5. Project Description

5.1 INTRODUCTION

The proposed Brucejack Gold Mine Project (the Project) will be located above the tree line in a mountainous area in northwestern British Columbia (BC; Figure 5.1-1). The gold-silver-base metal epithermal veins occur within schistose and pervasively altered volcanic and volcaniclastic rocks near the crest of a ridge at an elevation of about 1,400 metres (m). The proposed Brucejack Mine Site is surrounded by glaciers to the west, south, and east. Ore will be extracted using the long-hole open stoping method with a combination of rock and paste backfill. The underground mining operation will be based on conventional rubber-tired, diesel- and electric-powered mobile equipment, with loader mucking and truck haulage material handling via a decline ramp system.

A June 2014 Feasibility Study and Technical Report Update completed for the Brucejack Gold Mine Project (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC) provides the basis for the Project Description provided in this chapter. Most facility descriptions are at the preliminary design level, subject to refinement during detailed design for construction. The Project will require a two year Construction phase. The June 2014 feasibility study describes an 18 year Operation phase, while an earlier feasibility study (Tetra Tech 2013) had identified a 22 year Operation phase. For the purposes of the effects assessment chapters of this Application, an Operation phase of 22 years has been used as this is expected to provide, overall, a more conservative effects assessment associated with greater waste rock and tailings production and longer period of active disturbance prior to reclamation activities.

About 16.5 million tonnes (Mt) of ore will be processed on site using conventional crushing, grinding, flotation, and gravity separation to produce gold and silver in concentrate and doré. The mill building housing the process plant and water treatment plant, camp, truck shop, substation, and related facilities will be located in close proximity to the mine portals (Figure 5.1-2). Waste rock and tailings will be preferentially stored in the underground as backfill. Waste rock and tailings that cannot be used as backfill will be stored underwater in Brucejack Lake. The overall surface footprint of the Brucejack Mine Site and immediate infrastructure will be about 31 hectares (ha), excluding areas of waste rock and tailings that will be submerged in Brucejack Lake.

Access to the Project will be by an existing 73-kilometre (km)-long exploration access road that begins at Highway 37 and follows the drainages of Wildfire, Scott, and Todedada creeks to the Bowser River Valley where it follows the Bowser River for approximately 31 km before ascending the Knipple Glacier to the Brucejack Mine Site. The exploration access road will be upgraded to handle mine construction and operation traffic. The Knipple Transfer Area will be developed near the base of the glacier to support the transfer of personnel and materials from highway vehicles to specialized tracked vehicles or other vehicles equipped for glacier travel. The Knipple Transfer Area will have a footprint of about 2.7 ha.

Power for the Project will be supplied from the provincial electricity grid. A new 55-km-long transmission line will be constructed from the mine site to the Bowser River Valley and then southwesterly to connect with the provincial grid at the Long Lake Hydro Project near Stewart.

Workers will be housed in a camp on the mine and at the Knipple Transfer Area, and will be transported to and from the site over the access road from the Bowser Aerodrome, where they will be met by chartered aircraft for transport to major centres. Local workers will be transported to the site from Highway 37 by bus. When weather conditions prohibit use of the Bowser Aerodrome, the chartered aircraft will transport workers to a local community such as Terrace or Smithers, where they will be met by buses for transport to the mine.

Figure 5.1-1
Overall Layout of the Brucejack Project

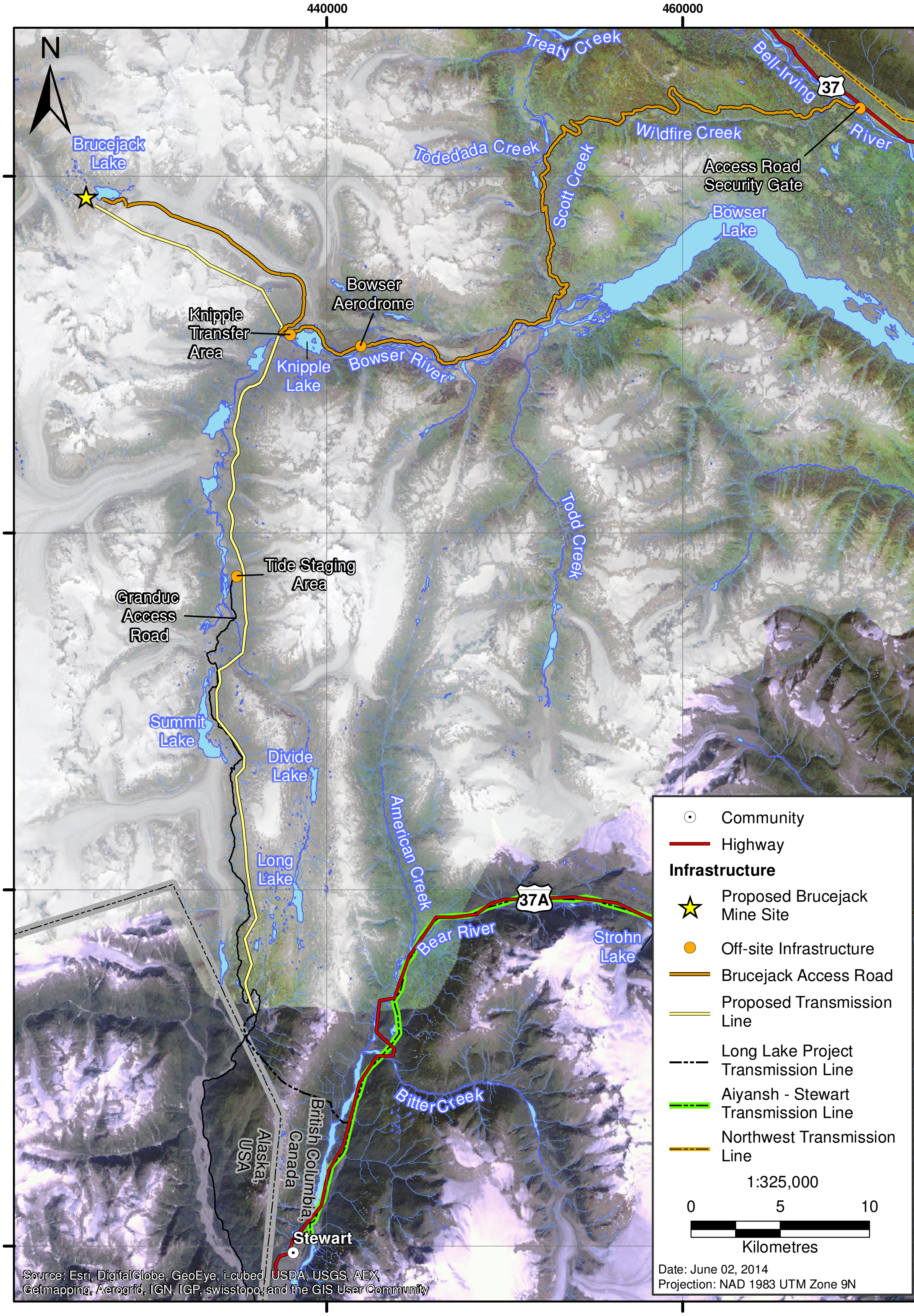

Figure 5.1-2
Mine Area General Arrangement

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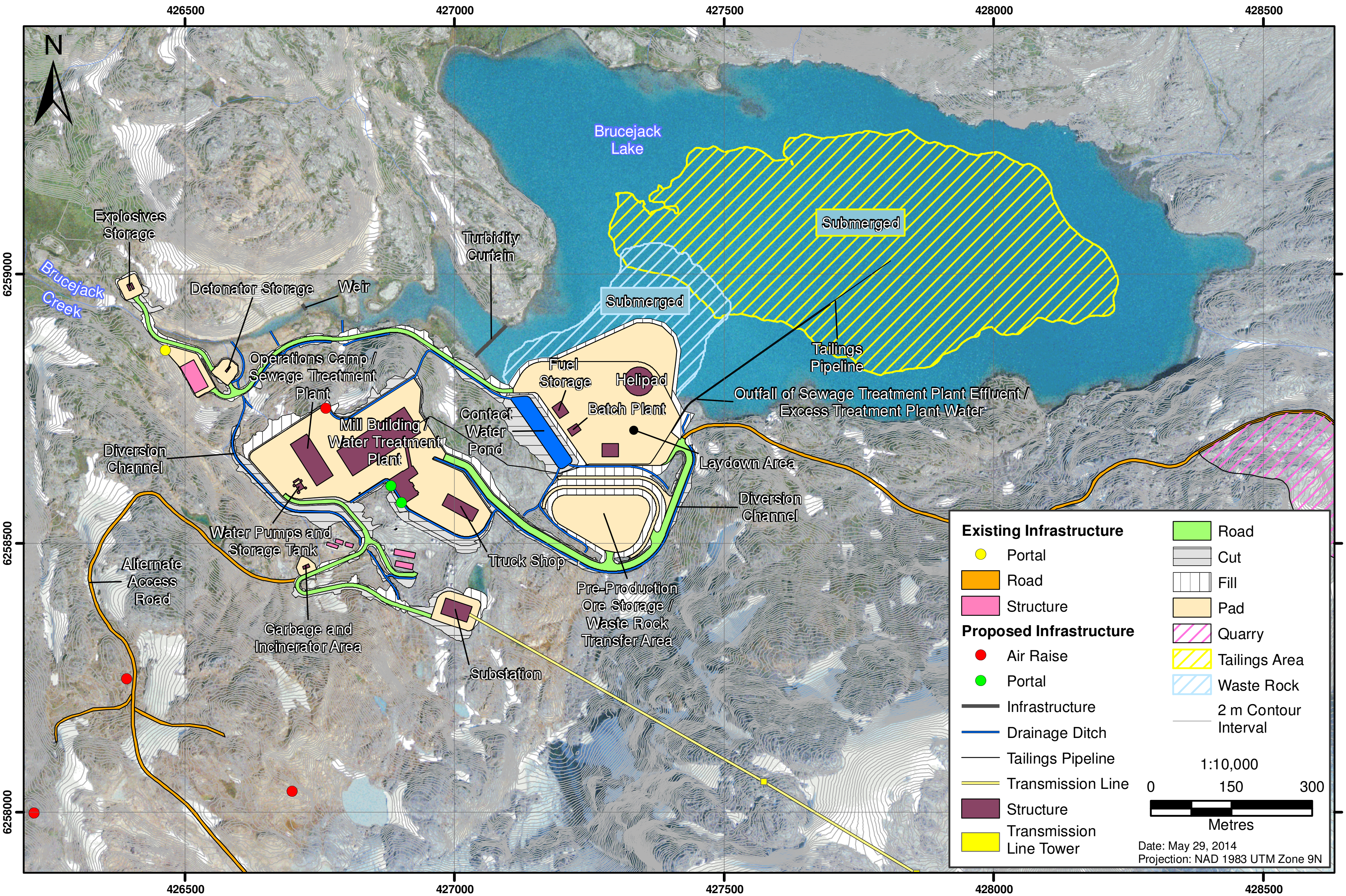

The overall footprint of the Project will be about 393 ha.

The Project design addresses difficult access conditions, potentially acid generating (PAG) or metal leaching (ML) ore, waste rock and tailings, limited space at the mine site area for infrastructure development, and adverse climate. A recent feasibility study update (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC) concluded that the Project is viable.

5.1.1 Regulatory Framework

The Project is subject to both the BC *Environmental Assessment Act* (2002) and the *Canadian Environmental Assessment Act, 2012* (2012). Ministerial approvals of the Project under the BC *Environmental Assessment Act* and *Canadian Environmental Assessment Act, 2012* are not the sole authorizations required to allow the Project to proceed. Other federal and provincial permits, licences, approvals, consents, and material authorizations will be required to address the technical and administrative details to construct, operate, decommission, and close the Project. These additional requirements are discussed in Chapter 2, Assessment Process. In particular, the Project requires: a *Mines Act* Permit Approving the Work System and Reclamation Program, as well as placement of a reclamation security; permits or approvals under the *Environmental Management Act* (2003) for the discharge or management of waste; licences under the *Water Act* (1996e) for the diversion and use of water; a licence under the *Forest Act* (1996b) for vegetation removal along the transmission line and at the Knipple Transfer Area and Aerodrome; and a tenure under the *Land Act* (1996c) to allow construction and use of the southern section of the transmission line not located on Pretium Resources Inc.'s (Pretivm's) mineral tenures (northern portion will be permitted under the *Mines Act* [1996d]; see below).

The *Mines Act* (1996d) and its associated *Health, Safety, and Reclamation Code for Mines in British Columbia* (BC MEMPR 2008) lay out a range of technical requirements that must be met before a permit will be issued and during the term of the permit. The Code prescribes standards for: measures to protect the occupational health of workers; personal safety and emergency preparedness; building, machinery, and equipment; electrical power systems; mine design and procedures; hoists and shafts; explosives transportation, storage, use, and disposal; protection of land and watercourses; and reclamation and closure. All Project infrastructure defined as part of the mine for the purposes of the *Mines Act* Permit have been designed and will be constructed, operated and closed in a manner consistent with these standards. All existing and proposed infrastructure will be considered part of the mine except the part of the transmission line extending from the Long Lake powerhouse to the southern edge of Pretivm's main block of mineral claims in accordance with guidance received from the BC Ministry of Energy and Mines (BC MEM). The access road, existing camps, Bowser Aerodrome, Knipple Transfer Area, approximately the northern one-third of the transmission line, and all surface and underground infrastructure at the mine proper will be defined as part of the mine under the *Mines Act* Permit and therefore regulated under the authority of the Act and Code.

The *Environmental Management Act* (2003) regulates the discharge of air contaminants, liquid effluent, and refuse into the environment and established the authority for the issuance of permits for such discharges. It also regulates the management of hazardous wastes. The Project will be constructed, operated, and closed in a manner that is consistent with the requirements of this act, including obtaining and complying with the conditions of any required permits or approvals.

The *Water Act* (1996e) regulates the diversion and use of water. A water licence will be required for the withdrawal and use of water from Brucejack Lake for process water or to maintain flow in the tailings discharge pipeline while tailings are being directed to the backfill plant. Water licences will also be required for the diversion of two small creeks at the mine site.

The *Forest Act* (1996b) regulates vegetation cutting or removal in Provincial Forests. Pretivm will apply for, obtain, and comply with the conditions of an Occupant Licence to Cut under the *Forest Act* for vegetation removal along the transmission line south of Knipple Glacier and at the Knipple Transfer Area and Bowser Aerodrome.

Pretivm will also apply for tenure under the *Land Act* (1996c) for the portion of the transmission line not included as part of the mine. This part of the transmission line will be constructed under a Licence of Occupation issued over the general alignment and covering the extent of vegetation removal and staging area development; upon completion of line construction, an application will be made for a statutory right of way over the long term right of way.

5.2 LOCATION AND CURRENT ACCESS

The Brucejack property is located at 56°28'20" N latitude by 130°11'31" W longitude, which is approximately 950 km northwest of Vancouver and 65 km north-northwest of Stewart (Figure 5.1-1). The Project is located within the Regional District of Kitimat-Stikine. The site is currently accessed by an exploration access road and by helicopter from staging sites along Highway 37 and the former Granduc Mine site north of Stewart.

5.3 MINERAL TENURES

Pretivm holds 260 mineral claims totalling about 104,136 ha in and around the Project (Figure 5.3-1). The claims extend from the proposed mine site area east to Highway 37 including parts of the Bowser River, Scott Creek, and Wildfire Creek watersheds, and along parts of the transmission line right of way. Additional information on Pretivm's mineral tenures for the Project is provided in Section 1.5, Project Tenure.

5.4 REGIONAL AND PROJECT GEOLOGY AND MINERALIZATION

5.4.1 Regional Geology

This discussion of regional geology is adapted from the 2013 Feasibility Study and Technical Report (Appendix 5-A), which in turn was compiled from previous reports by Jones (2012), Ghaffari et al. (2012), and Olssen and Jones (2012a).

The Brucejack Property is located in the western Stikine terrane (or Stikinia), the largest of several allocthonous terranes in the Intermontane Belt of the Canadian Cordillera. Stikinia, which is considered to be a multistage mid-Palaeozoic to Middle Jurassic island arc terrane that developed in an intraoceanic setting isolated from the North American continental margin (e.g., Gagnon et al. 2012), underlies much of western BC (Figure 5.4-1). Stikinia appears to have been accreted to the North American continental margin as early as the late Middle Jurassic (c. 173 Ma).

