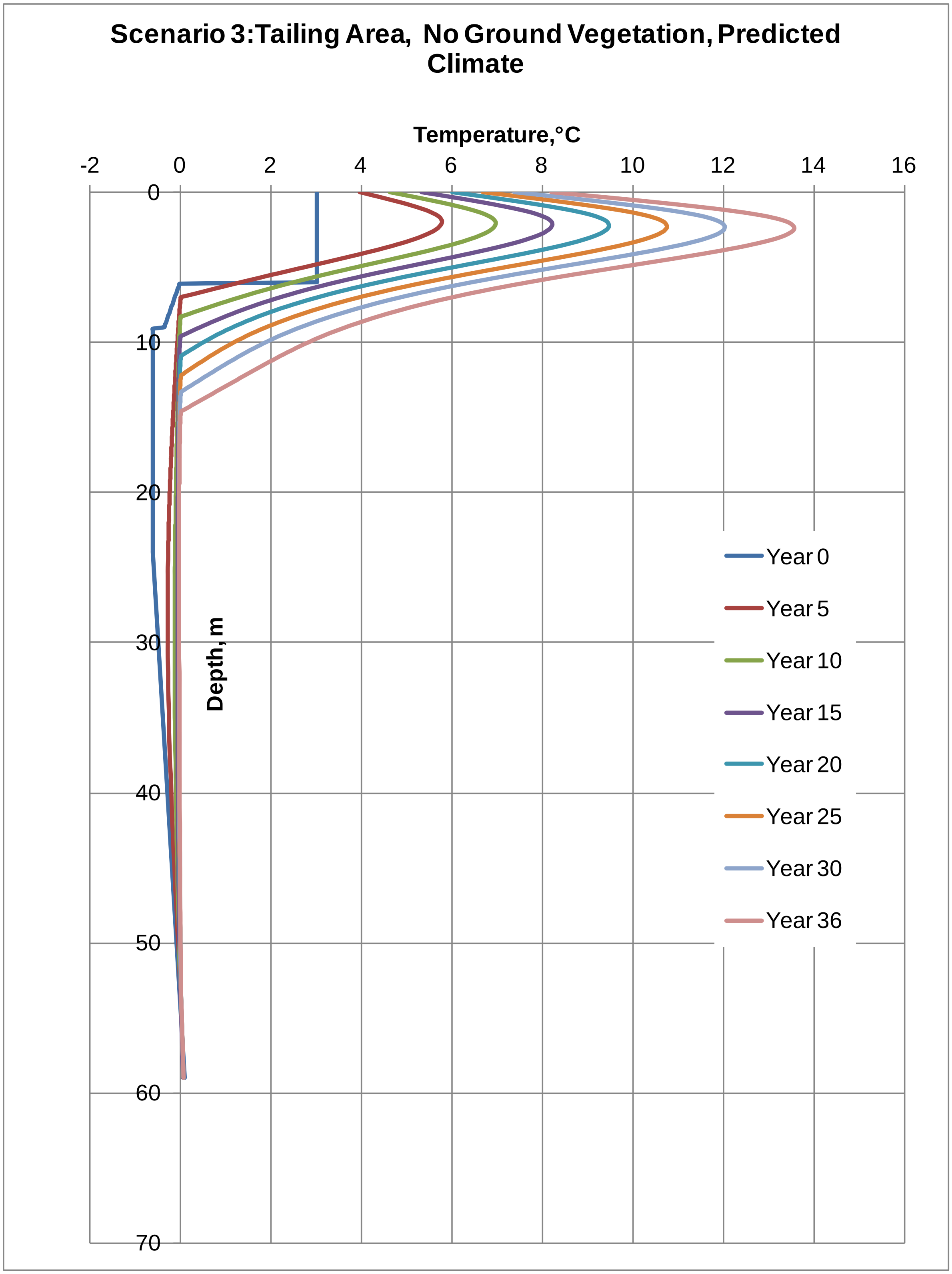


Figure F.5: Predicted Ground Temperatures for Scenario 4

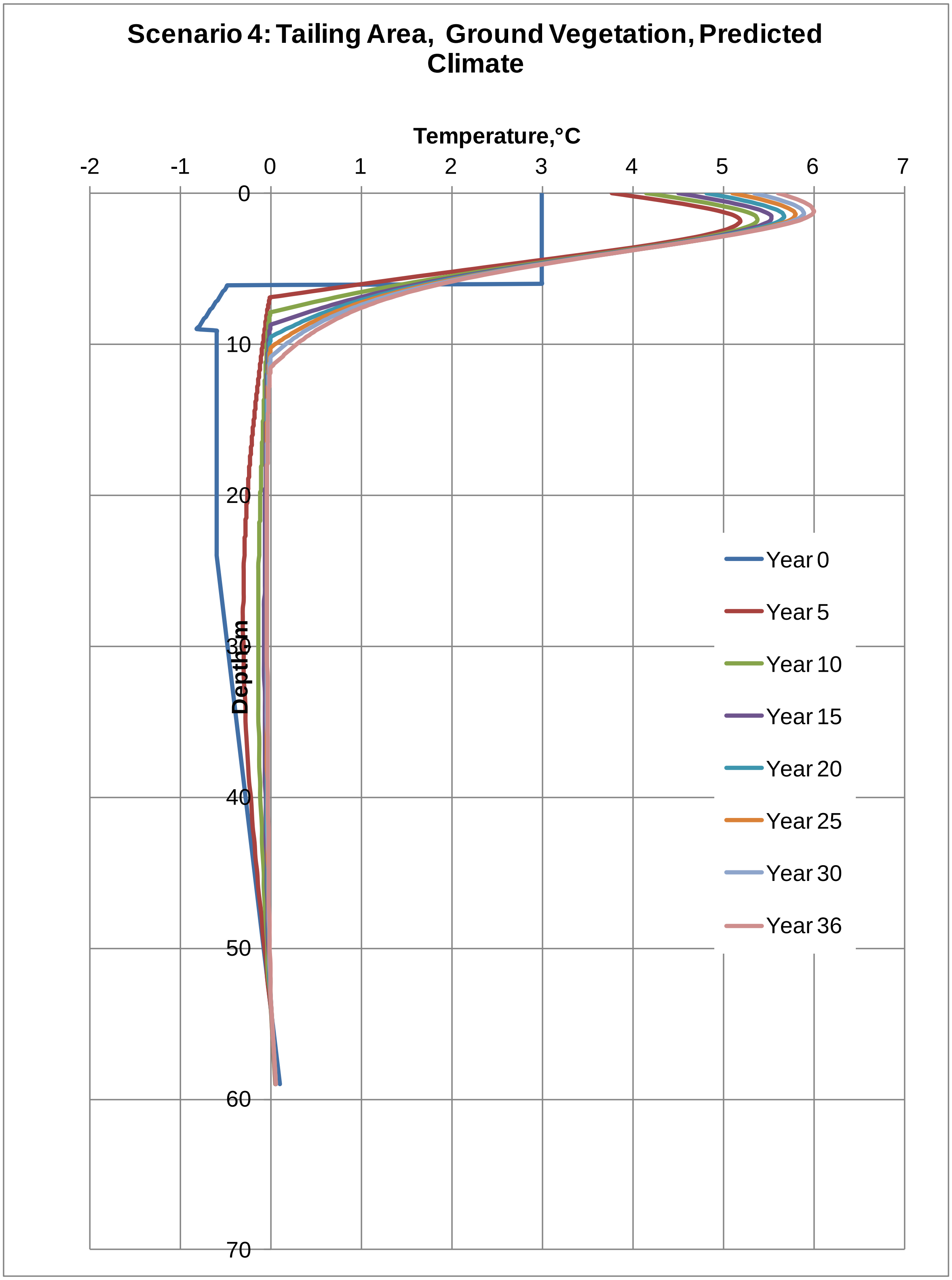


Figure F.6: Predicted Ground Temperatures for Scenario 5

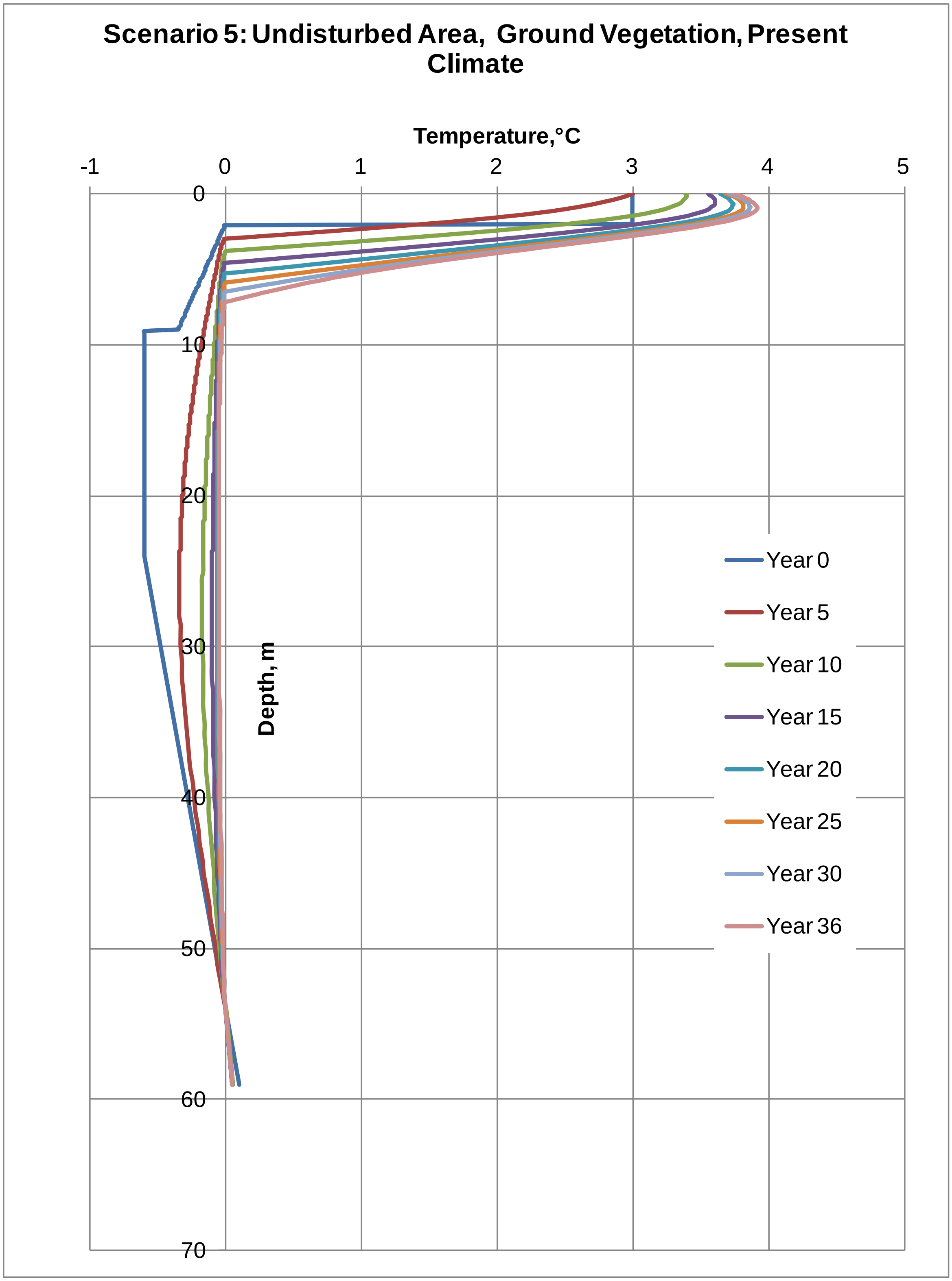


Figure F.7: Predicted Ground Temperatures for Scenario 6

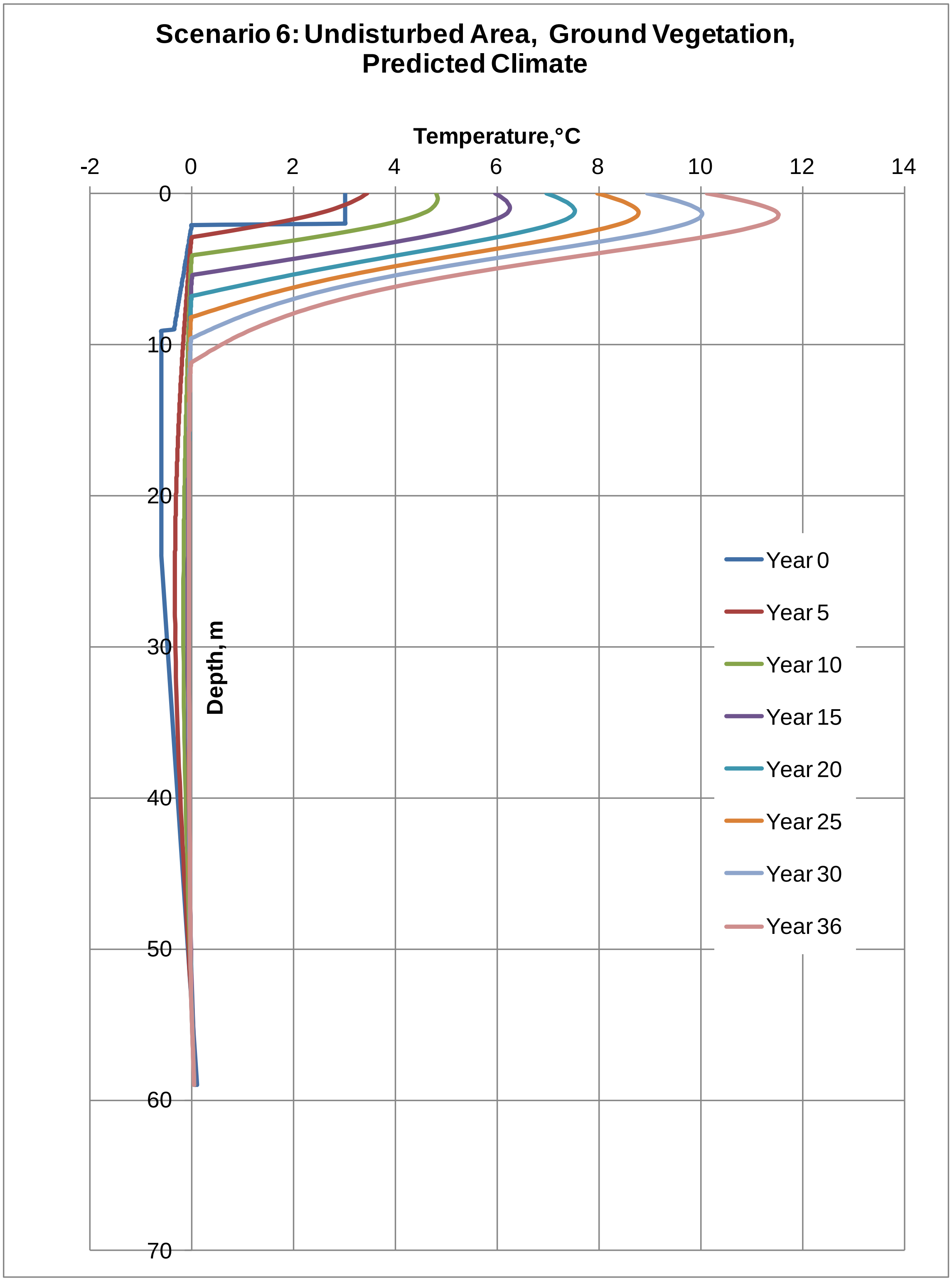
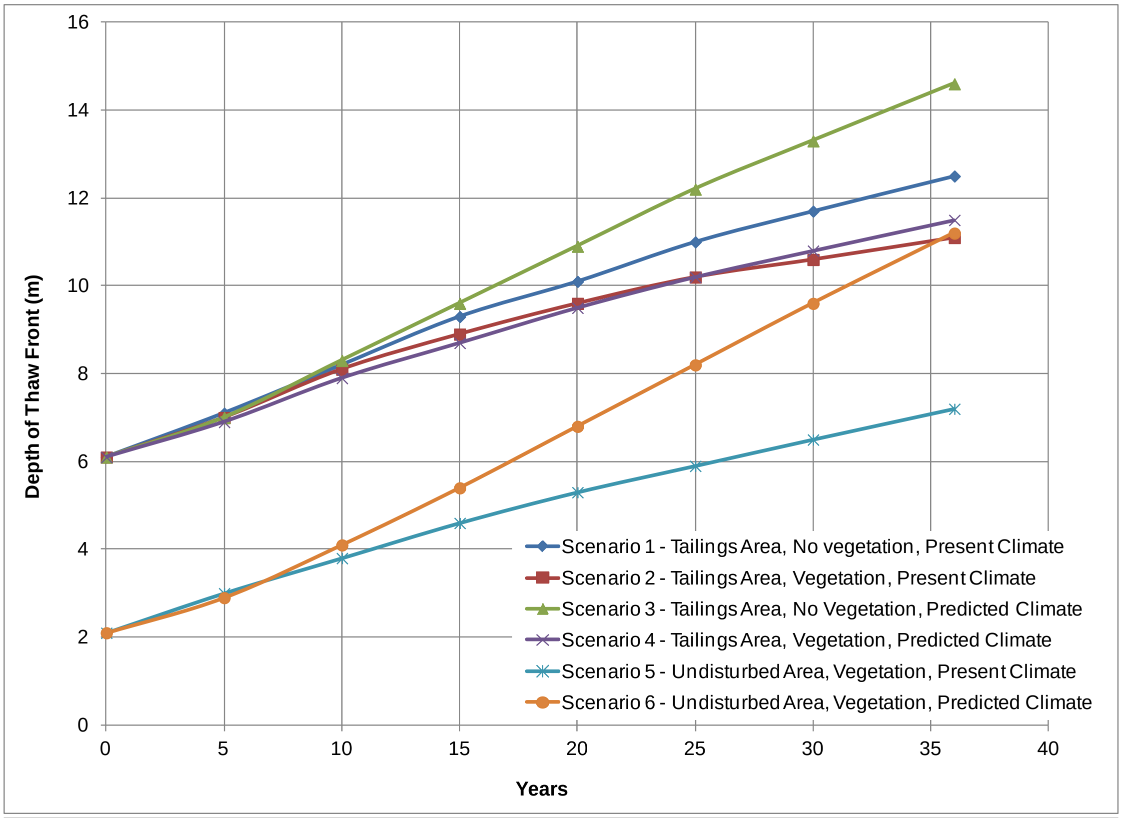


Figure F.8: Depth of Thaw with Time



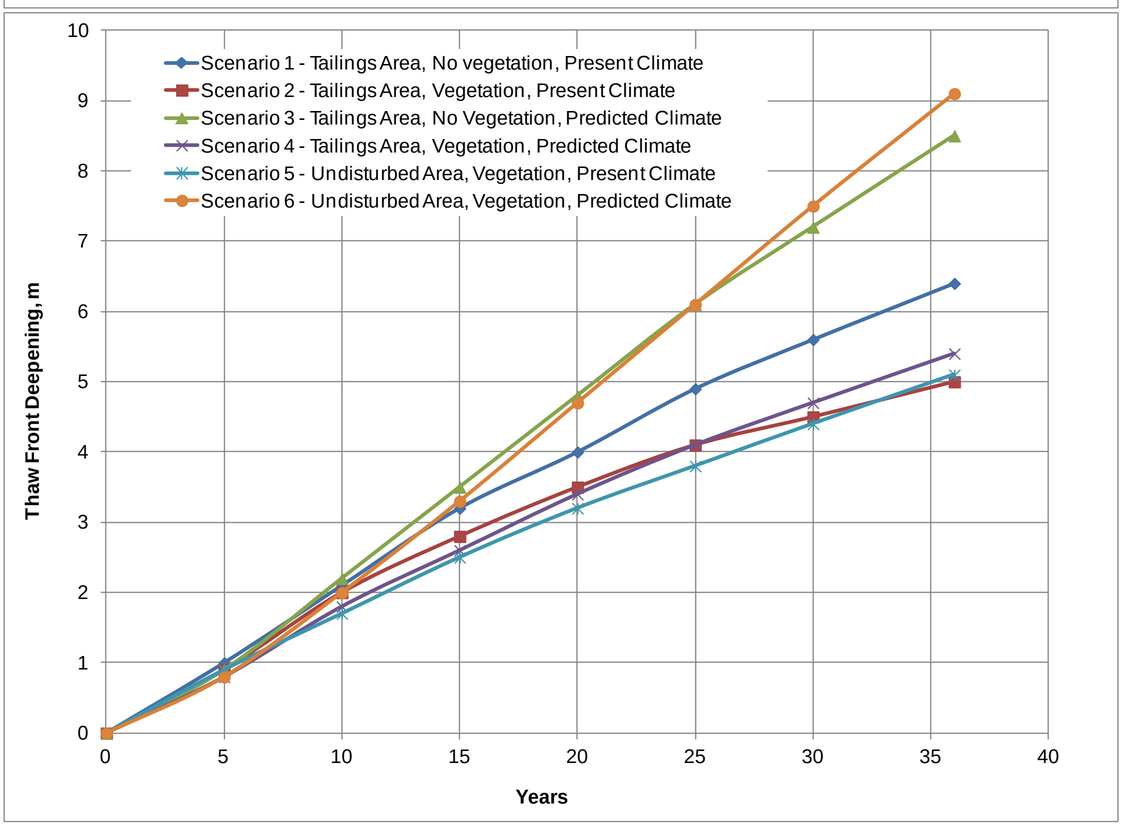
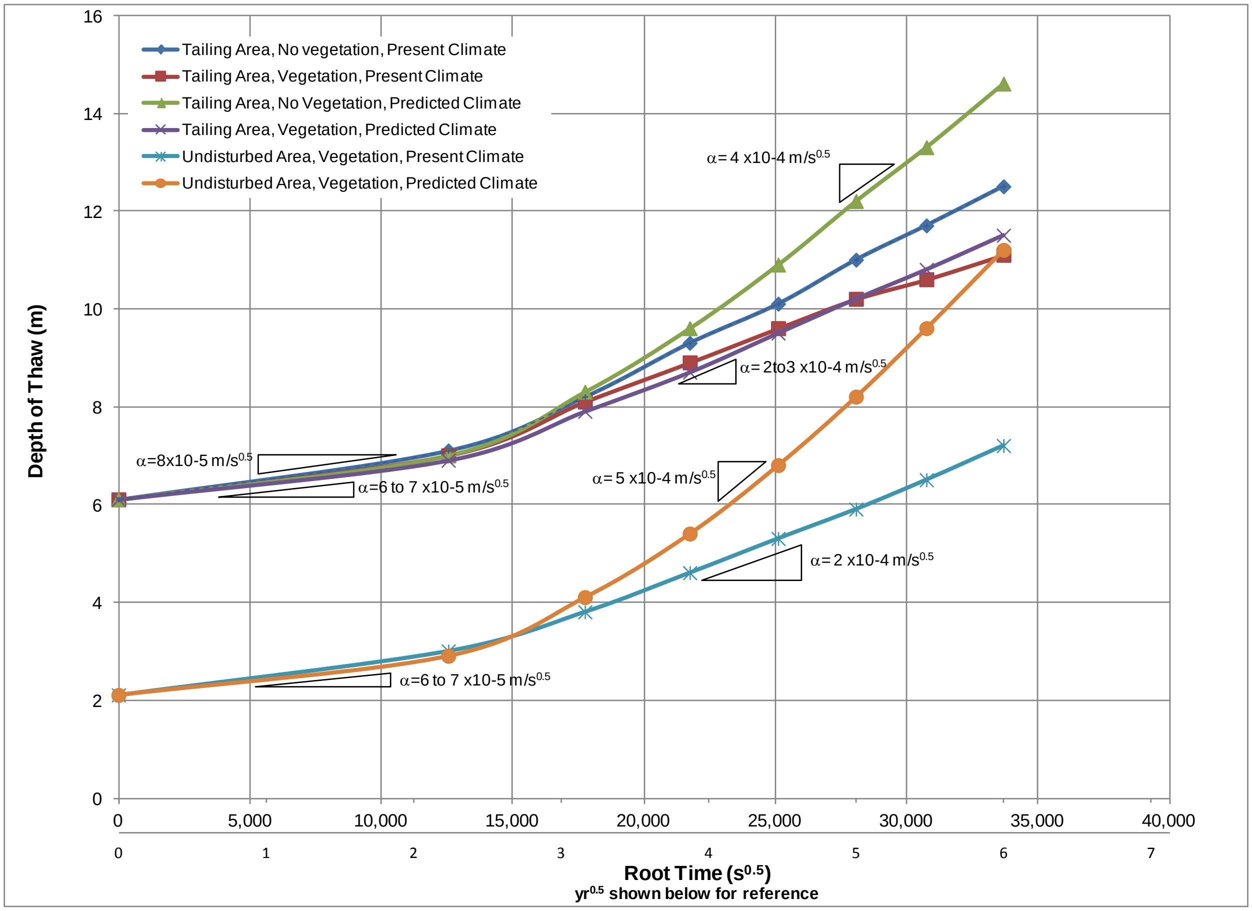


Figure F.9: Rate of Thaw



Appendix G – Erosion Control Best Management Practices (BMPs)

Monitoring and Maintenance

All best management practices (BMPs) will be monitored during and after high-flow events, and at least on a weekly basis, for failure to perform as expected, damages, exceeding design capacity, scour erosion and/or build-up of sediment. Monitoring during remediation will entail visual inspections, and spot measurements of performance, such as flow depth/velocity and turbidity (and TSS sampling as necessary). Potential remedial works could include:

- Erosion issues may be mitigated by installation of additional check dams, rock armouring, or other erosion control measures (e.g. rolled erosion control blankets, hydroseeding).
- Sediment should be removed prior to the accumulation reaching approximately one half sediment pond or check-dam height. Sediment accumulated should be removed to a stable location (no re-introduction into ditch or other watercourse).

Best Management Practices (BMPs)

