AVANTI KITSAULT MINE LTD
KITSAULT PROJECT

TAILINGS AND WATER MANAGEMENT FACILITIES FEASIBILITY STUDY
DESIGN REPORT
(REF. NO. VA101-343/6-2)

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EXECUTIVE SUMMARY

The Tailings Management Facility (TMF) has been designed for secure and permanent storage of 233Mt of tailings from the proposed mining operations. The tailings impoundment will be bounded by two embankments constructed with a combination of local borrow materials and waste rock from the mining operation, as well as cyclone sand. The TMF includes one rockfill embankment, one cyclone sand embankment, two cyclone sleds, bulk and cleaner tailings delivery and distribution pipeworks, freshwater channel diversions, a seepage collection system, a reclaim system to recycle water to the plant site and a surplus water system to release clean water that meets permit conditions to Lime Creek.

The TMF will meet all current Canadian Dam Association (CDA) Dam Safety Guidelines. The Dam Safety Guidelines assign each structure to a “Dam Class” based on the incremental losses resulting from failure of the dam with respect to loss of life, environmental and cultural values, as well as infrastructure and economic losses. The Dam Class defines the required Inflow Design Flood (IDF) and Earthquake Design Ground Motion (EDGM) for the design of the dam structure and water management systems. The associated Dam Class is VERY HIGH for both the South and Northeast Embankments.

The South Embankment will be constructed using the centreline technique. The Stage 1 South Embankment is a water retaining asphaltic core rockfill embankment. Construction rockfill materials and drainage materials will be obtained from the existing Patsy Dump or from waste rock from pit stripping operations. Ongoing expansions will include centreline embankment raises with a low permeability compacted cyclone sand zone and adjacent filter zones. Cycloned tailings sand will be produced on the embankment crest and discharged into the cyclone sand zone where it will be spread and compacted using bulldozers. The tailings and cyclone sand overflow will be discharged into the impoundment. Waste rock will be used to construct the stabilizing downstream shell zone and screened waste rock will provide appropriate filter zone materials to ensure a filter relationship between the tailings and the waste rock. The stage 1 vertical asphalt core that will be tied into the bedrock foundations will include a grout curtain at the abutment contacts to provide seepage control during initial operations and start-up, and seepage control for on-going raises will be provided by the compacted cyclone sand and embankment drainage zones.

The Northeast Embankment will be constructed initially as a water retaining starter embankment and raised using the downstream technique. The Stage 1 Northeast Embankment is a water retaining geosynthetic faced rockfill embankment. Ongoing raises will incorporate downstream raises using compacted cyclone sand. Sand will be produced from the tailings in cyclones on the embankment crest and discharged onto the downstream face where it will be spread and compacted using bulldozers. An underdrain system will be used to maintain a low phreatic surface in the embankment. The tailings and cyclone sand overflow will be discharged into the impoundment. Seepage control will be provided by the...
compacted cyclone sand and underdrainage system from ongoing raises and the stage 1 geosynthetics will be tied into the bedrock foundations with a grout trench extending along the abutments to elevation 805 m.

The Stage 1 embankment crest elevation has been selected to provide storage for the first two years of operation and on-going raising of the embankment crest will be carried out each year for the remainder of the mining operations.

Overall water management is the key to the success of all mining waste management systems. The TMF is located in the middle reaches of the Patsy Lake/Creek system and hence has the ability to divert some runoff from areas upstream of Patsy Lake/Creek, which can then be directed around the open pit to Lime Creek. The Project is located within an area where a significant overall surplus of water is unavoidable and hence an operational release of water is required in order to maintain a water balance in the TMF.

Diversion of runoff to the maximum practicable extent has been achieved by making provision for the diversion of Patsy Creek around the open pit on a bench constructed along the south wall of the pit.

Unthickened tailings slurry will be discharged from the mill via gravity. The design objective is to discharge the tailings slurry from the embankment faces in order to provide additional seepage control and maintain the surface pond remote from the embankments. The tailings distribution system has been designed for ease of operation and to minimise the number of pipeline moves during operations. There will be feeder lines to each of the cyclone sleds and separate bulk tailings lines to both embankments, as well as a cleaner tailings line to a separate area with the TMF.

Water for processing is recovered from the TMF supernatant pond using a floating reclaim pump-station. The water is pumped via a single reclaim pipeline to a head tank at the mill for reuse in the process. The elevation of the TMF pond initially increases significantly during the early years of operation. This reduces the required pumping head which continues to decrease throughout the life of the mine. The pump-station will be modified as appropriate during operations to accommodate these changes in head.

The reclaim water system is designed to extract surplus water from the TMF. A separate pump located on the reclaim barge will feed a single pipeline and direct water towards the water box, located north of the open pit. This water will then be discharged into Lime Creek west of the open pit.

A single fresh water pipeline connects Clary Lake to a freshwater tank at the mill to provide clean water for process use, fire water and potable water.
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Section 1.0 - INTRODUCTION

1.1 PROJECT DESCRIPTION

The Kitsault Project is located in north-western British Columbia within the Regional District of Kitimat-Stikine (RDKS), Canada, approximately 140 kilometres northeast of Prince Rupert, as shown on Figure 1.1. The Kitsault mine site is located within NTS maps 103P044 and 043, at an approximate latitude 55° 25' 19" N and longitude 129° 25' 10" E, and at approximately 600 metres elevation. The Project can be accessed from Terrace or Smithers via existing highways, forestry and mine access roads, and by float plane air service or boat from Prince Rupert. The project location is shown on Figure 1.1.

The Kitsault Project has an estimated mine life of 16 years. Ore production is estimated at 14.6 Mt/year. An approximate layout of the Project site is shown on Figure 1.2. A conventional crushing, grinding and flotation process rated at 40,000 tonnes/day will produce a molybdenum concentrate that will be shipped offshore. The Tailings Management Facility (TMF) has been sized with sufficient capacity to store tailings and water for the process. Furthermore, the water management components have been designed to maximise the diversion of clean water around the project components, while ensuring the capture of runoff from disturbed areas (contact water) throughout the site.

1.2 PROJECT BACKGROUND

The Kitsault deposit was first staked in 1911 and early stage investigations focused on a polymetallic vein, located to the southeast of the current Molybdenum deposit. Exploration continued on the Project in the 1920s and early 1930s. No further exploration occurred until 1959 when Kennco Exploration (Western) Limited (KEL) completed a diamond drilling program. KEL discovered an ore body in 1964 containing 36 million tonnes averaging 0.138% Mo (0.23% MoS₂). Construction of the Kitsault Mine began soon after. KEL commenced mining the property in 1968 and approximately 9.3 million tonnes of ore was produced with about 22.9 million pounds of Molybdenum being recovered until mining ceased in 1972 due to low metal prices. Climax Molybdenum Company of British Columbia purchased the property in 1973 and recommenced production in 1981. Mining was again halted because of low metal prices in 1982. Approximately 30 million lbs of Molybdenum were produced during these two periods of mining (BC MINFILE Report number 103P 120, Natural Resources Canada). The Kitsault Townsite was constructed during the later mining operation, but is currently abandoned except for caretakers.

Avanti Kitsault Mine Ltd. (Avanti) acquired the Kitsault Property in October 2008 and re-activated engineering and environmental work for the Project. Work required to obtain Provincial and Federal approval of an Environmental Assessment/Comprehensive Study has been conducted concurrently with the engineering studies.
1.3 SITE SELECTION

Knight Piésold Ltd. (KP) completed a trade-off study of three tailings disposal methods at three separate sites for the Kitsault Project in early 2009. The objectives of the trade-off study were to determine the advantages / disadvantages, compare preliminary costs of conventional slurry, thickened and filtered dry stack tailings disposal and ultimately select a preferred option for further design, and to enable delineation of a geotechnical site investigation program to support subsequent Preliminary Feasibility studies. The results were presented in the KP report “Tailings Disposal Options Trade-off Study, Ref. No 101-343/2-1”. TMF Site 6 was selected as the preferred site for the Pre-Feasibility Study (PFS) using conventional slurried tailings disposal methods.

A follow-up trade-off study was completed in the first quarter of 2010 to revisit TMF sites considered in the earlier study and apply knowledge gained from the PFS to ensure that the Kitsault Project incorporated the optimal location for the TMF in the upcoming feasibility study program. A secondary objective of this study was to evaluate the suitability of constructing two 100 million tonne (Mt) TMFs rather than a single 190 Mt impoundment. The follow-up site alternatives study was documented in the KP report “Tailings Management Facility Alternatives, Ref. No. VA101-343/3-5”. This study identified that TMF Site 10B was potentially the optimum TMF site with project cost savings potential in the order of $100M and construction schedule advantages. It also identified that Site 5 would likely result in much lower initial CAPEX costs. Both sites therefore merited further study as potential alternative tailings management facilities from Site 6.

AMEC and KP completed an optimization study on previously defined mine development concepts (MDC) to evaluate optimised TMF Sites 5, 6 and 10B, along with optimised locations for the Process Plant. The optimization study indicated that TMF 10B is the most cost-effective MDC. However, with the direct impact of fish bearing lakes and streams in this location, TMF 5 was considered preferable as it would not result in the direct loss of fish-bearing lakes or streams. Therefore, TMF Site 5 with the Process Plant on the plateau above the TMF to the north was selected as the optimum configuration for the Feasibility Study.

This MDC was chosen as the best alternative for technical, economic, environmental and social considerations. The relative advantages of this concept were:

- Lower Initial CAPEX and Total Cost for tailings storage compared to Site 6
- Compact mine development footprint maximises operational flexibility and reduces direct environmental impact
- Location below the process plant allows gravity flow of tailings and capture of runoff, seepage, and spills – resulting in lower environmental risks
- Patsy Creek and Patsy Lake are fishless, while the Clary Creek/Lake system includes a resident population of rainbow trout that were planted several decades ago, and
- Closure concepts are relatively simple with routing of final tailings pond supernatant into the adjacent mined out pit, vegetation of the tailings beaches and waste rock piles, and nearly all contact water will be directed towards the pit for a single point discharge.
1.4 SCOPE OF WORK

This report presents a feasibility level design for the Tailings Management Facility (TMF) and the associated water management facilities for the project site. Specific design items which are addressed in the report include:

- Site characteristics including hydrometeorology, regional geology, hydrogeology and seismicity
- Tailings characteristics
- The results of geotechnical investigations carried out at the TMF site
- Evaluation of the TMF foundations and identification of construction materials
- General design features including geotechnical considerations, water balance and initial process water supply requirements, operating requirements, ongoing construction, embankment stability, seepage analyses and control, tailings, reclaim and seepage collection systems, and final reclamation
- Capital costs (CAPEX) for initial and sustaining construction of the TMF and water management facilities, and
- Operational costs (OPEX) for operating the TMF and water management facilities.

The TMF has been designed to provide environmentally secure storage for disposal of 233 Mt of tailings. Specific overall features of the TMF are shown on Figure 1.2 and are listed below:

- South Embankment - Asphalt Core Rockfill water retaining starter embankment expanded as a compacted cyclone sand/waste rock embankment
- Northeast Embankment - Geomembrane Faced Rockfill starter embankment expanded as a compacted cyclone sand embankment
- Seepage collection ditches and ponds
- Bulk tailings distribution system
- Bulk tailings beaches
- Bulk tailings feeder lines to on-crest cyclones
- Cleaner tailings distribution
- Cleaner tailings cell
- Reclaim water system
- Surplus water system, and
- Supernatant water pond.

The South Embankment will be constructed across Patsy Creek as an Asphalt Core Rockfill Dam (ACRD) water retaining starter embankment and raised as a zoned compacted cyclone sand rockfill embankment. The Northeast Embankment will be constructed across the top of the Patsy Creek watershed as a Geomembrane Faced Rockfill Dam (GFRD) and raised as a compacted cyclone sand embankment. The embankments will be developed in stages throughout the life of the Project using compacted cyclone sand and waste rock materials using the centreline construction technique.

Multiple levels for seepage control have been included in the design to minimise seepage losses including the development of extensive tailings beaches (thereby isolating the Supernatant Pond from the embankments), toe drains to reduce seepage gradients, and contingency measures for groundwater recovery and recycling.
Construction of the Stage 1A South Embankment will commence in 2012. Approximately 10 million m$^3$ of water will be impounded prior to start-up (tailings deposition), and will be available for mill commissioning and early operations. This water will be collected from the runoff from the Patsy Creek watershed and from the disturbed catchment areas from mine construction activities. Mill process water for ongoing operations will be reclaimed from the TMF and supplemented with water from mine disturbance areas, if required. An annual water balance was completed for average precipitation conditions, as well as extreme condition scenarios. Under all scenarios an excess of contact water will exist each year of operations, requiring discharge to the receiving environment in order to maintain a water balance. With careful water management, a sufficient volume of water will be maintained in the tailings supernatant pond to satisfy ongoing water demands without requiring unnecessary staged raises beyond that required for the design basis. The results of the TMF water balance are discussed further in Section 6.0 and Appendix E.
Section 2.0 - TAILINGS CHARACTERISTICS

The Kitsault Project milling operation will produce two tailings streams from conventional milling of molybdenum ore. Mill throughput is anticipated to be 40,000 tonnes per day (tpd). The two types of tailings are designated scavenger (Bulk) tailings and cleaner (Pyritic) tailings. These two tailings streams will be piped and deposited into the TMF in separate areas. The bulk tailings will be produced at 36,000 tpd and will be essentially free of sulphide minerals. The pyritic tailings will be produced at 4,000 tpd and will contain sulphide minerals (primarily pyrite). The bulk tailings are low sulphur and are non-Potentially Acid Generating (non-PAG), while the pyritic tailings contain high levels of sulphur and are Potentially Acid Generating (PAG). The geochemical characteristics of both tailings types have been evaluated by SRK Consulting Inc. (SRK) as part of the feasibility design studies.

The bulk tailings slurry concentration is estimated to be 36.4% dry by weight, with a solids density of 2.7 t/m³. The pyritic tailings slurry concentration is estimated to be 17% dry by weight. Geotechnical testwork on the bulk, pyritic and cycloned tailings streams has not been conducted to date, and will be done as part of the detailed design studies for the TMF. Testwork will include index tests to confirm geotechnical classification of the material, as well as slurry settling, consolidation and permeability testing to determine the characteristics of the tailings streams following deposition.

The estimated particle size distribution derived from the process design has identified that the bulk tailings is coarse enough to generate a suitable sand quality with a single stage cyclone. This will allow construction of the cyclone sand zones on the South and Northeast Embankments with on-crest cycloning. Furthermore, the geochemical analysis of the bulk tailings stream conducted by SRK indicates that it will be non-PAG, which supports the use of cyclone sand in the construction of the TMF.
Section 3.0 - SITE CONDITIONS

3.1 PHYSIOGRAPHIC SETTING

The Kitsault Project is located in the Boundary Range of the Coast Mountains close to Alice Arm which branches northeast from Observatory Inlet. At the height of the Pleistocene glacial period the entire region underwent extensive glaciation which left deeply carved valleys and significant topographic relief characterised by steeply inclined slopes and thin veneers of colluvium overlying bedrock. Lower elevation peaks and ridges below 2000 metres are more rounded and subdued by the effects of ice-sheet erosion. The slopes are intermittently broken with small swamp covered benches with meandering stream courses that connect pothole lakes, ponds and swamps. Interbedded greywacke and argillite sedimentary rocks outcrop on surface throughout the project.