The Stikine terrane in northwestern BC consists of a series of unconformity-bound tectonostratigraphic elements, including: Palaeozoic island-arc rocks of the Stikine assemblage, Mesozoic island-arc rocks of the Upper Triassic Stuhini Group and Lower to Middle Jurassic lower Hazelton Group, and Middle to Upper Jurassic overlap assemblage sedimentary rocks of the Bowser Lake Group. Tertiary igneous and metamorphic rocks of the Coast Plutonic Complex occur to the west of the Stikine terrane in this area (MacDonald et al. 1996).

Figure 5.3-1
Pretivm's Brucejack Gold Mine Mineral Claim Holdings

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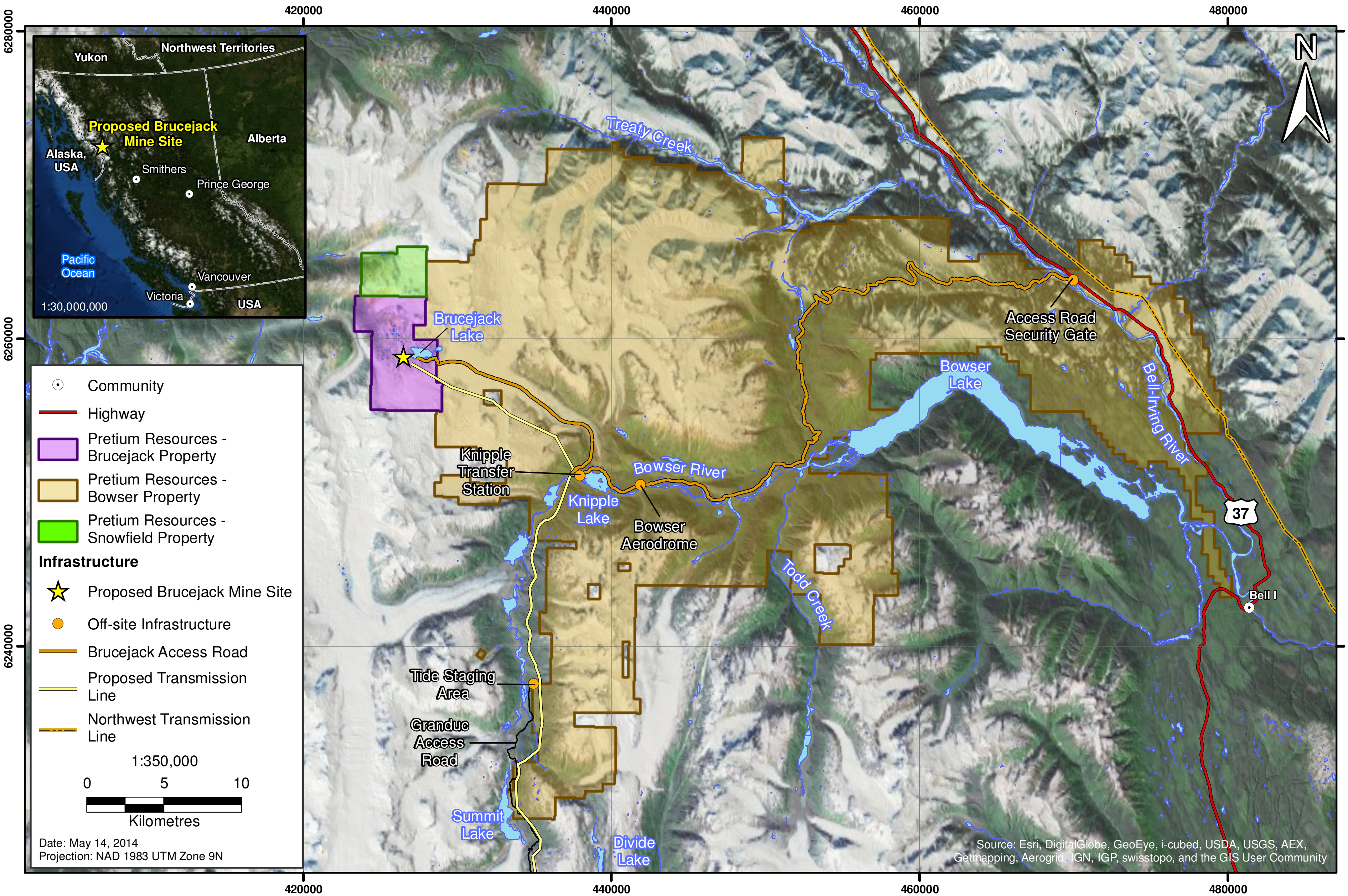
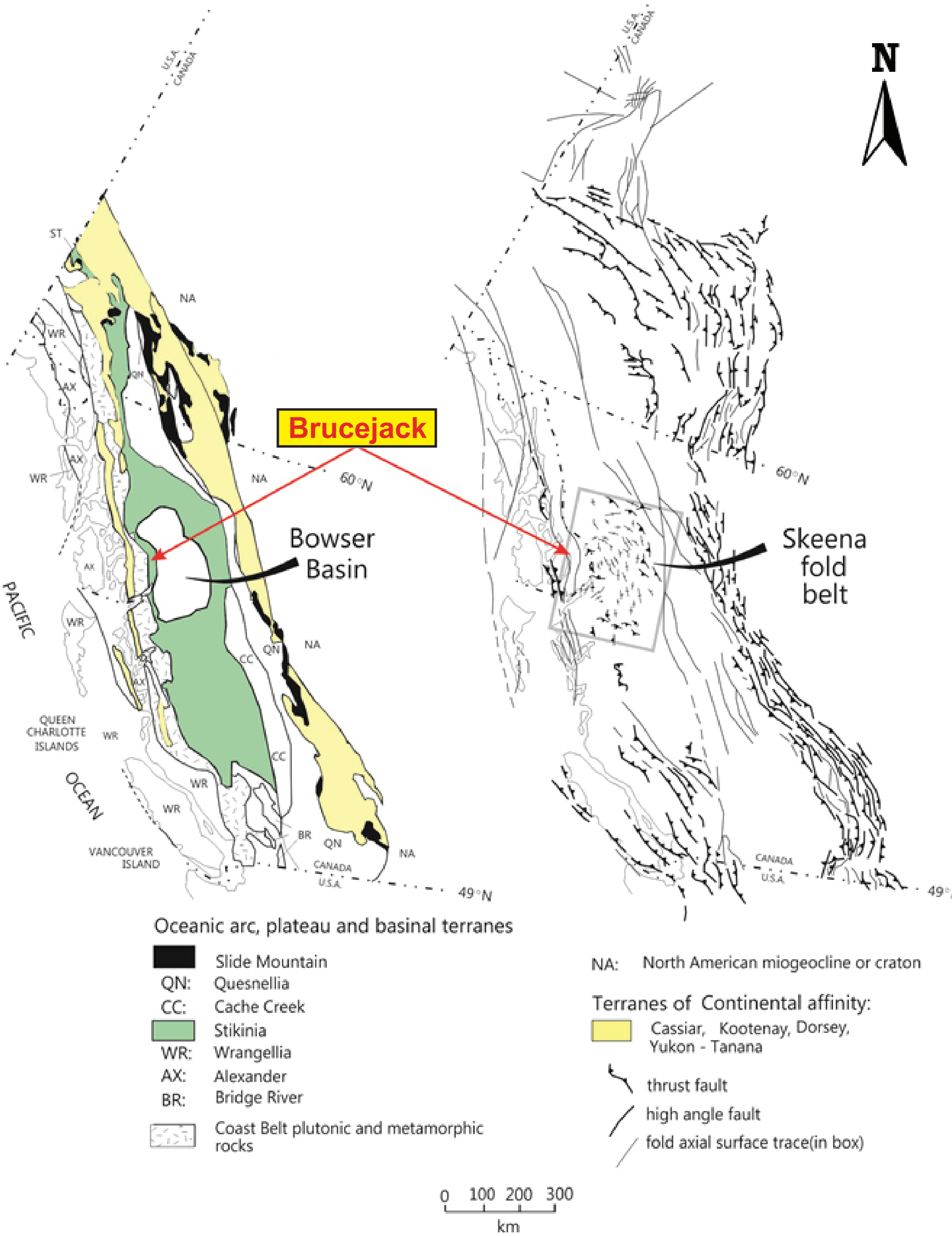


Tectonic Setting of the Brucejack Property in the Northwest Cordillera



Note: Shows location of the Project area in north-central Stikine terrane, as well as nearby Bowser Basin (left) and latest Jurassic to mid-Cretaceous SFB (right). Rectangle on right hand image represents location of Figure 1.4-2.

Source: Ghaffari et al. (2012)

At least four magmatic episodes and three mineralizing events have been recognized in northwestern Stikinia (Anderson et al. 2003): Late Triassic-Early Jurassic (205-196 Ma) alkaline porphyry-related magmatism and associated deformed mesothermal silver-gold veins (e.g., Red Mountain); Early Jurassic (196-187 Ma) alkaline porphyry-related epithermal and mesothermal gold-silver veins and base and precious metal deposits (e.g., Premier, Sulphurets, and Bronson Creek); Early to Middle Jurassic (184-183 Ma) small and poorly mineralized porphyry intrusions; and Middle Jurassic (175-172 Ma) calc-alkaline and tholeiitic back-arc magmatism and syn- to epigenetic back-arc basin-related stratabound base and precious metal deposits (e.g., Eskay Creek, RDN property).

The northwest part of Stikinia (in particular the volcanic and sedimentary rocks of the Hazelton Group) and related Early Jurassic plutons represent perhaps the most well-endowed metallogenetic assemblage in BC. In addition to the Brucejack Property, this area also includes nearby former producers such as Eskay Creek, Silbak-Premier, Big Missouri, Dolly Varden, Torbrit Silver, Granduc, and Anyox (Figure 5.4-2). Furthermore, adjacent properties host significant precious and base metal resources (e.g., Snowfield, Kerr-Sulphurets-Mitchell [KSM] and Red Mountain deposits) as well as a number of high-potential mineral occurrences (e.g., Homestake Ridge, Silver Coin, Big Missouri, Clone, and Tennyson Properties). The KSM deposits, along with the Snowfield and Brucejack deposits together comprise what is commonly referred to as the Sulphurets Mining Camp.

Several major compressional tectonic events affected rocks of the Stikine terrane in northwestern BC throughout the Mesozoic. The earliest event in the Late Triassic to Early Jurassic affected Palaeozoic and Triassic rocks of the Stikine assemblage and Stuhini Group.

A second, younger event in the Late Jurassic through Late Cretaceous, which has been associated with accretion of the outboard Insular terranes west of the Coastal Plutonic Complex and the formation of the Skeena fold belt (SFB), resulted in widespread, predominantly east-verging fold and thrust deformation of rocks in western Stikinia (Figures 5.4-1 and 5.4-2). Deformation associated with the Middle Jurassic accretion of Stikinia to the North American continent appears to have mainly affected rocks of eastern Stikinia (e.g., Evenchick et al. 2007).

5.4.2 Local Geology – the Sulphurets Mining Camp

The Sulphurets Mining Camp, which includes the Brucejack Property, is located on the eastern limb of the broad McTagg anticlinorium, a major north-trending mid-Cretaceous structural culmination in the western SFB (Figure 5.4-3). Sedimentary and volcanic rocks of the Upper Triassic Stuhini Group form the core of the anticlinorium, and are successively replaced outwards towards the west, north, and east of the core by progressively younger rocks of the Lower to Middle Jurassic volcanic and lesser sedimentary rocks of the Hazelton Group followed by sedimentary rocks of the Bowser Lake Group.

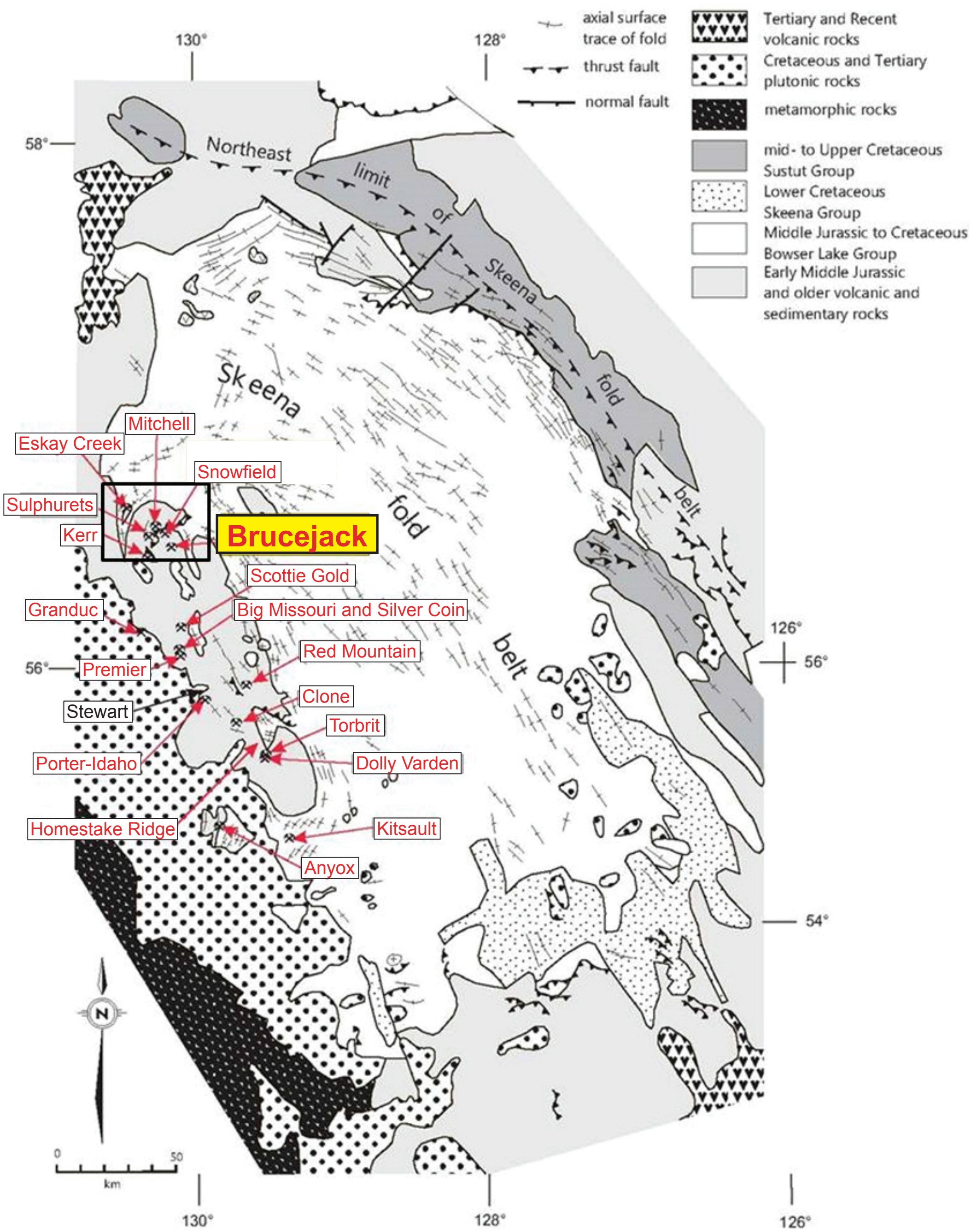
Details of the local geology of the Sulphurets Mining Camp in northwestern BC presented in this section are partly drawn from existing literature, as outlined in Tetra Tech (2014), and from work conducted by Pretivm's geologists.

5.4.2.1 Stratigraphic Setting and Major Mineral Deposits

The Stuhini Group, which generally underlies the western and northern parts of the Sulphurets Mining Camp (Figure 5.4-4), is characterized by fine-grained and well-stratified sedimentary rocks and subordinate mafic volcanic arc-related rocks. The sedimentary package includes dark grey turbiditic siltstone, minor interbedded micritic limestone, and thick sequences of immature conglomerate and sedimentary breccia. Mafic volcanic rocks in this unit include alkalic pyroxene- and hornblende-phyric massive and pillowed basaltic flows, flow breccia, and tuff.

Figure 5.4-2

Regional Structural and Stratigraphic Setting of the Brucejack Project Property and Sulphurets Mining Camp in Northwest BC



Note: Shows significant past-producing mines, as well as selected advanced exploration projects.