The Erosion and Sediment Control Plan (ESCP) is primarily based on the application of widely used BMPs and industry practices adopted from several sources listed in the reference section. BMPs are those practices that are currently believed to provide the most effective, practicable means of preventing and reducing erosion and sediments transportation from non-point sources at a construction site. Although BMPs considered key to the implementation of the ESCP for Mount Nansen are presented in the following sections, the list is not comprehensive and not all the BMPs presented will necessarily be required. The contractor can develop site-specific BMPs if site conditions dictate.

BMPs reduce erosion potential by stabilizing exposed soil or reducing surface runoff flow velocity. There are generally two types of erosion control BMPs that are used:

- source control BMPs for protection of exposed surfaces; and
- conveyance BMPs for control of runoff.

Experience and adaptive management are integral to the successful selection of the appropriate BMPs and the design and implementation of an overall erosion and sediment control plan. Erosion control BMPs will be implemented prior to and during construction to minimize erosion and sediment discharge into the surrounding environment. The BMPs are divided into the following general categories:

- clearing, stripping and grubbing;
- watercourses-temporary buffer area;
- runoff collection ditches;
- diversion ditches;
- check dams;
- temporary sediment traps and sediment basins;
- surface roughening;
- silt fence;
- temporary seeding;

- mulching;
- stockpiles;
- slopebreaks;
- waterbars; and
- monitoring and maintenance.

Plan Implementation and Responsibility

The implementation of the ESCP will be adapted to changing site conditions through all phases of construction. This plan services as guidance; however, implementation will rely heavily on the onsite personnel to determine suitability and adequacy of these measures.