The Coast Mountain Plutonic Complex is located approximately two kilometres to the east of the site and is associated with intense igneous activity and lava flows. This intrusive activity includes the Alice Arm Intrusives that are associated with the Kitsault Molybdenum deposit emplacement along with other mineralised deposits in Alice Arm. Recent plateau-type trachyandesite lava flows (previously identified by others as basalt) dominate the topography northeast of the deposit. These lava flows form well-developed columnar jointed cliff faces over 100 metres high.

3.2 DAM CLASSIFICATION

A hazard classification was completed to determine design earthquakes and storm events for the TMF South and Northeast Embankments. The selection of appropriate design earthquake and flood events has been based on the criteria provided by the Canadian Dam Association’s (CDA’s) “Dam Safety Guidelines” (2007). The dam classification criteria from the CDA 2007 guidelines are shown in Table 3.1. The suggested design floods and earthquake levels based on the CDA 2007 guidelines are shown in Table 3.2.

Classification of a tailings dam is carried out by considering the potential incremental consequences of a failure. That is, those consequences of dam failure which are in addition to the impacts that would occur from the earthquake or flood event alone. The consequences of failure include life safety and economic, social and environmental impacts.

The South Embankment has been assigned a VERY HIGH consequence category based on “loss of life” criteria for open pit workers working in the adjacent open pit. The economic consequences (including clean-up, repair and remedial works) and socio-economic impact to the mine would also be very high.

The Northeast Embankment was assigned a VERY HIGH consequence category based on “significant loss or deterioration of critical fish or wildlife habitat and very high economic losses affecting important infrastructure or services.” The potential for loss of life is likely minor following an embankment failure from the Northeast Embankment. If failure resulted in the release of tailings and/or process water it would have a significant environmental impact on downstream watercourses, particularly for the Clary Creek watershed. The economic consequences (including clean-up, repair and remedial works) and socio-economic impact to the mine would also be very high.
3.3 HYDROMETEOROLOGY

Meteorological and hydrological data have been collected at the Kitsault site since late 2008, and were also collected on site in various capacities from the 1960’s through the 1990’s. The details are presented in the Knight Piésold report “Engineering Hydrometeorology Report, Ref. No. VA101-343/9-1” dated July 15, 2010. The findings of the study indicate that the available site and regional dataset was adequate to provide a reasonable basis for describing and quantifying the meteorological characteristics of the Project area, for the purpose of water balance modelling, engineering design, and environmental assessment. The ongoing collection of data through 2010 will provide additional data that will help validate the current meteorological estimates, which will be updated when warranted.

The meteorological parameter estimates herein are for the Kitsault project site meteorological stations, located at elevation 682 metres.

The key findings of the study are:
- The mean annual temperature is estimated to be 3.7 °C, with minimum and maximum mean monthly temperatures of -5.8 °C and 12.4 °C occurring in January and July, respectively.
- The mean annual wind speed is approximately 1.9 m/s.
- The mean annual relative humidity is approximately 80.5%.
- The mean annual lake evaporation (potential evapotranspiration) is estimated to be 450 mm.
- The mean annual precipitation is estimated to be 2000 mm, with 45% falling as rain and 55% falling as snow.
- The mean annual unit runoff for Lime Creek at the mouth is 45.7 l/s/km².
- The mean annual unit runoff for Patsy Creek at its confluence with Lime Creek is 45.1 l/s/km².
- The mean annual unit runoff for Clary Creek at the outlet of Clary Lake is 45.1 l/s/km².
- The annual hydrographs for creeks in the Kitsault area typically have a bi-modal shape, with the highest peak occurring in the spring freshet period and a secondary peak occurring in late fall or early winter.
- Return period peak flows and 7-day low flows were estimated for Lime Creek at the mouth, Patsy Creek at the Lime Creek confluence, and Clary Creek above Clary Lake. The 200-year peak flow values are 140 m³/s, 22 m³/s, and 112 m³/s, respectively. Respective 10-year 7-day low flows are estimated to be 0.08 m³/s, 0.01 m³/s, and 0.06 m³/s.
- The effective annual runoff coefficient for natural drainage areas in the project area is estimated to be approximately 0.70.
- Climate change has not been considered explicitly in the hydrometeorological estimates, and appropriate allowances should be made where necessary.

3.4 GEOLOGIC SETTING

The Kitsault geologic setting has previously been described and mapped by Carter (1964 and 1982) and Steininger (1981). The Kitsault Molybdenum ore deposit is located within the geologic province of Cordilleran Intermontane tectonic belt in British Columbia. The Kitsault Project lies within the Boundary Range of the Coast Mountains, near the northeastern edge of the Eastern Coast Belt, lying between the Intermediate Belt to the east and the Western Coast Belt and Wrangellia to the west. The Boundary Range extends north from the Kitimat Range along the British Columbian and Alaskan border towards the
Yukon Territory. Rock types present within this belt range in age from Devonian to early Cenozoic, typically consisting of sedimentary, granitic, volcanic island and continental arc formations, and glaciomarine and non-marine clasts eroded mainly from uplifting of the Omineca Belt. Significant deformation has occurred in this region of the province, primarily caused by compression and extension transitional forces.

3.5 REGIONAL GEOMORPHOLOGY

Extensive glaciation has left deeply carved valleys adjacent to higher peaks. Peaks and ridges are more rounded at lower elevations (below 2000 metres), subdued by the effects of ice-sheet erosion that has left few surficial deposits. The project area is characterised by steeply inclined slopes dissected by deeply incised gullies. Bedrock typically outcrops throughout the project site and is frequently mantled by a thin veneer of colluvial deposits. The colluvium generally becomes thicker towards the toes of slopes, with the thickest deposits being the colluvial fans and cones, which develop as a result of debris flows from snow avalanches and rock falls. The colluvium is expected to be very thin or absent on the hillside spurs and on the upper hill slopes. Rock fall talus deposits are found along the bases of the columnar jointed lava flow cliff faces. Fluvial deposits, predominantly comprising sands and gravels, are anticipated along the active fluvial channels.

The steep slopes are intermittently broken with small swamp-covered benches and deeply incised gullies. Meandering stream courses connect pothole lakes and ponds on swamp covered benches. Organic deposits are located throughout the project area overlying undulating bedrock benches. These are commonly saturated with water and consist mainly of the accumulated remains of mosses, sedges, or other vegetation.

Interbedded gravels, sands and silts were deposited subaqueously in ice-proximal glaciomarine environments. These deposits graded distally to massive silty clay up to 25 metres thick. Eventually, valley glaciers retreated and the sea level dropped. Extensive meltwater-braided stream plains formed in front of the glaciers, terminating in marine water, and forming large deltas. The glaciers deposited the Kwinatahi Till, a compacted till up to 50 metres thick in the eastern part of the Nass valley area. Ice thinned during the deglaciation period and became confined to valleys and fjords, and the Kinskuch Till was deposited in the north-eastern part of the Nass valley (McCuaig, S. 2003).

The sea level during the Pleistocene glaciation was much higher due to the weight of glacial ice causing isostatic depression. This phenomenon is evidenced in the Kitsault area by the presence of glaciomarine deposits at elevations of up to 30 metres above the present sea level. There are glaciomarine clays, deltaic deposits and old beach deposits in Alice Arm that are at a considerable height above sea level indicating a maximum submergence of approximately 150 metres (Holland, 1976). Glaciomarine sediments were deposited during sea level high stands in glacial periods. These deposits still remain in river deltas such as at Roundy Creek. Glaciofluvial materials, typically sand and gravel, are deposited in a series of terraces associated with different sea levels at the mouths of rivers and creeks.

The regional surficial geology was mapped by McCuaig (2003) at a scale of 1:100,000. The Kitsault Project area is displayed on Figure 3.3.
3.6 REGIONAL GEOLOGY

The dominant host bedrock for the project area is comprised of the Upper Jurassic to Lower Cretaceous period Bowser Lake Group sedimentary rocks. The Bowser Lake Group typically consists of interbedded greywacke and argillite with minor conglomerate and limestone metamorphosed to greenschist facies. Individual beds vary in thickness from a few centimetres to upwards of 15 metres with a ratio of roughly 80% greywacke, 19% argillite and 1% limestone and conglomerate. The Bowser Lake Group lithology has been locally metamorphosed to greenschist facies consisting of roughly 35% crystalline and rock fragments in a fine grained matrix. Regionally, the Bowser Lake Group has a northwest strike and a steep northeast dip, but numerous variations to this trend are interrupted by small scale folding.

The Bowser Lake Group sedimentary rocks have undergone intense intrusive activity related to the Coast Range Crystalline Complex located approximately two kilometres away. The Alice Arm Intrusives were emplaced from 50 to 55 Million years ago in the sedimentary rocks surrounding Alice Arm (Carter 1982). Many of the Alice Arm Intrusives are associated with Molybdenum mineralization. Intrusives associated with Molybdenum mineralisation are multiphase diorite, quartz monzonite, and younger felsic units hosted in the sedimentary rocks. Surrounding the intrusives are hornfels aureoles that are a reaction to intrusion emplacement and extend up to 750 metres outward from the intrusive contact. Cross cutting relationships within the intrusive complex indicate that multiple mineralisation events produced the deposits.

The Kitsault property contains three known Molybdenum deposits: Kitsault, Bell Moly, and Roundy Creek. The Kitsault deposit is within the Lime Creek Intrusive Complex that consists of quartz diorite, granodiorite and decreased amounts of quartz monzonite. Mineralisation within the deposit is related to the last two phases of the Lime Creek Complex, the Central Stock (granodiorite) and the Northeast Porphyry (porphyritic granodiorite). Hornfels aureoles in the host sedimentary rocks were likely produced in reaction to intrusions along the eastern boarder of the Coast Plutonic Formation. Swarms of northeast striking lamprophyre dykes were later intruded into the sedimentary rocks between 34 to 36 Million years ago (Carter, 1964 and 1982). These swarms consist of several hundred dykes per kilometre and range in thickness from a few centimetres to 15 metres.

Northeast of the deposit are 0.6 to 1.6 million-year-old olivine basalt lava flows (Carter, 1964). These plateau-type lava flows are flat lying to gently dipping and extend over considerable distances. These lava flows are displayed as well-developed columnar jointed cliff faces over 100 metres high with talus slopes at the cliff base.

The area has undergone extensive glaciation, and at the height of the Pleistocene glacial period, thick ice flowed over the entire region. Pre-glacial valleys on the western side of the Coast Mountains offered an easier route for ice flowing westward to the sea. The Kitsault River valley, incised before the Pleistocene period, served as a main drainage path for the westward flow of glacial ice and was deepened by the passage of ice through it. Strongly developed lineations displayed by drift forms and sculptured bedrock provides an indication of the direction of Pleistocene ice movement.
The regional bedrock geology was mapped by Steininger (1981) and Carter et. al. (1986) and then digitised and made available from the British Columbia Government MEMPR at a scale of 1:100,000. The Kitsault Project area is displayed on Figure 3.4.

3.7 HYDROGEOLOGY

A Hydrogeological Assessment for the Kitsault Project site is included in Appendix A. A summary of the hydrogeological model is discussed below.

Groundwater regimes are commonly defined as regional, intermediate and local systems of groundwater flow (Freeze and Cherry, 1979). Where local relief is negligible, only regional systems develop. Where there is pronounced local relief, only local systems develop. The local relief at this site would indicate that local flow systems dominate, with recharge on high ground and discharge primarily in the valley floors. The groundwater flow directions have been estimated using the measured piezometric levels and are illustrated on Figure A.3. In general the groundwater table is a subdued reflection of the ground surface.

The Kitsault site simplified hydrogeologic units may be represented by:

- Glaciofluvial sands and gravels of varying thickness with a high hydraulic conductivity in the vicinity of the mouths of rivers and creeks along Alice Arm.
- Glaciomarine sediments with a relatively low hydraulic conductivity in river deltas near Alice Arm.
- Colluvial deposits with relatively high hydraulic conductivity as a thin veneer over bedrock along the toe of steep slopes.
- Fluvial deposits with relatively high hydraulic conductivity along active fluvial channels.
- Bedrock with low hydraulic conductivity.

In general, groundwater recharge is expected along the mountain slopes and in the headwaters of each catchment. Groundwater will flow down the slopes within the thin veneer overburden and weathered bedrock materials and within the bedrock towards stream channels. Groundwater will either discharge into streams or flow sub parallel to stream valleys in alluvial deposits.

The rate of groundwater recharge can be approximated by estimating the rate of groundwater discharge into streams during late winter low flows. Streamflow was either measured or synthesised for a 15 year period of record for three streamflow stations, near the mouth of Lime Creek, on Patsy Creek near the confluence with Lime Creek and at the discharge point of Clary Lake (KP Ref. No. VA101-343/9-1). The unit runoff (streamflow divided by catchment area) for the three stations is approximately 6 l/s/km². Therefore, groundwater recharge rate is approximately 200 mm/year or about 10 percent of the annual precipitation of about 2000 mm/yr. Based on the conditions observed on site, 10 percent of annual precipitation contributing to groundwater is a reasonable value.

3.8 SEISMICITY

3.8.1 Seismic Hazard

The region of coastal northwest British Columbia and the southwest Yukon Territory is one of the most seismically active areas in Canada. The seismic hazard in the region is also influenced by
the seismically active region of southeast Alaska, including the panhandle. The coastal region has experienced many large earthquakes, including events with magnitudes in the range of Magnitude 7.0 to 8.0+. These earthquakes are typically associated with the Queen Charlotte fault, Fairweather fault (the northern extension of the Queen Charlotte fault) and the eastern Denali fault system.

The high seismicity offshore and west of the project site is associated with the Queen Charlotte fault, which runs underwater along the west coast of the Queen Charlotte Islands and defines the boundary between the Pacific and North America tectonic plates. A Magnitude 8.1 earthquake occurred along this fault in 1949 (approximately 320 km from the project site). This event is the largest recorded earthquake in Canada since 1700. In 1958 a Magnitude 7.9 earthquake occurred farther north along the Fairweather fault. However, the level of seismicity and associated seismic hazard within northwest British Columbia reduces significantly with distance from the coast.

There has been much study in recent years concerning the possibility of a great interplate earthquake of Magnitude 9+ along the Cascadia subduction zone, located west of Vancouver Island and extending as far as northern California. The last great earthquake to occur along this subduction zone was in 1700. Such an event in the future would likely be located over 500 km from the project site, and therefore the amplitude of ground motions experienced at the site would be very low due to attenuation over such a large distance. Figure 3.2 shows the regional tectonics and historical seismicity.

A review of historical earthquake records and regional tectonics indicates that the Kitsault Project site is situated in a region of low seismic hazard. To provide seismic ground motion parameters for the project site a probabilistic seismic hazard analysis has been carried out using the database of Natural Resources Canada (NRC). The results are summarised in Table 3.3 in terms of earthquake return period, probability of exceedance (for a 15 year design operating life) and the median peak ground acceleration. For dam structures it is recommended that the mean peak ground acceleration be used for design (CDA Dam Safety Guidelines, 2007). The mean peak ground acceleration is typically approximately 15 to 20 percent greater than the median value. Estimated mean average values are included in Table 3.3. For a return period of 475 years (10% probability of exceedance in 50 years), the corresponding peak acceleration is only 0.08g, confirming a low seismic hazard for the site.

### 3.8.2 Design Earthquakes

Consistent with the current design philosophy for geotechnical structures such as dams, two levels of design earthquake have been considered: the Operating Basis Earthquake (OBE) for normal operations, and the Maximum Design Earthquake (MDE) for extreme conditions (ICOLD, 1995). Values of mean peak ground acceleration and design earthquake magnitude have been determined for both the OBE and MDE.