Source: Ghaffari et al. (2012)

Figure 5.4-3

Local Structural and Stratigraphic Setting of the Brucejack Property and Sulphurets Mining Camp

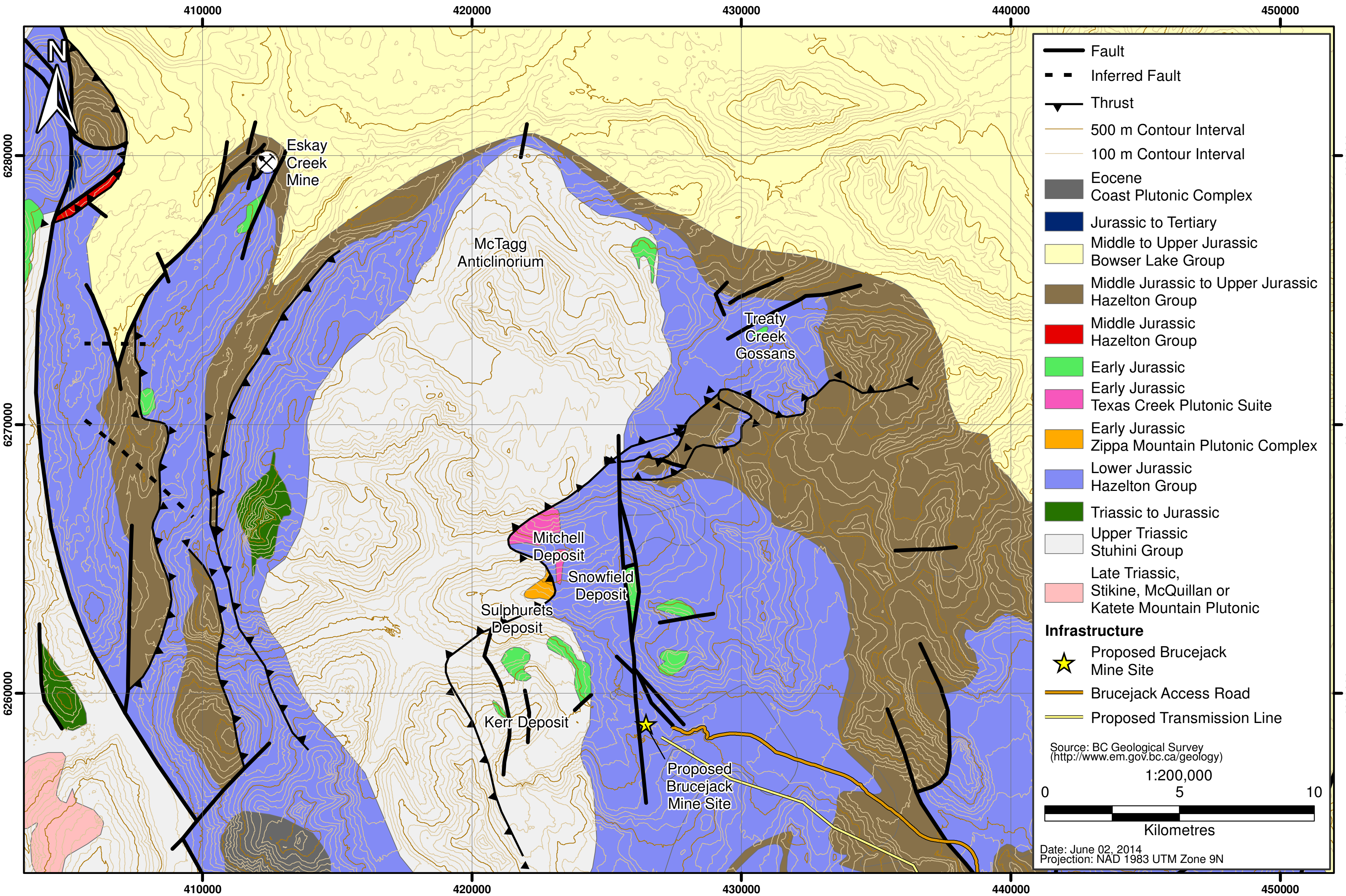
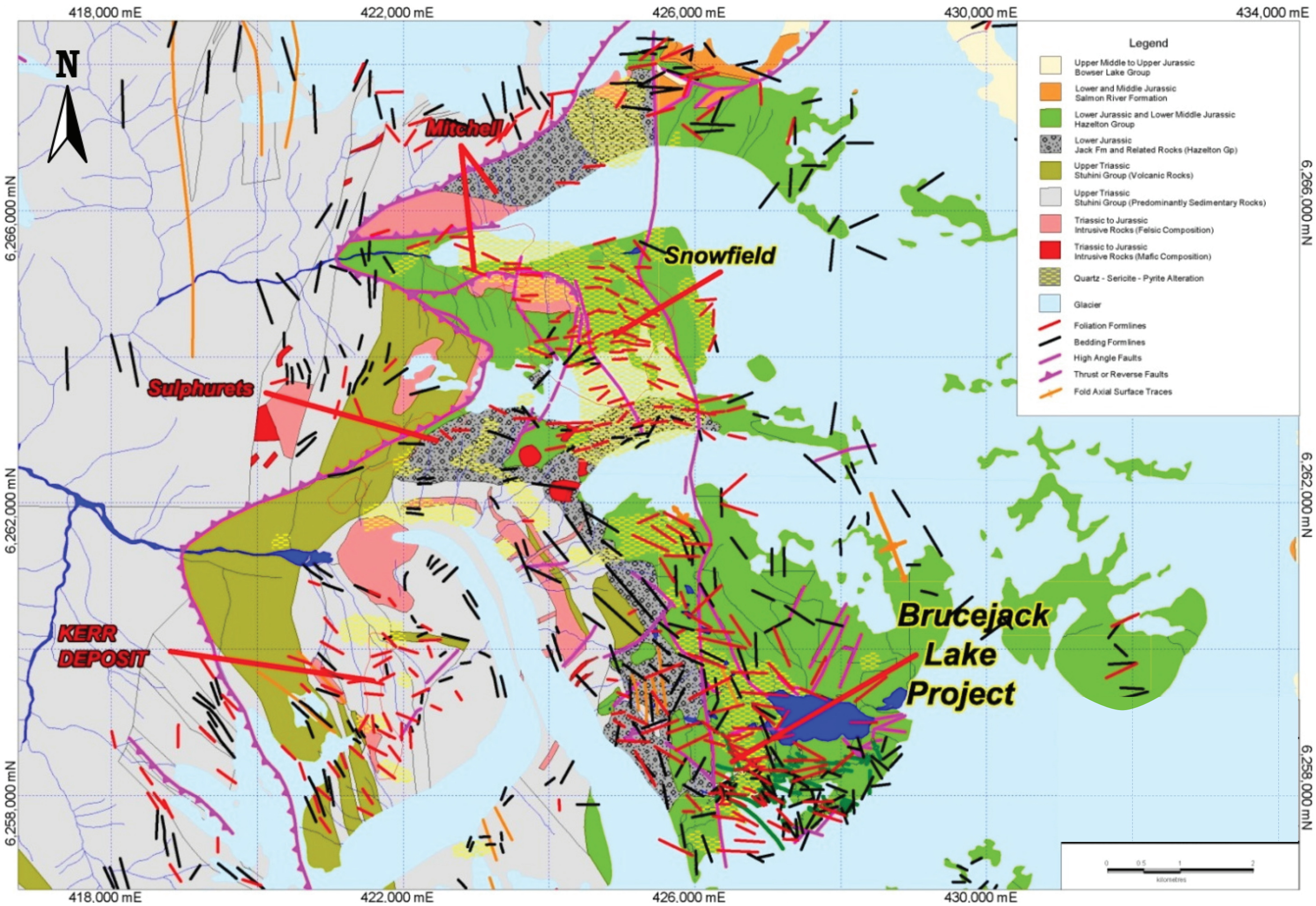


Figure 5.4-4

Sulphurets Mining Camp
Geology and Mineralization



Source: Ghaffari et al. (2012)

The central and eastern parts of the Sulphurets Mining Camp are largely underlain by subaqueous to locally subaerial arc-related volcanic and subordinate sedimentary rocks of the lower Hazelton Group, which unconformably overlie the Stuhini Group. The lowermost unit of the lower Hazelton Group, the Lower Jurassic Jack Formation, is characterized by polylithic (granitoid and volcanic) pebble to boulder conglomerate and limy fossiliferous sandstone and siltstone. The Jack Formation appears to be conformably overlain by the volcanic rocks of the lower Hazelton Group, which generally consist of thick massive plagioclase (± hornblende, K-feldspar, and pyroxene)-phyric andesitic and dacitic flows, breccias, and related predominantly pyroclastic fragmental rocks, with subordinate mafic and felsic rocks and minor siltstone and mudstone layers of the Unuk River Formation. These rocks are overlain by well-bedded green, maroon, and grey andesitic to dacitic pyroclastic and epiclastic rocks, mafic flows, and minor carbonaceous mudstone, chert and limestone of the Betty Creek Formation, which are in turn disconformably overlain by the Mount Dilworth Formation. The Mount Dilworth Formation is characterized by dacitic and rhyolitic tuff, welded ash-flow tuff, volcanic breccia, flow-layered lava domes, and subordinate interbedded limy fossiliferous sandstone.

The upper Hazelton Group, which is limited to the northern and extreme eastern parts of the Sulphurets Mining Camp, is characterized by distinctive black carbonaceous pyritic mudstone, light and dark banded tuffaceous siltstone, and local amygdaloidal basalt of the Salmon River Formation. These rocks display unconformable relationships to the rocks of the lower Hazelton Group. Recent re-examination of stratigraphic sections through the Hazelton Group (Gagnon et al. 2012) has suggested that the term "Salmon River Formation" be replaced by "Iskut River Formation." These rocks clearly delineate the outline of the anticlinorium in the broader Sulphurets area (Figure 5.4-3).

Rocks of the Middle to Upper Jurassic Bowser Lake Group, which are generally characterized by clastic basin-fill sediments including submarine fan, pro-delta slope, shelf, and fan delta sedimentary assemblages, are limited to the extreme north and northeast of the Sulphurets Mining Camp (see Figure 5.4-3). These rocks display conformable to disconformable relationships to the underlying Hazelton Group rocks.

Plutonic rocks are located in the western and northern parts of the Sulphurets Mining Camp, and occur as dikes, sills, and plugs, which generally intrude Stuhini Group rocks. These rocks, the so-called "Mitchell intrusions" of Kirkham and Margolis (1995), include diorite, monzodiorite, monzonite porphyry, syenite porphyry, quartz syenite porphyry, porphyritic aplitic low-silica granite, sodic albite-hornblende porphyry, and K-feldspar megacrystic porphyry. Monzonitic, syenitic, and granitic intrusions display a close spatial and temporal relationship to porphyry-style copper ±gold ±molybdenum mineralization in the KSM deposits.

A number of internally consistent uranium-lead zircon dates from pre-, syn- and post-mineral intrusive phases of the Mitchell intrusions at the KSM deposits suggest that porphyry-style mineralization was emplaced between 192 and 195 Ma. This Early Jurassic age is consistent with a number of galena lead dates for mineralization from these deposits, as well as for mineralization from the Snowfield deposit and from the West Zone on the Property. All of these dates plot in the "Jurassic cluster" of galena lead dates defined by Alldrick, Gabites, and Godwin (1987) and Alldrick et al. (1990) for the so-called "Stewart Mining Camp." Other regionally close mineral deposits that have similar age dates include Silbak-Premier and Big Missouri.

5.4.2.2 Alteration and Mineralization

Large, coalescing hydrothermal alteration haloes are developed around the intrusive complexes. Potassic K-feldspar alteration associated with copper and gold mineralization is widespread in the Mitchell Intrusions and adjacent Stuhini Group rocks. Propylitic and chlorite-sericite alteration is also developed around the KSM intrusions and the Snowfield deposit, often overprinting earlier potassic alteration at KSM. Quartz-sericite-pyrite alteration is widely developed in the Stuhini Group and lower Hazelton Group rocks further to the east of the intrusions in the Sulphurets Mining Camp (Figure 5.4-4), and also occurs as a pervasive overprint to earlier alteration in the intrusive rocks.

Altered Stuhini Group rocks and Mitchell intrusions are the main host rocks to porphyry-style mineralization at the Kerr (copper-gold), Sulphurets (gold-copper), and Mitchell (gold-copper-molybdenum) deposits. Mineralization at the KSM deposits occurs within a gold-enriched copper porphyry system controlled by a series of dikes, sills and plugs, and is associated with quartz veinlet stockworks and sheeted quartz veinlet arrays mainly in the altered host rocks adjacent to the intrusions. Pyrite and chalcopyrite are the dominant sulphide minerals, with minor molybdenite, and trace amounts of tennantite, bornite, sphalerite, and galena. All mineralization is hypogene, except for small remnants of preserved weak supergene mineralization at higher elevations.

5.4.2.3 Structural Setting and Metamorphism

Rocks in the Sulphurets Mining Camp have been affected by folding, faulting, penetrative cleavage formation, late stage quartz vein formation, and low-grade lower greenschist facies (or lower) regional metamorphism. Rocks of the Stuhini Group were subjected to intense ductile deformation during the Late Triassic to Early Jurassic prior to the deposition of the Hazelton Group rocks. Ductile deformation during the Late Jurassic to Late Cretaceous development of the SFB resulted in the formation of the major structural culmination of the McTagg anticlinorium and associated fold and thrust structures that affected the Stuhini Group through Bowser Lake Group rocks in the Sulphurets Mining Camp.

Penetrative cleavage (foliation) development was associated with the Late Jurassic to Late Cretaceous event and affected most of the altered and unaltered rocks in the area, where host rock mineral assemblage (i.e., the presence and concentration of phyllosilicates in the rock) permitted its development. Age dating (Ar-Ar) of sericite within pressure shadows about pyrite provide a minimum age for this deformation at 110 ± 2 Ma. Foliation orientations, whilst variable within the Sulphurets Mining Camp, are dominantly east-west trending on the Brucejack Property (Figure 5.4-4). This orientation is in contrast to the more-regional scale north-northwest to north-east orientation of structural fabrics (particularly foliation) that is more in accordance with typical Cordilleran structural trends. The east-west trending foliation orientations coincide with a distinct westward-oriented “kink” in the McTagg anticlinorium (Figure 5.4-3), which is possibly a reflection of the warping of this structure about a protrusion of more strain-resistant rocks inboard of the culmination that resulted in apparent north-south compression in this part of the area. The existence of such a strain resistor might also have resulted in the development of the southeast-vergent fold-induced thrusts during strain accommodation to the east of the anticlinorium axis. The Snowfield deposit is considered to be part of the upper Mitchell deposit that was thrust southeastwards over lower Hazelton Group rocks during the Late Jurassic to Late Cretaceous deformation.

Mineralized quartz (±carbonate, ±adularia) veins, vein networks, and vein stockworks in and around the various mineral deposits in the Sulphurets Mining Camp display clear and abundant evidence for significant post-mineralization deformation, including tight through isoclinally folded veins, rootless intrafolial folded veins, apparently ptygmatically folded veins in less competent and deformed host rocks, boudinaged veins, rootless boudinaged veins hosting gold mineralization tracing out tight folds and terminating at the vein contacts, transposition of veins into foliation planes with extension cracks perpendicular to the foliation, pinch-and-swell deformed veins with cuspate and lobate margins wrapped by the foliation, mesoscale folded stockworks, brecciated veins, fracture offset veins, and other small-scale post-mineral deformation features. These features are visible on the microscope (including strained and partially recrystallized quartz in veins and vein stockworks), hand-specimen, drill core, and outcrop scales.

Development of the McTagg anticlinorium effectively exposed older pre-Salmon River Formation rocks in the Sulphurets Mining Camp. Rocks of the Hazelton Group and Bowser Lake Group, which are located on the eastern limb of the north-plunging anticlinorium, display moderate to steep dips towards the southeast, east, and northeast, indicative of an overall eastward tilting of the original strata and porphyry-associated mineralization in this area as a result of the Late Jurassic to Late Cretaceous deformation event.

En echelon arrays of late shallow southeast-dipping (25° to 40°) veins with vertical or steeply-oriented crystal fibres in thin crack-seal textures cut across foliated and unfoliated altered and mineralized rocks, mineralized veins, and unaltered rocks throughout the region. Arrays of similarly late sigmoidally-folded veins with a top-to-the-southeast sense of shear are also present. These late quartz veins have been interpreted as having formed during the southeast-vergent thrusting that produced the Sulphurets and Mitchell thrusts in the eastern part of the anticlinorium.