The key personnel involved in the implementation of this plan will include:

- Construction Manager (CM);
- Contractor; and
- Construction Environmental Monitor (CEM).

Descriptions of the planned BMPs are provided below.

Clearing, stripping and grubbing

Vegetation removal boundaries will be clearly marked and visible to the contractor to avoid unnecessary vegetation clearing. Vegetation removal activities will be scheduled as close as possible to construction activities to reduce exposure and potential for erosion of surface soils.

The CEM will be onsite to monitor the boundaries during clearing in the vicinity of watercourses (prior to Site Isolation), to ensure that the stream channel and water quality are not impacted during these activities. The CEM will determine appropriate scheduling (and appropriate erosion control measures) for stripping, depending on the terrain and status of Site Isolation.

Any tracks or trails left from skidding activities (i.e. machine tracks) that are a potential 'channel' for runoff will be remediated prior to onset of significant scour erosion. Measures may include regrading, or placement of windrows.

Stripping and grubbing will begin on upslope (and/or furthest from watercourse/ditch), and proceed downslope (toward watercourse/ditch) where practical, to maintain a vegetated buffer between cleared area and surface water which will assist in filtering any runoff. Material should be pushed parallel to the watercourse (along contour).

Watercourses-Temporary Buffer Area

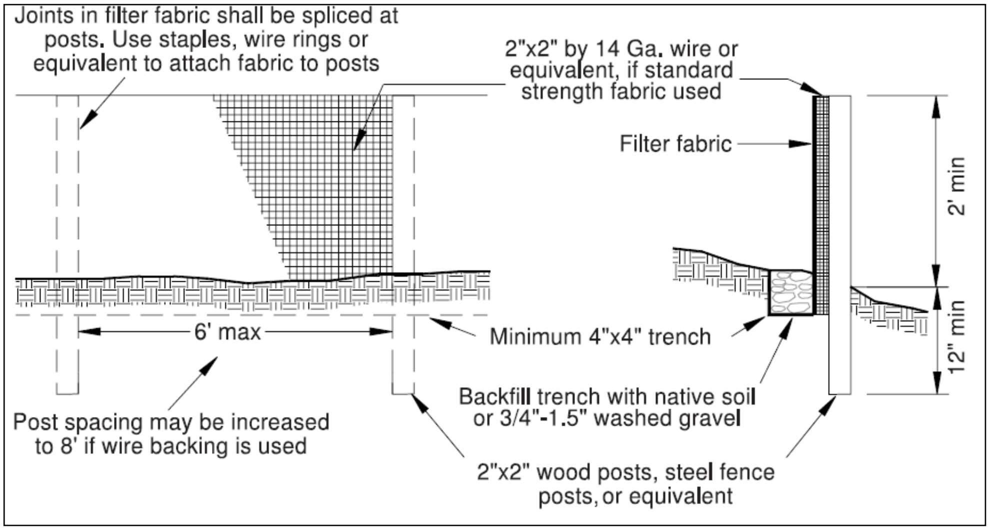
A temporary buffer area around watercourse crossings will serve as an effective means of controlling runoff into watercourses. The CEM will assess all streams to determine a suitable buffer width. General minimum requirements for the temporary vegetated buffer are outlined below:

- 5-10 m on either side of streams; and
- 2-5 m on either side of non-classified drainages.

Clearing of trees and shrubs may still occur in the buffer area, but stripping and grubbing will be delayed.

Where it is not possible or reasonable to leave a temporary vegetated buffer around a stream, or vegetated buffer is deemed inadequate to manage runoff, temporary erosion control BMPs will be required (e.g. silt fence or/and straw bale barriers) as determined by the CEM. Illustrative examples of silt fences and straw bale barriers are presented in Figures G.1 and G.2, respectively.

Figure G.1: Examples of a Silt Fence



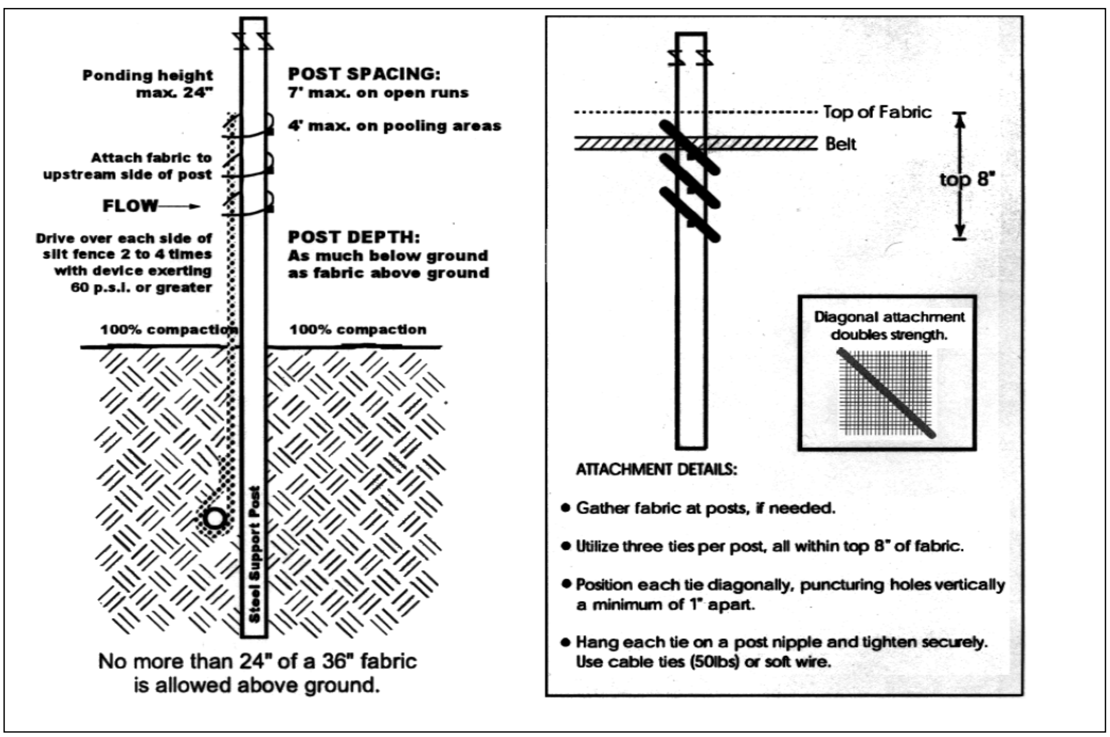
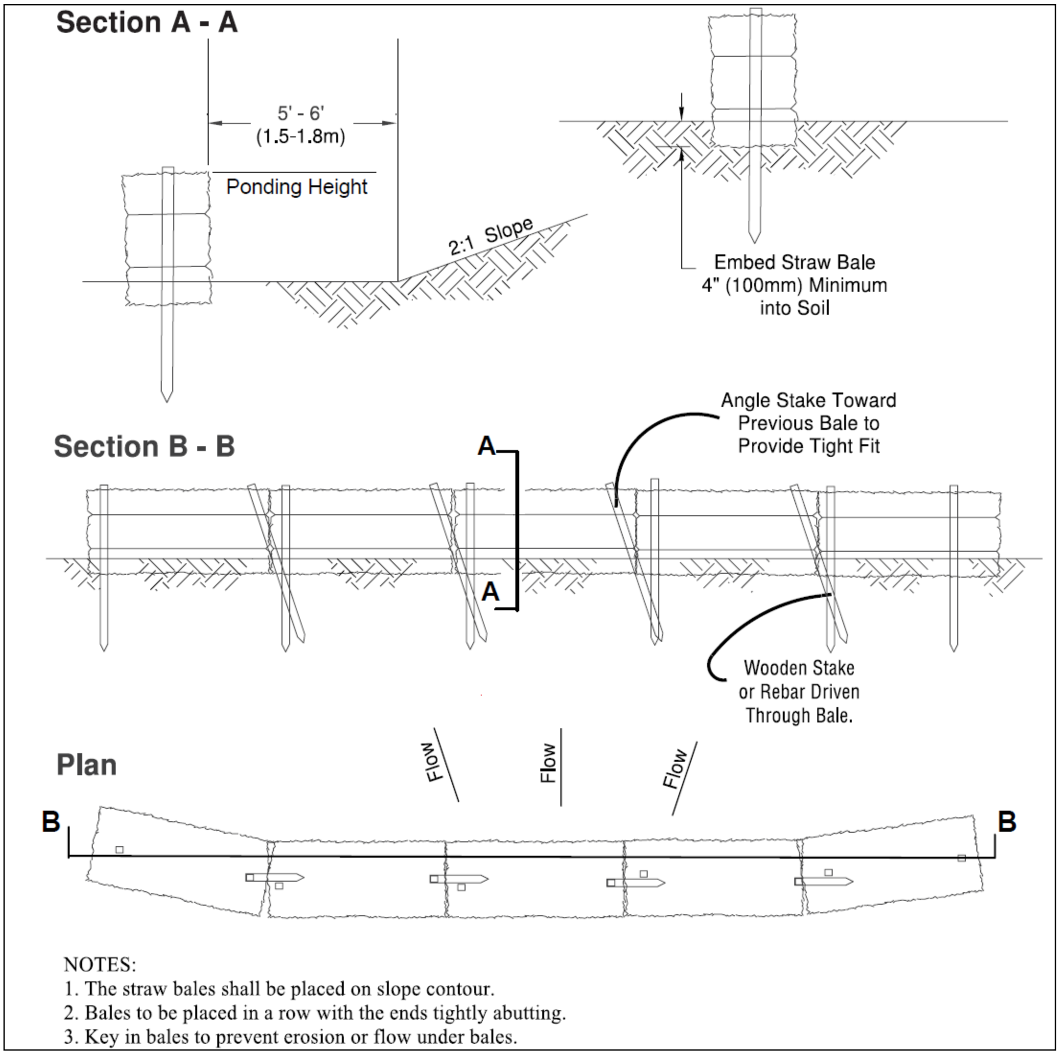


Figure G.2: Example of Straw Bale Barrier



A silt fence is a perimeter control geotextile fence to prevent sediment sheet flow from entering receiving waters. Silt fencing downslope from erosion-susceptible terrain intercepts sheet flow runoff. Intercepted drainage pools along the uphill side of the fence and the standing water promotes sediment settling. Drainage in contact with the fence is filtered by the geotextile. The fabric's small pores will filter coarse particles and severely restrict water exfiltration rates. Barrier locations are informally chosen based onsite features and conditions (e.g. soil types, climate, terrain features, sensitive areas, etc.), design plans, existing and anticipated drainage courses, and other available erosion and sediment controls. Typical barrier sites are catch points beyond the toe of fill or on sideslopes above waterways or drainage channels. Silt fences are not recommended for wide low-flow, low-velocity drainage ways, for concentrated flows, in continuous flow streams, for flow diversion, or as check dams. Silt fencing will be trenched to ensure that it is properly anchored.

Runoff Collection Ditches

A runoff collection ditch intercepts construction water runoff and diverts it to a stabilized area where it can be effectively managed. Collection ditches are used within construction areas to collect runoff and convey it to appropriate sediment control features. General locations and conditions may include:

- below disturbed existing slopes to divert sediment-laden water to control facilities;
- at or near the downstream perimeter of the construction area to prevent sediment-laden runoff from leaving the site;
- below disturbed areas before stabilization to prevent erosion;

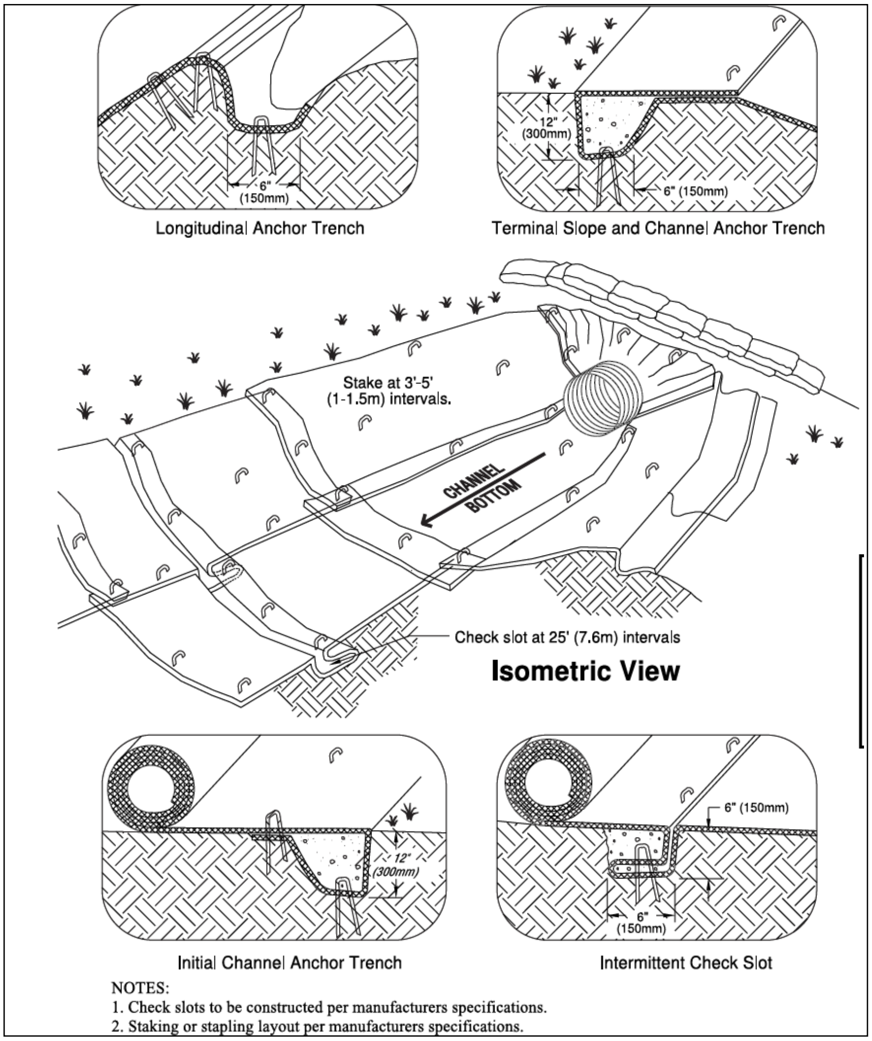
Collection ditches may be either temporary or permanent structures and will be sized to convey the runoff from a 1 in 25 year return period 24-hour storm assuming that the entire footprint area has been disturbed and contributes sediment laden runoff to the seepage collection and recycle ponds. Collection ditches may be lined with riprap, vegetation or erosion control nets and blankets (see Figure G.3 for an example); provides guidance in estimating peak flows from a 1 in 25-year storm. Estimate peak flows from a disturbed area can be estimated as a proportion to the nearest catchment area size. The ditch designs will be based on steady, uniform flow analyses.