The OBE is usually selected from the results of a probabilistic hazard evaluation. The hazard level selected for the OBE is often chosen as the earthquake with a 10% probability of
exceedance in 50 years (with a corresponding return period of 475 years). For design of the TMF, the OBE has been conservatively taken as the 1 in 475 year return period event. The probability of exceedance for this event is only about 3% for a 15 year operating period. The mean peak acceleration is 0.08g for the 1 in 475 year earthquake. A conservative design earthquake magnitude of 7.0 has been selected for the OBE, based on a review of regional tectonics, potential seismic source zones in the region (as defined by Adams and Halchuk, 2003) and historical seismicity. The TMF would be expected to function in a normal manner after the OBE.

The TMF embankments have been assigned a VERY HIGH dam classification (as defined in Section 3.2) based on the criteria for design earthquakes provided by the CDA "Dam Safety Guidelines" (2007), presented in Table 3.2. The CDA Guidelines recommend that a dam with a VERY HIGH classification be designed for a probabilistically derived MDE having an annual exceedance probability (AEP) of 1/5,000 (return period of 5,000 years). However, Avanti have requested that a more stringent hazard classification and associated design event be used in the dam design. Consequently, a conservative MDE corresponding to the 1 in 10,000 year earthquake has been used for the South and Northeast Embankments, with a median average maximum acceleration of 0.30g. The corresponding estimated mean average maximum acceleration value used for embankment design is 0.36g. A design earthquake magnitude of 7.5 has been selected for the MDE, based on a review of regional tectonics, potential seismic source zones in the region and historical seismicity. Limited deformation of the tailings embankments is acceptable under seismic loading from the MDE, provided that the overall stability and integrity of the TMF is maintained and that there is no release of stored tailings or water (ICOLD, 1995).

3.9 INFLOW DESIGN FLOOD

The VERY HIGH dam classification for the South and Northeast TMF Embankments necessitates that the Inflow Design Flood (IDF) be 2/3 between the 1 in 1000 year return period flood and the Probable Maximum Flood (PMF), respectively as outlined in the CDA 2007 Guidelines. However, as Avanti have requested that a more stringent hazard classification and associated design event be used in the dam design, the IDF will be the PMF. The spillway for the TMF will be sized to convey the PMF without consideration of the runoff attenuation provided by the supernatant pond maintained below the spillway crest. This is a very conservative design assumption, and by ignoring the attenuating effect of this large storage volume, allowance is made for the possibility of multiple storm events, and the possibility of mine site water management problems that could result in temporary encroachment on the storm storage. Furthermore, it should be noted that the operating facility will likely have significant storage capacity available when a storm occurs since the embankments are constructed and operated with multiple raises and each embankment reaches the design freeboard condition immediately prior to initiation of the next raise.
Section 4.0 - GEOLOGICAL AND GEOTECHNICAL CONDITIONS

4.1 GENERAL

A feasibility stage geotechnical site investigation program was conducted from July 1 to August 23, 2010 to define the site geological and geotechnical characteristics for designing the tailings management facility. The primary objectives of the site investigation program were to evaluate geotechnical and hydrogeological conditions at the TMF site and other proposed mine site infrastructure to support feasibility engineering design and to install long-term groundwater monitoring wells to support environmental baseline studies. The detailed geotechnical investigation program information is provided in the Knight Piésold report, “Feasibility Study Geotechnical Site Investigations, Ref. No. VA101-343/6-1”. A description of the completed work program is provided below.

The 2010 geotechnical site investigation program included the following activities:

- A total of 1287 metres was drilled in 25 geotechnical drillholes (K10-01GT to K10-27GT, with the exception of drillhole K10-07GT and K10-26GT which was drilled for pit slope design and exploration by others) using diamond and ODEX drilling techniques.
- Detailed geotechnical logging of drill core was carried out in all drillholes to characterise the rock mass quality.
- Unconfined Compressive Strength testing of selected representative core samples collected from geotechnical drillholes.
- In-situ packer hydraulic conductivity testing was conducted to evaluate the permeability of the rock mass.
- Monitoring wells were installed in selected drillholes to allow for long-term groundwater sampling.
- Monitoring wells were developed to remove fines from screened zones and allow indicative groundwater quality samples to be obtained.
- Response tests were conducted in monitoring wells to estimate the hydraulic conductivity of the completion zone.
- Seventy vibracore drillholes (VC10-01 to VC10-70) were drilled to investigate overburden thickness along the Northeast TMF Embankment and the Low Grade Stockpile (LGS).
- Four test pit excavations (TP10-01 to TP10-04) were made using machine and hand dug techniques.
- Laboratory index test work on soil samples recovered from the borrow identification program and test pit program.

Drillhole locations and machine dug test pit locations were accessed via existing mining and forestry roads and by helicopter. Locations were chosen to get as close to planned drilling sites as possible, while minimizing the vegetation disturbance and crossing of waterways.

4.2 GEOTECHNICAL MATERIAL CHARACTERISTICS

The geotechnical conditions of the overburden and rock mass have been assessed based on all the relevant geological and geotechnical information from drillholes, test pits, site reconnaissance and laboratory test results. The site is characterised by the following sequences of overburden and bedrock.
4.2.1 Organic Material

Typically wet soft fibrous organic material that overlays bedrock around the project area. Little other overburden materials were found on site. This material will be required to be removed before construction.

4.2.2 Widdzech Mountain Lava Flows

Recent plateau-type trachyandesite lava flows dominate the topography northeast of the deposit. These lava flows form well-developed columnar jointed cliff faces over 100 metres high in places with talus resulting from instability deposited at the cliff base. These plateau-type lava flows are flat lying to gently dipping and extend over considerable distances. Drillholes K10-09GT and K10-14GT drilled through the lava flow and found a thickness of 46 to 118 m thickness (finding the contact at 809 (in northeast) to 830 (in south) masl elevation). Drillhole K10-09GT found a series of lava flow layers (4 layers) in the drill core between 24 and 35 m thick. A groundwater level was found at approximately 23 m depth (905 ma sl elevation). Lava flow mapping of the contact between the lava flow and the Bowser Lake Group was estimated from topography and outcrops to be at 805 masl on the Northeast Embankment and 900 masl at the South Embankment.

Field data indicates the rock mass typically has a low permeability with hydraulic conductivities estimated by in-situ testing to be in the order of $10^{-7}$ to $10^{-5}$ cm/s. Tests on the Lava Flow samples produced UCS values ranging from 24 to 303 MPa, with a mean of 84 MPa; Young’s Moduli ranging from 13 to 75 GPa, with a mean value of 46 GPa; and Poisson’s Ratios ranging from 0.28 to 0.57, with a mean value of 0.40.

4.2.3 Bowser Lake Group Sedimentary Rocks

The primarily basement bedrock is Bowser Lake Group greywacke and argillite. The Bowser Lake Group typically consists of interbedded greywacke and argillite with minor conglomerate. Individual beds vary in thickness from a few centimetres to upwards of 15 metres with a ratio of roughly 80% greywacke, 19% argillite and 1% limestone and conglomerate. Regionally, the Bowser Lake Group has a northwest strike and a steep northeast dip, but numerous variations to this trend are interrupted by small scale folding. Where faulting and intense jointing do not occur, these rocks are strong and display good competency.

The rock mass is classified as ‘FAIR’ to ‘GOOD’ rock using Bieniawski’s Rock Mass Rating classification (RMR 89) with RMR values ranging from 50 to 70 and a mean value of 60. Rock Quality Designation (RQD) values range from 50 to 90%. Field rock strength estimates indicate the rock is strong to very strong with an estimated field UCS of 100 to 250 MPa. Where faults or intense jointing occur, the rock was less competent and characterised by small blocks with minor clay seams and fault gouge. Graphite is commonly found coating joint faces and most often encountered near weaker argillite contacts. These argillite layers were generally less than 10 metres thick. Across the site, greywacke layers are seen as topographic highs and the weaker argillite layers are seen as topographic lows.
Field data indicates the rock mass typically has a low permeability with hydraulic conductivities estimated by in-situ testing to be in the order of $10^{-7}$ to $10^{-5}$ cm/s. Tests on the Bowser Lake Group samples produced UCS values ranging from 21 to 303 MPa, with a mean of 98 MPa; Young’s Moduli ranging from 13 to 88 GPa, with a mean value of 51 GPa; and Poisson’s Ratios ranging from 0.14 to 0.57, with a mean value of 0.39.

4.3 SOUTH EMBANKMENT FOUNDATION CONDITIONS

The South TMF Embankment is strategically located to optimise the natural topography. The foundation conditions are characterised by thin colluvium cover on the side slopes in a deeply incised v-shaped valley with exposed bedrock. The end of the historic Patsy Waste Dump is located on the right abutment of the embankment in the valley bottom. Drillhole K10-04GT intersected 10.6 metres of loose waste rock material. Three drillholes (KP10-22GT, 04GT and 23GT) were drilled in the vicinity of the proposed South TMF Embankment. The bedrock geology consisted of bedded Bowser Lake Group greywacke and argillite that is generally classified as ‘FAIR’ to ‘GOOD’ rock. RMR values range from 40 to 70 with a mean of 60. UCS testing results indicated the rock mass is strong to very strong with UCS values ranging from 100 to 300 MPa.

The rock mass permeability was found to be low, with hydraulic conductivities ranging from $10^{-5}$ to $10^{-7}$ cm/s that are consistent with depth. Water testing has shown the rock mass in the foundation is generally of low permeability and for the most part will not require grouting. However, the jointed nature of the embankment foundation rock mass includes steeply dipping and sheet joints parallel to the creek valley which increase significant risk of individual seepage paths through the foundations. The depth and extent of curtain grouting will have to be determined by additional geotechnical investigations during the detailed engineering stage of the embankment.

4.4 NORTHEAST EMBANKMENT FOUNDATION CONDITIONS

The Northeast TMF Embankment will be constructed at an elevation of approximately 760 metres along the northeast side of the Patsy Lake catchment. This site is strategically located to optimise the natural topography. The embankment is approximately 1560 metres in length, and a height of up to 100 metres. The starter embankment will be constructed using local quarry, with staged raises being constructed with cyclone sand. The site is characterised by thin topsoil and organic peat deposits overlying an undulating bedrock surface. Vibracore drillholes that were drilled along the embankment alignment to investigate the organic deposit thickness found between 1 and 5 m of organics overlying bedrock that will need to be removed prior to construction.

Five drillholes (KP10-14GT, 18GT, 17GT, 16GT and 15AGT) were drilled in the vicinity of the proposed Northeast TMF Embankment. Drillholes K10-15AGT, 16GT, 17GT and 18GT encountered shallow bedrock and Bowser Lake Group sedimentary rocks. The bedrock is bedded Bowser Lake Group greywacke and argillite that is generally classified as ‘FAIR’ to ‘GOOD’ rock. RMR values range from 40 to 70 with a mean of 60. UCS testing results indicated the rock mass is strong to very strong with UCS values ranging from 100 to 300 MPa. The rock mass permeability is low, with hydraulic conductivities ranging from $10^{-5}$ to $10^{-7}$ cm/s that are consistent with depth.
Drillhole K10-14GT was drilled downstream of the TMF to investigate lava flow thickness and permeability at the northern end of the embankment. Lava flow thickness was found to be 33.7 m thick at this drillhole. The trachyandesite lava flow is classified as ‘GOOD’ rock. RMR values range from 40 to 70 with a mean of 60. The rock mass permeability is low, with hydraulic conductivities ranging from $10^{-5}$ to $10^{-7}$ cm/s that are consistent with depth. UCS testing results indicated the rock mass is strong to very strong with UCS values ranging from 100 to 300 MPa. The contact between the lava flow and the underlying Bowser Lake Group was found at 34 metres depth, at elevation 842 metres.
Section 5.0 - TAILING MANAGEMENT FACILITY DESIGN

5.1 GENERAL

The principal design objectives for the Tailing Management Facility (TMF) are to ensure protection of the regional groundwater and surface waters both during operations and in the long-term (after closure), and to achieve effective reclamation at mine closure. The design of the TMF has taken into account the following requirements:

- Permanent, secure and total confinement of all solid waste materials within an engineered disposal facility
- Control, collection and removal of free draining liquids from the tailings during operations for recycling as process water to the maximum practical extent
- Collection and diversion of water from upstream of the TMF, open pit, and plant site areas during operations
- The inclusion of monitoring features for all aspects of the facility to ensure performance goals are achieved and design criteria and assumptions are met, and
- Staged development of the facility over the life of the Project.

The overall Project general arrangement of the TMF is shown on Figure 1.2. General arrangement plan views illustrating the staged development are shown on Figures 5.1 to 5.5 with embankment cross sections through the TMF embankments shown on Figures 5.6 and 5.7.

5.2 DESIGN BASIS

The mine will operate at a 40,000 tpd mill throughput of which 36,000 tpd will be scavenger (bulk) tailings and 4,000 tpd will be cleaner (pyritic) tailings deposited within separate areas of the tailings facility basin. The open pit will yield 233 Mt of ore and 178 Mt of waste rock removal during a mine life of approximately 16 years. A portion of the waste rock materials from the open pit will be used to construct the TMF which will impound tailings solids and process water. A summary of the design basis and operating criteria for the TMF is given in Table 5.1. The tailings production schedule from Year 1 to Year 16 is shown in Table 5.2.

The depth/area/capacity relationship for the TMF is shown on Figure 5.11. The filling schedule for the TMF is shown on Figure 5.12. The TMF embankments allow for staged expansions as the elevation of the stored tailings and ponded water increases with time. The South Embankment will be initially constructed as an asphaltic core rockfill dam for stage 1 with on-going expansions during operations using cyclone sand and rockfill. The Northeast Embankment will be constructed as a geosynthetic rockfill dam with cyclone sand used for ongoing raises. The starter embankments will be constructed using rockfill from the Patsy Dump, waste rock from mining operations and quarried rock from local borrow areas.

The filling curve for the TMF at the design throughput of 40,000 tonnes per day is shown on Figure 5.12. The Stage 1 embankment crest elevation has been selected to provide storage for the first two years of operations and on-going raising of the embankment crest will be carried out annually during the summer months of operations. TMF general arrangements for Stage 1A, Stage 1B and Stage 1C, Stage 7 and...
Stage 15 are provided on Figures 5.1 to 5.5, respectively. The material requirements for the initial construction of each embankment are summarised in Table 5.3, and the ongoing embankment requirements are summarised in Tables 5.4 and 5.5 over the sixteen years of operations.

5.3 LAYOUT AND OPERATING STRATEGY

5.3.1 General

Specific overall features of the TMF are listed below:
- South Embankment - Asphalt Core Rockfill water retaining starter dam expanded as a compacted cyclone sand/waste rock dam
- Northeast Embankment - Geomembrane Faced Rockfill starter dam expanded as a compacted cyclone sand dam
- Seepage collection ditches and ponds
- Bulk tailings distribution system
- Bulk tailings beaches
- Bulk tailings feeder lines to on-crest cyclones
- Cleaner tailings distribution
- Cleaner tailings cell
- Reclaim water system
- Surplus water system, and
- Supernatant water pond.