The Brucejack Fault is a late, steeply dipping, northerly striking brittle structure which forms a distinct topographical feature in the centre of the Sulphurets Mining Camp (Figure 5.4-4). Pre-existing folds, thrust faults, alteration, and mineralization zones are cut by the Brucejack Fault as well as by many other similar late northerly-striking faults. Movement on the fault is probably complex and has been difficult to determine. A much thicker section of Hazelton Group rocks on the east side of the fault suggests considerable east-side-down displacement, which may be interpreted as reflecting post-depositional displacement. Kirkham and Margolis (1995) indicate that the Brucejack Fault appears to have an east-side down dip-slip displacement of greater than 500 m with a dextral strike-slip component in the area north of the Snowfield deposit, and approximately 100 m of dextral strike-slip with uncertain dip-slip on the Property. Davies, Lewis, and Macdonald (1994) noted that, northwest of Brucejack Lake, preserved slickenside and cast elongation lineations on a steeply west-dipping surface indicate dip-slip offset of potentially between 700 m and 800 m with a reverse fault sense of movement (i.e., west-side up). Stratigraphic contacts a short distance northwest of the Brucejack Lake have been interpreted as indicating a possible strike separation of between 200 m to 300 m, and dip-slip displacement is likely less than in the north. In contrast, Britton and Alldrick (1988) considered that displacement on the Brucejack Fault was on the order of tens of metres. Elsewhere in the Sulphurets Mining Camp the northerly, north-easterly and north-westerly striking brittle faults, and rare east-west striking faults, display typically steep dips, steeply-plunging fault fabrics, and locally normal-dextral oblique displacements of up to tens of metres.

The possibility that the Brucejack Fault structure was formed as a result of late brittle deformation reactivation of a pre-existing syn-depositional fault developed at or near a volcanic sub-basin margin during deposition of the lower Hazelton Group is being considered based on recent fieldwork. If this hypothesis is correct then, given the spatial proximity of the fault to the alteration and contained mineralization zones on the Brucejack Property (Figure 5.4-4), it may have partly controlled the hydrothermal alteration and mineralization in this part of the Sulphurets Mining Camp.

Rocks of the Sulphurets Mining Camp were subjected to, at most, lower greenschist facies metamorphism, characterized by epidote, calcite, quartz, and chlorite, and the absence of biotite, hornblende, and actinolite in andesitic volcanic rocks and sedimentary rocks outside of the areas of hydrothermal alteration. The peak metamorphic temperature probably did not exceed 275°C (assuming a 3 km depth of burial).

5.4.3 Property Geology

The information in this section on the Property geology is summarised and updated from the work of Mr. Charles Greig, Senior Geologist for Pretivm, as presented in Olssen and Jones (2012b).

Geology on the Property can generally be characterized as a northerly-trending, broadly arcuate, concave-westward structural-stratigraphic belt of variably altered rocks. This belt is bisected on the western side of the Property by a prominent topographic lineament, the Brucejack Fault (Figures 5.4-3 and 5.4-4). To the south of Brucejack Lake, the belt generally displays a north-easterly trend, rotating towards the northwest north of the lake. The arcuate trend is outlined by the stratified rocks and the intensely quartz-sericite-pyrite altered rocks. Most of the defined mineral resources on the Property are located within the intensely altered zone.

5.4.3.1 Lithology and Stratigraphy

Triassic Stuhini Group

Rocks of the Upper Triassic Stuhini Group, which are typically fine-grained and well bedded siltstone and mudstones with minor micritic limestone, conglomerate, and sedimentary breccia, are limited to the western parts of the Property, west of the Brucejack Fault. These rocks are intruded by a number of mafic to felsic predominantly alkalic intrusions, a number of which have been dated as Early Jurassic in age. The Upper Triassic clastic rocks have been folded across steep northerly-trending folds and related faults and were deformed and eroded prior to deposition of the lowermost rocks of the Hazelton Group.

Lower Jurassic Lower Hazelton Group

The majority of the lithological units mapped on the Property appear to correlate reasonably well with those of the Unuk River and Betty Creek Formations of the Early Jurassic lower Hazelton Group, as described by Britton and Alldrick (1988). Pretivm has, however, elected not to assign formation-level regional stratigraphic names to these rocks until the current detailed field mapping is complete, due to the existence of complicated lateral facies variations and the diachronous nature of many of the units.

Unconformably overlying the Triassic rocks are rocks of the Lower Jurassic Hazelton Group. They comprise five principal intercalated rock types.

1. Heterolithic volcanic conglomerate, most common at the base and typically coarse-grained (Jack formation).
2. Massive and locally well-layered medium to dark green volcanic siltstone containing common carbonate concretions, and subordinate litharenite and locally-derived pebble conglomerate;
3. Hornblende and/or feldspar-phyric volcanic rocks, principally flows and related coarse fragmental rocks.
4. Weakly stratified heterolithic green to dark green volcanic pebble to boulder conglomerate, sandstone and local mudstone, containing zones of intensely silicified conglomerate.
5. Pyroclastic rocks, including medium- and coarse lapilli tuff and tuff-breccia, with minor intercalated intensely silicified zones. The flows include several subtypes which may be distinguished by the grain size and compositions of their phenocryst assemblages generally fine- to medium-grained hornblende and plagioclase feldspar, ±medium- and locally coarse-grained potassium feldspar—they are typically rich in groundmass potassium feldspar, and are essentially latites to trachydacites or trachyandesites.

Previously, some of the rocks straddling the Brucejack Fault were mapped as intrusive (e.g., Davies, Lewis, and Macdonald 1994). Based on drilling and detailed mapping across the Property over the last three years, Pretivm now interprets the majority of the rocks on the Property as being extrusive. Most of the bodies of massive fine-grained rocks contain local fragmental layers, which are interpreted to represent interflow block tuff or flow-breccia. In addition, there is little or no evidence in the vicinity of the larger masses for associated dikes, and little evidence for contact aureoles. In a number of outcrops, there is clear evidence for the incorporation of large, angular fragments of these bodies, which are texturally distinctive (they typically contain abundant fine- to medium-grained hornblende and/or feldspar phenocrysts within an aphanitic groundmass) within marginal and/or overlying fragmental units. Furthermore, the relatively massive rocks are commonly interlayered with clastic sedimentary rocks near their basal contacts, and locally they contain fragments of lithologies which are known to be Upper Triassic in age. The various Early Jurassic hornblende feldspar-phyric rocks display variable ages over a range of 15 Ma, as determined from preliminary uranium-lead dating, which is more consistent with an extrusive interpretation.

The polylithic conglomerate and overlying pyroclastic fragmental units appear to have been favourable sites for channelling hydrothermal fluids due to the presence of numerous stratiform intensely silicified zones within these relatively porous and permeable rocks. Intense silica flooding with an associated cross-cutting network of crack-seal and hydraulic fractures filled with cryptocrystalline quartz indicates that these zones may have acted as local pressure caps during fluid infiltration that induced local overpressure conditions and subsequent hydraulic fracturing. The presence of multiple zones of intense silicification that are effectively stratiform and which are present at different stratigraphic levels within the conglomerate and younger fragmental units suggests a continuum of fluid infiltration, silica ponding, over-pressurization, and hydraulic fracturing. A Late Triassic uranium-lead age obtained by Pretivm on one of these silicified zones hosted within these Early Jurassic volcano-sediments therefore reflects the detrital age of one of the pebble or cobble clasts (most likely rhyolite). The intensely silicified zones have been intersected in the Valley of the Kings (VOK) Zone (particularly on the southern limb of the VOK syncline), as well as in the West Zone, Gossan Hill, and Golden Marmot. These units were previously variably interpreted as submarine rhyolite flows (which is irreconcilable with the geochronology), dikes, sills, or chert horizons (e.g., McPherson, McDonough, and Roach 1994).

Well-bedded green, maroon, and grey andesitic to dacitic pyroclastic and epiclastic rocks comparable to rocks of the Betty Creek Formation, are present to the northeast and southeast of Brucejack Lake, off the eastern edges of the Brucejack geological map in Figure 5.4-5.

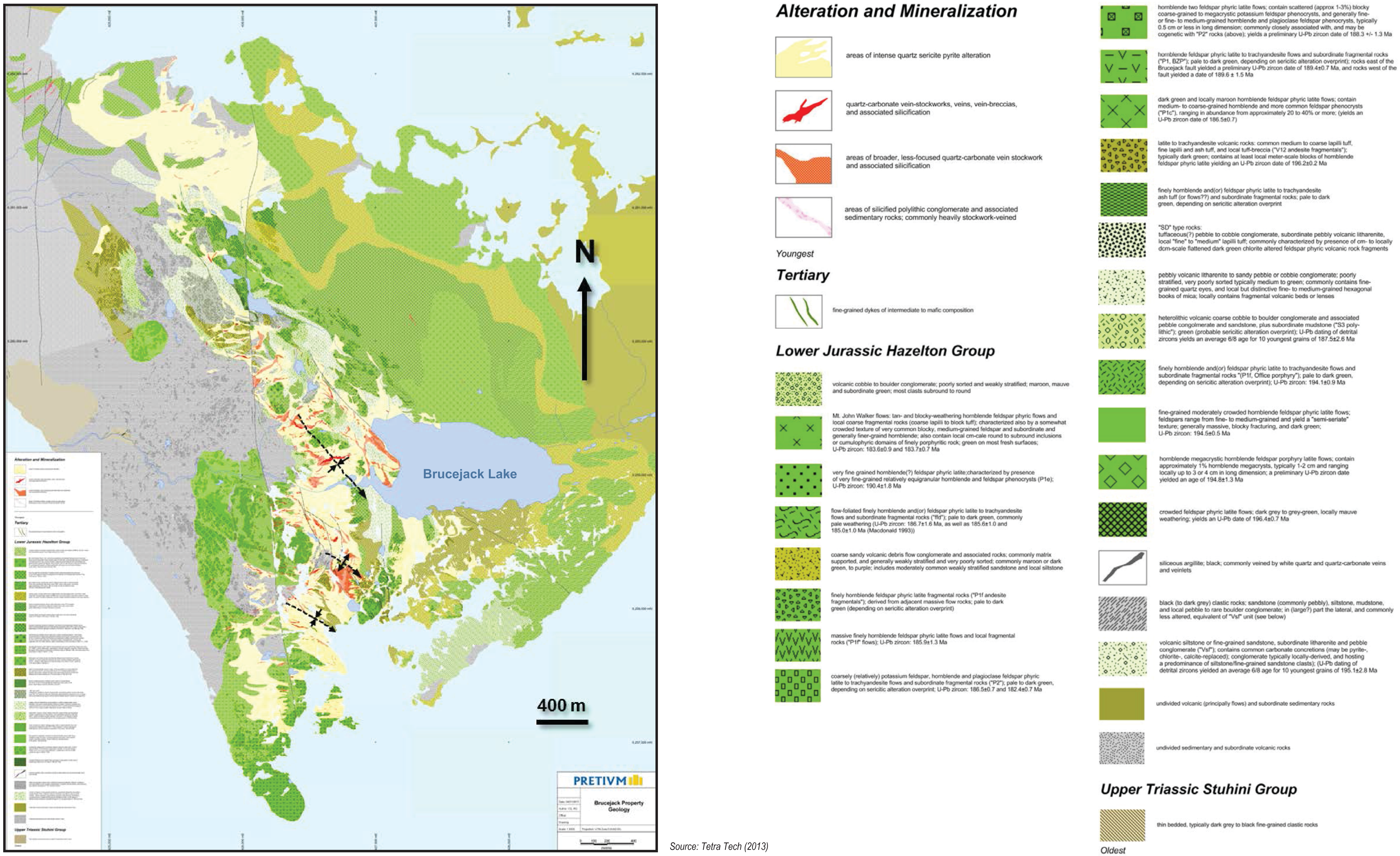
There are almost no intrusive rocks east of the Brucejack Fault, other than a limited number of narrow post-mineral and post-tectonic amygdaloidal mafic dikes. This is in contrast to the increased abundance in intrusives noted west of the Property (e.g., Kirkham and Margolis 1995).

The overburden in the area of the Project consists of a veneer of well-graded glacial till over bedrock. Grain size varies from sand to gravel, with some silt and clay, and variable quantities of cobbles and boulders. Clasts are subrounded to rounded, and color varies from orangey brown to grey. Overburden thickness varies but is generally less than 5 m and often less than 1 m. A thin (often less than 0.5 m, but occasionally up to 3.0 m) layer of sandy organics overlies the overburden.

5.4.3.2 Alteration and Mineralization

The prominent gossanous alteration features on the Property define a distinctive north-south trending and west-concave arcuate belt that is generally located on the east of the Brucejack Fault. This belt is characterized by a broad band of variably but generally intensely quartz-sericite-pyrite altered rocks of up to several hundred metres or more across, and approximately 5 km in strike extent. The quartz-sericite-pyrite alteration typically contains between 2 and 20% pyrite, and, depending on the alteration intensity, can preclude protolith recognition.

Figure 5.4-5
Brucejack Property Geology



Source: Tetra Tech (2013)

High grade gold (± silver) mineralization is predominantly located within this alteration band and is generally associated with vein-stockwork systems of varying intensity. These stockwork systems display good continuity along-strike (several tens of metres to several hundreds of metres) and are characterized by the presence of mesothermal to epithermal veins of quartz, quartz-carbonate, quartz-adularia, and pyrite that are typically on the order of millimetres to tens of centimetres in thickness and which form intense crosscutting networks within the stockworks. In rare cases, the veins may range up to nearly 10 m in thickness. Most high grade zones are either on the margins of, or contained within, a zone of bulk mineralization. Bulk low grade mineralization zones (locally up to several grams per tonne gold) tend to be associated with disseminated anhedral pyrite. Zones and veins of euhedral pyrite are barren.

Vein mineralization includes trace to 10% combined disseminated pyrite, tetrahedrite, tennantite, arsenopyrite, chalcopyrite, galena, sphalerite, pyrargyrite, polybasite, acanthite, and rare native gold and electrum. The presence of base metals and/or arsenopyrite in veins and vein stockworks is only weakly correlated to gold mineralization, and therefore is not considered an indicator thereof. Where visible, gold in the form of electrum typically occurs as coarse aggregates or late stage fracture fillings, as rims on subhedral quartz crystals, or as lace-like networks formed interstitially to quartz and quartz-carbonate, as well as around coarse grains of adularia, where the latter is present. Seams of electrum up to a centimetre in thickness have also been observed in sericitized country rocks, with little obvious association to veins.

Appreciable silver grades are generally present in mineralized zones where gold to silver ratios are less than 1:10; all of the known bonanza grade intersections on the Property have gold to silver ratios of roughly 2:1. Silver-dominant veins tend to be restricted in extent. High-grade silver mineralization occurs as silver sulphides and sulphosalts that are related to adularia-rich veins in which adularia pseudomorphs bladed calcite, indicative of epithermal conditions. Preliminary mineral zonation patterns (e.g., gold:silver ratios, absence/presence of adularia and/or base metal veining, and meso- versus epithermal vein textures) on the Property suggest down temperature thermal gradients towards the east (i.e., up stratigraphy) and north. However, it is likely that a complex combination of temporal (overprinting by later stage lower temperature hydrothermal fluids) and spatial (distal, lower temperature parts of the system) controls on mineralization probably occurred in response to the telescoping porphyry system, which did not necessarily affect all previously mineralized parts of the system equally.

Mineralized quartz veins, vein networks, and vein stockworks in and around the various mineral deposits on the Property have been affected by significant post-mineralization deformation. The various deformation features noted from the broader Sulphurets Mining Camp (see Section 5.4.2.3.) are developed throughout the mineralized zones on the Property. The nature, spatial, and geological associations of the mineralization within a zoned alteration environment proximal to known porphyry bodies with associated porphyry-style mineralization, coupled with the intense deformation of the bulk mineralized host-rocks, veins, and vein stockworks argue for the high grade mineralization on the Property being formed in a porphyry-driven hydrothermal system, which was subsequently deformed during subsequent, post-mineral tectonism. Vein development in response to the later tectonic event appears to be limited to late unmineralized shallow southeast-dipping veins and sigmoidal shear veins (see Section 5.4.2.3).