Diversion Ditches

A diversion ditch is a channel lined with vegetation, riprap, or other flexible material designed for the conveyance and management of non-contact surface runoff to a receiving system without causing erosion. The main design considerations are the volume and velocity of the water expected in the channel. All diversion ditches should be designed to carry the appropriate peak flow. All diversion ditches will discharge through a stabilized outlet designed to handle the expected runoff velocities and volumes from the ditch without scouring. The selection of a type of lining should be based upon the design flow velocities.

Diversion ditches will be constructed upgradient of disturbed areas to intercept clean surface water runoff. The ditches will be sized to convey the 24-hour, 1 in 25 year peak storm for the estimated catchment size. Where fine grain soils have been exposed, appropriate erosion protection materials will be installed based on the estimated magnitude of flow and the flow velocity.

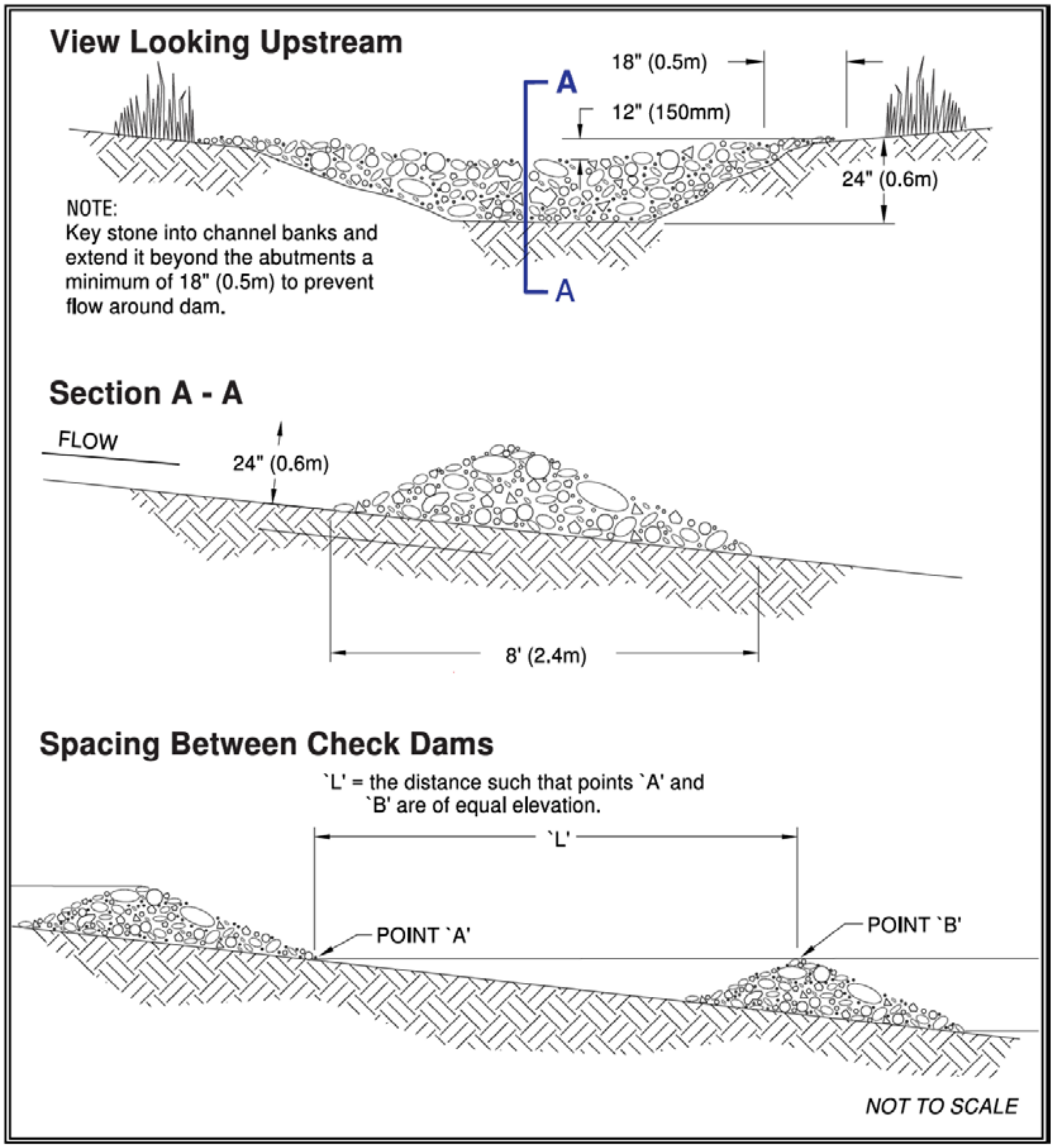
Figure G.3: Example of Nets and Blankets for Runoff Collection Ditches



Check Dams

The purpose of check dams is to minimize scour erosion by decreasing flow velocities in the ditch, and slow water and allow settling prior to stream crossings. Figure G.4 provides an illustrative figure of a check dam. Rock is the preferred material for check dams, as it can be deposited relatively easily into the ditch and manually contoured. Straw Bale checkdams will be used only as a temporary installation within ditches.

Figure G.4: Example of Check Dam



Where necessary, check dams will be installed as the ditch is constructed or as soon as possible following completion of a ditch line to ensure scour erosion is mitigated.

Check dams will span the entire width of the ditch. The dam will have a depressed centre to allow water to flow preferentially over the centre and avoid scouring at the edges. The height of the dam will be below the height of the ditch to prevent overflow during high-flow conditions.

Appropriate intervals for check dams are based on ditch grade and dam height. Check dams are required at more frequent intervals at increasing road grade to provide an adequate retention area to slow water velocities. If check dams are installed too far apart, they may cause erosion and scour rather than prevent it.

Temporary Sediment Traps and Sediment Basins

A sediment trap is a temporary structure that is used to detain runoff from small drainage areas so that sediment can settle out. Examples are shown in Figures G.5 and G.6. Sediment traps/basins generally are used for relatively small drainage areas and will be located in areas where access can be maintained for sediment removal and proper disposal. A sediment trap/basin can be created by excavating a basin, utilizing an existing depression, or constructing a dam on a slight slope downward from the work area. Sediment-laden runoff from the disturbed site is conveyed to the trap/basin via ditches, slope drains, or diversion dikes. The trap/basin is a temporary measure, with a nominal design life of approximately six months, and is to be maintained until the site is permanently protected against erosion by vegetation and/or structures.

Figure G.5: Sediment Trap and Outlet

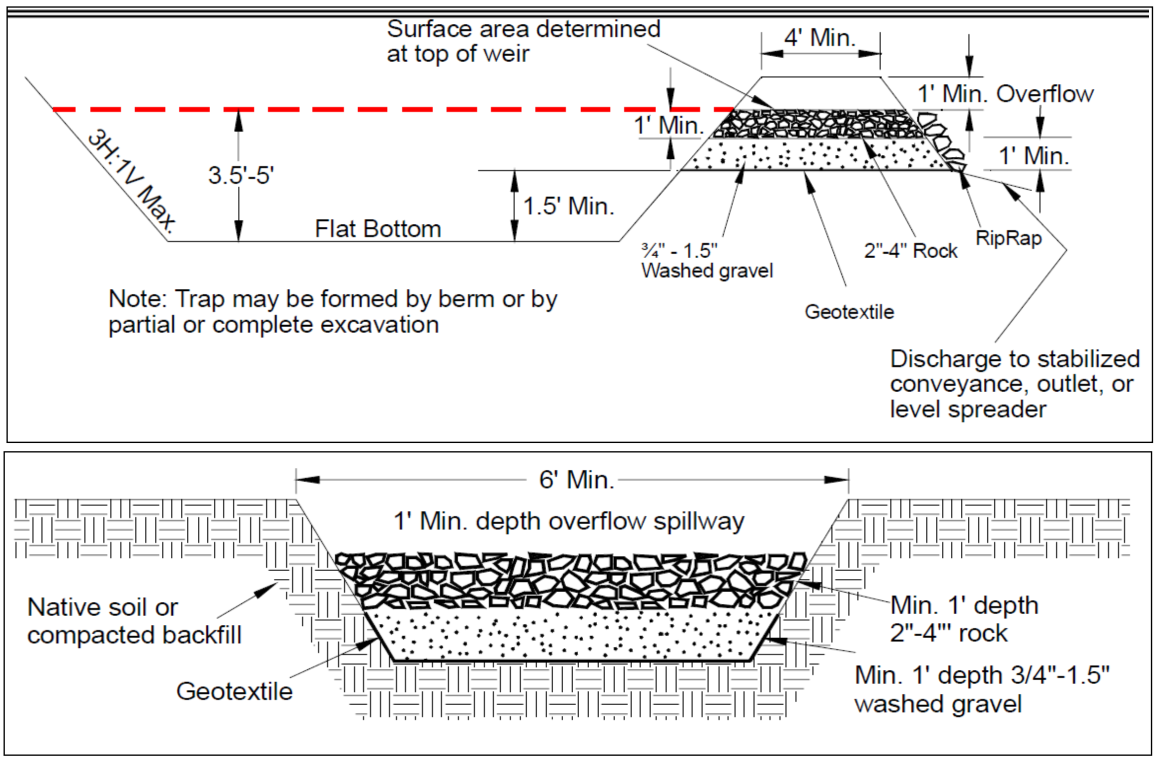
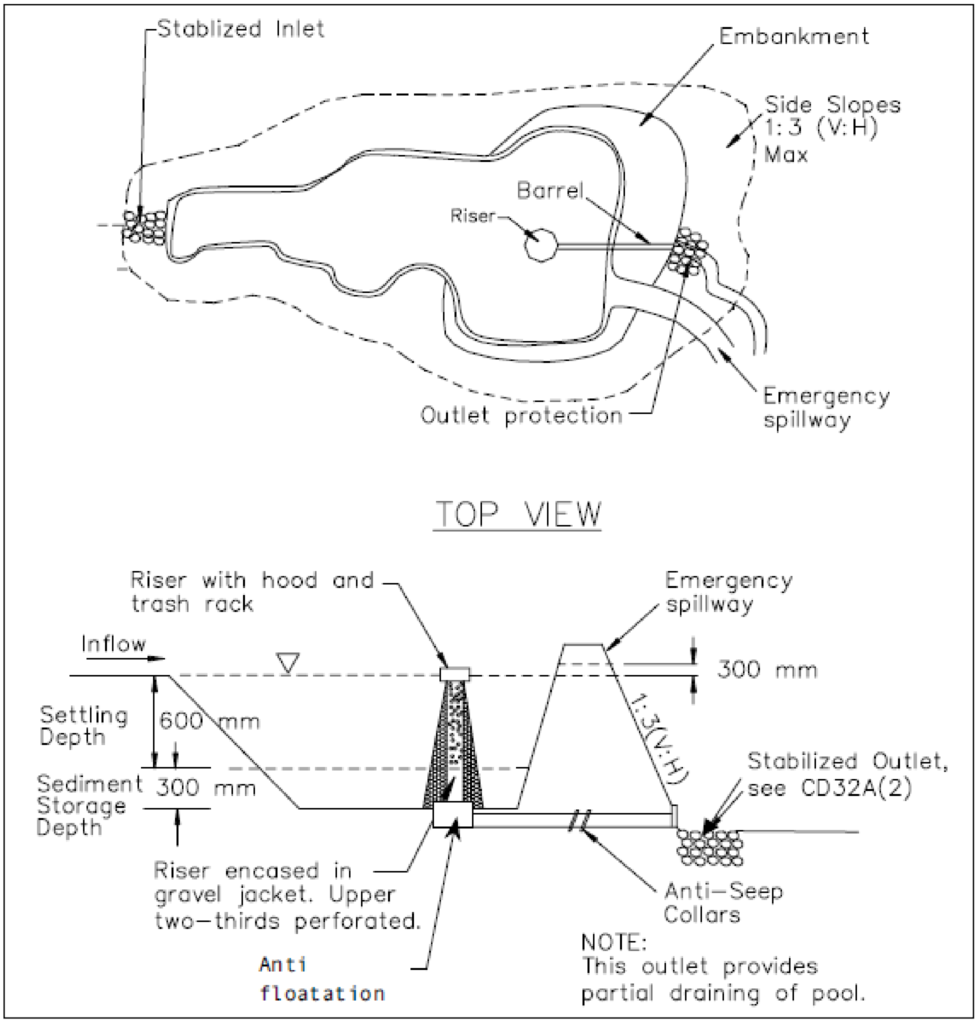