5.3.2 South Embankment

The South Embankment will be constructed using the centreline technique. The Stage 1 South Embankment will be a water retaining asphaltic core rockfill dam. Construction rockfill materials and drainage materials will be obtained from the existing Patsy Dump or from waste rock from pit stripping operations. Ongoing raises will include centreline raises with a vertical low permeability compacted cyclone sand zone and adjacent filter zones. Sand will be produced from the tailings in cyclones on the embankment crest and discharged into the cyclone sand zone where it will be spread and compacted using bulldozers. The tailings and cyclone sand overflow will be discharged into the impoundment. Waste rock will be used to construct the stabilizing downstream shell zone and screened waste rock will provide appropriate filter zone materials to ensure a filter relationship between the tailings and the waste rock. Seepage control will be provided by the compacted cyclone sand and embankment drainage zones from ongoing raises and the stage 1 vertical asphalt core that will be tied into the bedrock foundations and a grout curtain at the abutment contacts.

5.3.3 Northeast Embankment

The Northeast Embankment will be constructed initially as a water retaining starter embankment and raised using the downstream technique. The Stage 1 Northeast Embankment will be a water retaining geosynthetic faced rockfill dam. Ongoing raises will include downstream raises using compacted cyclone sand. Sand will be produced from the tailings in cyclones on the
embankment crest and discharged onto the downstream face where it will be spread and compacted using bulldozers. An underdrain system will be used to maintain a low phreatic surface in the embankment. The tailings and cyclone sand overflow will be discharged into the impoundment. Seepage control will be provided by the compacted cyclone sand and underdrainage system from ongoing raises and the stage 1 geosynthetics tied into the bedrock foundations with a grout trench up to elevation 805 m.

5.3.4 Water Management

Overall water management is the key to the success of all mining waste management systems. The TMF is located in the middle reaches of the Patsy Lake/Creek catchment and hence has the ability to collect runoff from areas impacted by the mining operation, which can then be recycled for reuse or discharged to Lime Creek. The Project is located within an area where a significant overall surplus of water is unavoidable and hence runoff from upstream areas not impacted by the mining operation will be diverted to the maximum practicable extent.

Diversion of runoff to the maximum practicable extent possible has been achieved by diverting the upper catchment areas of the Patsy Creek watershed and making provision for the diversion of Patsy Creek around the open pit on a bench along the south wall of the pit.

Water accumulating in the TMF surface pond will be recycled for reuse in the process as required. Surplus water will be discharged into the Lime Creek watershed where it will mix with runoff from upstream areas not impacted by the mining operation.

The crest elevations of the TMF embankment raises have been selected to provide sufficient freeboard to contain the runoff from a PMP storm assuming all the diversion systems fail. Notwithstanding this, each embankment crest will include an emergency spillway so that the safety of the embankments can never be compromised. The final crest will contain a spillway capable of handling the runoff from a PMF event over the entire upstream catchment.

5.3.5 Tailings Distribution

Two tailings streams will be generated in the process plant and transported to the TMF. Scavenger (bulk) tailings will be transported to both the Northeast and South Embankments by either the cyclone feed lines or the bulk tailings distribution lines. Cleaner (pyrite) tailings will be transported to a separate location within the TMF near to the reclaim barge in the pyrite tailings line with deposition in an area that maintains the tailings solids in a subaqueous state perpetually. The cyclones are expected to operate during the summer and fall months in order to generate the required volume of sand for embankment construction. The balance of the bulk tailings discharge during the summer and fall months not required for cycloning, as well as the full bulk tailings stream during the winter and spring months will be discharged from both embankment crests using spigots to build tailings beaches.
5.3.6 Cyclone Sand Construction

Embarkment construction using cyclone sand will take place during the eight warmer months in the year. Bulk tailings will be deposited from the embankment crests during the remainder of the year and when not producing sand for embankment construction. The tailings distribution system therefore requires pipelines for whole tailings flow and cyclone feed flow for each embankment.

The particle size distribution of the Kitsault mill tailings is a key consideration in determining the suitability of the bulk tailings to provide cyclone sand fill material of suitable quality and sufficient quantity. Coarser tailings are preferred, as a higher sand fraction or ‘split’ can be realised. A low percentage of fines is also preferred, in order to promote rapid drainage and to facilitate compaction.

Significant features of the cyclone sand construction at the TMF include the following:

- The cyclone sand sleds will be located at an elevation such that discharge of sand and combined cyclone overflow can be achieved by gravity. Relocation of the cyclone sleds will be required on an annual basis. Pumping may be required in the final raises of the TMF.
- The cyclone sand sleds will be fed directly from the mill using off-take connections from and to feeder lines that will transport bulk tailings.
- The cyclone underflow (sand fraction) will be discharged by gravity from the cyclone sand sleds as a slurry of approximately 55% solids by weight. These lines will be laid across a downstream bench below the crest of the TMF confining embankment and extended at intervals down the downstream face for deposition of sand into confining “cells” for use as construction material.
- The fine cyclone overflow material (fine tailings) will be returned back and discharged directly into the TMF from existing off-takes in pipelines laid along the upstream embankment crest and around the periphery of the TMF.
- Additional solids collection and water recovery measures will be required at the downstream embankment toe. These include sediment collection ponds, drainage recovery pumping and pipeworks systems, plus a seepage recovery pond and pump-back system.
5.4 EMBANKMENT CONSTRUCTION

5.4.1 South and Northeast Embankment Fill Zones

The South Embankment will comprise the following zones:

- Asphalt Core Zone - Machine compacted asphaltic concrete is virtually impervious, flexible, resistant to erosion and aging, workable and compactable and offers jointless core construction. The asphalt concrete mix has viscoelastic-plastic and ductile properties and provides a “self healing” ability should cracks develop in the core wall. The maximum core thickness starts at 0.9 metres and decreases to 0.5 metres. The asphaltic concrete is compacted at a temperature around 160 degrees Celsius depending on the type of bitumen used and is given immediate lateral support from the adjacent zones in the embankment. Placement of the core wall and filter zones proceed simultaneously with equal layer thickness usually limited to 0.2 m and compaction is achieved by vibratory rollers. The rollers operate in a coordinated manner, side by side, to avoid lateral displacement of the hot asphalt. This construction procedure gives the hot asphaltic concrete immediate lateral support and close interloading along the core-filter interface. The bitumen content is usually a little higher than to just theoretically fill the voids in the aggregates and corresponds to a range of 5.5 to 6% (of total weight). This produces a mix that is easy to place and compact. In the narrow V-shaped valley with steep flanks, cross-valley arching may occur. In detailed design the stresses in the plane of the core and shear distortions, dilation and potential cracking require detailed evaluation.

The South and Northeast Embankments will comprise the following zones:

- Zone F - The filter zone will be placed simultaneously with the asphaltic concrete placing machine. The width on each side of the asphalt core will be 2.5 metres. The filter zone will consist of crushed hard rock with a maximum grain size of 60mm, \( d_{50} > 10 \) mm and \( d_{15} < 10 \) mm. Crushed angular rock will be used to support the core and placing machine.

- Zone T – The transition zone will consist of a constant horizontal width of 5 metres and will act as a filter layer and prevent movement of the Zone F material into the rockfill Zone C. The transition material will be well graded with a maximum size of 300 mm, between 65 and 80\% passing a 100 mm sieve, between 35 and 45\% passing a 20 mm sieve, between 17 and 27\% passing a 5 mm sieve and less than 4\% passing a 0.1 mm sieve. The transition material will be selected from moderately weathered to fresh ground rock. This material type will be placed in 0.50 m thick layers to an approximately horizontal surface in such a way as to prevent segregation of the particles and will be subsequently compacted with at least 4 passes of a 15 ton vibratory roller, and in accordance with the results of the trial embankment tests. Vibratory compaction of these layers is required to increase the deformation modulus.

- Zone C - A well compacted zone on either side of the transition zones will be constructed using good quality dense rockfill. The material will be placed in layers of maximum 0.8 to 1 metre after compaction with a corresponding maximum grain size which allows proper compaction. Oversize rock will not be greater than the lift thickness.
5.4.2 Cyclone Sand Zones

Cyclone sand slurry will be discharged into each construction cell to depths of 0.5 m to 2.0 m, and will be heavily track packed by dozers. Water expelled from the sand by the track packing will drain from the cells for collection in the downgradient water management ponds at the toe of the embankment. The draining and track packing will provide compacted zones of cyclone sand that meet 95% Standard Proctor compaction density specification. The in situ density, moisture content, and fines content will be obtained from within 48 hours of sand placement. This design relies on maintaining a free-draining downstream sand embankment for static stability and to reduce risk of deformation due to liquefaction under seismic loading.

5.4.3 Stage 1 Construction

The South Embankment will be initially constructed in three stages: Stage 1A, 1B, and 1C. The Northeast Embankment will be constructed during Stage 1C. Cofferdams will be constructed at the South and Northeast Embankments in order to drain and prepare the foundations prior to Stage 1A, 1B, and 1C embankment construction activities. Surface and groundwater downstream of the Stage 1A, 1B, and 1C embankments will be collected in dewatering sumps and pumped around the cofferdams for discharge.

Construction of Stage 1A will commence approximately two years before mill start-up in order to capture spring runoff from the 2013 freshet season. The Stage 1B crest elevation of 750 m is required at the South Embankment prior to the spring freshet. Stage 1C will proceed immediately following completion of Stage 1B to reach elevation 805 m prior to the start of milling. A detailed construction execution plan is provided in Appendix D.

5.4.4 Staged Expansions

The total cyclone sand fill requirement for the tailings embankments is approximately 12.8 Mm³ or 12.5% of the scavenger tailings volume. The embankment will be raised using the centreline method of construction at the South Embankment and using the downstream technique at the Northeast Embankment once the tailings beaches have been established. Construction of each of the embankment stages will be scheduled to correspond with material availability from the Open Pit and the tailings discharge rate.

5.5 SEEPAGE COLLECTION SYSTEM

5.5.1 General

Seepage will largely be controlled by the low permeability zones of the starter embankments constructed prior to development of the tailings beach, the tailings deposit, and the low permeability foundation materials. Seepage at the South Embankment and Northeast Embankment will follow the natural topography and report either to the South Seepage Collection Pond (wet well) or to the two Northeast Seepage Collection and Recycle Ponds, developed at topographic low points. The seepage recovery system for the tailings embankment will comprise a system of seepage collection trenches, seepage collection ponds, and a seepage pumpback
5.6 TAILINGS CONSOLIDATION

Ongoing consolidation of the tailings is an important consideration for the design and construction of the TMF during operations and after closure. Consolidation occurs continuously during deposition, and will continue after completion of operations until all excess pore pressures have dissipated. The density of the deposit will increase slightly once tailings deposition ceases at closure and self weight consolidation continues, assisted by surface desiccation due to evaporation.

The tailings will remain partially consolidated during operations and for a period of time after closure until all excess pore water pressures have dissipated. The actual time taken for complete consolidation will be dependent on the in situ consolidation characteristics of the tailings material.

5.7 TAILINGS MANAGEMENT FACILITY SEEPAGE ANALYSES

5.7.1 Seepage Analyses

Knight Piésold carried out a steady state seepage analysis for the TMF to determine the phreatic surface for stability modelling and to estimate inflows for embankment drainage system design. The analyses were conducted using the finite element computer program SEEP/W.

The seepage rate through foundation materials and embankment fill zones will be influenced by the following factors:

- Permeability of the embankment zones
- Permeability of the foundation materials
- The thickness and permeability of the tailings stored within the TMF
- Seepage gradients in the embankment and foundation zones, and
- The seepage area available (increases with time during operations).

Permeability values for the embankment fill, tailings and foundation were based on lab test results and/or typical conservative values for similar materials.
The seepage flow rate is expected to vary over the life of the TMF, as it is gradually filled with tailings. The tailings deposit will increase in thickness and decrease in permeability due to ongoing consolidation during operation of the TMF. Seepage rates were estimated for both the Stage 1 TMF and the final TMF configurations. These were found to be approximately 8 L/s and 33 L/s, respectively. The majority of this seepage is expected to be recovered by the multiple seepage collection system. A description of the seepage model and the detailed results of the analysis are presented in Appendix C1.

The predicted phreatic surface generated from the seepage modelling was used in the subsequent stability analysis.

5.8 EMBANKMENT STABILITY ANALYSES

Embankment stability analyses were carried out to investigate the stability of the embankments under both static and seismic conditions. The cross sections analysed were those previously used in the seepage analysis. The analyses comprised checking the stability of the embankment arrangement for each of the following cases:

- Static conditions during operations and post-closure
- Earthquake loading from the Operating Basis Earthquake (OBE) and the Maximum Design Earthquake (MDE), and
- Post-earthquake conditions using residual (post-liquefaction) tailing strengths.

The stability analyses were carried out using the limit equilibrium computer program SLOPE/W. In this program a systematic search is performed to obtain the minimum factor of safety (FOS) from a number of potential slip surfaces. FOS were computed using Morgensten & Price’s Method.

In accordance with international recommendations (ICOLD, 1995) and standard industry practice, the minimum acceptable FOS for the tailings embankments under static conditions is 1.3 for short-term operating conditions and 1.5 after closure of the TMF. A FOS of less than 1.0 is acceptable for earthquake loading conditions provided that calculated embankment deformations resulting from seismic loading are not significant and that the post earthquake stability of the embankment maintains a factor of safety greater than 1.2.

The results of the stability analyses satisfy the minimum requirements for FOS and indicate that the proposed design is acceptable to maintain both short term (operational) and long term (post-closure) stability.

The seismic analyses indicate that any embankment deformations during earthquake loading from the OBE or MDE would be minor, and would not have any significant impact on embankment freeboard or result in any loss of embankment integrity. The results also indicate that the embankments are not dependent on tailings strength to maintain overall stability and integrity.

Details of the embankment stability assessment are presented in Appendix C2.
6.1 WATER MANAGEMENT OBJECTIVES

The site water management plan describes strategies and provides guidance for the control of water from the project area during construction and operations. The objective of the water management plan is to manage water in order to provide sufficient water to support the mill water requirements, while mitigating environmental impacts to downstream receiving waters, namely Lime Creek and Lake 901. Water will be controlled in a manner that minimises erosion in areas disturbed by construction activities and prevents the release of sediment laden water to the receiving environment. This includes the collection and diversion of surface water runoff, sediment control ponds and pump back systems. The key facilities for the water management plan are:

- Open Pit
- Mill
- Tailings Management Facility (TMF) – South and Northeast embankments
- Water Box
- Waste Rock Management Facility (WRMF)
- Low Grade (LG) Stockpile
- Diversion and water management structures, and
- Sediment and erosion control measures for the facilities listed above.

A general layout of the mine site is shown on Figure 6.1. The following sections describe the water management strategies, design elements and facilities through the construction (pre-production) and operations phases.

6.2 WATER MANAGEMENT AND EROSION CONTROL

The aim of the water management plan is to utilise water within the project area to the maximum practicable extent. The water management plan involves collecting and managing site runoff from disturbed areas and maximizing the recycle of process water. Surplus water will be stored on site within the TMF and used for the milling process, with the excess water being released to Lime Creek. The water supply sources for the project are as follows:

- Precipitation runoff from the mine site facilities
- Water recycle from the TMF supernatant pond
- Freshwater from Clary Lake for potable, fire and mill processing
- Groundwater from Open Pit dewatering and depressurization wells, and
- Treated septic and grey water, in small quantities, from the camp.

Sediment and erosion control strategies will include establishing diversion and runoff collection ditches, constructing sediment control ponds, and stabilizing disturbed land surfaces to minimise erosion.