The currently hypothesis for the mineralization on the Property is that it represents a deformed transitional meso- to epithermal porphyry-associated quartz stockwork in pervasively altered (quartz-sericite-pyrite; i.e., within the sericite alteration zone of Sillitoe [2010]) lower Hazelton Group rocks. The bulk mineralization may have been formed shortly after consolidation of the volcanic pile due to reactions between these rocks and seawater (e.g., Margolis 1993), possibly as a result of hydrothermal fluid circulation driven by a distal and developing porphyry system. Progressive development and telescoping of the porphyry system in rocks of the volcanic pile would then have resulted in widespread and zoned porphyry-style alteration and mineralization, with the high grade gold and gold-silver mineralization generated in a transitional meso- to epithermal environment slightly more distal (i.e., down temperature) from the intrusive stock/dike/sill body than the KSM and Snowfield deposits.

Thermal perturbations associated with pulsing in the porphyry system would likely have resulted in a succession of alteration and mineralization imprints and overprints within such a transitional and active environment and possibly induced upgrading and zonation of the precious metal mineralization, especially considering constraints on gold mobility in this environment (e.g., Gammons and Williams-Jones 1997).

More than 40 gossanous zones of gold, silver, copper, and molybdenum mineralization have been identified along the length of the arcuate band of altered rocks as a result of periodic exploration over the past several decades (Figure 5.4-6). A subset of these was selected for additional follow-up exploration in 2011 by Pretivm (Figure 5.4-7). A total of five zones was modelled for mineral resource estimation: the Bridge Zone, VOK, West Zone, Gossan Hill, and Shore Zone. These zones range from deformed high-grade gold-rich, silver-poor zones such as VOK, through deformed high grade gold-silver zones like the West Zone, to high-tonnage but relatively low-grade zones like the Bridge Zone. Recent geological interpretation has shown that the area previously covered by the Galena Hill Zone is actually an extension of the VOK and this area has now been incorporated into the VOK.

Bridge Zone

The Bridge Zone is located about 1,500 m south of the West Zone and is centred on a 3-ha nunatak surrounded by ice of the eastern arm of the Sulphurets glacier. Gold mineralization at the Bridge Zone is hosted by plagioclase-hornblende phyric volcanic rocks that are moderately to strongly sericite-chlorite altered, with disseminated and stringer pyrite making up a few percent of the rock by volume. Mineralization occurs both in low grade bulk tonnage associated with the altered host rocks, and in deformed quartz vein and vein stockwork associated moderate to high grade styles. The moderate to high grade mineralization is generally associated with east-west trending quartz vein and vein stockworks that dip steeply to the north.

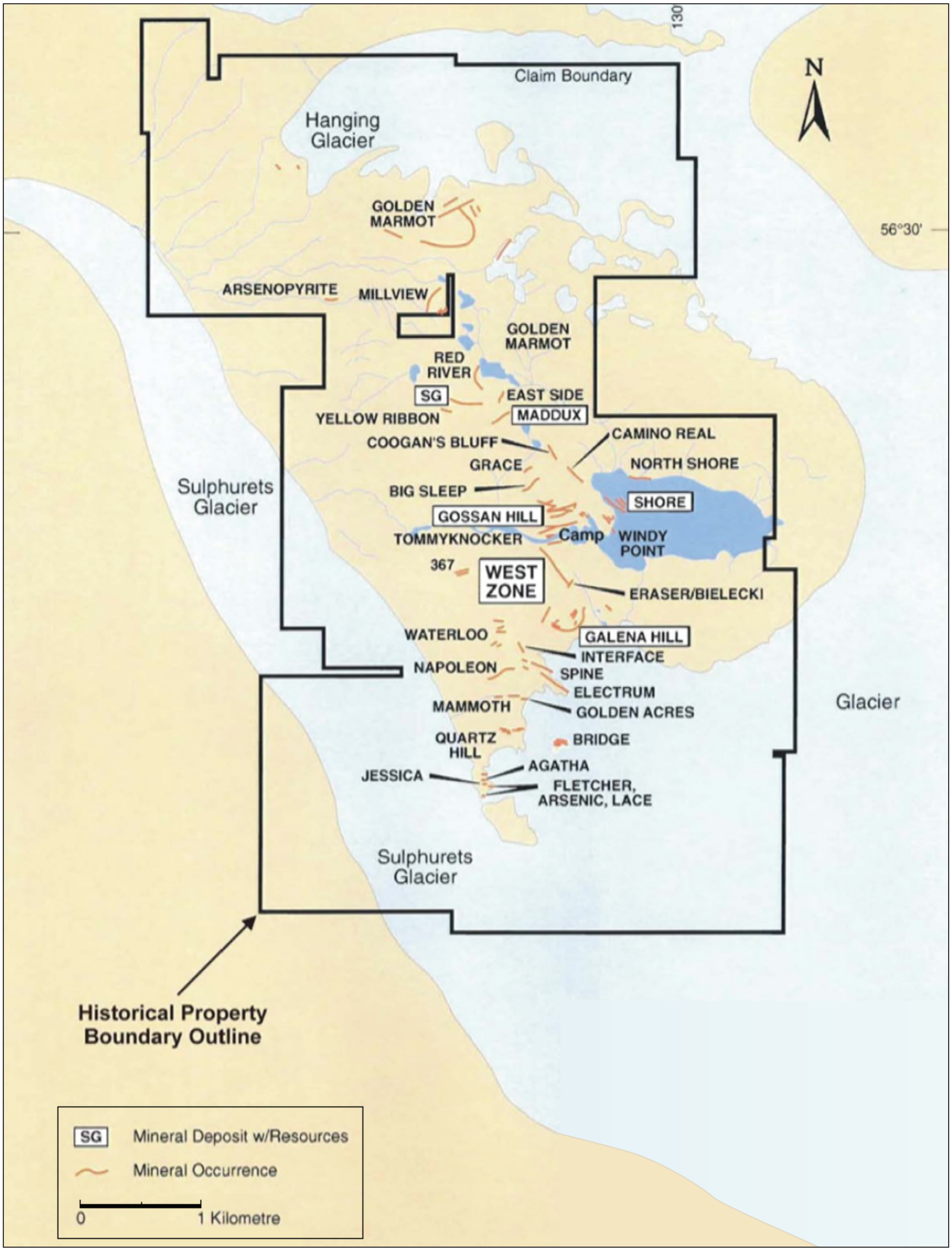
Quartz ± chlorite ± sericite veins, ranging from 20 cm to 200 cm in thickness, are fairly common and contain minor to trace amounts of pyrite, sphalerite, galena, molybdenite, and an unknown dark grey, possibly silver-bearing sulphosalt (or salts). Some of the veins contain appreciable concentrations of molybdenum and rhenium, with the molybdenum/rhenium ratio similar to that at Pretivm's Snowfield deposit.

The pervasive nature of the mineralization in the Bridge Zone, the association of this mineralization with molybdenum and rhenium, and the spatial proximity of the intensely hydrothermally altered and mineralized southern limb of the VOK syncline (immediately to the north of the Bridge Zone; see below), suggests that the Bridge Zone rocks were relatively proximal to an intrusive body (stock/sill/dike/other narrow apophysis) of the mineralizing porphyry system.

Valley of the Kings Zone

High grade gold mineralization at the VOK, the current focus of the Project, occurs in a series of west-northwest trending sub-vertical corridors of structurally reoriented vein stockworks and subordinate vein breccias, hosted in a folded sequence of fine grained volcanic siltstone and sandstone, variably silicified polylithic volcanic conglomerate, and fragmental latite volcanic rocks (Figures 5.4-8 and 5.4-9). Relatively massive latite flows are present to the immediate north and south of this mineralization host rock sequence.

Figure 5.4-6
Historical Map with Mineral Deposits and Occurrences



Note: Modified after Budinski (1995)
Source: Ghaffari et al. (2012)

Figure 5.4-7

Brucejack Property Mineralization Zones

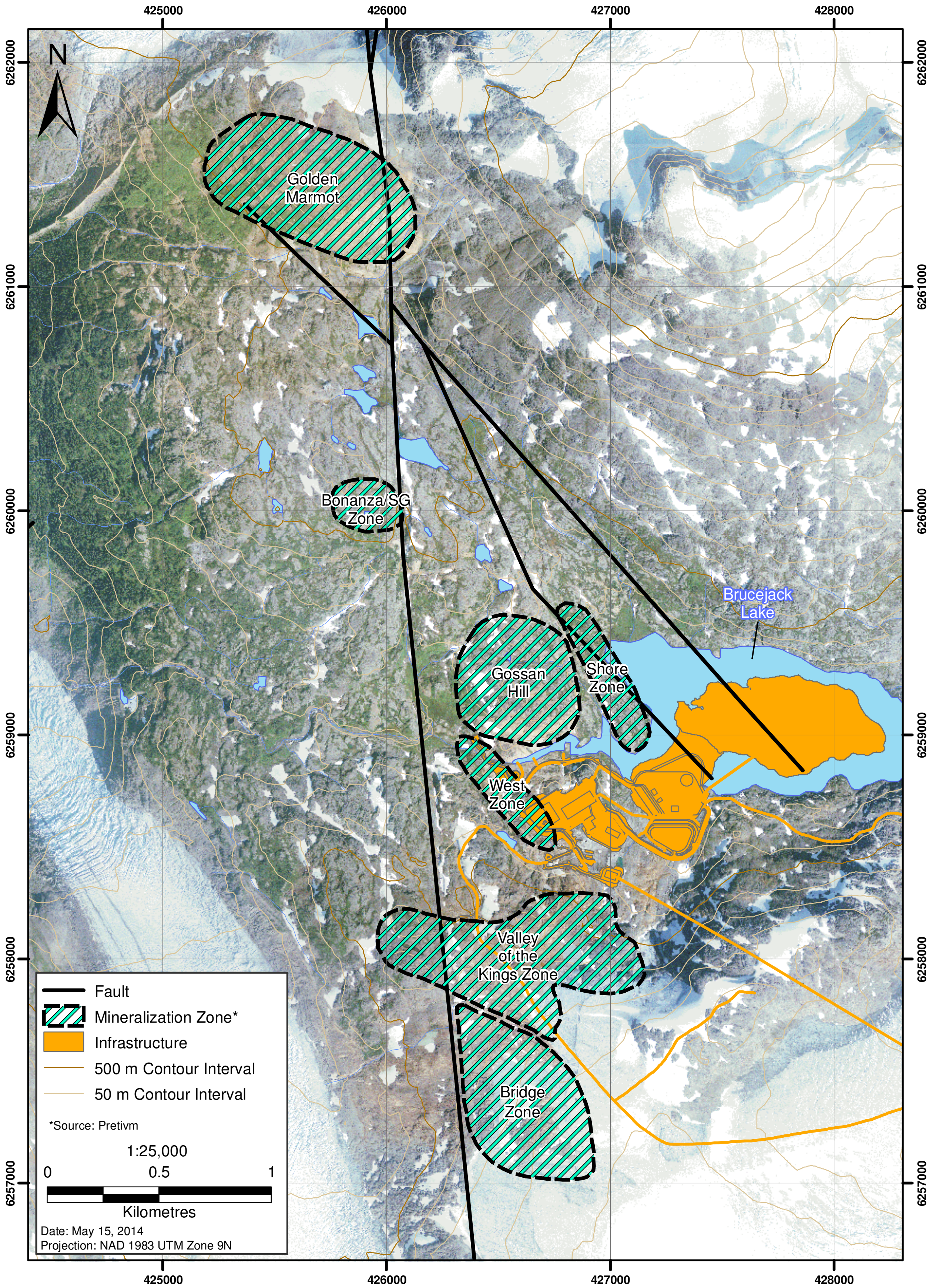
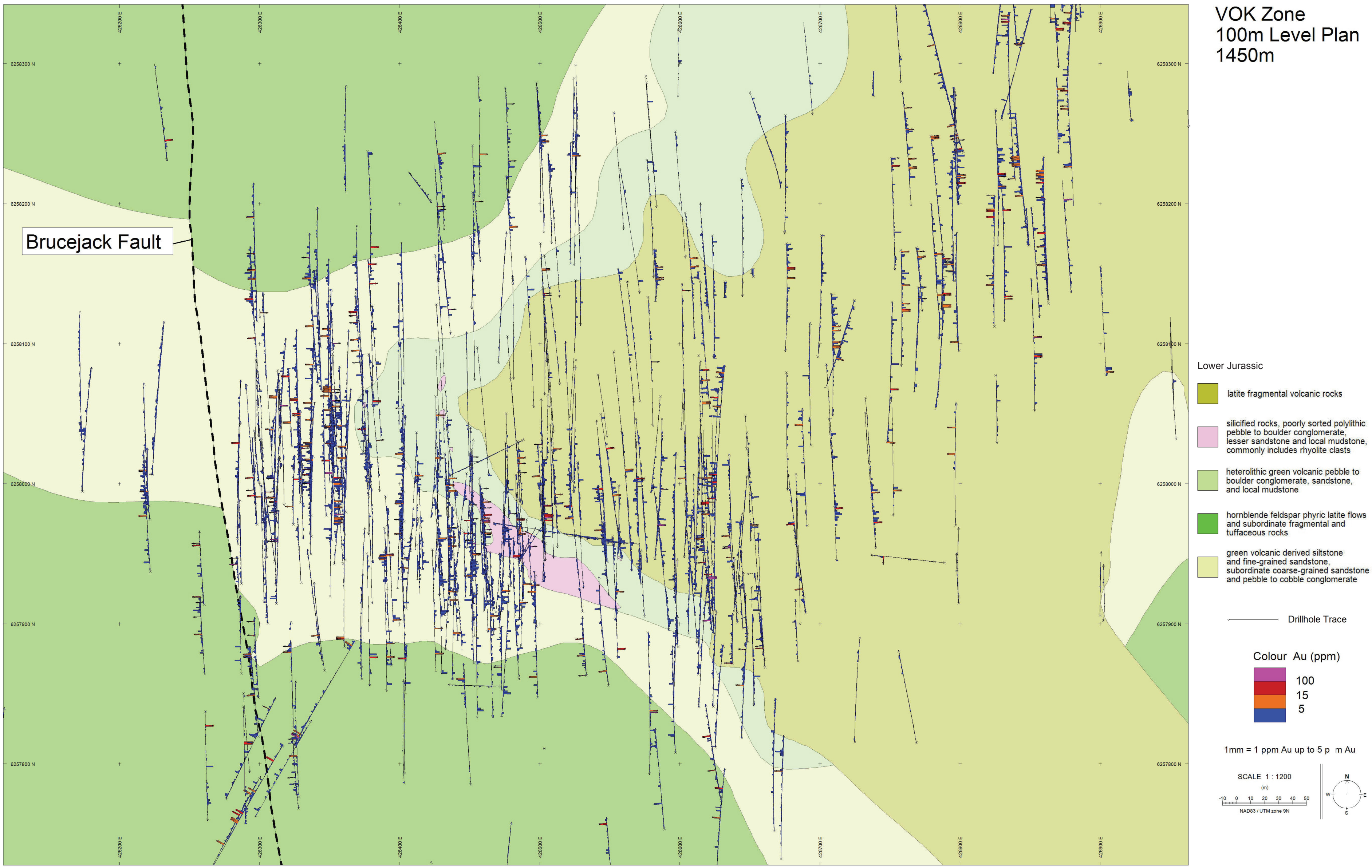