Figure G.6: Sediment/De-silting Basin

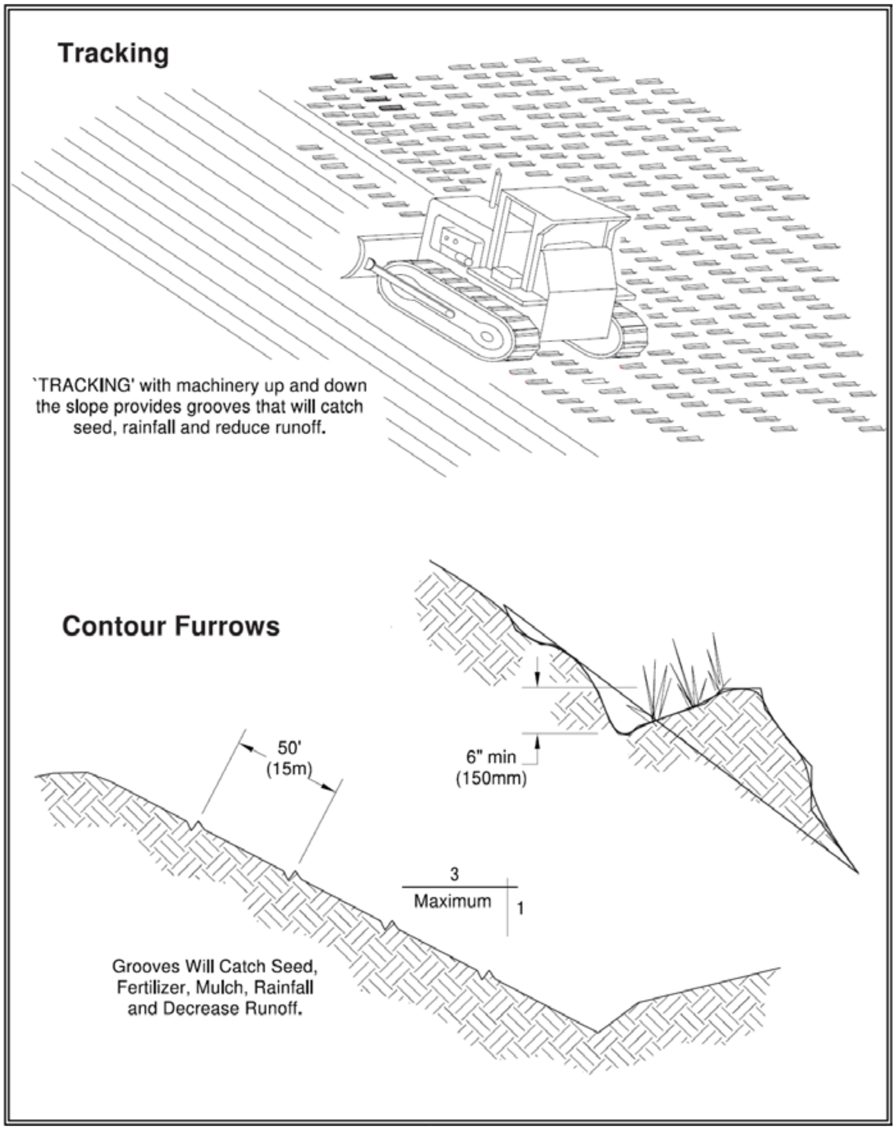


Temporary sediment traps and sediment basins will be constructed at the end of collection ditches to detain sediment-laden runoff long enough to allow the majority of the sediment to settle out. The size of the temporary sediment trap/basin is dependent on the size of the ditch. The exact locations and final geometry of each trap will be field fitted to integrate with the terrain to minimize disturbance. The sediment traps/basins will be checked regularly for sediment cleanout; if the sediment trap/basin has accumulated sediment to one half of the wet storage it will be cleaned out. If the sediment trap is clogged by sediment and/or debris, the trap will be removed and cleaned, or replaced. Water from sediment basins and traps will flow to holding ponds or other BMPs.

Surface Roughening

Cut and fill slopes will be roughened with tracked machinery where appropriate to reduce runoff velocity, increase infiltration, reduce erosion and aid in the establishment of vegetative cover with seed. Figure G.7 provides an illustrative example. The roughening will be carried out by a tracked machine moving up and down the slope surfaces, creating undulations on the soil surface. This procedure is simple, inexpensive and provides immediate short-term erosion control for bare soil where vegetative cover is not yet established. A rough soil surface provides more favourable moisture conditions which will aid in seed germination compared to hard, compacted smooth surfaces.

Figure G.7: Surface Roughening



Following stockpiling, grading activities or embankment construction, soils will be left in a 'rough' state to encourage vegetation establishment and decrease potential severity of erosion from surface runoff. Surface tracking will be applied in areas where smoothing or compacting has occurred.

Temporary Seeding

Exposed slopes and other disturbed areas will be seeded to establish vegetative cover. The purpose of temporary seeding is to stabilize the soil and reduce damage from wind and/or water until permanent stabilization is accomplished. Seeding is applicable to areas that are exposed and subject to erosion for more than 30 days, and is usually accompanied by surface preparation, fertilizer, and mulch. Temporary seeding may be accomplished by hand or mechanical methods, or by hydraulic application (hydroseeding), which incorporates seed, water, fertilizer, and mulch into a homogeneous mixture (slurry) that is sprayed onto the soil.

Hydroseeding with mulch is recommended; however, dry seeding may be adequate in some areas. The choice of seeding will be determined by the CEM. Depending on the seasonal conditions, anticipated ditch flows, and seed mix, approximately three weeks is typically required for stable vegetation establishment. Where there is inadequate time to establish a stable base, alternative or temporary measures may be appropriate, as determined by the onsite CEM.

Mulching

Mulching is the application of a uniform protective layer of straw, wood fibre, wood chips, or other acceptable material on or incorporated into the soil surface of a seeded area to allow for the immediate protection of the seed bed. The purpose of mulching is to protect the soil surface from the forces of raindrop impact and overland flow, foster the growth of vegetation, increase infiltration, reduce evaporation, insulate the soil, and suppress weed growth. Mulching also helps hold fertilizer, seed, and topsoil in place in the presence of wind, rain, and runoff, and reduces the need for watering. Mulching may be utilized in areas that have been seeded either for temporary or permanent cover.

There are two basic types of mulches: organic mulches and chemical mulches. Organic mulches likely to be used include straw, hay, wood fibre, wood chips, and bark chips. This type of mulch is usually spread by hand or by machine (mulch blower) after seed, water, and fertilizer have been applied. Chemical mulches, also known as soil binders or tackifiers, are composed of a variety of synthetic materials, including emulsions or dispersions of vinyl compounds, rubber, asphalt, or plastics mixed with water. Chemical mulches are usually mixed with organic mulches as a tacking agent to aid in the stabilization process, and are not used as a mulch alone, except in cases where temporary dust and erosion control is required.

Hydroseeding, sometimes referred to as hydro-mulching, consists of mixing a tackifier, specified organic mulch, seed, water, and fertilizer together in a hydro-slurry and spraying a layer of the mixture onto a surface or slope with hydraulic application equipment. The choice of materials for mulching should be based on soil conditions, season, type of vegetation, and the size of the area.

Stockpiles

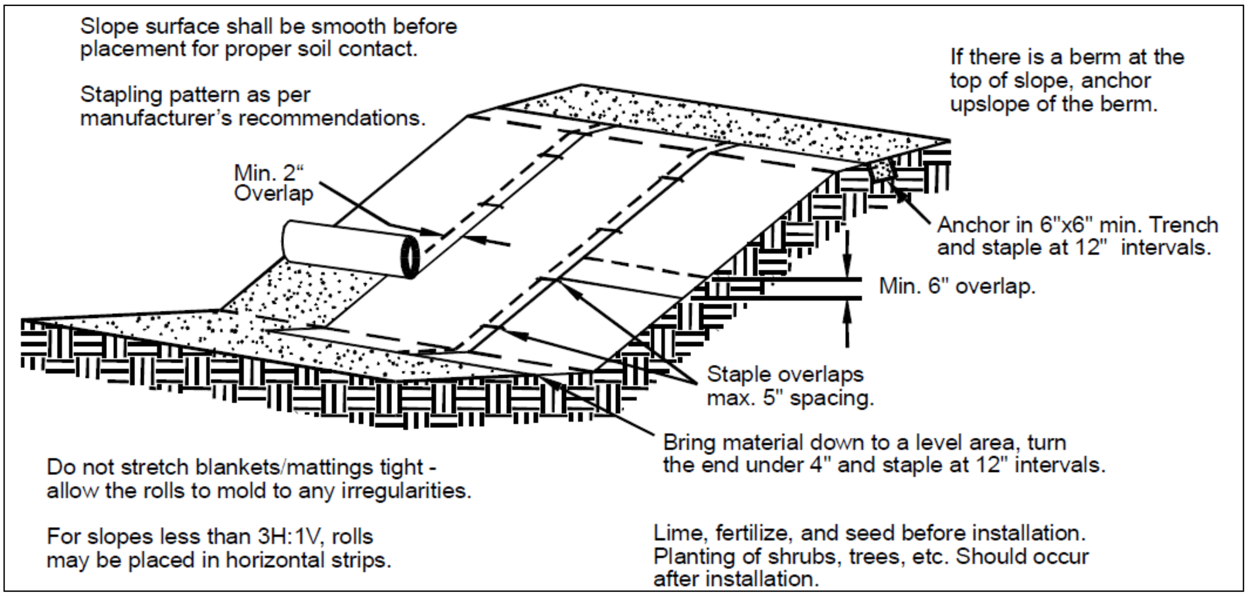
During construction of the water management structures, such as the holding ponds, topsoil stockpiles created from the strippings of these footprints will not be isolated. Until commissioning of the water management structures, erosion and sediment management will be of high importance for these stockpiles, and the CEM will be responsible to ensure that adequate measures are in place.

All stockpiles will be graded to a stable slope configuration, as determined by a qualified professional. Upslope diversion ditches will be installed as required. Downslope contact water collection ditches will be established as soon as the holding pond is available.

If required, defined and stabilized channel(s) will be installed following final grading of stockpiles to manage runoff off the top of the pile. The channel will be stabilized with appropriate erosion protection or other means where required to prevent erosion.

Following stockpiling and grading activities, soils will be left in a 'rough' state to encourage vegetation establishment and decrease potential severity of erosion from surface runoff. In lieu of stable vegetation establishment, a temporary cover over erodible soils in sensitive areas can be achieved using geotextile fabric (nets and blankets, see Figure G.8). The fabric can be placed loosely over soils for very temporary function (i.e. less than one day), or keyed in or staked to provide a more stable protection. Also silt fence or earthen berms will be installed at the downslope side of the stockpiles to contain any sediment-laden runoff and minor sloughs.

Figure G.8: Nets and Blankets Over Slopes



Slope Breaks

Long slope embankments in erosive materials will have some measure of 'slope breaks' incorporated into the design or installed following completion of construction of the slope. Slope breaks shorten the slope length and flow velocity of runoff, limiting the extent and severity of scour erosion, and encouraging vegetation establishment. Measures may include grooved or serrated slopes, stepped or terraced slopes, or placement of fibre rolls or straw wattles, representative examples being shown on Figures G.9 through G.11.

The CEM, Construction Manager and Contractor will consult to determine appropriate measures on a slope-specific basis, based on erodibility, the slope angle, location of the embankment/ accessibility, expected lifespan, and construction method, following adaptive management principles.