Activities that have the potential to require sediment and erosion control include clearing vegetation and stripping topsoil, stockpiling topsoil, and constructing roads and infrastructure. Potential hazards from these activities, in the absence of planned mitigation measures, include increased surface erosion from
disturbed areas, increased sediment load to downstream receiving environments, and siltation or erosion of downstream watercourses or waterbodies.

Sediment mobilization and erosion will be managed throughout the site by:

- Installing sediment controls prior to construction activities
- Limiting the disturbance to the minimum practicable extent
- Reducing water velocity across the ground, particularly on exposed surfaces and in areas where water concentrates
- Progressively rehabilitating disturbed land and constructing drainage controls to improve the stability of rehabilitated land
- Ripping of rehabilitation areas to promote infiltration
- Protecting natural drainages and watercourses by constructing appropriate sediment control devices such as collection and diversion ditches, sediment traps and sediment ponds
- Restricting access to rehabilitated areas, and
- Constructing surface drainage controls to intercept surface runoff.

Installation of temporary erosion and sediment control features or “Best Management Practices” (BMPs) will be the first step towards controlling sediment and erosion during construction. All temporary sediment and erosion control features will require regular maintenance. The temporary erosion and sediment control features will be reclaimed after achieving soil and sediment stabilization.

6.3 DESIGN ELEMENTS

6.3.1 General

The design criteria for the following design elements are described below and summarised in Table 6.1.

6.3.2 Cofferdams and Pumping Systems

The south and northeast TMF embankment cofferdams will be designed to provide storage of runoff from the 1 in 10 year 24 hr precipitation event with freeboard allowance. Pumping systems for the cofferdams will be designed to restore the cofferdam water levels to normal operating conditions within 7 days.

6.3.3 Sediment and Erosion Control Elements and “Best Management Practices”

Sediment and erosion control elements will be implemented prior to and during construction to minimise erosion and sediment discharge into surrounding areas. The sediment and erosion control elements that will be used include: diversion ditches, runoff collection ditches, and sediment control ponds.
Diversion Ditches
The water management plan includes constructing diversion structures to either route water to areas within the mine site where it is required or to divert clean water for release to the environment. Major diversion structures include the South diversion channel that diverts the south Patsy Creek upslope catchment around the TMF, WRMF and Open Pit into Lime Creek.

The South diversion channel will be sized to convey the 1 in 200 year return period peak instantaneous discharge values for Patsy Creek. Further details of the derivation of the design flow values can be found in the KP report “Engineering Hydrometeorology Report” (Knight Piésold, 2010).

Runoff Collection Ditches
A runoff collection ditch intercepts construction water runoff and diverts it to a stabilised area where it can be effectively managed with appropriate sediment control measures.

Collection ditches may be either temporary or permanent structures and will be sized to convey runoff from a 1 in 10 year 24 hour precipitation event in accordance with the design specifications for the sediment control ponds.

Sediment Control and Seepage Collection Ponds
A sediment control pond is used to detain runoff from a disturbed area so that sediment can settle out and be captured. All sediment control ponds will be designed according to the “DRAFT Guidelines for the Design, Size, and Operation of Sedimentation Ponds used in Mining”, as issued by the BC Ministry of Environment, Lands, and Parks (BC MOE, 1996).

These ponds will be situated downstream of the TMF embankments and will collect surface runoff from the embankments and seepage through the embankments. All water collected will be pumped back to the TMF. Surface water runoff and seepage through the South TMF Embankment and East WRMF will be collected in the south water management pond, a ‘wet well’, which will be located within the toe of the WRMF, and which is located upstream of the Open Pit. Seepage through the Northeast TMF Embankment will be collected in ditches and conveyed to two ponds, Northeast water management pond 1 and Northeast water management pond 2, that will be located at topographic low points along the embankment toe.

BMPs will also be implemented throughout the site to reduce the potential for erosion by stabilizing exposed soil or reducing the velocity of surface runoff. The BMPs include:
• Surface roughening
• Temporary seeding
• Sediment traps and sediment basins, and
• Mulching.
6.4 WATER MANAGEMENT AND EROSION CONTROL PLAN

6.4.1 Construction

Water management during construction of the TMF, Open Pit and associated facilities is shown on Figure 6.1 to 6.3, and will consist of the following components:

- Establishing water management and sediment control structures including cofferdams, pumping systems and diversion ditches:
  - The South diversion channel will be constructed along the southern part of the Patsy Creek catchment to diverted clean water from the upslope catchment areas around the TMF and Open Pit construction areas.
  - A series of upstream cofferdams and pumping systems will be required to dewater the South Embankment footprint during construction.
  - All runoff from the Open Pit will be collected in a sediment pond located within the ultimate pit down-gradient of the pre-stripping area. The runoff from this pond will then be released to Lime Creek during the construction period.
  - The South water management wet-well will be constructed to collect runoff from the South Embankment construction. This in-stream pond will be located within the ultimate toe of the East WRMF.

6.4.2 Operations

All water in contact with the mine facilities, including the East WRMF, the Open Pit, and the LG stockpile will be collected and either conveyed to the TMF or released to Lime Creek, as shown on Figure 6.4. The TMF surplus water will be released to Lime Creek via the Water Box. The specific water management plan for the TMF, Open Pit and associated facilities during operations is outlined below:

- TMF:
  - All runoff from within the TMF catchment will be stored within the TMF.
  - Process water will be discharged into the TMF with the tailings at a rate of approximately 892 l/s (at full production).
  - Tailings supernatant water will be reclaimed and pumped back to the mill for process water requirements.
  - Surplus water above the pond capacity of 10 million m³ at the TMF will be pumped to the Water Box and then released to Lime Creek. This surplus flow can be pumped at varying rates throughout the year to meet the discharge requirements, as there will be a separate surplus pumping system.
  - A tailings deposition strategy will be implemented to selectively develop tailings beaches along the embankments and the lava flows to the North, thereby producing an extensive low permeability zone that facilitates seepage control. The operational supernatant pond volume will be managed by selective tailings deposition to ensure that the beaches are saturated, thus reducing the potential for dust generation.
  - The South and Northeast water management ponds will collect seepage and sediment laden runoff from the TMF embankments and the East WRMF and treat contact water for
sediment. This water will then be pumped back to the TMF, or in the case of the South Embankment/East WRMF, could be released directly to Lime Creek.

- **Open Pit:**
  - The South diversion channel around the Open Pit will be maintained throughout the mine life.
  - A diversion along the south wall of the Open Pit will be constructed early in operations to convey the diverted Patsy Creek catchment towards Lime Creek. This will be maintained until closure when the diverted flows will be allowed to flow directly into the Open Pit until it is full, at which time it will discharge to Lime Creek.
  - Open Pit dewatering will continue throughout the mine life with dewatering flows either being pumped to the TMF or discharged directly to Lime Creek.

### 6.4.3 Closure

Once active mining from the pit has ceased and the low-grade stockpile is processed during the final two years of operations, pit dewatering will cease and some or all of the surplus contact water from the site will be directed to the Open Pit to facilitate pit filling. The quantity of surplus contact water that will be directed to the Open Pit during this time, and once active tailings deposition ceases will be dictated by the flow requirements of the receiving environment.

Water diversions around the TMF, low-grade stockpile and south of the Open Pit will be breached to return water courses to their natural direction. The Northeast Sediment Control Ponds will be pumped back to the TMF until such time that water quality is suitable for passive release perpetually. All benches and slopes will be reclaimed in such a manner to prevent erosion and minimise suspension of sediments.

### 6.5 SITE WATER BALANCE

#### 6.5.1 General

A stochastic analysis was carried out on the base case monthly operational mine site water balance using the GoldSim© software package. The intent of the modelling is to estimate the magnitude and extent of any water surplus and/or deficit conditions in the TMF based on a range of possible climatic conditions. The modelling timeline includes one pre-production year (Year -1), and 16 years of operation (Years 1 to 16) at a rate of 40,000 dry metric tonnes per day. Mill water requirements will be supplied from the TMF pond and slurry water will report to the TMF during all mining years. Inputs to the water balance include net direct and runoff precipitation, seepage losses, mill requirements, and water lost to tailings void spaces. Details of the water balance model are included in Appendix E.

#### 6.5.2 Results

The water balance indicates that the mine site is in surplus conditions during all years of operations. Surplus water to be discharged to the environment from the TMF is in the order of 9 million m³/year under the median scenario.
6.6 **SURPLUS WATER QUALITY MODEL**

A preliminary simple mass balance mixing model was developed to assess the resultant water quality that will discharge from the project area throughout operations. The objective of conducting a preliminary model at this time in the design of the project is to identify whether or not active water treatment will be necessary.

Contact water will be derived from:
- Tailings Management Facility
- East Waste Rock Management Facility
- Low-grade stockpile, and
- Open Pit.

Surplus water from the site will be directed to a single point discharge west of the Open Pit, in the remnants of Patsy Creek just upstream of the confluence with Lime Creek. Water quality was assessed at this point (Point A), as well as two more points downstream (Points B and C). Point C is located near the mouth of Lime Creek at the bridge. The resultant water quality has been compared to provincial and federal guidelines, as well as the baseline that exists for the project. Appendix H presents the details of the model.

Site specific water quality objectives (SSWQOs) will be developed during the Environmental Assessment and Permitting processes. The results of this preliminary model indicate some exceedances of generic provincial and federal water quality guidelines. As each source term from the site (TMF, waste rock, low-grade stockpile and open pit) are predicted to have different water quality, the management of the discharge of excess contact water on-site combined with setting SSWQOs may result in suitable water quality for discharge without active systems of water treatment during operations.

A detailed water quality model is being developed as part of the Environmental Assessment Application. All geochemical testwork, along with the historic on-site water chemistry, is being used as inputs to the detailed model. Results of the water quality model for use in impact assessment will provide the needed detail to establish SSWQOs to assist the management of surplus water for the Kitsault Project during operations and in closure.
Section 7.0 - PIPEWORK SYSTEMS

This section describes the design considerations and assumptions used to establish pipeline size and material selection, pumping needs and equipment selection for the eight major external pipelines. Figure 7.1 contains a block diagram summarizing the various process streams, and a table with the most important design parameters. The eight major process streams are:

- Scavenger (bulk) and cleaner (pyritic) tailings pipelines including delivery to the TMF and to the cyclones
- Reclaim water pipeline
- Surplus water discharge pipeline
- Clary Lake freshwater supply pipeline, and
- Seepage/Runoff collection pipelines:
  - Northeast Embankment
  - South Embankment / East WRMF, and
  - Low-Grade Stockpile.

The pipelines will be constructed of steel when large diameters and high pressures are required. High Density Polyethylene (HDPE) pipes will also be considered where practical and economical. Pipelines will be free draining wherever possible, with drainage outlets at any low points and air valves or vents at high points, as required.

The pipelines will typically be laid on grade, alongside existing or purpose built access roads. Pipes will be protected from vehicle traffic by posts, concrete or earth barriers, or local burial. Thermal expansion and contraction will be managed with local pipeline anchorage, burial or cover. Pipeline corridors will be wide enough to accommodate pipe snaking, as may be required for HDPE pipes. Local select fill cover will be considered at appropriate locations to reduce potential damage from terrain hazards. Pipeline crossings of access roads will be made in buried culverts to allow for pipe inspection and replacement without the need for road closures.

7.1 TAILINGS TRANSPORT AND DISTRIBUTION TO TMF

Tailings will be generated in the process plant as either rougher scavenger (bulk) or cleaner (pyritic) streams. The tailings transport and distribution system has been designed assuming that 90% of the total tailings are bulk with the balance (10%) being pyritic. The actual volume of pyritic tailings generated by the process plant may be less than the designed 10%; however the bulk tailings lines have been designed to handle the entire 40,000 tpd throughput, so no significant changes to the pipeline sizes would be required. The bulk tailings will be distributed on both the Northeast and South Embankments, while the pyritic tailings will be distributed separately in a separate area of the TMF away from both embankments. Since the Northeast Embankment, as well as a portion of the South Embankment, will be constructed with cyclone sand generated from the bulk tailings stream, a distribution box located in the process plant will provide the necessary volume of bulk tailings to the cyclone sand sleds located on both embankments.

Appendix G provides a technical memo that describe in detail the tailings distribution and cyclone sand systems. The following sub-sections summarise each aspect of the systems.
7.1.1 General

The size distribution and rheology for the bulk tailings are not available at this time. The slurry concentration is assumed to be 36.4% dry by weight, with the solids density of 2.7 t/m³. The total tailings production is 14.6 million tonnes per year.

7.1.2 Cyclone Sand

The Northeast Embankment will be primarily raised using cyclone sand generated from the bulk tailings stream. Two cyclone sleds will be constructed and placed on the crest of the Northeast Embankment. Once the necessary tailings have been generated for each year on the Northeast Embankment, one sled will be brought across to the South Embankment to produce the small quantity of cyclone sand that will be needed for the upstream zone at this embankment.

Each cyclone sled contains two cyclones each. Initial calculations have shown that a single large cyclone treating the same amount of tailings per sled will be sufficient. However, in order to allow for a change in particle size distribution, twin smaller cyclones were chosen for the Feasibility Study.

7.1.3 Tailings Delivery to Cyclones

A tailings distribution box has been designed in the process plant to split bulk tailings either to the cyclones or the bulk tailings lines to each embankment. The distribution box for the tailings stream is a passive device. Make-up water will ensure that a constant volumetric flow to the cyclone sleds is assured at all times, although given the low ratio of cyclone sled feed to the whole tailings, it will be unlikely that the make-up water will be often required.

Initially pinch valves are used to control flow rate to each cyclone sled, while pumps will be used in the final raises of each embankment. At the TMF the tailings will be discharged at a single point for each operating pipeline. The discharge point is controlled with isolation valves along the pipeline directing flow to the appropriate point. The discharge points are located to allow for beach development in the case of whole tailings or feed to the cyclone sled in the case of cyclone feed.

Two cyclone feed lines to the Northeast Embankment and one cyclone feed line to the South Embankment have been designed. A 16” DR 17 HDPE pipeline provides the necessary capacity to feed the cyclones and generate the needed sand for embankment construction during the summer and fall months.

7.1.4 Bulk Tailings Delivery to the TMF

Bulk tailings delivery has been designed to handle 40,000 tpd in either of the two pipelines, one to the Northeast Embankment and one to the South Embankment. The tailings will be directed through the distribution box and be transported to the TMF in 28” DR 15.5 HDPE pipelines. Calculations indicate that pumps will not be required to transport and distribute bulk tailings throughout the life of the TMF.
Construction of the Northeast Embankment using cyclone sand will take place during the summer and fall months. During this period, the small quantity of cyclone sand required at the South Embankment will also be generated. Generally, beach development will occur on the Northeast Embankment during the summer and fall months, with beach development occurring on the South Embankment during the winter and spring months. As with the cyclone sleds, the bulk tailings discharge point will be controlled with isolation values located along the embankment crests.

7.1.5 Pyritic Tailings Delivery to the TMF

Pyritic tailings will be transported in a 12" HDPE pipeline along the reclaim line road. This tailings stream will be deposited in a permanently saturated portion of the TMF, away from the beaches, so as to prevent oxidation of the pyritic tailings.