Figure 5.4-8

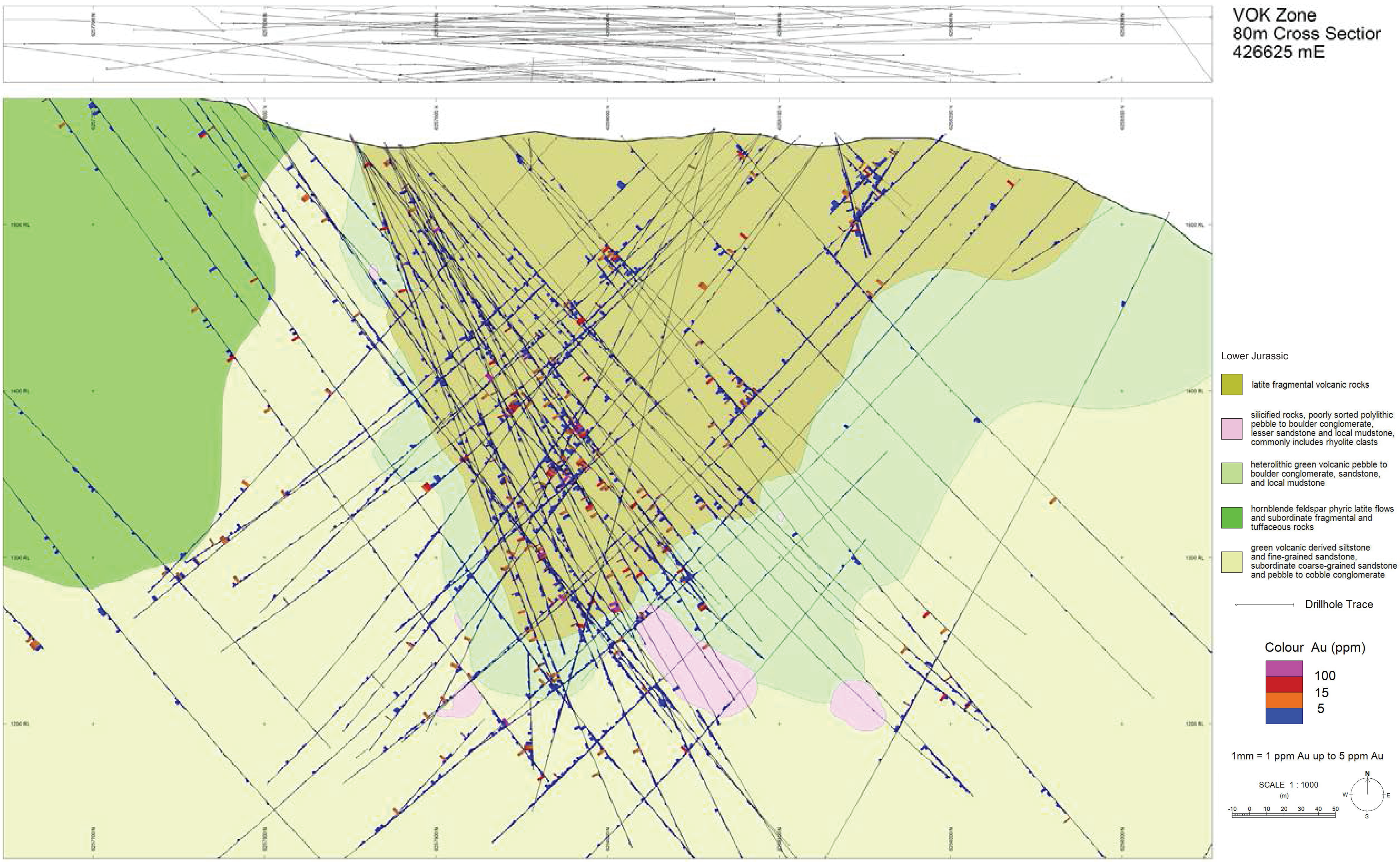
1,450 m Level Plan of the VOK Zone



Source: Pretivm (2013)

Figure 5.4-9

South-North Cross-section along Easting 426625 E, VOK Zone



Source: Pretivm (2013)

Gold is typically present as gold-rich electrum within deformed quartz, and quartz-carbonate (±adularia?) vein stockworks, veins, and subordinate vein breccias, with grades ranging up to 41,582 ppm gold and 27,725 ppm silver over 0.5 m. The gold occurs both as inclusions in euhedral pyrite, as well as interstitially in textural equilibrium with strained quartz (exhibiting primary recrystallization textures), carbonate, several generations of pyrite, and, to a lesser extent, vein-hosted sericite. Gold has also been found in the central parts of deformed quartz veins, as dendritic lattice works pervasive throughout deformed quartz, and quartz-carbonate veins, as well as in the matrix of hydrothermal breccias. The various textural associations of gold suggest a multi-stage paragenesis for gold mineralization.

The relatively common association of gold and pyrite suggests a link in their precipitation. The presence of pyrite in a porphyry-epithermal environment indicates elevated levels of hydrogen sulphide in the magmatic-hydrothermal fluids, which suggests gold solubility and mobility as bisulphide complexes (e.g., Gammons and Williams-Jones 1997). Destabilization of the bisulphide complex during pyrite precipitation, brought on by changes to one or more physicochemical parameters (e.g., change in pH, oxidation state, fluid mixing, depressurization, cooling, sulphur activity), would result in gold precipitation. Gold is also present in veins and silica-flooded host rocks that do not contain pyrite. This indicates that gold precipitation is not solely linked to pyrite, and that other factors have also played a role in controlling gold mineralization during the genesis of the VOK Zone.

Early pyrite precipitation during initial porphyry development is ubiquitous in the host rocks to the VOK mineralization. This would have created a favourable environment for gold remobilization, enrichment, and transportation as bi-sulphide compounds above the telescoping porphyry system, as the hydrothermal fluids would effectively be unbuffered by the already altered host rocks (e.g., Gammons and Williams-Jones 1997). An increase in the residency time of the cooling hydrothermal fluid in previously mineralized rocks (mineralized during the earlier porphyry phase) beneath siliceous cap rocks, where the gold is transported as bisulphides is considered a key factor in the generation of the elevated grades in the VOK Zone.

While quartz veining and stockworks are common throughout the zone, the majority of significant gold intersections are confined to corridors within a 100 m to 125-m-wide zone on the southern limb of the syncline. The orientation of these corridors is sub parallel to the fold axis, with some of the stockworks being spatially associated with intensely silicified zones developed in and at the contacts of the polylithic conglomerate, as well as in the overlying fragmental volcanic rocks. Asymmetrical alteration is present on either side of the intensely silicified conglomerate zones, with (the underlying rocks more heavily altered than those above, being almost completely metasomatized to green sericite in places. Coupled with evidence for hydraulic and tectonic fracturing and brecciation of the siliceous zones and previously-formed stockwork and veins, these features suggest that the siliceous zones formed in response to silica flooding of the preferentially permeable conglomerate, and then acted as local pressure seals that were eventually brecciated as a response to local overpressure conditions. The intensely silicified zones generally appear to be sub-parallel to the stratigraphy.

Gold:silver ratios within the VOK Zone are typically 2:1 or higher. Variations in this ratio, which could be a function of thermal gradients developed at the time of mineralization, are suggested by a visible increase in the proportion of silvery electrum (at the expense of more gold-coloured electrum) with a concomitant increase in the proportion of vein-hosted adularia towards the eastern parts of the zone. Additional precious metals-bearing minerals found in the VOK Zone, typically in trace quantities, include silver sulphides, acanthite, pyrargyrite and tetrahedrite, and associated base metal-bearing sulphides include sphalerite and galena. Low grade bulk tonnage mineralization, associated with disseminated anhedral pyrite, forms a halo within the altered rocks, surrounding the high grade mineralization corridors.

The VOK Zone is currently defined over 1,200 m in east-west extent, 600 m in north-south extent, and 650 m in depth. Drilling during the 2012 drilling program resulted in the extension of the VOK Zone west across the Brucejack Fault, thereby making the zone open to the west, as well as to the east and at depth.

West Zone

The West Zone gold-silver deposit (Figures 5.4-10 and 5.4-11) is hosted by a northwesterly trending band of intensely altered Lower Jurassic latitic to trachyandesitic volcanic and subordinate sedimentary rocks, as much as 400 m to 500 m thick, which passes between two more competent bodies of hornblende plagioclase hornblende phyric flows (Figure 5.4-10). The stratified rocks dip moderately to steeply to the northeast and are intensely altered, particularly in the immediate area of the precious metals mineralization. The West Zone appears to form the northern limb of an anticline that links up with the VOK to the south (Figure 5.4-10), and the southern limb of a syncline that extends further to the north.

The West Zone deposit itself comprises at least 10 quartz veins and mineralized quartz stockwork ore shoots, the longest of which has a strike length of approximately 250 m and a maximum thickness of about around 6 m. Most mineralized shoots have vertical extents that are greater than their strike lengths. Veins and stockworks in this zone display clear evidence of post-mineral ductile and brittle deformation. The West Zone is open along strike to the southeast, and at depth to the northeast.

In terms of hydrothermal alteration, the West Zone is marked by a central silicified zone that passes outwards to a zone of sericite ± quartz ± carbonate and then an outer zone of chlorite ±sericite ±carbonate. The combined thickness of the alteration zones across the central part of the Zone is between 100 and 150 m.

Gold in the West Zone occurs principally as electrum in quartz veins and is associated with, in decreasing order of abundance, pyrite, sphalerite, chalcopyrite, and galena. Besides being found with gold in electrum, silver occurs in tetrahedrite, pyrargyrite, polybasite and, rarely, stephanite and acanthite. Gangue mineralogy of the veins is dominated by quartz, with accessory adularia, albite, sericite, and minor carbonate and barite. The increased abundance of silver in the West Zone may suggest that this zone was formed down temperature gradient from the VOK (either spatially or temporally). The West Zone is open to the southeast, northwest, and northeast (i.e., towards the Gossan Hill Zone).

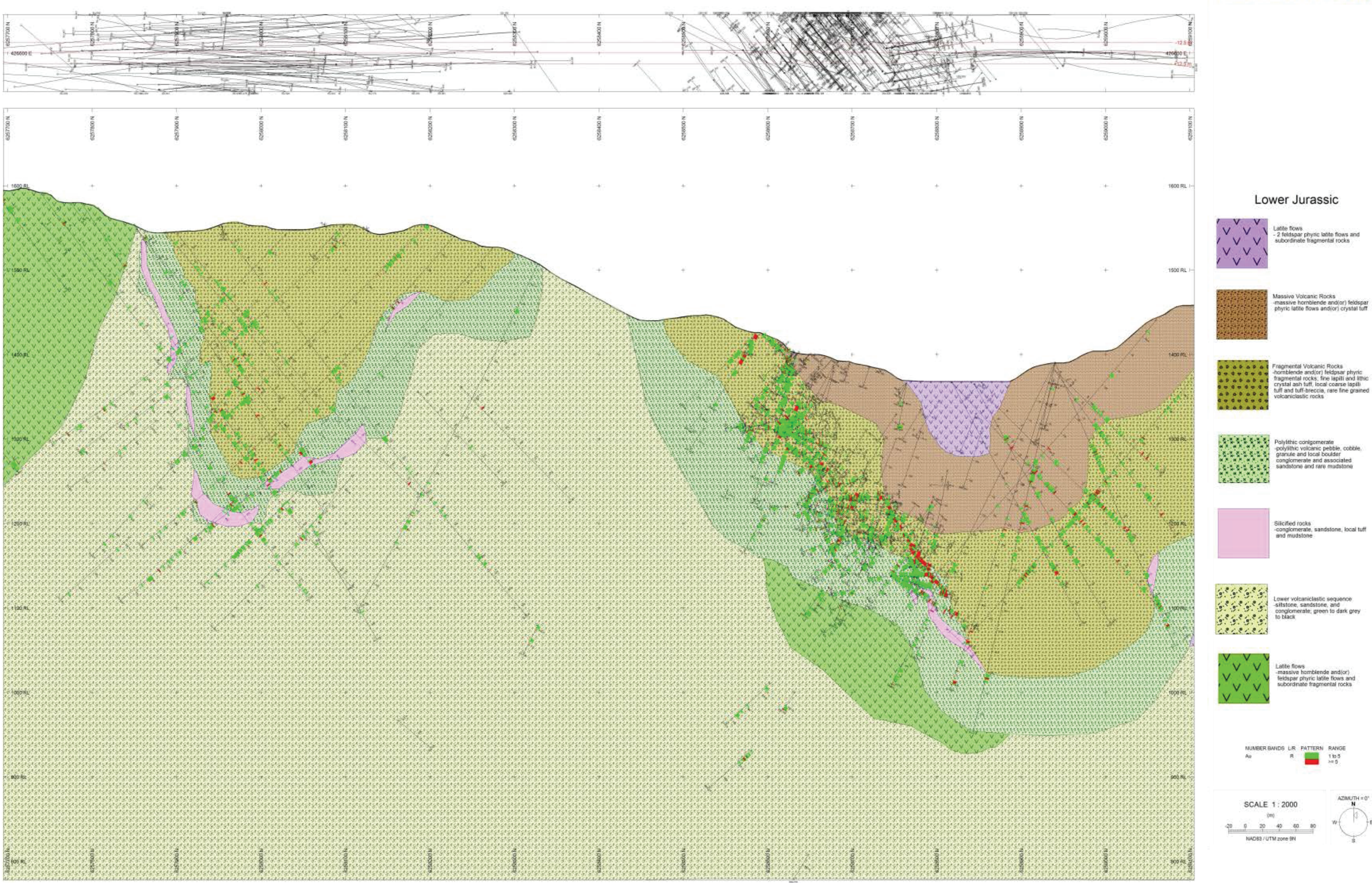
Gossan Hill

The mineralized zone known as Gossan Hill is a circular area, about 400 m in diameter, of intense quartz-sericite-pyrite alteration developed in Lower Jurassic volcanic rocks (Figures 5.4-6 and 5.4-7). The visually impressive alteration zone at Gossan Hill is host to at least eleven deformed quartz vein and quartz vein stockwork structures, most of which trend east-west and dip steeply to the north. Individual structures are up to 250 m long and 20 m thick.

Precious metal mineralization at Gossan Hill occurs both as low grade bulk tonnage and high grade styles. The low grade bulk tonnage style is associated with fine quartz stockworks and anhedral pyrite. Higher-grade gold mineralization at Gossan Hill differs somewhat from other zones on the Property in that it is associated with the larger quartz lenses, particularly where they contain local aggregates of pyrite, tetrahedrite, sphalerite, and galena. Electrum is observed in the bonanza grade intersections, while silver also occurs in tetrahedrite, pyrargyrite, and polybasite. The Gossan Hill deposit remains open along strike, across strike, and at depth.

Figure 5.4-10

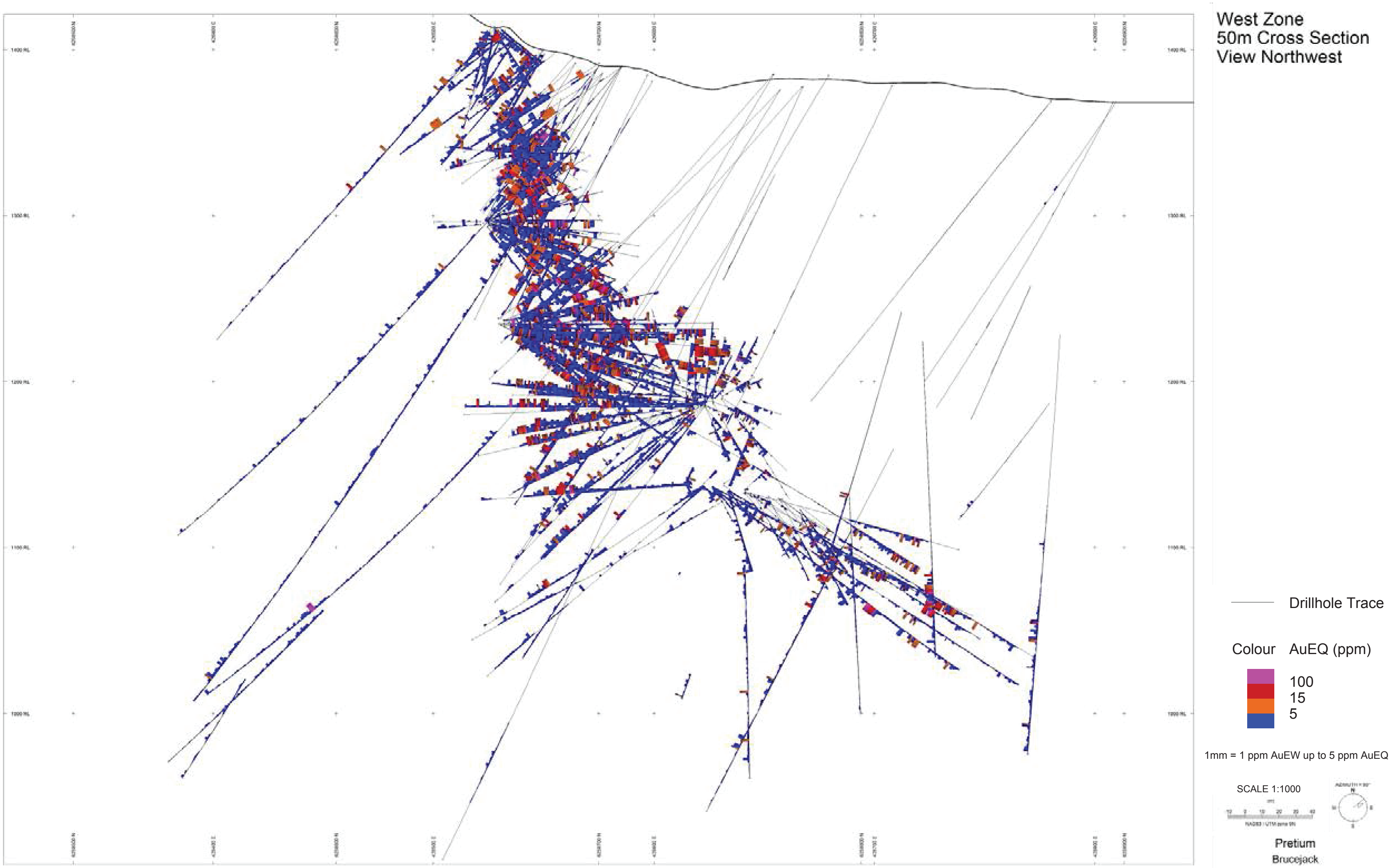
VOK to West Zone Geological Section 426600 E - Looking West



Source: Pretivm (2013)

Figure 5.4-11

West Zone Drillholes and Assay Cross-section



Source: Pretivm (2013)

Shore Zone

The Shore Zone is a relatively small gold-silver deposit located along the northeastern shore of the peninsula that extends into the west end of Brucejack Lake (Figures 5.4-6 and 5.4-7).