Figure G.9: Gradient Terraces for Slope Erosion Control

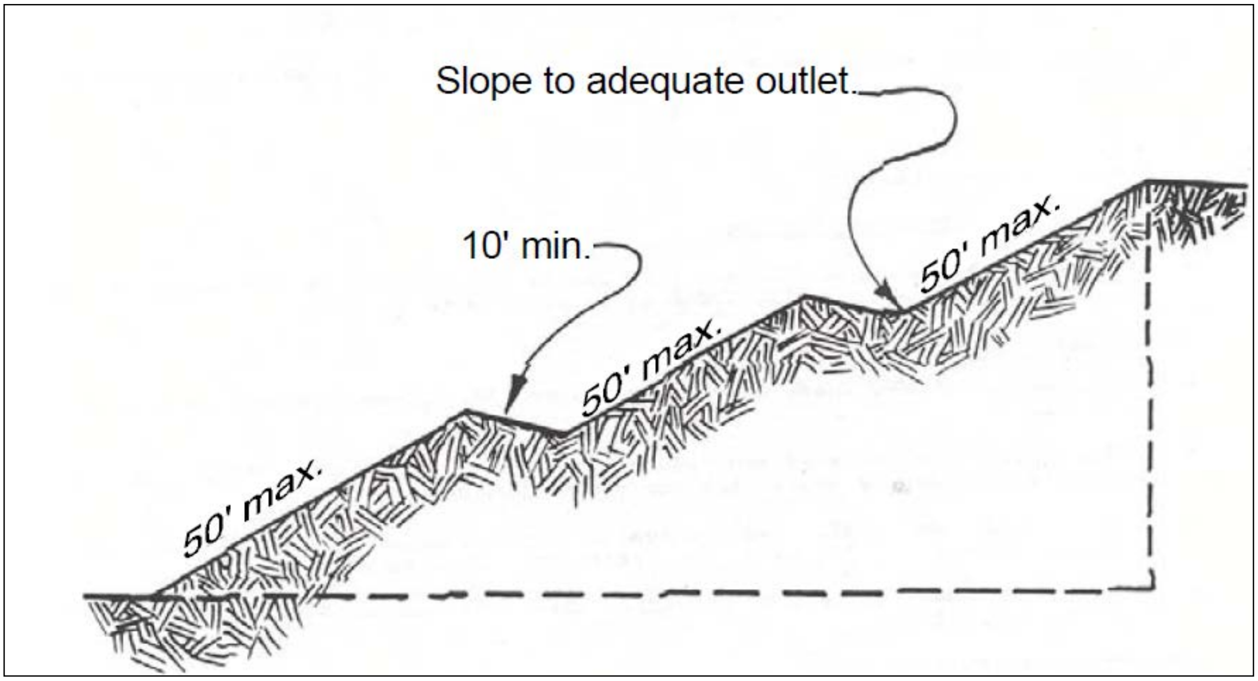


Figure G.10: Fibre Rolls for Slope Erosion Control

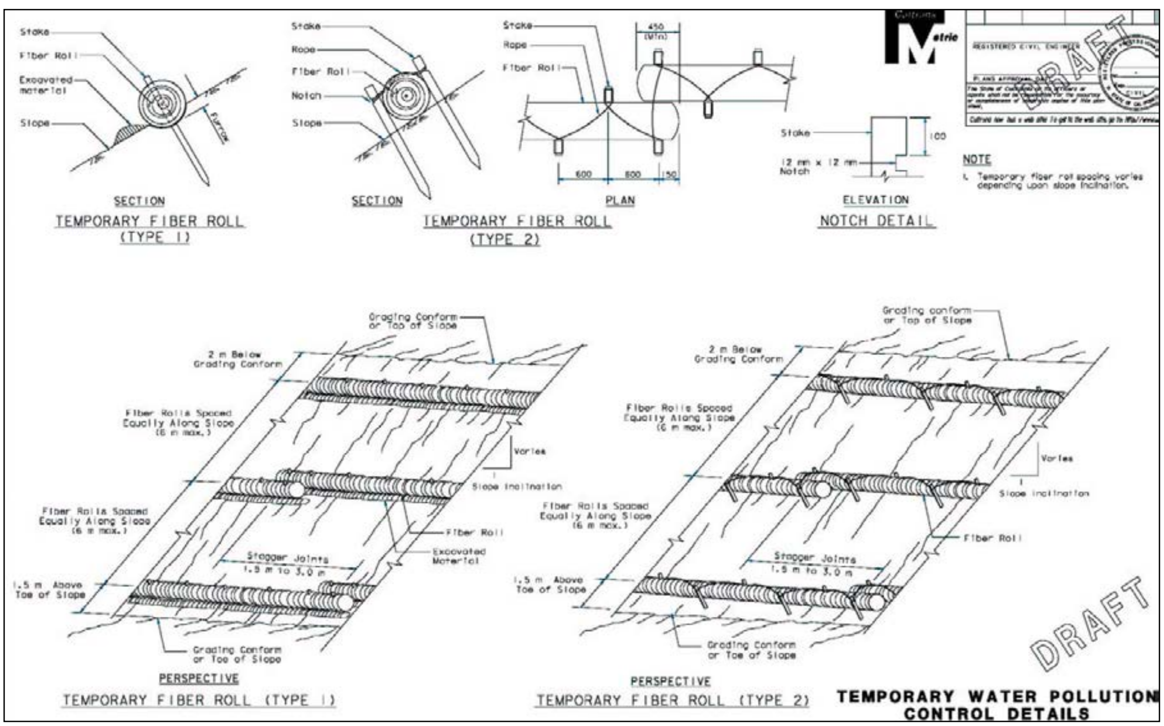
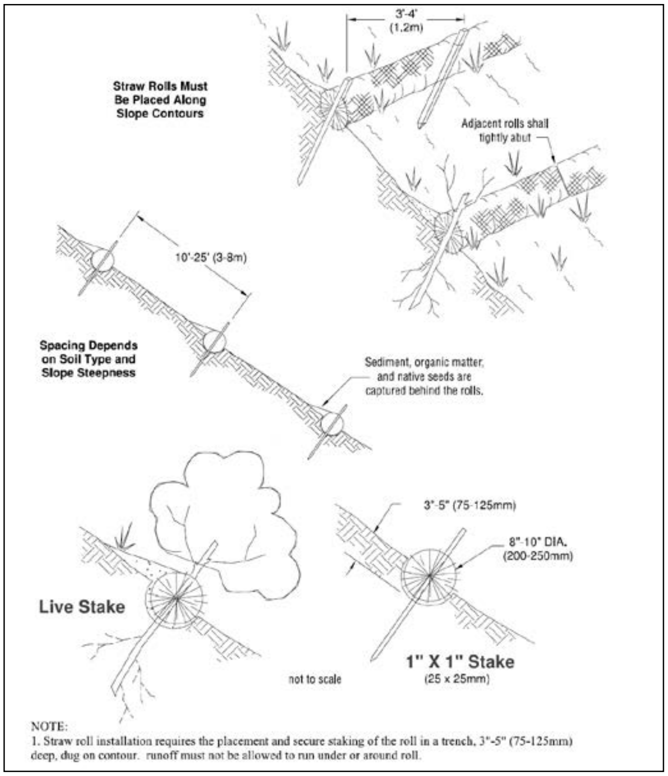


Figure G.11: Straw Wattles for Slope Erosion Control



Waterbars

Waterbars serve to reduce sheet flow and surface erosion of areas of exposed soils by diverting runoff towards a stable vegetated area or ditch. Waterbars may be appropriate in areas of steep grades over highly erodible soils.

Spacing of waterbars will be based on slope grade and general erodibility of soils. Installation will extend to the crest of the approach hill. Waterbars must direct water into stable vegetation, and not into a ditch which will channel water toward the watercourse unless the ditch is adequately prepared with check dams and armouring, as appropriate.

Monitoring and Maintenance

All BMPs will be monitored during and after high-flow events, and at least on a weekly basis, for failure to perform as expected, damages, exceeding design capacity, scour erosion and/or build-up of sediment. Monitoring will entail visual inspections, and spot measurements of performance, such as flow depth/velocity and turbidity (and TSS sampling as necessary). Required remedial works will be identified and reported to the Construction Manager and Contractor. Implementation of the remedial works will be overseen by the CEM where the activities could significantly impact water quality. Potential remedial works could include:

- Erosion issues may be mitigated by installation of additional check dams, rock armouring, or other erosion control measures (e.g. rolled erosion control blankets, hydroseeding).

- Sediment should be removed prior to the accumulation reaching approximately one half sediment pond or check-dam height. Sediment accumulated should be removed to a stable location (no re-introduction into ditch or other watercourse).

Appendix H – Photos from September 2013 Site Visit

Photo 1: Low percentage of natural revegetation at the Mount Nansen Site, Brown-McDade Pit

Photo 2: Western trenches showing erosion down the centre

Photo 3: Vigorous growth on trench sidecast material on northern trenches

Photo 4: Horizontal cuttings staked by EDI at Pony Creek

Appendix I – Recommended Treatment Options and Strategy

Recommended Treatment Options and Strategies

An overview of the recommended treatments and strategies, rates of application (if applicable) and potential source material are provided as follows. In addition to these, some alternative treatments/strategies not identified in the case studies, including the use of biochar, are described. Field trials are highly recommended to confirm site-specific reclamation success at Mount Nansen and to determine the most appropriate combination of treatments for a cost effective solution.

Specific reclamation prescriptions recommended for disturbed areas of Mount Nansen are provided in Section 7.4, Preliminary Reclamation Plan.

Site Preparation-Rough and Loose

Rough and loose was by far the most effective method of creating topographic heterogeneity. It is a bioengineering treatment whereby depressions (microsites) and mounds are created through mechanical processing of the surface (Sweigard et al., 2007). This process creates topographic diversity that aids in trapping moisture in the microsites where seeds can lodge, seedlings can grow, and roots can penetrate. The roughened surface also helps to reduce erosion. This technique has been successful in reclamation trials at several Sites across Yukon (Carter and Tobler, 2013; Hewitt et al., 2013; Lysay et al., 2009; MERG, 2000) including those described in the previous section.

Method

In order for reclamation to be successful, the workable land surface must be a minimum of 1.5 m deep (Sweigard et al., 2007). The compatibility of this depth with the stability and functional requirements of finished grades will need to be assessed on a location specific basis during detailed design. In order to achieve this, large excavators are used to excavate large holes in the surface. The excess soil is then placed to the left of the hole that was just opened, half a bucket width from the hole so it is half in and half out of the hole. A second hole is then excavated half a bucket width to the right of the first hole. Material from this hole is then placed between the first and second holes. A third hole excavated half a bucket width to the right of the second hole, with the excavated soil placed between the second and third holes. The process of excavating holes and dumping soil is continued until the reasonable operating swing of the excavator is reached (Polster, 2013).

Rate and Timing

The ideal time to undertake this work is in spring, once the active layer thaws.

Potential Material Source

The rough and loose technique utilizes existing soil material at the Site.

Seeding with Native Species

Seeding with native species is preferred over agronomic species because native species are more tolerant to local conditions and are expected to have a higher success of germination. Furthermore, numerous studies, in addition to those described above, have shown that agronomic species are not desirable for reclamation purposes as they can out-compete native vegetation and cause successional stagnation (Kimmins, 1987). As discussed in Section 7.3.1, some northern case studies showed that seeded agronomic legumes did not survive long or did not appear to contribute significantly to surface vegetation coverage.

Furthermore, agronomic species are often intended for rapid colonization for erosion control. The surfaces subject to erosion at the Mount Nansen Site will be graded to minimize erosion potential, so there is likely negligible benefit to be gained from agronomics.

Method

Collection is ideally done by the local community to facilitate social license and because of their familiarity with local plant phenology (i.e. timing of flowering and setting seed). Summit would work with a crew to collect seed, identifying the species of focus and using methods outlined in the Yukon Revegetation Manual (Matheus and Omtzigt, 2011). Seed collection timing is typically in the fall, but is dependent on the species, and is often required for more than one year because seed production varies from year to year. Grass, forb and shrub (birch) species are collected and stored separately for processing, storage and scarification prior to sowing (Matheus and Omtzigt, 2011).

Selectively broadcast seed by hand in target areas, such as microsites, or hydroseed the entire area with a mulch tackifier.

Seeding Rate

Previous northern mine reclamation studies have used between 12 kg/ha and 75 kg/ha.

Potential Material Source

Native seeds can collected from within the OIC and surrounding area (the native seed collection method is described above). They can also be sourced from seed suppliers that will collect and propagate seed for the Site. Potential suppliers include: Premier Pacific Seed, Surrey, BC; Natures Garden Seed Company, Duncan, BC; and Western Seed and Erosion Ltd., Langley, BC.

Patch Planting

Patch planting is a reclamation strategy applied to large mine areas, whereby only patches of the disturbed areas are treated with ground preparation, seeding, fertilizing, live staking and other reclamation methods. The goal is that these patches will eventually contribute to the natural revegetation of those nearby areas that are intentionally left bare by providing a source of propagules (Game et al., 1982). This strategy can be an effective means of revegetating harsh sites with limited resources available for reclamation.

Natural revegetation via patching planting of disturbed surfaces involves three phases:

(1) vegetative cover establishment primarily through development of new patches via colonization by propagules from adjacent undisturbed land,

(2) increase in vegetative cover primarily through existing patch expansion and secondarily by new patch establishment; and

(3) coalescence or a merging of existing patches. The coalescence of patches results in a drop in patch density and a rapid rise in patch dominance (Game et al. 1982).

Method

In open disturbed areas, such as the pit and waste rock area, patch planting will be subject to a combination of treatments such as seeding, staking, live transplanting and application of amendments such as fertilizer, much, coarse woody debris and/or biochar[14]. The proximity to a seed source (the outside edges) is an important factor in stimulating natural revegetation.

Rate

In open disturbed areas, patch plantings should be 20 m along a side, a maximum of 50 m apart and cover approximately 10% of the disturbance, or 2.5 patches/ ha.

Potential Material Source

Material sources are outlined under the respective treatments.

Fertilization

Fertilization is an important part of reclamation; however, fertilizers play a minor role in building the necessary stable organic matter fraction required in a self-sustaining ecosystem (Fedkenheuer et al., 1987). Based on field trials by the Yukon Government, a single application of inorganic fertilizer applied at a rate that is typically recommended for agricultural land will stimulate growth (Craig et al., 1998). Multiple applications are not recommended as they have been shown to affect species abundance relationships and result in low diversity and high productivity in the short term (Luken, 1990).

Method

Apply using a hydraulic seeder and walking or mounted on an All-Terrain Vehicle.

Rate

Previous northern mine reclamation studies have used between 60 kg/ha and 240 kg/ha of fertilizer in trial plots. Fertilizers used in these studies include ammonium nitrate and/or an 8-24-24 mix of nitrogen-phosphorus-potassium (EDI, 2009). Site-specific fertilizer prescriptions should be developed prior to beginning any fertilization program.

Potential Material Source

Inorganic commercial fertilizers may be purchased from distributers in Whitehorse (e.g. Porter Creek Garden Centre and Yukon Gardens). Larger quantities may be more economically purchased in bulk from wholesale suppliers.

Mulch

Mulches are non-living organic materials spread over the soil surface to reduce erosion and aid plant establishment by conserving moisture and moderating soil temperatures. Several types of mulches can be used, including manufactured mats or thick or thin layers of organic materials (e.g. wood saw dust or straw).

[14] Biochar is a by-product of combustion of wood, fish or animal bone produced under oxygen-limited conditions.

Scattering mulch, such as straw (or a straw mulch blanket), sawdust and mulched wood, can add organic matter to the soil and aid in nutrient and moisture retention (note that mulch also raises the carbon to nitrogen ratio, potentially reducing the amount of bioavailable nitrogen, which should be considered at the Site when determining fertilizer application timing and rates). Mulch can also protect bare soils from erosion and provide habitat for a variety of organisms that are important for nutrient cycling.

Methods

The most common mulching technique is a wood fibre applied with a hydraulic seeder with mechanical agitation. It can be applied at the same time as fertilizer. Mulching typically is accompanied by fertilization in order to provide an adequate supply of bio-available nutrients.

Rate

Previous trials on mine sites in the US have used between 2 and 3 tons/acre or approximately 0.8 and 1.2 tonnes/ha (MDNR, 2004; Brenner, 1990).

Potential Material Source

Sawdust may be available from saw mills such as Arctic Inland Resources Ltd., Dawson Yukon or from landscape supply locations in Whitehorse such as Solstice Landscaping or Yukon Tree Services. Other mulches may need to be sources from outside the territory.