7.2 RECLAIM WATER

The reclaim system is designed to deliver 120% of the process water requirements for a nominal throughput of 40,000 tpd. The water will be pumped from the TMF surface water (supernatant) pond to a process water holding tank at the mill for reuse in the process. The pumps will be mounted on the barge (floating pump station). The average elevation of the tailings supernatant pond will increase steadily over the project life, with seasonal variations due to snowmelt, runoff, precipitation, evaporation, and consumption of water in the tailings voids. The rising elevation will significantly reduce the pumping head requirements over the life of the project and allow modifications to the pumps, or their mode of operation, to minimise power consumption.

7.2.1 Reclaim Barge

A floating pump station (or reclaim barge) will recover water from the supernatant pond to a process water head tank located at the mill. The nominal pumping capacity of the reclaim pumps will match 120% of the peak process demand. The proposed barge will be located on the northwest side of the TMF pond, approximately half way between the South and the Northeast Embankments. The pump station will include two running pumps and one identical installed standby pump (spare). The barge will be linked to the shore by mooring lines, a hinged access walkway, and a pontoon supported reclaim discharge line with connecting ball joints. The barge will be periodically relocated closer to shore as the elevation of the supernatant pond rises.

In addition to the three reclaim pumps (two running and one spare), the same barge will be used for housing an additional pump for discharging the surplus water from the TMF surface water pond to the Water Box and ultimately to Lime Creek. This pump is designed to discharge the annual surplus water in a period of six months. It will be identical and have the same characteristics as the three reclaim pumps, but will be connected to a separate pipeline.

There will be two offtakes from the barge, one for the reclaim and the other for the surplus water pipeline. The reclaim discharge line will be a 30" diameter, 0.375" wall thickness steel pipe, and will include an isolation valve and a check valve to facilitate barge relocation and maintenance.
The surplus water line will be a 24" diameter, 0.375" wall thickness steel pipe. It will also have an isolation valve and a check valve for pump relocation and maintenance purposes. The reclaim pipe selection criteria are described in Section 7.2.3 and the surplus system is described in Section 7.3.

7.2.2 Reclaim Water Pipeline

A single pipeline will deliver the reclaim water from the TMF water surface pond (elevation varies) to the process water head tank at the mill (elevation 920 masl). The proposed pump intake will be located on the northwest side of the TMF pond, approximately half way between the South and the Northeast Embankments. The water surface elevation will change from about 785 masl at start-up to about 855 masl at the end of the operations. The reclaim pipeline will follow a purpose built access road from the barge westward to the intersection with the mill service road. From this intersection the reclaim pipeline will head north and share the pipeline corridor with the South Embankment tailings pipelines up to the mill. The total start-up length of the reclaim water pipeline will be 2770 m with a design flow of 3330 m$^3$/h. The length of this pipeline will reduce to 1960 m in the final year due to barge relocation.

The factors considered in the reclaim water pipeline design, material selection, and sizing include:

- Welded, coupled or flange jointed steel pipes will be used due to high pressure requirements. As an alternative, HDPE pipes may be used for the sections closer to the mill where space permits, pipe diameter and pressure ratings are acceptable, thermal movement can be adequately controlled, and it is cost effective.
- The pipeline will be placed in its final locations, to the extent possible. Sections of the line that will require removal or relocation will be Victaulic coupled or flange joined.
- All sections of the pipeline will have the same rating and coupling systems to simplify construction and maintenance.
- Pumping requirements and design pressures will decrease with the ongoing increase in elevation of the TMF supernatant pond.

Based on these selection parameters, a single 30" diameter, 0.375" wall thickness steel pipe is selected for the design flow. This pipeline will be permanent for the life of the Project for most of its length. Modifications and shortening of the pipeline will be required at its connection with the reclaim barge, which will be dictated by raises of the TMF supernatant pond.

7.3 SURPLUS WATER

Surplus water will be discharged from the TMF surface water pond to the Water Box and ultimately to Lime Creek downstream of the open pit. The surplus water pumping system will share the same barge with the reclaim water pumping system as described in Section 7.2.1. This section describes the surplus water pipeline from the barge to the discharge point at the Water Box.
7.3.1 **Surplus Water Pipeline**

A single pipeline will carry the surplus water from the reclaim barge (elevation varies) to the water box (elevation 725 masl). The surplus water pipeline will run in parallel with the reclaim pipeline and follow a purpose built access road from the barge westward to the intersection with the mill service road. From this point on, the surplus pipeline will follow the service road towards the South Embankment, and from the top of the ridge it will follow the crusher access road down to the Water Box. The total start-up length will be approximately 3350 m with a design flow of 1660 m³/h. The length of this pipeline will reduce to 2540 m in the final year due to barge relocation.

The factors considered in the surplus water pipeline design, material selection, and sizing include:

- Welded, coupled or flange jointed steel pipes will be used. As an alternative, HDPE pipes may be used for the gravity section of the pipe from the top of the ridge to the Water Box where space permits, pipe diameter and pressure ratings are acceptable, thermal movement can be adequately controlled, and it is cost effective.
- The pipeline will be placed in its final locations and along existing road structures, to the extent possible. Sections of the line that will require removal or relocation will be Victaulic coupled or flange joined.
- All sections of the pipeline will have the same rating and coupling systems to simplify construction and maintenance.
- Air valves or vents will be used at high points, as required.
- Pumping requirements and design pressures will decrease with the ongoing increase in elevation of the TMF supernatant pond.

Based on these selection parameters, a 24” diameter, 0.375” wall thickness steel pipe is selected for the design flow. This pipeline will be permanent for the life of the Project for most of its length. Modifications and shortening of the pipeline will be required at its connection with the reclaim barge, which will be dictated by raises of the TMF supernatant pond.

7.4 **CLARY LAKE FRESHWATER SUPPLY SYSTEM**

The freshwater system is designed to provide 120% of the clean water demand for various purposes of the Project, including water for process use, and potable and fire water for the mill and the camp. A preliminary assessment confirms that consistent water supply can be achieved from Clary Lake throughout the year. The water will be pumped from the lake to a freshwater holding tank at the mill. The holding tank will provide storage for times when the system is not operating during pump maintenance or other interruptions, as well as additional water for fire fighting. The Clary Lake water quality has not been determined at this time. The level of treatment necessary for potable water will be assessed in future studies. If required, a potable water treatment facility will be located on the potable water line downstream of the holding tank.
7.4.1 Freshwater Pipeline

A single pipeline will connect Clary Lake to the fresh water holding tank at the mill. The water will be pumped from an intake structure at the lake (elevation 650 masl) to a fresh water holding tank at the mill (920 masl). To allow for easier pump maintenance without supply interruption, two identical vertical turbine pumps will be used to provide the combined peak discharge and the necessary head. The intake design will use a slotted pipe section at the end of the suction line, enclosed in a meshed frame to prevent fish entry into the pumps. The pipeline will be laid along the existing access road and along the new proposed mill access road. The total pipeline length will be 5900 m with a design flow rate of 120 m$^3$/h.

The factors considered in the freshwater pipeline design, material selection, and sizing include:

- Welded, coupled or flange jointed steel pipes will be used due to high pressure requirements.
- The pipeline will be placed in its final location and along existing road structures, to the extent possible.
- All sections of the pipeline will have the same rating and coupling systems to simplify construction and maintenance.
- The pipeline will be covered or buried to prevent freezing in cold winter months.
- Drain valves will be considered for low points in the line to allow for pipe draining and to prevent freezing.
- Pumping requirements and design pressures will remain constant for the life of the Project.
- The holding tank will have sufficient capacity to satisfy the needs for process and potable water, and contain the necessary volume of water for fire fighting.

Based on these selection parameters, an 8" diameter, 0.322" wall thickness steel pipe is selected for the design flow. The entire pipeline will be permanent for the life of the Project.

7.5 SEEPAGE COLLECTION AND RECYCLE SYSTEMS

There will be several different systems used to collect and recycle seepage and local runoff water for the various components of the Project:

1. Two seepage ponds located downstream of the Northeast Embankment will intercept and collect cyclone sand water and seepage from the TMF embankment underdrain system, and also collect surface runoff from the embankment and the surrounding area.

2. A vertical sump or wet-well located downstream of the South Embankment and East Waste Rock Management Facility (East WRMF) will collect seepage from the TMF and the East WRMF, the surface runoff from the embankment, the East WRMF and the surrounding area, as well as the leakage from the drainage ditches located to the south of the East WRMF.

3. A vertical sump located downstream of the Low-Grade Stockpile will collect seepage and surface runoff from the stockpile.

7.5.1 General

Common to all three systems is a large variation in flows throughout the year. All systems will experience no flow or very low flows in the winter, and peak flows in June during the snowmelt
season. The peak flows are approximately three times larger than the flows during other months in the year. This considerable variation in flows along with the type of storage available at each location dictated the type of pumping systems to be used in each application. Each one of the above systems is described in more detail in Sections 7.5.2 through 7.5.4.

The factors considered in the design, material selection, and sizing of seepage pipelines include:

- HDPE pipes will be used where space permits, pipe diameter and pressure ratings are acceptable, thermal movement can be adequately controlled, and it is cost effective. Welded, coupled or flange jointed steel pipes will be used as an alternative, where required.
- Pipelines will be placed in their final locations and along existing roads to the extent possible. The construction of new roads will be minimised.
- The lower sections of seepage recycle pipelines will be constructed downstream of the ultimate embankment toe so that they do not need to be relocated throughout the life of the facility. The upper and the discharge sections of the seepage lines will require extension and relocation as the TMF embankments are raised.
- As sections of the pipeline are relocated or added for different embankment stages, the new sections will have the same rating and coupling systems to simplify construction and maintenance.
- Air valves or vents will be used at high points in the line to prevent negative pressures in the lines during drainage.
- Pumping requirements and design pressures may increase significantly with each raise. The pipeline diameter, pressure rating, and initial pump capacity will meet the long term requirements. Booster stations or additional pumps may be installed for later stages or to handle peak flows where needed.

7.5.2 Northeast Embankment Seepage/Runoff Collection and Recycle System

Cyclone sand water, seepage and local runoff will be stored in two seepage ponds downstream of the Northeast Embankment, and will be pumped back from the ponds (elevation 764 masl) to the top of the embankment (elevation varies). The embankment elevation will increase with each stage and consequently, the pumping requirements will increase with time. Centrifugal pumps are selected to pump the water from the two seepage ponds. They are sized to handle 120% of the design discharge and the maximum head created by the final embankment elevation of 863 masl. A single 16” DR 11 HDPE pipeline will be laid from each seepage pond across the embankment to the top, from where a short section of the pipeline will continue down-slope for discharge into the TMF. As the embankment is raised, the pipelines will be extended to accommodate for the change. The total final length of each pipeline will be approximately 900 m with a design flow rate of 360 m³/h.

7.5.3 South Embankment/East WRMF Seepage/Runoff Collection and Recycle System

Seepage water from the TMF and the East WRMF, as well as the local runoff and ditch leakage will be collected in a vertical sump or wet-well downstream of the South Embankment/East WRMF area (elevation 609 masl). The water will be pumped to the TMF across the top of the South Embankment (final elevation 863 masl). Considering that there is no sizeable storage
space available at this location, the pumping system was designed to handle 120% of the peak June flows. Three vertical turbine pumps in parallel will be used to cover the range of flows throughout the year and to handle the increasing heads due to embankment raises. Due to high pressures, a single 24” diameter, 0.375” wall thickness steel pipeline is selected for the entire length to the top of the South Embankment. From there, a short section of an HDPE pipeline will continue down-slope for discharging into the TMF. As the embankment and the waste rock management facility are raised, the pipeline will be relocated and extended to accommodate for the change. The total final length of the pipeline will be approximately 2000 m with a design peak flow rate of 1500 m$^3$/h.

Seepage water chemistry has not been determined at this time, but if adequate, an alternative option has been considered to release the South Embankment/East WRMF seepage and runoff water directly to the Patsy Creek diversion in the south wall of the Open Pit and ultimately to Lime Creek.

7.5.4 Low-Grade Stockpile Seepage/Runoff Collection and Recycle System

Seepage water and local runoff from the Low-Grade Stockpile will be collected in a vertical sump downstream of this area (elevation 675 masl). The water will be pumped to the Water Box (elevation 725 masl) and from there released to Lime Creek. Considering that there is no sizeable storage space available at this location, the pumping system was designed to handle 120% of the peak June flows. Two vertical turbine pumps in parallel will be used to cover the range of flows throughout the year. A single 8” DR 13.5 HDPE pipeline is selected for the entire length. The pipeline will be permanent and follow the Low-Grade Stockpile access road. The pipeline will be approximately 1100 m long with a design peak flow rate of 190 m$^3$/h.
8.0 - INSTRUMENTATION AND MONITORING

8.1 GENERAL

Geotechnical instrumentation will be installed in the tailings embankments and foundation during construction and over the life of the Project. The instrumentation will be monitored during the construction and operation of the TMF to assess embankment performance and to identify any conditions different to those assumed during design and analysis. Amendments to the ongoing designs and/or remediation work can be implemented to respond to the changed conditions, should the need arise.

Geotechnical instrumentation, comprising vibrating wire piezometers, slope inclinometers and movement monuments will be installed at one plane along the South Embankment and two planes at the Northeast Embankment. Groundwater wells will be installed at suitable locations downstream of each embankment.

8.2 INSTRUMENTATION

Vibrating wire type piezometers will be installed in the embankment foundations, fill and tailings materials to measure pore water pressures during initial placement and operations. The piezometers will be distributed throughout the various foundation and fill zones to provide a spectrum of monitoring data. The piezometer leads will be appropriately routed from the fill to read-out panels for ease of monitoring.

Movement monuments will be installed on the embankment crests following the completion of selective embankment raises to monitor deflections along the slope and crest of the embankments. Periodic surveying of the monument locations will provide early warning of movements and possible acceleration of movement which often occurs prior to failure.

Groundwater monitoring/recovery wells will be installed at appropriate locations along the downstream toes. The wells will be used to recover samples for water quality monitoring. The three instrumentation planes have been identified as follows:
- Instrumentation Plane South Embankment, and
- Instrumentation Plane NE1 and NE2.

8.3 MONITORING PROGRAM

Instrumentation monitoring will be routinely completed during construction and operations. Measurements during construction will be taken and analysed on a daily basis to monitor the response of the rockfill and foundation from rockfill loading.

The frequency of monitoring for the piezometers and inclinometers may be decreased to bi-monthly readings once the effects of initial construction have dissipated. Surface movement monuments should be surveyed twice per year during operations. Water quality monitoring of the seepage through the embankment and foundation shall be monitored as outlined in the water quality monitoring program.
Section 9.0 - CLOSURE AND RECLAMATION

9.1 GENERAL

The primary objective of the closure and reclamation initiatives will be to eventually return the TMF site to a self-sustaining facility with pre-mining usage and capability. The TMF will be required to maintain long-term stability, protect the downstream environment and manage surface water. Activities that will be carried out during operations and at closure to achieve these objectives are discussed in the following sections.

9.2 DECOMMISSIONING AND CLOSURE

Upon mine closure, surface facilities will be removed in stages and full reclamation of the TMF will be initiated. General aspects of the closure plan include:

- Selective discharge of scavenger tailings around the facility during the final years of operations to establish a final tailing beach that will facilitate surface water management and reclamation.
- Dismantling and removal of the tailings and reclaim delivery systems and all pipelines, structures and equipment not required beyond mine closure.
- Construction of overflow channels. This full closure scenario will also work well in the event of premature closure of the mine.
- Removal of the seepage collection pump-back systems at such time that suitable water quality for direct release is achieved.
- Removal and regrading of all access roads, ponds, ditches and borrow areas not required beyond mine closure.
- Long-term stabilization of all exposed erodible materials.