This zone is characterized by deformed quartz veins and quartz vein stockworks up to 100 m in length, which are hosted in deformed and quartz-sericite-pyrite altered trachyandesite, sandstone and pebble conglomerates of the lower Hazelton Group. The zone has a strike length of approximately 530 m and a maximum width of 50 m. The northwest-southeast trend of the zone is coincident with a pronounced lineament that extends southeastward from the Brucejack Fault beneath Brucejack Lake, and which is likely a fault. It is likely that the Shore Zone forms the eastern limb of the meso-scale syncline, linking up with the West Zone underneath the Gossan Hill Zone.

Given the intense folding displayed by the lower Hazelton Group rocks in this area, as well as the variable competency of the rocks in this part of the Property, it is likely that a combination of ductile deformation and rock competency differences controlled the orientation of this zone. Way-up structures in steeply northeast dipping sedimentary units in the Shore Zone indicate that it likely forms the northern limb of a parasitic southeast plunging anticline. The aforementioned lineament likely utilised the ductile deformation-prepared northwest-trending zone of structural weakness for propagation during late brittle deformation.

The veins and vein stockworks consist predominantly of quartz with minor carbonate and barite, with patchy sulphide mineralization consisting of variable quantities of pyrite, tetrahedrite, sphalerite, galena, and arsenopyrite. Electrum has been observed in trace amounts. Silver is present in some of the highest concentrations observed at the Brucejack Property. This observation, together with the stratigraphic (up stratigraphy) and spatial position (i.e., relatively far northeast of the Bridge Zone) of the Shore Zone, provides further evidence for thermal gradient-induced mineral zonation across the Property.

5.4.3.3 Structure and Metamorphism

Hazelton Group rocks and mineralized vein stockworks on the Property display significant multi-phase post-mineralization deformation. The Property is characterized by the presence of steep structural elements, including steeply dipping planar features such as bedding, foliation, and brittle faults, and steeply plunging linear features, such as fold hinges, pencil cleavage, or mineral lineation. These structural elements are associated with the Late Jurassic to Late Cretaceous Skeena Fold Belt deformation, and deform unaltered and altered rocks, as well as mineralized veins and stockworks.

Foliation

Foliation on the Property is pervasive, although it is best developed in the most intensely altered rocks. The foliation is defined by muscovite in altered rocks, and by sericite and chlorite in less altered rocks. The foliation displays a dominantly east-west trend across the Property, with a sub-vertical dip that is generally to the north, but which does vary about the vertical.

Foliation orientation appears to be locally controlled by the presence of proximal competent rock masses that acted as strain resistors during deformation (e.g., the relatively competent hornblende feldspar phyric volcanic flow that forms the southern and south-western margin of the West Zone probably controlled the northwest trend of the foliation in this area).

Within the broader zones of veining, individual veins, veinlets, and narrower stockwork zones have been partially to completely reoriented sub-parallel to the foliation in the host rocks. The most intensely foliated rocks tend to be altered rocks immediately adjacent to the veins and stockworks.

A second, locally developed foliation has been observed in the footwall to West Zone, Gossan Hill, and Golden Marmot. The development of this foliation, which is also typically steep, is generally associated with the most intensely foliated and altered lithologies. A steeply southeast plunging intersection cleavage lineation (or pencil structure) is often associated with the presence of the second foliation, and is sub-parallel to mesoscale fold axes. Pencil cleavage is also developed at the intersection of steep (and commonly curvilinear) joint sets with the steep foliation.

Folding

Rocks on the Property have been folded into a series of tight, moderate to steeply east- to southeast-plunging south-vergent synclines and anticlines, with wavelengths on the order of approximately a hundred metres. Smaller-scale parasitic folds (few metres scale) with similar orientations to these folds are locally developed. These folds are generally quite difficult to recognise in the field, and have been delineated using both field observations and lithological domain trace element analyses (Figure 5.4-5 and Figure 5.4-12). They tend to be best delineated in the field by following the contacts between older, predominantly clastic rocks and the younger, predominantly volcanic flows and associated coarse volcanic fragmental rocks of the lower Hazelton Group. The east-west trending fabric, which generally tends to be axial planar to these folds, is interpreted as having formed at the same time as this folding event.

The variation in intensity of folding between less competent clastic rocks and more competent volcanic flows suggests preferential strain partitioning in the less competent rocks during deformation. The more competent rocks possibly acted as strain resistors which locally controlled folding of the less competent rocks (e.g., the westward tightening up of the syncline in the VOK between the two porphyritic flows in this part of the Property).

The plunge of the minor folds varies and several lines of evidence suggest that they may reflect refolding of northerly-trending tight, upright “early” mid-Cretaceous Skeena Fold Belt-age folds across roughly east-west axes. These later folds and the east-west foliation are spatially associated with the area of the footwall (and immediate hanging wall) of the regional-scale Mitchell thrust system, suggesting that they may have developed in the latter stages of SFB development.

Brittle Faulting

Steep post-mineral late brittle faults, which cut deformed unaltered and altered rocks and deformed mineralized veins and vein stockworks, are present across the Property. Many form well-defined lineaments, with that of the Brucejack Fault being the most prominent. Few have any well-defined offsets, and most offsets appear relatively minor (less than several tens of metres). An exception is noted in the area near the western margin of the Sulphurets Glacier, to the north-west of Brucejack Creek, where clean and well-exposed outcrops show apparent dextral offsets of up to 20 or more metres along north-trending faults occupying lineaments which are sub-parallel to the Brucejack Fault.

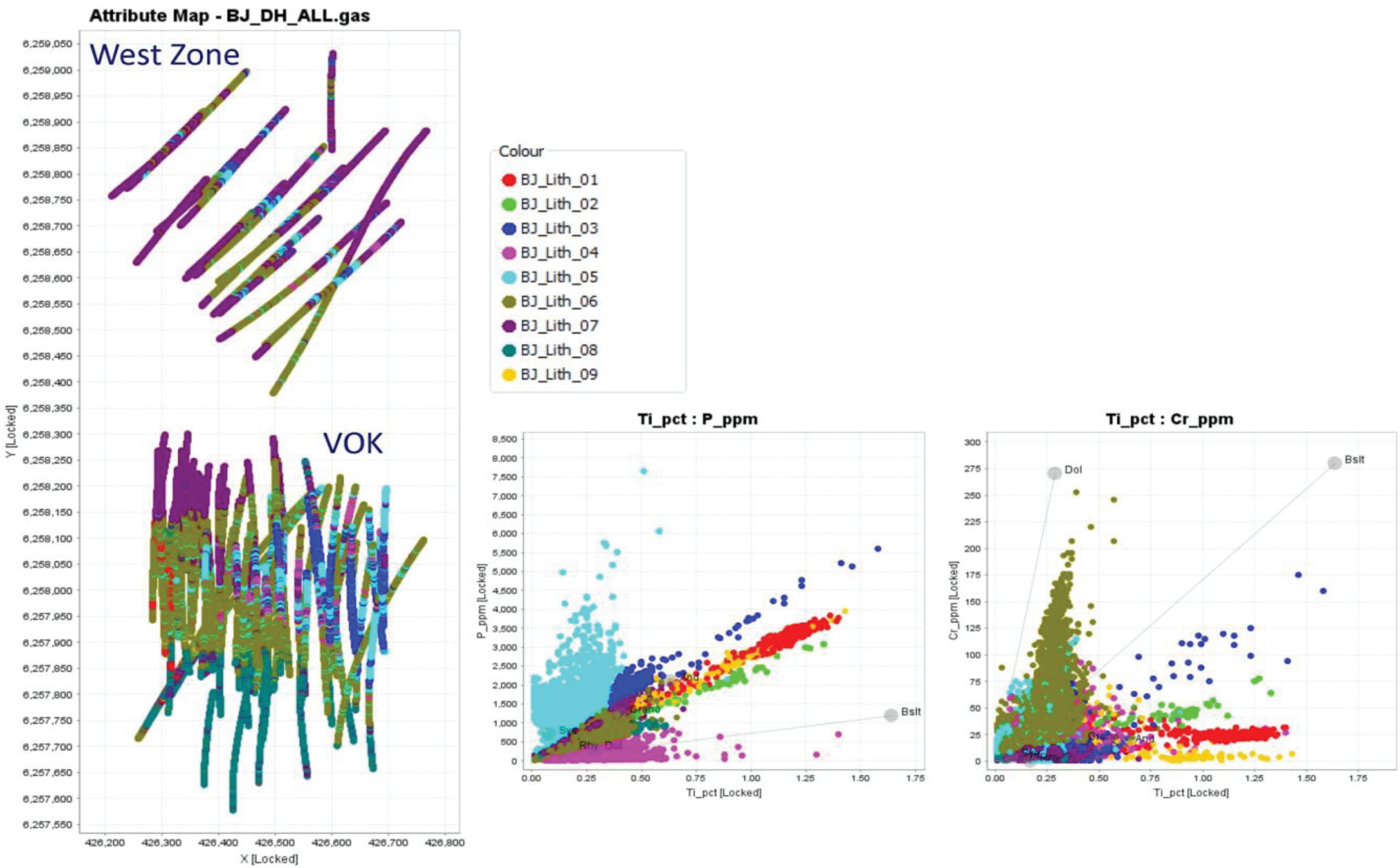
Numerous smaller-scale north-trending brittle features on the Property show similar apparent displacements. Discussion of the offset along the Brucejack Fault is presented in Section 5.4.2.3.

Metamorphism

The rocks on the Property appear to have experienced low grade metamorphism (lower greenschist facies, or lower) around 110 Ma associated with the Skeena Fold Belt deformation. See Section 5.4.2.3 for further discussion on the metamorphism of the rocks of the Sulphurets Mining Camp.

Figure 5.4-12

Trace Element Analysis by Lithology for VOK and West Zone



Source: Pretivm (2013)

5.4.3.4 Geochronology

Uranium-lead zircon and rhenium-osmium molybdenite age dates have been obtained from suitable geologically-constrained surface and drill core samples collected from across the Property (Figure 5.4-13). Zircon age dating was conducted at the Pacific Centre for Isotopic and Geochemical Research analytical facility, Department of Earth, Ocean, and Atmospheric Sciences, University of British Columbia. Molybdenite age dates were determined at the Radiogenic Isotope Facility, Department of Earth and Atmospheric Sciences, University of Alberta, having been contracted through ALS Environmental in North Vancouver.

Magmatic zircons constrain the volcano-sedimentary rock sequence underlying the Property to between c.196 Ma and c.182 Ma, consistent with previous stratigraphic interpretations which placed these rocks in the Lower Jurassic Lower Hazelton Group. Detrital zircons hosted in immature volcaniclastic conglomeratic rocks display a range of Triassic and Jurassic ages (from c.222 Ma to c.183 Ma), which are interpreted as indicating uplift and erosion of an earlier island arc assemblage (Stuhini Group) during the formation of the Lower Jurassic Hazelton Group. This is consistent with the presence of a regional-scale angular unconformity between rocks of the Stuhini and Hazelton Groups, as well as the volcano-sedimentary growth basin interpretation for the Lower Hazelton Group rocks on the Property. Both magmatic and detrital zircons display a decrease in age towards the east across the Property, consistent with the regional geological way up on this (the eastern) side of the McTagg Anticlinorium.

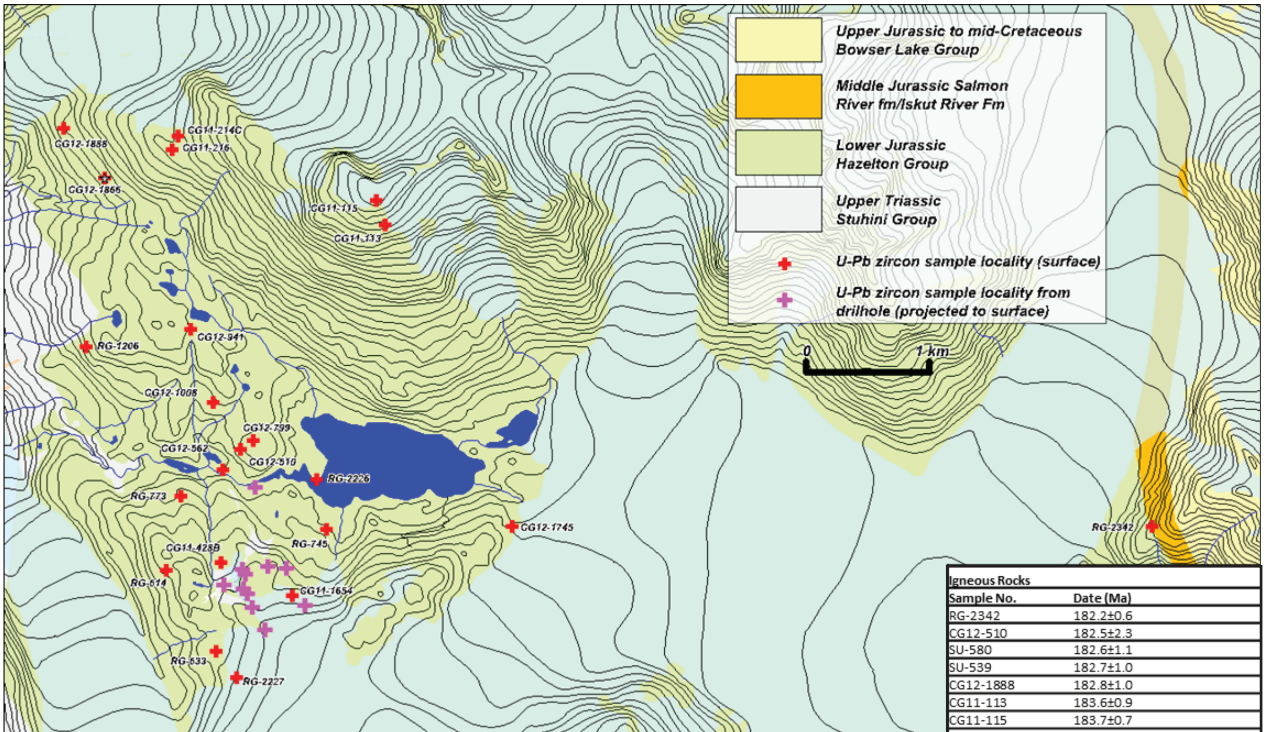
Rhenium-osmium ages obtained from two vein-hosted molybdenite samples yielded age dates of 191.5 ± 0.8 Ma and 190.2 ± 0.8 Ma. These samples were collected from drill hole SU-151 in the Bridge Zone, which is directly south of VOK, and represent the oldest mineralization age reported from the Property. Rhenium-osmium age dates collected from Pretivm's Snowfield porphyry gold-copper deposit indicate an age of 191.1 ± 0.8 Ma for porphyry mineralization, which is statistically indistinguishable from the Brucejack molybdenite age dates. This indicates that the hydrothermal system responsible for the molybdenum mineralization in the porphyritic flows in the Bridge Zone was contemporaneous to the porphyry system developed in the upper (i.e., Snowfield) parts of the Mitchell Stock. This dating provides further evidence for the suggested link between at least the onset of magmatic-hydrothermal mineralization on the Property and a subjacent porphyritic intrusive. The similarity in molybdenum/rhenium ratios in rocks from the Bridge Zone to those in the Snowfield deposit further supports this contention.