Coarse Woody Debris

Woody debris can act as an important source of nutrients, control erosion, create microsites, provide habitat for a variety of plants and animals, and influence soil and sediment transport and storage (Harmon et al., 1986). Applications of coarse woody debris have been effectively used in reclamation in southern areas of BC (MFLNR, 1997), and are being used in northern mine reclamation because of their ability to create micro-sites sheltered from wind and aid in erosion control (Lysay et al., 2010). Fine branches, tops and especially foliage contain significant quantities of certain nutrients and can be added as a soil amendment to improve soil physical properties, enhance nutrient status and increase mineral soil organic matter content (MFLNR, 1997).

Methods

Coarse woody debris can be scattered randomly on disturbed areas, perpendicular to steep slopes. Contact with the ground maintains more moisture and allows entry of organisms which can double the decomposition rate (Parminter, 2002).

Rate

The application rate for coarse woody debris for the Mount Nansen Site is limited by availability. Density of course woody debris application is variable, but based on literature approximately one third of the application area (30%) would be reasonable (Harmon et al., 1986).

Potential Material Source

Additions of coarse woody debris, such as willow and birch are recommended for disturbed areas of the Site. Willow and birch are readily available and can be cut and collected from undisturbed areas of the OIC. If possible, coarse woody debris can be transported in from various locations in the surrounding area, such as, Arctic Inland Resources Ltd., Dawson, YT; Dimok Timber, Haines Junction, YT; Cove Tom, Watson Lake, YT; or Timberspan Speciality Sawmill, Prince George, BC.

Live Staking and Live Silt Fencing

Live staking involves inserting live, vegetative cuttings into the ground in a manner that allows the cutting (stake) to take root and grow. Using live stakes can create a root mat that stabilizes the soil by reinforcing and binding soil particles together and reducing erosion. The live-staked plants serve as pioneer species until other plants become established and provide wildlife habitat.

In riparian environments live silt fences can be used to reduce sediment movement by slowing flow in low-gradient streams. Live silt fences are rows of cuttings (usually willow) that are placed across the creek bed, perpendicular to the bank. These cuttings slow flow velocity, decrease erosion of channel banks, trap sediments, filter water, and help retain nutrients in the soil to be available to plants (Polster, 2011).

Method

Live stakes are cut from established willow and poplar, and are cut 5 cm below the bud in early spring when the tree is still dormant. The best wood is two to five years old. Inserting stakes horizontally instead of vertically has proven successful in northern regions because it allows for contact with organic matter above the permafrost layer (Carter and Tobler ,2013).

Rate

Live stakes are typically placed 0.3 to 1 m apart (Government of Alberta Transportation, 2011).

Potential Material Source

Material for staking can be sourced from the extensive willow and from trembling aspen (*Populus tremuloides*) at the south end of Dome Creek within the OIC.

Transplanting

Transplanting refers to moving a rooted plant from one location to another. Species that have been successfully transplanted in northern projects include black spruce, Alaska birch, trembling aspen and prickly rose (MERG, 2000, MPERG, 2009). Transplanting can also include moving a solid mat of vegetated material in one piece to another location. This strategy would speed up the revegetation soil stabilization process in high-value areas such as Dome Creek.

Method

Suitable shrubs (willow or prickly rose) can be moved insitu from undisturbed areas with easy access using an excavator and then transplanted by hand or with an excavator as the rough and loose surface is being created. To be successful the main root mass must be kept intact. Trees from commercial sources could also be transplanted. These would be placed midway on a mound, and on mid to lower slopes.

For vegetative mats, an excavator can used to lift the vegetation mats from undisturbed areas within the OIC boundary. A truck can then transport these mats to designated patches. The ground should be prepared roughly, but somewhat smooth to allow contact between the base of the mat and the substrate. Transplantation should be done in early spring or fall, when vegetation is dormant.

Rate

The rate of placement of individual transplanted species should approximately 1 m apart. However, depending on the size of the transplanted species and its root system, more space may be required between transplants. Rate of transplanting of vegetation mats is limited by available sources.

Potential Material Source

Commercial tree seedlings would likely have to be sourced in BC, unless a grower is contracted to collect cones and propagate local white spruce. Aspen, rose (*Rosa* spp.) and birch could be sourced within the OIC. The vegetated banks of the exploration trenches may be a source of native vegetation mats, as these will be disturbed as part of trench reclamation.

Biochar

Biochar is a by-product of combustion of wood, fish or animal bone produced under oxygen-limited conditions. In southern climates, biochar has proven to have many benefits for the environment, including increasing soil pH, water-holding capacity, and plant growth, as well as promoting hydrocarbon degradation at contaminated sites (YRC, 2012). Biochar can be mixed with soil to stimulate and enhance soil microbe populations. Microbes are important for attracting fungi, which connect the roots of plants and enhance soil health. Field trials by the Yukon Research Centre and the University of Saskatchewan are currently underway in Whitehorse and in Iqaluit, Nunavut. Results from these trials can be used to inform recommendations for Mount Nansen.

Method

Add biochar to the surface of the soil in areas that have been identified for patch plantings in the spring.

Rate

Field trials being conducted at Zakus Farms, Yukon, utilize biochar at a rate of 5 tons/ha (YRC, 2012).

Potential Material Source

Biochar can be sourced from Zakus Farms, approximately 30 km north of Whitehorse (Biochar Yukon, 2012). Depending on source supply and cost, use of this material may be cost prohibitive. A cost-benefit analysis should be conducted to determine if this is a cost effective method.

Appendix J – Detailed Road Decommissioning Description

All mine roads will need to be decommissioned while public roads will remain open. Decommissioning of the former mining roads will ensure that future vehicular access will not be possible. Other public roads will remain open for continued use.

The purpose of road decommissioning will be to stabilize the road footprint and restore natural drainage patterns while maintaining water quality and reducing the risk of landslides. The level of decommissioning activities that are required to achieve these objectives will vary depending on characteristics of each road segment. Factors such as slope failure risks, safety hazards, erosion potential, water quality, and water quantity will all influence the chosen mitigation strategies. Typically the road decommissioning will include most, if not all of the following activities.

All culverts along the road will be carefully removed. Removal of stream culverts may require restoration of the natural stream channel width and gradient, and armouring of the stream banks with rock. Cross-culverts will be removed and replaced with cross-ditches to move surface runoff from the road top and roadside ditches to non-erodible soils down slope. Cross-ditches located on longitudinal grades may require ditch blocks or rip rap installed to intercept ditch runoff. Cross-ditches located at natural low spots will not require ditch blocks and will be broader with gentler slopes to capture the converging runoff. Rock riprap or other available material suitable for slope protection will be placed at all cross-ditch outlets. Cross-ditches will be prepared for natural revegetation and may be planted or seeded with local species to prevent erosion of exposed fine grained soils.

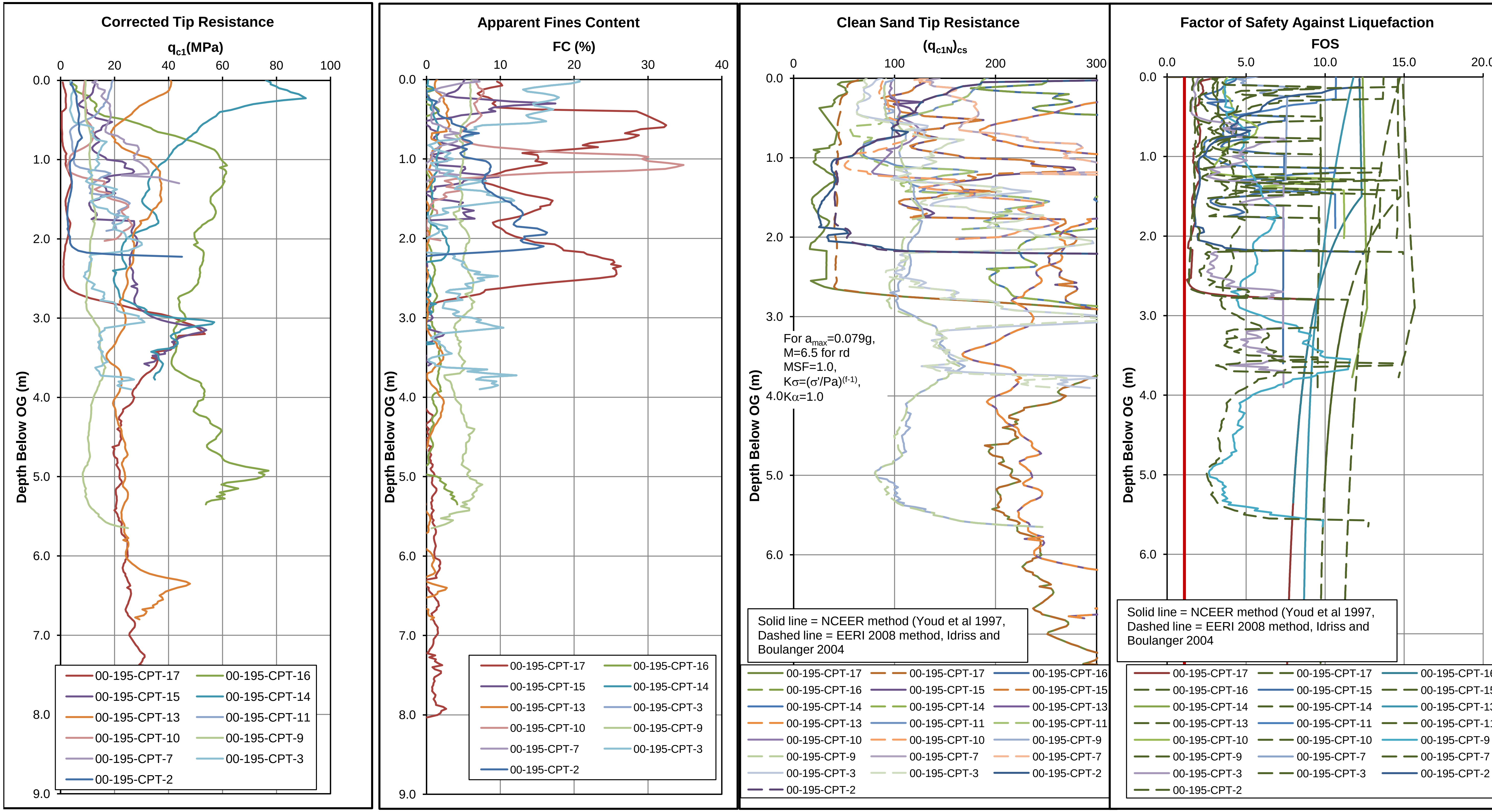
Along the entire length of the decommissioned roads, the top surface will be scarified and left in a condition that promotes natural revegetation. Where waste rock is present in the road prism it will be removed and disposed of in a designated site prior to scarification of the remaining road structure. Any available local windrowed topsoil may be reused on the surface.

Where the road is located on steep side slopes or potentially unstable terrain, slopes angles may need to be restored by pulling back side cast material on select sections of road to reduce the risk of slope failure. Any potentially unstable fills will be removed. Waterbars, berms or outsloping of the remaining road structure may also be required in some areas to intercept water running down the road and divert it to the stable slopes below. Slopes will be scarified to help re-establish natural vegetation successional pathways. Vegetated slopes will improve slope stability and reduce erosion potential.

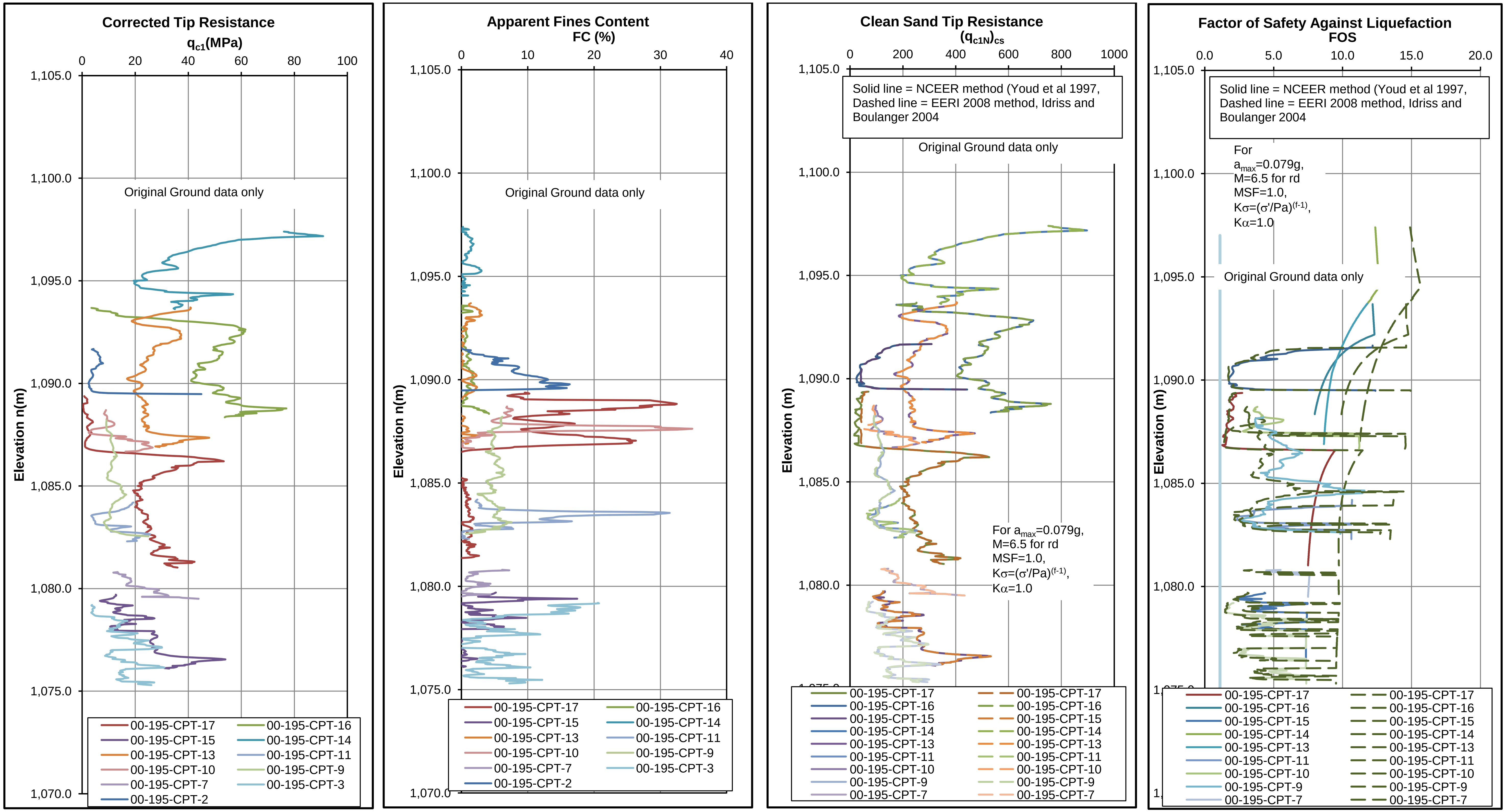
Where roads are located on stable terrain with gentler side slopes, road fills are expected to be stable and will remain in place. Re-sloping of the road top will be completed in select locations to control surface runoff, limit erosion of fine grained soils, and facilitate the removal of culverts.