The possibility of creating a self-sustaining fishery in the closed facility is being explored jointly with the Environmental Assessment team. The Kitsault Project general arrangement plan after closure is shown on Figure 9.1.

9.3 ONGOING MONITORING REQUIREMENTS

The seepage collection ponds and recycle pumps downstream of the Northeast Embankment will be retained until monitoring results indicate that any seepage from the TMF is of suitable quality for direct release to downstream waters. The groundwater monitoring wells and all other geotechnical instrumentation will be retained for use as long term monitoring devices.

Post-closure requirements will also include an annual inspection of the TMF and an ongoing evaluation of water quality, flow rates and instrumentation records to confirm design assumptions for closure.
Section 10.0 - QUANTITIES AND COST ESTIMATES

Initial Capital, Sustaining Capital and Operating costs were developed from quantities for the Tailings Management Facility and Water Management aspects for the Kitsault Project. The Basis of Estimate for the costs are included in Appendix F1. The Initial Capex, Sustaining Capex and Opex costs are included in Appendix F2.

Initial Capex, Sustaining Capex and Opex were reviewed with AMEC to align as much as possible many of the common values, such as labour rates, productivity factors and power costs that were being used on the entire study. AMEC incorporated the Capex and Opex costs into the overall financial model of the Feasibility Study for the Kitsault Project and made final edits based on refinements in various aspects of the overall estimate. Hence, the costs found in Appendix F2 need to be read in conjunction with those found in the AMEC Feasibility Study Report.
Section 11.0 - REFERENCES


www.em.gov.bc.ca/Mining/Geolsurv/Publications/catalog/bcgeolmap.htm


SECTION 12.0 - CERTIFICATION

This report was prepared and approved by the undersigned.

Prepared & Reviewed:

Bruno Borntraeger, P.Eng.
Specialist Engineer / Project Manager

Prepared & Reviewed:

Greg Smyth
Senior Project Manager

Approved by:

Ken J. Brouwer, P.Eng.
Managing Director

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# TABLE 3.1

**AVANTI KITSAULT MINE LTD**  
**KITSAULT PROJECT**  
**TAILINGS AND WATER MANAGEMENT FACILITIES FEASIBILITY STUDY DESIGN REPORT**  
**DAM CLASSIFICATION**

<table>
<thead>
<tr>
<th>Dam Class</th>
<th>Population at Risk ¹</th>
<th>Incremental Losses</th>
<th>Environmental and Cultural Values</th>
<th>Infrastructure and Economics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>None</td>
<td>0</td>
<td>Minimal short-term loss No long-term loss</td>
<td>Low economic losses; area contains limited infrastructure or services</td>
</tr>
</tbody>
</table>
| 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 |
| 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, public transportation, and commercial facilities |
| 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) |
| 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) |

## NOTES:

1. **DEFINITIONS FOR POPULATION AT RISK:**  
   - **NONE** - THERE IS NO IDENTIFIABLE POPULATION AT RISK, SO THERE IS NO POSSIBILITY OF LOSS OF LIFE OTHER THAN SEASON. THROUGH UNFORSEEABLE MISADVENTURE.  
   - **TEMPORARY** - PEOPLE ARE ONLY TEMPORARILY IN THE DAM-BREACH INUNDATION ZONE. (E.G., SEASONAL COTTAGE USE, PASSING THROUGH ON TRANSPORTATION ROUTES, PARTICIPATING IN RECREATIONAL ACTIVITIES).  
   - **PERMANENT** - THE POPULATION AT RISK IS ORDINARILY LOCATED IN THE DAM-BREACH INUNDATION ZONE. (E.G., AS PERMANENT RESIDENTS). THREE CONSEQUENCE CLASSES (HIGH, VERY HIGH, EXTREME); THREE CONSEQUENCE CLASSES (HIGH, VERY HIGH, EXTREME) ARE PROPOSED TO ALLOW FOR MORE DETAILED ESTIMATES OF POTENTIAL LOSS OF LIFE. (TO ASSIST IN DECISION-MAKING IF THE APPROPRIATE ANALYSIS IS CARRIED OUT).

2. **IMPLICATIONS FOR LOSS OF LIFE:**  

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* Reproduced from Table 2-1 of the Canadian Dam Association's (CDA) "Dam Safety Guidelines", 2007.
### TABLE 3.2

**AVANTI KITSAULT MINE LTD.**  
**KITSAULT PROJECT**

**TAILINGS AND WATER MANAGEMENT FACILITIES FEASIBILITY STUDY DESIGN REPORT**  
**SUMMARY OF PROBABILISTIC SEISMIC HAZARD ANALYSIS**

<table>
<thead>
<tr>
<th>Return Period (Years)</th>
<th>Probability of Exceedance ³ (%)</th>
<th>Median Peak Acceleration ², ³ (g)</th>
<th>Mean Peak Acceleration ⁵ (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>13.9</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>475</td>
<td>3.1</td>
<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td>1000</td>
<td>1.5</td>
<td>0.10</td>
<td>0.12</td>
</tr>
<tr>
<td>2500</td>
<td>0.6</td>
<td>0.14</td>
<td>0.17</td>
</tr>
<tr>
<td>5000⁴</td>
<td>0.0</td>
<td>0.21</td>
<td>0.25</td>
</tr>
<tr>
<td>10000</td>
<td>0.01</td>
<td>0.30</td>
<td>0.36</td>
</tr>
</tbody>
</table>

**NOTES:**

1. PROBABILITY OF EXCEEDANCE CALCULATED FOR A DESIGN OPERATING LIFE OF 15 YEARS.

   \[ q = 1 - \exp (-L/T) \]

   WHERE \( q \) = PROBABILITY OF EXCEEDANCE  
   \( L \) = DESIGN LIFE IN YEARS  
   \( T \) = RETURN PERIOD IN YEARS

2. PEAK ACCELERATIONS ARE VALUES FOR VERY DENSE SOIL OR SOFT ROCK (SITE CLASS C, AS DEFINED BY THE NATIONAL BUILDING CODE OF CANADA, 2005).

3. MEDIAN PEAK ACCELERATIONS WERE PROVIDED BY THE NATURAL RESOURCES CANADA (NRC) SEISMIC HAZARD CALCULATION.

4. THE MEDIAN PEAK ACCELERATION FOR RETURN PERIODS OF 5000 AND 10,000 YEARS WERE OBTAINED BY EXTRAPOLATION OF THE NRC SEISMIC HAZARD DATA.

5. THE MEAN PEAK ACCELERATION IS REQUIRED FOR SEISMIC STABILITY ANALYSIS OF DAMS (CDA GUIDELINES) AND WAS ESTIMATED BY MULTIPLYING THE MEDIAN VALUE BY A FACTOR OF 1.2.
TABLE 3.3

AVANTI KITSAULT MINE LTD
KITSAULT PROJECT

TAILINGS AND WATER MANAGEMENT FACILITIES FEASIBILITY STUDY DESIGN REPORT
SUGGESTED DESIGN FLOOD AND EARTHQUAKE LEVELS

<table>
<thead>
<tr>
<th>Dam Class</th>
<th>Annual Exceedance Probability</th>
<th>Inflow Design Flood&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Earthquake Design Ground Motion&lt;sup&gt;3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td></td>
<td>1/100</td>
<td>1/500</td>
</tr>
<tr>
<td>Significant</td>
<td></td>
<td>Between 1/100 and 1/1000&lt;sup&gt;4&lt;/sup&gt;</td>
<td>1/1000</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td>1/3 between 1/1000 and PMF&lt;sup&gt;5&lt;/sup&gt;</td>
<td>1/2500&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>Very high</td>
<td></td>
<td>2/3 between 1/1000 and PMF&lt;sup&gt;5&lt;/sup&gt;</td>
<td>1/5000&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>Extreme</td>
<td></td>
<td>PMF&lt;sup&gt;5&lt;/sup&gt;</td>
<td>1/10,000</td>
</tr>
</tbody>
</table>

NOTES:

ACRONYMS: AEP, ANNUAL EXCEEDANCE PROBABILITY; EDGM, EARTHQUAKE DESIGN GROUND MOTION; IDF, FLOW DESIGN FLOOD; PMF, PROBABLE MAXIMUM FLOOD.

1. AS DEFINED IN TABLE 3.1: DAM CLASSIFICATION.
2. EXTRAPOLATION OF FLOOD STATISTICS BEYOND 1/1000 YEAR FLOOD (10<sup>−3</sup> AEP) IS DISCOURAGED.
3. AEP LEVELS FOR EDGM ARE TO BE USED FOR MEAN RATHER THAN MEDIAN ESTIMATES FOR THE HAZARD.
4. SELECTED ON THE BASIS OF INCREMENTAL FLOOD ANALYSIS, EXPOSURE, AND CONSEQUENCES OF FAILURE.
5. PMF HAS NO ASSOCIATED AEP. THE FLOOD DEFINED AS "1/3 BETWEEN 1/1000 AND PMF" OR "2/3 BETWEEN 1/1000 YEAR AND PMF" HAS NO DEFINED AEP.
6. THE EDGM VALUE MUST BE JUSTIFIED TO DEMONSTRATE CONFORMANCE TO SOCIETAL NORMS OF ACCEPTABLE RISK. JUSTIFICATION CAN BE PROVIDED WITH THE HELP OF FAILURE MODES ANALYSIS FOCUSED ON THE PARTICULAR MODES THAT CAN CONTRIBUTE TO FAILURE INITIATED BY A SEISMIC EVENT. IF THE JUSTIFICATION CANNOT BE PROVIDED, THE EDGM SHOULD BE 1/10,000.

* Reproduced from Table 6-1 of the Canadian Dam Association's (CDA) "Dam Safety Guidelines", 2007.
### TABLE 5.1

**AVANTI KITSAULT MINE LTD**  
**KITSAULT PROJECT**  
**TAILINGS AND WATER MANAGEMENT FACILITIES FEASIBILITY STUDY DESIGN REPORT**  
**DESIGN BASIS AND OPERATING CRITERIA**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESIGN CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.0 GENERAL</strong></td>
<td></td>
</tr>
</tbody>
</table>
| Regulations | • Ministry of Forests, Mines and Lands (MFML)  
• Ministry of Environment (MoE) – Water Stewardship Division  
• IHSR (Industrial Health and Safety Regulations) |
| Codes and Standards | • NBC and related codes  
• CAN/CSA  
• HSRC (Health, Safety and Reclamation Code for Mines in British Columbia)  
• ASTM  
• ACI  
• ANSI |
| Mine Production | • Total ore milled 233 Million tonnes  
• Mill throughput 40,000 tpd  
• 16 operating years |
| Climate | • Mean annual precipitation = 2000 mm  
• Annual evaporation = 450 mm  
• Mean annual temp = 3.7°C |
| **2.0 WATER MANAGEMENT** | |
| Site Water Management Priorities During Operations | • 10 million m³ Freshwater required for startup.  
• Divert clean water around the site.  
• Minimize surface disturbances using staged construction and maximize concurrent reclamation practices.  
• Minimize seepage from tailings impoundment.  
• Collect and recycle runoff from Plantsite and other disturbed areas.  
• Release contact water to single location in Lime Creek.  
• Maximize recycle of water from TMF supernatant pond for process water. |
| Site Water Management Priorities During Closure | • Supernatant pond to be discharged to open pit to facilitate pit flooding.  
• Discharge from flooded pit via discharge channel to Lime Creek. |
| **3.0 PLANTSITE** | |
| Mill Elevation | • ~908 m |
| Total Tailings Production Information | • 36,000 tpd Scavenger (Bulk) Tailings (13.14 Mt/a)  
• 4,000 tpd Cleaner (Pyritic) Tailings (1.46 Mt/a) |
### TABLE 5.1

AVANTI KITSAULT MINE LTD
KITSAULT PROJECT

TAILINGS AND WATER MANAGEMENT FACILITIES FEASIBILITY STUDY DESIGN REPORT

DESIGN BASIS AND OPERATING CRITERIA

<table>
<thead>
<tr>
<th>Item</th>
<th>Design Criteria</th>
</tr>
</thead>
</table>
| Tailings Stream            | • Tailings settled dry density  
|                            |   o Scavenger Tailings = varies from 1.3 to 1.35 t/m³  
|                            |   o Cleaner Tailings = 1.3 t/m³  
|                            |   • SG solids:  
|                            |     Scavenger 2.80, Cleaner 3.14  
|                            | • Scavenger tailings 35% solids; (64% sand, 36% fines (silt & clay))  
|                            | • Cleaner tailings 17% solids; (3% sand, 97% fines (silt & clay))  |

#### 4.0 OPEN PIT WASTE MATERIALS

- Open Pit Overburden and Waste Rock
  - Based on mining schedule
  - Dry density (placed)
  - 2.4 tonnes/m³ Waste rock

#### 5.0 TAILING MANAGEMENT FACILITY DESIGN CRITERIA

- Total Storage Capacity
  - Scavenger Tailings Facility – 158.8 M m³ tailings solids
  - Cleaner Tailings Facility - 17.9 M m³ tailings solids
  - Cyclone sand used for embankment construction – 11.8 M m³
  - Total solids volume storage = 164.9 M m³
  - Supernatant pond volume = 10.0 M m³
  - PMP Flood Storage = 4.0 M m³
  - Total Storage Requirement – 178.9 M m³

#### 6.0 EMBANKMENTS

- Dam Classification
  - CDA Dam Safety Guidelines, 2007
  - South Embankment and Northeast Embankment = VERY HIGH classification
  - Inflow Design Flood = PMF
  - Earthquake Design Ground Motion = 1/5000

- Embankments
  - South Emb. – Asphaltec Core Rockfill starter dam. Dam raised as a rockfill/compacted cyclone sand dam
    - Starter Crest elevation 805 m (125 m high under emb. centerline)
    - Final Crest elevation – 863 m
  - Northeast Emb. – Geomembrane Faced Rockfill starter dam. Dam raised using compacted cyclone sand
    - Starter Crest elevation 805 m (10 m high under emb. centerline)
    - Final crest elevation 863 m

- Embankment Crest Width
  - 15 m starter and ongoing raises

- Design Freeboard:
  - Minimum 3 m – 1 m wave run-up.