Further details of road decommissioning and related activities will be developed as part of detailed engineering.

Appendix K – CPT Liquefaction Screening



Corrected Tip Resistance
qc1(MPa)
Depth Below OG (m)
00-195-CPT-17
00-195-CPT-16
00-195-CPT-15
00-195-CPT-14
00-195-CPT-13
00-195-CPT-11
00-195-CPT-10
00-195-CPT-9
00-195-CPT-7
00-195-CPT-3
00-195-CPT-2
Apparent Fines Content
FC (%)
Clean Sand Tip Resistance
(qc1N)cs
For amax=0.079g,
M=6.5 for rd
MSF=1.0,
Kσ=(σ'/Pa)(f-1),
Kα=1.0
Solid line = NCEER method (Youd et al 1997,
Dashed line = EERI 2008 method, Idriss and
Boulanger 2004
Factor of Safety Against Liquefaction
FOS



Corrected Tip Resistance
q_{c1}(MPa)
Elevation n(m)
Original Ground data only
Apparent Fines Content
FC (%)
Clean Sand Tip Resistance
$(q_{c1N})_{cs}$
Elevation (m)
Solid line = NCEER method (Youd et al 1997, Dashed line = EERI 2008 method, Idriss and Boulanger 2004
For a_{max}=0.079g, M=6.5 for rd MSF=1.0, $K\sigma=(\sigma'/Pa)^{(f-1)}$, $K\alpha$=1.0
Factor of Safety Against Liquefaction
FOS
00-195-CPT-17
00-195-CPT-16
00-195-CPT-15
00-195-CPT-14
00-195-CPT-13
00-195-CPT-11
00-195-CPT-10
00-195-CPT-9
00-195-CPT-7
00-195-CPT-3
00-195-CPT-2

Appendix L – Water Treatment Equipment List

Equipment List
Project: Mt Nansen Water Treatment Plant

Item #	Description	Quantity	Model	Detailed description	Unit cost	Total cost	Supplier
Civil							
Building							
1	Building	1	Econonox 40' by 82'	Includes material only. Two man doors and two frames for garage doors (doors not included). R-12 insulation. Building size: 12.2 m (width) by 25 m (length) by 8 m (clearance height).	$ 190,000	$ 190,000	CANAM
2	Installation	1			$ 144,000	$ 144,000	CANAM
3	Freight	1			$ 228,000	$ 228,000	CANAM
4	HVAC system	1		Quote from previous experience and adjusted for current building size.	$ 64,628	$ 64,628	
	Sub-total Building					**$ 626,628**	
Outdoor Piping							
5	Pit Lake feed lines	6000	75 mm HDPE DR17	Unit cost for pipe $5.70/m, cost of installation $1.34/m (assumed from Worley Parsons Fusion Cost Spreadsheet for HDPE)	$ 7.04	$ 42,240	Fabco
6	Tailings Pond feed lines	1000	75 mm HDPE DR17	Unit cost for pipe $5.70/m, cost of installation $1.34/m (assumed from Worley Parsons Fusion Cost Spreadsheet for HDPE)	$ 7.04	$ 7,040	Fabco
7	process water	3000	50 mm HDPE DR17	Unit cost for pipe $5.70/m, cost of installation $1.34/m (assumed from Worley Parsons Fusion Cost Spreadsheet for HDPE)	$ 3.99	$ 11,970	Fabco
8	Sludge purge lines	1000	50 mm HDPE DR17	Unit cost for pipe $5.70/m, cost of installation $1.34/m (assumed from Worley Parsons Fusion Cost Spreadsheet for HDPE)	$ 3.99	$ 3,990	Fabco
	Sub-total Outdoor Piping					**$ 65,240**	
Mechanical							
Pumps							
9	Self-priming diesel pump on skid feeding plant	3	FNSGF-8H	Franklin pump, diesel motor, 9.8 HP with electric starter and battery. Mounted on platform with wheels.	$ 7,960	$ 23,880	Technosub
10	Self-primping pump, spare parts	1		Inlet and outlet hoses up to 200 m in length.	$ 4,300	$ 4,300	Technosub
11	Effluent return pump #1 and #2	2	ANSIMax AA8	15 HP, 3500 RPM, Cast Steel pumps	$ 5,400	$ 10,800	Gould Pumps
12	Sludge recycle pump #1 and #2	2	Peristaltic Pump, SPX-40	Cost includes inlet/outlet dampener and drive, freight, delivery 4-6 weeks. Does not include taxes.	$ 11,500	$ 23,000	Hayward-Gordon
13	Spare Parts	1	Peristaltic Pump, SPX-40	Inlet/Outlet Pusation Dampener PVC/Neoprene, 5 HP VFD NEMA 4X	$ 4,000	$ 4,000	Hayward-Gordon
14	Sludge purge pump #1	1	Peristaltic Pump, SPX-20	Cost includes freight, delivery 4-6 weeks. Does not include taxes.	$ 8,000	$ 8,000.00	Hayward-Gordon
15	Sump Pumps	3		5 HP weir pump. Quote from previous project (TC131514.600.1)	$ 16,650	$ 49,950	Estimation
16	Barrel Pump	3		Flux Barrel pump	$ 1,000	$ 3,000	Estimation
	Sub-total Pumps					**$ 126,930**	

Tanks/Reservoirs							
17	Lime Sludge Mix Tank	1	OT-66	300 L LLPE tanks with cover, 26" diameter.	$ 535	$ 535	Chemaction
18	Lime Sludge Mix Tank support for agitator	1		Support for agitator	$ 305	$ 305	Chemaction
19	Reactors #1 and #2	2		Quoted tank made out of Steel 44w. H=D=2.55m. Cost increased by 9% to account for a tank volume of 13 m3 rather than the quoted 12 m3. Costs include taxes and shipping.	$ 37,917	$ 75,834	Fournier
20	pH Adjustment Reactor	1		Steel 44w., D= 1.35m, H=1.5m. Costs include taxes and shipping. Taxes not included.	$ 20,000	$ 20,000	Fournier
21	Transport of Fournier Reactors	1		Transport from supplier to Carmacks	$ 15,000	$ 15,000	Fournier
22	Lamella Clarifier	1	Model LGS-300/55fB	Costs including freight, excluding unloading and erection at site. All pieces are pre-welded. Quote in USD.	$ 97,500	$ 97,500	Parkson
	Sub-total Tanks					**$ 209,174**	
Agitators							
23	Lime Sludge Mixer	1			$ 2,070	$ 2,070	Estimate
24	#1 Reactor Agitator	1	GC-3		$ 4,070	$ 4,070	Hayward-Gordon
25	#2 Reactor Agitator	1	GC-3		$ 4,070	$ 4,070	Hayward-Gordon
26	#1 pH Adjustment Agitator	1	GC-2	1.53 m shaft, 0.3 m impeller. Does not include delivery or taxes.	$ 3,320	$ 3,320	Hayward-Gordon
	Sub-total Agitators					**$ 13,530**	
Lime Feed System:							
27	Bulk Bag feeder and batch makeup system	1	12453-R1	Includes 1 ton monorail hoist/trolley, hopper, knife gate, volumetric feeder, motor, 1000 L tank, mixer and all automation and controls to operate the system. Including taxes and excluding shipping.	$ 125,000	$ 125,000	Chemaction
28	Lime Dosing Pump	2	Peristaltic Pump, Dura 10-CL-SP	1/3HP Motor, 115 Volts	$ 3,768	$ 7,536	Chemaction
29	Hose for pump	2	7903746	Hose for Dura-10 pump	$ 532	$ 1,064	Chemaction
30	Lime pump skid	1	*9900400		$ 25,725	$ 25,725	Chemaction
	Lime Slurry Tank	1	OT-66	400L agitated tank, price inflated based on cost of a 300 L tank.	$ 713	$ 713	Chemaction
	Sub-total Lime Feed System					**$ 160,038**	
Ferric Sulphate System:							
31	Ferric Sulphate Storage Tank	1	Polywest #40148	1890 L polyethylene tank, Dimensions: D=1.2 m, H=1.8 m	$ 622	$ 622	Polywest
32	Dosing Pump	2	DLTA1608PVT2010U D1131FR0		$ 2,755	$ 5,510	Chemaction
33	External wiring for control system	2	1001301		$ 81	$ 162	Chemaction
34	Dosing system	1	7904316	250 mL PVC	$ 2,915	$ 2,915	Chemaction
35	Transfer panel	1	CHES0905	4-20mA, 3 relay, manual and automatic control	$ 767	$ 767	Chemaction

36	FRP dosing system support	1	CAI SUPPORT FRP DOUBLE		$ 800	$ 800.00	Chemaction
	Sub-total Ferric Sulphate System					**$ 10,776**	
Acid Dosing System:							
37	Acid Storage Tank	1	Polywest #40803	397 L Polyethylene tank for 50% acid. Dimensions: D=0.6, H= 1.6m	$ 264	$ 263.83	Polywest
38	Dosing Pump	2	DL1608PVT2010UD1031F	Delta dosing pump.	$ 2,755	$ 5,510	Chemaction
39	External wiring for control system	2	1001301		$ 81	$ 162	Chemaction
40	Transfer board	1	CHES0905	4-20mA, 3 relay, manual and automatic control	$ 767	$ 767	Chemaction
41	Duplex dosing control panel	1	CHES0905	Material: PVDF	$ 12,460	$ 12,460	Chemaction
42	FRP dosing system support	1	CAI SUPPORT FRP DOUBLE		$ 800	$ 800	Chemaction
	Sub-total Acid Dosing System					**$ 19,963**	
Peroxide Addition System:							
43	Wave Control Peroxide Package	1		Includes transfer pump package, peroxide injection pump package, shelter, flow metering componenets and controls.	$ 117,600	$ 117,600	Wave Control
	Sub-total Peroxide Addition System					**$ 117,600**	
Floc Addition System:							
44	Floc Dosing System, Mixers and Tanks	1	PolyRex	Includes hopper, screw feeder, wetting cone, two tanks of 300L, agitator, controls for dosing system.	$ 79,580	$ 79,580	Chemaction
	Floc skid	1	Netzsch	Skid, two pumps, valves, controls, and pipings.	$ 53,000	$ 53,000	Chemaction
	Sub-total Flocculant Preparation System					**$ 132,580**	
Utilities							
45	Blower	2	V-DTE3	Elmo Rietschle, operating at 60 Hz, designed for 4 m3/h at 7.25 psig. Taxes included, including shipping.	$ 1,022	$ 2,044	Aircom Technologies
46	Compressor	1	ES6-10H Performance Air System	Rated for 36 acfm at 125 psig. 10 HP 575V/3Ph/60Hz, TEAO motor. 120 Gallon Air Receiver Tank, Dryer & Filtration. Shipping included.	$ 13,440	$ 13,440	Comairco
	Sub-total Air System					**$ 15,484**	

47	Booster water pump package	1	G&L pump #15SV4GHE20	Includes two multistage direct driven pumps	$ 23,000	$ 23,000	John Brooks
48	Process water reservoir	1			$ 2,000	$ 2,000	estimate
49	Hot water tank	1			$ 1,000	$ 1,000	estimate
	Sub-total process water					**$ 26,000**	
Ancillary systems							
50	Lab	1			$ 10,000	$ 10,000	Estimation from Serge
51	Forklift	1	Sellick SLP508/60/80	Sellick Rough Terrain Forklift (Diesel engine). F.O.B. From Edmonton	$ 86,000	$ 86,000	Cervus Equipment.
52	Sewage retention tank	1	FRM-7000	3.2 m by 1.7 m by 1.8 m (High)	$ 2,000	$ 2,000	MEI Assainissement
53	Toilet	1		Quote from previous experience	$ 200	$ 200	Zurn
54	Toilet sink	1		Quote from previous experience	$ 150	$ 150	Zurn
55	Sink basin	1		Quote from previous experience	$ 100	$ 100	Zurn
	Sub-total Ancillary Systems					**$ 98,450**	
Safety equipment							
56	Emergency Shower and Eye Wash Station	3	8317CTFP-3 with option 9201E STD	Quote from previous experience	$ 7,800	$ 23,400	Pacesetter Sales
57	UV System - 30 GPM	3	Pro-30	Quote from previous experience	$ 3,880.00	$ 11,640	Techneaulogic
58	Fire suppression system	1		Quote from previous experience	$ 100,000	$ 100,000	SimplexGrinnell
59	Fire hydrants	2		Quote from previous experience	$ 5,257	$ 10,514	estimate
	Sub-total Safety Equipment					**$ 145,554**	
Total Mechanical Costs						**$ 1,076,079**	