- Stability Criteria
  - During Construction Minimum FOS = 1.3
### TABLE 5.1

**AVANTI KITSAULT MINE LTD**  
**KITSAULT PROJECT**  
**TAILINGS AND WATER MANAGEMENT FACILITIES FEASIBILITY STUDY DESIGN REPORT**  
**DESIGN BASIS AND OPERATING CRITERIA**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESIGN CRITERIA</th>
</tr>
</thead>
</table>
|                               | Long term (Closure) Minimum FOS = 1.5  
|                               | Post liquefaction case Minimum FOS = 1.2                                                                                                                                                                                                                                                                                                                                                                           |
| Seepage Control Measures      | Multiple levels of control  
|                               | • South Embankment – low permeability asphaltic central core connected to the low permeability rock foundation  
|                               | • Northeast Embankment – low permeability HDPE geomembrane connected to low permeability bedrock  
|                               | • Seepage recycle ponds and groundwater monitoring / recycle wells downstream of TMF  
|                               | • Monitor groundwater quality  
|                               | • Recycle seepage as necessary to prevent adverse downstream water quality impacts                                                                                                                                                                                                                                                                                                                                   |
| Starter Embankment            | • 2 years storage (approximately)                                                                                                                                                                                                                                                                                                                                                                           |
| Stage Expansion Construction Method | • Annual raises using compacted cyclone sand, Zone F/T and Zone C rockfill from pit stripping                                                                                                                                                                                                                                                                                                                                 |
| Embankment Fill Material      | • Local borrow areas from within tailings basin, existing waste dumps and waste rock from open pit                                                                                                                                                                                                                                                                                                                                 |

### 7.0 PIPEWORKS

**Tailings Discharge**  
• Discharge cyclone underflow from a single point at various locations on crest  
• Discharge cyclone overflow from a single point at various location on the crest  
• Control deposition to promote beach development for ongoing raises and to prevent freezing during winter operations, as required  
• Cyclone underflow directed to cells in downstream fill

**Tailings Delivery & Distribution**  
• Scavenger and Cleaner Tailings delivery pipelines  
• Scavenger tailings line to carry 100% design flow  
• Two Scavenger tailings delivery pipelines  
• One Scavenger tailings delivery pipeline in operation at all times  
• Cleaner tailings line to carry 100% design flow  
• Gravity discharge from mill used where sufficient head is available  
• Pump stations as required when gravity discharge is not possible

**Reclaim System**  
• Water recovery from Scavenger and Cleaner Tailings Cells to be combined and recovered from one single pond.  
• Floating barge pump-station at TMF to reclaim tank at Plantsite  
• Reclaim offtake line flushing connection to tailings pipelines
<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESIGN CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.0 CYCLONE SAND PRODUCTION</td>
<td></td>
</tr>
</tbody>
</table>
| Function | • Collect and treat coarse fraction of tailings solids for construction of the tailings embankments  
• Discharge tailings underflow and overflow to suit embankment construction and beach development schedule. |
<p>| Underflow Pipelines | • 16” DR 17 HDPE |</p>
<table>
<thead>
<tr>
<th>YEAR</th>
<th>YEAR</th>
<th>STAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-1</td>
<td>2013</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>14,029</td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td>14,600</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>14,600</td>
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<tr>
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<td>14,600</td>
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<tr>
<td></td>
<td>2019</td>
<td>14,600</td>
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<tr>
<td></td>
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<td>14,600</td>
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<td></td>
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<td>14,600</td>
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<td></td>
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<td>14,600</td>
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<td></td>
<td>2023</td>
<td>14,600</td>
</tr>
<tr>
<td></td>
<td>2024</td>
<td>14,600</td>
</tr>
<tr>
<td></td>
<td>2025</td>
<td>14,600</td>
</tr>
<tr>
<td></td>
<td>2026</td>
<td>14,600</td>
</tr>
<tr>
<td></td>
<td>2027</td>
<td>14,600</td>
</tr>
<tr>
<td></td>
<td>2028</td>
<td>14,600</td>
</tr>
</tbody>
</table>

**TABLE 5.2**

**AVANTI KITSAUULT MINE LTD**

**KITSAUULT PROJECT**

**TAILINGS AND WATER MANAGEMENT FACILITIES FEASIBILITY STUDY DESIGN REPORT**

**TAILINGS PRODUCTION SCHEDULE**
### TABLE 5.3

**AVANTI KITSAULT MINE LTD**

**KITSUALT PROJECT**

**TAILINGS AND WATER MANAGEMENT FACILITIES FEASIBILITY STUDY DESIGN REPORT**

**STAGE 1 EMBANKMENTS - CONSTRUCTION MATERIAL QUANTITY SUMMARY**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Area</th>
<th>Year</th>
<th>Year</th>
<th>Elevation (m)</th>
<th>Embankment Quantities</th>
<th>Subtotals (m³)</th>
<th>Total (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>U/S Zone C (m³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Asphalt Core (m³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Zone F (m³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Zone T (m³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>D/S Zone C (m³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1A</td>
<td>South Emb</td>
<td>-2</td>
<td>2012</td>
<td>725</td>
<td>1,051,862</td>
<td>3,304</td>
<td>23,560</td>
</tr>
<tr>
<td>S1B</td>
<td>South Emb</td>
<td>-1</td>
<td>2013</td>
<td>750</td>
<td>839,314</td>
<td>4,616</td>
<td>32,913</td>
</tr>
<tr>
<td>S1C</td>
<td>South Emb</td>
<td>-1</td>
<td>2013</td>
<td>805</td>
<td>1,189,973</td>
<td>20,781</td>
<td>148,186</td>
</tr>
<tr>
<td></td>
<td>Northeast Emb</td>
<td>-1</td>
<td>2013</td>
<td>805</td>
<td>9,563</td>
<td>7,650</td>
<td>367,370</td>
</tr>
<tr>
<td>S1C</td>
<td>Northeast Emb</td>
<td>-1</td>
<td>2013</td>
<td>805</td>
<td>3,090,712</td>
<td>28,701</td>
<td>212,309</td>
</tr>
<tr>
<td>Subtotal</td>
<td>ALL</td>
<td></td>
<td></td>
<td>805</td>
<td>3,090,712</td>
<td>28,701</td>
<td>212,309</td>
</tr>
</tbody>
</table>

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**M:\1\01\00343\06\A\Report\2-Tailings Storage Facility Report\Rev 0\Tables\Table 5.2 to 5.5 (Tailings & Embankment Vols).xls\Table 5.3**

---

**Print 1/27/2011 14:40**
# TABLE 5.4

AVANTI KITSault Mine Ltd  
Kitsault Project  
Tailings and Water Management Facilities  
Feasibility Study Design Report  
Summary of Waste Rock Volumes for  
Ongoing South Embankment Construction

<table>
<thead>
<tr>
<th>YEAR</th>
<th>YEAR</th>
<th>STAGE</th>
<th>Elevation</th>
<th>South Embankment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Zone C Rockfill (m³)</td>
</tr>
<tr>
<td>2</td>
<td>2015</td>
<td>S2A</td>
<td>805</td>
<td>2,297,000</td>
</tr>
<tr>
<td>2</td>
<td>2015</td>
<td>S2B</td>
<td>813</td>
<td>246,000</td>
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<tr>
<td>2</td>
<td>2015</td>
<td>S2</td>
<td>813</td>
<td>29,400</td>
</tr>
<tr>
<td>3</td>
<td>2016</td>
<td>S3A</td>
<td>818</td>
<td>106,000</td>
</tr>
<tr>
<td>3</td>
<td>2016</td>
<td>S3</td>
<td>818</td>
<td>19,600</td>
</tr>
<tr>
<td>4</td>
<td>2017</td>
<td>S4A</td>
<td>823</td>
<td>77,000</td>
</tr>
<tr>
<td>4</td>
<td>2017</td>
<td>S4</td>
<td>823</td>
<td>19,800</td>
</tr>
<tr>
<td>5</td>
<td>2018</td>
<td>S5</td>
<td>828</td>
<td>20,400</td>
</tr>
<tr>
<td>6</td>
<td>2019</td>
<td>S6</td>
<td>833</td>
<td>20,800</td>
</tr>
<tr>
<td>7</td>
<td>2020</td>
<td>S7A</td>
<td>833</td>
<td>3,485,000</td>
</tr>
<tr>
<td>7</td>
<td>2020</td>
<td>S7B</td>
<td>837</td>
<td>136,000</td>
</tr>
<tr>
<td>7</td>
<td>2020</td>
<td>S7</td>
<td>837</td>
<td>16,900</td>
</tr>
<tr>
<td>8</td>
<td>2021</td>
<td>S8A</td>
<td>841</td>
<td>117,000</td>
</tr>
<tr>
<td>8</td>
<td>2021</td>
<td>S8</td>
<td>841</td>
<td>17,200</td>
</tr>
<tr>
<td>9</td>
<td>2022</td>
<td>S9A</td>
<td>845</td>
<td>97,000</td>
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<tr>
<td>9</td>
<td>2022</td>
<td>S9</td>
<td>845</td>
<td>17,500</td>
</tr>
<tr>
<td>10</td>
<td>2023</td>
<td>S10A</td>
<td>849</td>
<td>76,000</td>
</tr>
<tr>
<td>10</td>
<td>2023</td>
<td>S10</td>
<td>849</td>
<td>17,800</td>
</tr>
<tr>
<td>11</td>
<td>2024</td>
<td>S11A</td>
<td>852</td>
<td>44,000</td>
</tr>
<tr>
<td>11</td>
<td>2024</td>
<td>S11</td>
<td>852</td>
<td>13,600</td>
</tr>
<tr>
<td>12</td>
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<td>858</td>
<td>13,800</td>
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<tr>
<td>14</td>
<td>2027</td>
<td>S14</td>
<td>861</td>
<td>13,800</td>
</tr>
<tr>
<td>15</td>
<td>2028</td>
<td>S15</td>
<td>863</td>
<td>13,800</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>6,681,000</strong></td>
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</table>

M:\1\01\00343\06\A\Report\2-Tailings Storage Facility Report\Rev 0\Tables\[Table 5.2 to 5.5 (Tailings & Embankment Vols).xls\]Table 5.4
## TABLE 5.5

**AVANTI KITSAULT MINE LTD**  
**KITSAULT PROJECT**

**TAILINGS AND WATER MANAGEMENT FACILITIES FEASIBILITY STUDY DESIGN REPORT**  
**SUMMARY OF CYCLONE SAND VOLUMES FOR ONGOING NORTHEAST AND SOUTH EMBANKMENT CONSTRUCTION**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>YEAR</th>
<th>STAGE</th>
<th>ELEVATION</th>
<th>COMPACTED IN PLACE VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Northeast Embankment (m³)</td>
</tr>
<tr>
<td>2</td>
<td>2015</td>
<td>S2</td>
<td>813</td>
<td>605,000</td>
</tr>
<tr>
<td>3</td>
<td>2016</td>
<td>S3</td>
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<tr>
<td>4</td>
<td>2017</td>
<td>S4</td>
<td>823</td>
<td>568,000</td>
</tr>
<tr>
<td>5</td>
<td>2018</td>
<td>S5</td>
<td>828</td>
<td>671,000</td>
</tr>
<tr>
<td>6</td>
<td>2019</td>
<td>S6</td>
<td>833</td>
<td>786,000</td>
</tr>
<tr>
<td>7</td>
<td>2020</td>
<td>S7</td>
<td>837</td>
<td>709,000</td>
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<td>8</td>
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<td>9</td>
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<td>S9</td>
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<td>873,000</td>
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<td>10</td>
<td>2023</td>
<td>S10</td>
<td>849</td>
<td>957,000</td>
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<tr>
<td>11</td>
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<tr>
<td>14</td>
<td>2027</td>
<td>S14</td>
<td>861</td>
<td>942,000</td>
</tr>
<tr>
<td>15</td>
<td>2028</td>
<td>S15</td>
<td>863</td>
<td>942,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>10,813,000</strong></td>
</tr>
</tbody>
</table>

M:\1\01\00343\06\A\Report\2-Tailings Storage Facility Report\Rev 0\Tables\Table 5.2 to 5.5 (Tailings & Embankment Vols).xls\Table 5.5
## DESIGN ELEMENT

### 1.0 Hydrometeorology

<table>
<thead>
<tr>
<th>Climate Conditions</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Annual Precipitation = 2000 mm</td>
</tr>
<tr>
<td></td>
<td>Mean Annual Evaporation = 450 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Storm Events</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 in 10 year 24 hour precipitation = 133 mm</td>
</tr>
<tr>
<td></td>
<td>1 in 100 year 24 hour precipitation = 188 mm</td>
</tr>
<tr>
<td></td>
<td>1 in 200 year 24 hour precipitation = 204 mm</td>
</tr>
<tr>
<td></td>
<td>1 in 1000 year 24 hour precipitation = 244 mm</td>
</tr>
<tr>
<td></td>
<td>PMP = 557 mm</td>
</tr>
</tbody>
</table>

### 2.0 TMF Embankment Cofferdams

<table>
<thead>
<tr>
<th>Function</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Series of coffer dams to provide minimal storage of runoff from upslope catchments during embankment construction</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>South Embankment Cofferdam</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inflow Design Flood (IDF) = 1 in 10 year 24 hour precipitation</td>
</tr>
<tr>
<td></td>
<td>Catchment Area = 5.1 km²</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Northeast Embankment Cofferdam</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inflow Design Flood (IDF) = 1 in 10 year 24 hour precipitation</td>
</tr>
<tr>
<td></td>
<td>Catchment Area = 28.6 ha</td>
</tr>
</tbody>
</table>

### 3.0 South Diversion Channel

<table>
<thead>
<tr>
<th>Function</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Provide diversion of runoff from upstream of TMF, East WRMF and Open Pit during construction and operations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inflow Design Flood</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inflow Design Flood (IDF) = 1 in 200 yr peak instantaneous discharge in Patsy Creek (Obedkoff)</td>
</tr>
<tr>
<td></td>
<td>Catchment Area = 6.6 km²</td>
</tr>
<tr>
<td></td>
<td>Estimated Peak Inflow = 29.5 m³/s</td>
</tr>
<tr>
<td></td>
<td>Estimated Runoff Volume = 1.34 million m³ of water</td>
</tr>
</tbody>
</table>

### 4.0 Seepage and Sediment Control Ponds

<table>
<thead>
<tr>
<th>Function</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collect and store seepage and sediment laden runoff from TMF embankments during construction and operations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>South Water Management Pond</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inflow Design Flood (IDF) = 1 in 10 year 24 hour precipitation</td>
</tr>
<tr>
<td></td>
<td>Catchment Area = 0.92 km²</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Northeast Water Management Pond 1</th>
<th>Design Criteria</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Inflow Design Flood (IDF) = 1 in 10 year 24 hour precipitation</td>
</tr>
<tr>
<td></td>
<td>Catchment Area = 0.15 km²</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Northeast Water Management Pond 2</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inflow Design Flood (IDF) = 1 in 10 year 24 hour precipitation</td>
</tr>
<tr>
<td></td>
<td>Catchment Area = 0.39 km²</td>
</tr>
</tbody>
</table>
LEGEND:

- DIVERSION CHANNEL
- TRANSMISSION LINE
- 100 m CONTOUR
- 20 m CONTOUR
- RIVER/CREEK
- OCEAN
- WASTE ROCK MANAGEMENT FACILITY
- EAST WASTE ROCK MANAGEMENT FACILITY
- NORTH WASTE ROCK MANAGEMENT FACILITY
- MANAGING FACILITY
- STOCKPILE
- FAULT
- NORMAL FAULT

BEDROCK GEOLOGY

- COAST INTRUSION GRANODIORITE, QUARTZ DIORITE
- ALICE ARM INTRUSIONS
- BASALTIC VOLCANIC ROCKS
- BOWSER LAKE GROUP - INTERBEDDED ARGILLITES AND GREYWACKE
- UNDIVIDED SEDIMENTARY ROCKS

NOTES:
1. BEDROCK GEOLOGY SOURCED FROM BC GOVERNMENT, MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES (MEMPR).
2. CO-ORDINATE GRID IS IN METRES. DATUM: NAD83
3. PROJECTION: UTM ZONE 9
4. SCALE: 1:40,000
5. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:60,000 FOR 11x17 (TABLOID) PAPER. ACCORDING TO CHANGES IN PRINTER SETTING OR PRINTED PAPER SIZE.

REGIONAL BEDROCK GEOLOGY

FRAIN 2000, FIG 3.2

HD Embankment
Taking Lake
Illiance River
Nass River
Clary Lake
Patsy Lake
Alice Arm
Lime Creek
Roundy Creek
Nass River
Kitsault Pit (Approx.)
East Waste Rock Management Facility