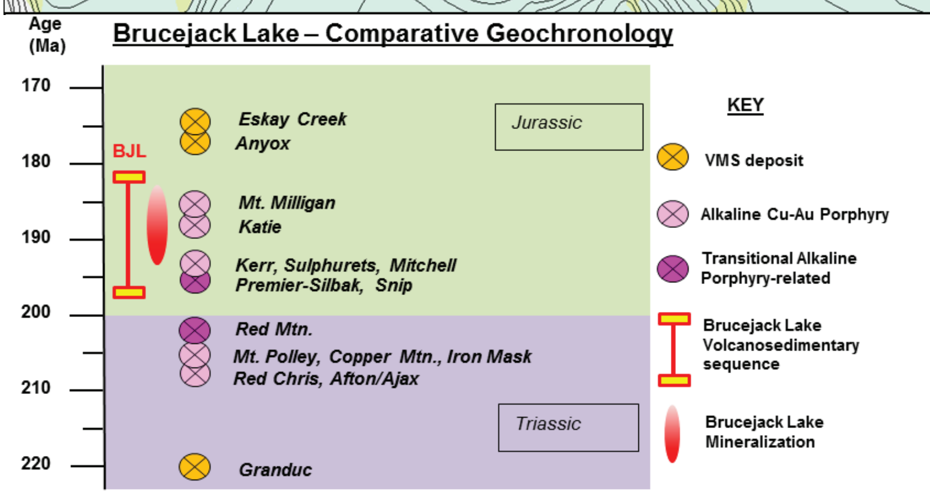
A uranium-lead zircon age date of 182.7 ± 1.0 Ma obtained for a deformed post-mineral mafic dike provides a minimum age for the mineralization, with the youngest altered and mineralized flows dated at c.185 Ma. These data indicate that the mineralizing systems were relatively long-lived, spanning approximately 8 million years, and coeval with island arc volcanism. Sillitoe (2010) notes that porphyry deposit clusters, like those in the vicinity of the Property, may remain active for 10 million years or longer. The Brucejack geochronological data are consistent with field observations that the volcanic basin formation and mineralization were pre-tectonic with respect to the pervasive Cretaceous deformation, for which an age of c.110 Ma has been reported in the literature (e.g., Kirkham and Margolis 1995).

The host rock and mineralization ages from the Property overlap with dates determined for known alkaline porphyry copper-gold deposits in the Intermontane Belt (see Figure 5.4-13), particularly those of the nearby KSM deposits. The spatial, stratigraphic, and geochronological association between the Brucejack deposits and the KSM porphyry intrusive rocks suggest a genetic link between the high grade gold mineralization at Brucejack and the KSM deposits. However, the age constraints on the Brucejack hydrothermal system indicate it may have been driven, in part, by a somewhat younger and relatively long-lived porphyritic stock, or a series of successive porphyritic stocks, emanating from the same deep-seated arc-related magmatism that led to the formation of the slightly older KSM deposits.

Figure 5.4-13

Brucejack Property Geochronology





Igneous Rocks	
Sample No.	**Date (Ma)**
RG-2342	182.2±0.6
CG12-510	182.5±2.3
SU-580	182.6±1.1
SU-539	182.7±1.0
CG12-1888	182.8±1.0
CG11-113	183.6±0.9
CG11-115	183.7±0.7
CG11-214C	184.2±0.7
CG12-1745	184.3±1.7
SU-526	184.4±0.4
RG-2226	185.0±0.9
SU-450	185.7±0.8
RG-745	185.9±1.3
CG11-1654	186.5±0.7
CG12-1866	186.8±0.9
CG12-799	188.3±1.3
CG12-1008	189.1±0.7
RG-2227	189.2±0.5
SU-262	189.4±0.7
RG-633	189.6±1.5
RG-773	190.45±0.17
CG12-563	193.8±1.1
CG11-428B	194.1±0.9
RG-1206	194.5±0.5
RG-614	194.8±1.3
SU-277	196.24±0.14
CG12-941	196.4±0.7
Sedimentary Rocks (Detrital Zircon Dates)	
Sample No.	**Date for youngest grain (Ma)**
SU-307	214.9±12.4
CG11-216	219 to 221 or older
SU-299	183.3±8.0
SU-303	191.9±9.4
SU-475	209.9±2.0
SU-202	216.1±9.0

Source: Pretivm (2013)

5.4.4 Deposit Types

The following section is derived directly from the report *Pretium Resources Inc.: Brucejack Project Mineral Resources Update Technical Report*, by Ivor W.O. Jones, M.Sc., CP, FAusIMM and dated November 20, 2012. Minor changes have been made for report consistency.

Based on the geological discussions presented in Section 1.4, Project Location, Access, and History, the gold-silver quartz (± carbonate, barite, adularia) and minor base metal (galena, sphalerite and rare chalcopyrite) veins and vein stockworks of the Brucejack deposits are considered as having been formed in a transitional meso- to epithermal porphyry-associated quartz stockwork system in pervasively altered (quartz-sericite-pyrite; the Sericite alteration zone of Sillitoe (2010; Figure 5.4-14) lower Hazelton Group rocks between 192-190 Ma and 184 Ma. Progressive development and telescoping of a porphyry system in the volcanic pile resulted in a widespread zonation of porphyry-style alteration and mineralization, and multiple stages of vein and alteration overprinting. Gold concentration and subsequent deposition probably occurred as a result of complex interactions between various physicochemical parameters (e.g., pressure, temperature, pH, activities of oxygen, sulphur, and other volatiles, concentration of dissolved salts, differential permeability of the volcanic pile) in the magmatic-heated seawater hydrothermal system developed above the pulsing porphyry system.

Metal deposition was likely triggered by a combination of structural preparation, depressurization, cooling, phase separation, solution mixing, and fluid-host rock interactions. Geological, mineralization, and alteration features of the Snowfield deposit (Armstrong, Brown, and Puritch 2011) suggest that this deposit is more proximal to the porphyry apophysis, most likely in the Chlorite-Sericite alteration zone of Sillitoe (2010; Figure 5.4-14).

5.5 MINERAL RESOURCES

Mineral resources were estimated in February 2014 using the Canadian Institute of Mining, Metallurgy and Petroleum *Standards on Mineral Resources and Reserves, Definitions and Guidelines* by Snowden Mining Industry Consultants (Snowden 2014).

A threshold grade of 0.3 g/t gold was found to generally identify the broad zones of mineralization in the drill cores at West Zone and VOK. At VOK, a 1 g/t gold to 3 g/t gold threshold grade was used together with Pretivm's interpretation of the lithological domains, to interpret high-grade corridors within the broader mineralized zones, and define a series of mineralized domains for estimation.

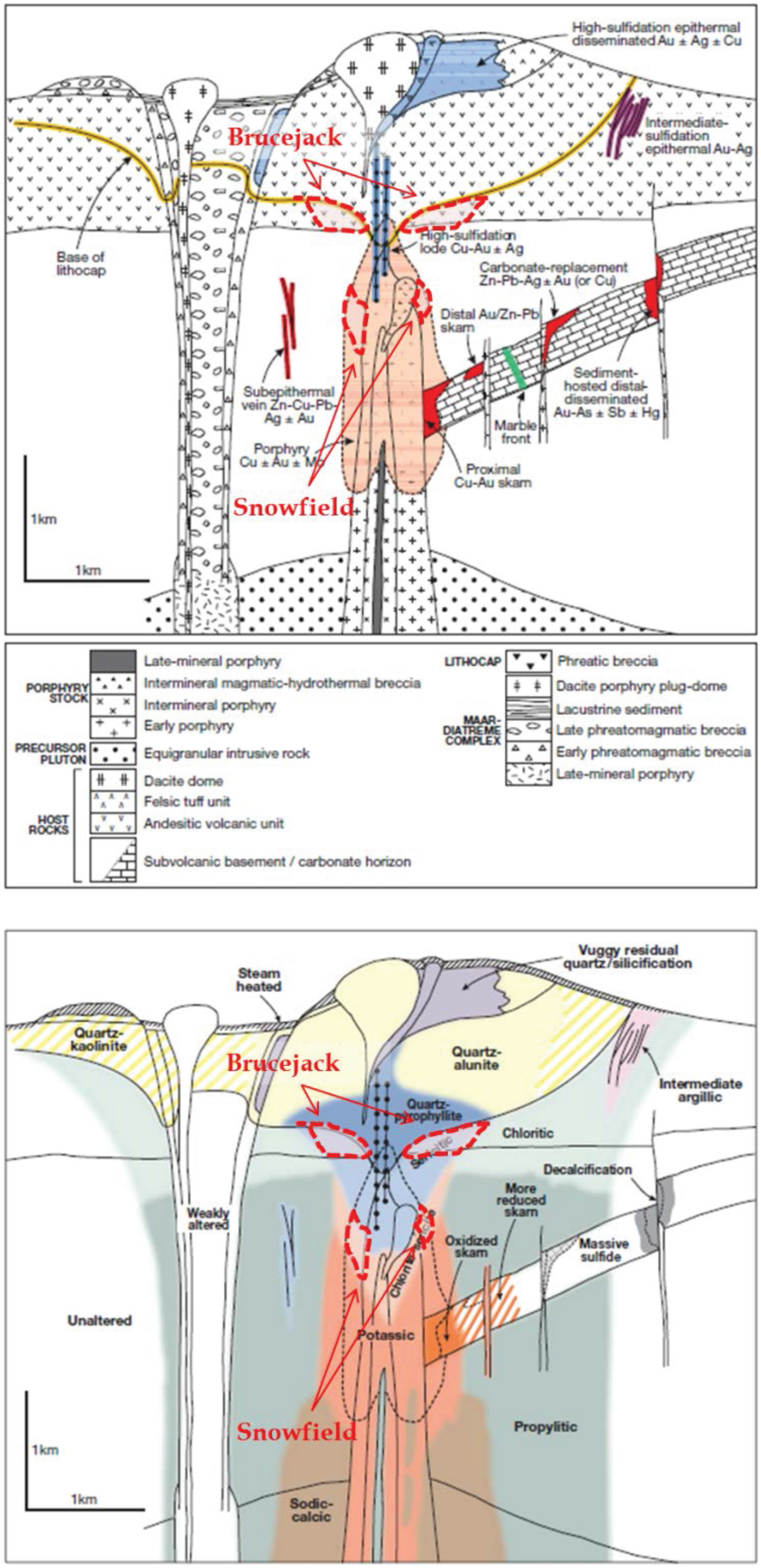
All data were composited to the dominant sample length of 1.5 m prior to analysis and estimation. Statistical analysis of the gold and silver data was carried out by lithological domain (at the VOK) and mineralized domain. Review of the statistics indicated that the grade distributions for the mineralization within the different lithologies are very similar and as a result these were combined for analysis. This is in agreement with field observations which indicate that the stockwork mineralization is superimposed on the stratigraphic sequence. The summary statistics of composite samples from all domains exhibit a strong positive skewness with high coefficient of variation and some extreme grades.

Because of the extreme positive skew in the histograms of the gold and silver grades within the high-grade domains, Snowden elected to use a non-linear approach to estimation, employing the use of indicator and truncated distribution kriging. In this approach the proportion of high grade in a block was modelled, as was the grade of the high grade portion, and the grade of the low grade portion.

The high grade population, which contains a significant number of samples with extreme grades, required indicator kriging methods for grade estimation. The low grade population was estimated using ordinary kriging on the truncated (low grade; under 5 g/t Au and under 50 g/t Ag) part of the grade distribution.

Figure 5.4-14

Brucejack Deposit Mineralization within Context of Porphyry Systems



Source: Modified after Sillitoe (2010)

Density was estimated using simple kriging of specific gravity measurements determined on sample pulps by ALS Chemex. As part of the 2012 drilling program, Pretivm selected a portion of the samples (207 samples) to undergo core density measurements in addition to the usual pulp specific gravity measurements to assess the impact of porosity on the density. A further 204 samples were collected for specific gravity and density measurements as part of the 2013 underground drilling program to increase the comparative dataset. The results of the comparison indicate that the core density is on average the same as the pulp specific gravity within the siliceous zone and 3% lower on average for all other rock types. Bulk density estimates in the final model were determined by simply factoring down pulp specific gravity estimates by 3% in all lithologies except in the intensely silicified conglomerate.

Grade estimates and models were validated by: undertaking global grade comparisons with the input drillhole composites; visual validation of block model cross sections; grade trend plots; and comparing the results of the model to the bulk sample cross cuts.

The resource classification definitions (Measured, Indicated, Inferred) used for this estimate are those published by the Canadian Institute of Mining, Metallurgy and Petroleum in their document *CIM Definition Standards* (CIM 2014).

In order to identify those blocks in the block model that could reasonably be considered as a Mineral Resource, the block model was filtered by a cut-off grade of 5 g/t AuEq. The gold-equivalent calculation used is: AuEq = Au + (Ag/53). These blocks were then used as a guide to develop a set of wireframes defining coherent zones of mineralization which were classified as Measured, Indicated, or Inferred and reported (Table 5.5-1 and Table 5.5-2).

Table 5.5-1. VOK Mineral Resource Estimate Based on a Cut-off Grade of 5 g/t AuEq - December 2013 [1, 4, 5]

Category	Tonnes (millions)	Gold (g/t)	Silver (g/t)	Contained[3]	
				Gold (Moz)	Silver (Moz)
Measured	2.0	19.3	14.4	1.2	0.9
Indicated	13.4	17.4	14.3	7.5	6.1
M + I	15.3	17.6	14.3	8.7	7.0
Inferred[2]	5.9	25.6	20.6	4.9	3.9

[1] Mineral Resources which are not Mineral Reserves do not have demonstrated economic viability. The estimate of Mineral Resources may be materially affected by environmental, permitting, legal, marketing, or other relevant issues. The Mineral Resources reported here were estimated using the Canadian Institute of Mining, Metallurgy and Petroleum (CIM), CIM Standards on Mineral Resources and Reserves, Definitions and Guidelines prepared by the CIM Standing Committee on Reserve Definitions and adopted by CIM Council.
[2] The quantity and grade of reported Inferred resources in this estimation are uncertain in nature. There has been insufficient exploration to define these Inferred Resources as an Indicated or Measured Mineral Resource and it is uncertain if further exploration will result in upgrading them to an Indicated or Measured Mineral Resource category.
[3] Contained metal and tonnes figures in totals may differ due to rounding.
[4] The Mineral Resource estimate described here is defined using 5 m by 5 by 5 m blocks in the well drilled portion of West Zone (5 m by 10 m drilling or better) and 10 m by 10 m by 10 m blocks in the remainder of West Zone and in VOK.
[5] The gold equivalent value is defined as AuEq = Au + Ag/53.

Classification was applied based on geological confidence, data quality, and grade variability. Areas classified as Measured Resources at West Zone are within the well-informed portion where the resource is informed by 5 m by 5 m or 5 m by 10 m spaced drilling. Measured Resources within the VOK are informed by 5 m by 10 m to 10 m by 10 m underground fan drilling and restricted to the vicinity of the underground bulk sample.

Table 5.5-2. West Zone Mineral Resource Estimate Based on a Cut-off Grade of 5 g/t AuEq - April 2012 [1, 4, 5]

Category	Tonnes (millions)	Gold (g/t)	Silver (g/t)	Contained[3]	
				Gold (Moz)	Silver (Moz)
Measured	2.4	5.85	347	0.5	26.8
Indicated	2.5	5.86	190	0.5	15.1
M + I	4.9	5.85	2.67	0.9	41.9
Inferred[2]	4.0	6.44	82	0.8	10.6

[1, 2, 3, 4, 5] - see notes to Table 5.5-1.

Areas classified as Indicated Resources are informed by drilling on a 20 m by 20 m to 20 m by 40 m grid within the West Zone and VOK. In addition, some blocks at the edge of the areas with 20 m by 20 m to 20 m by 40 m drilling, were downgraded to Inferred where the high grades appear to have too much influence. The remainder of the Mineral Resource is classified as Inferred Resources where there is some drilling information (and within around 100 m of drilling) and the blocks occur within the mineralized interpretation.

Areas where there is no informing data and/or the lower grade material is outside of the mineralized interpretation are not classified as a part of the Mineral Resource.

The Mineral Resource was reported above a 5 g/t AuEq cut-off grade for the VOK and West Zone (Table 5.5-1 and Table 5.5-2).

Figure 5.5-1 shows the distribution of drill holes completed for the assessment of the Project, to the end of 2012.

5.6 GEOCHEMICAL CHARACTERIZATION

Between 2011 and 2013, Pretivm completed an assessment of the metal leaching/acid rock drainage (ML/ARD) characteristics of materials that will be disturbed, excavated or exposed as a result of the planned mining activities (Appendix 5-B, Brucejack Environmental Assessment ML/ARD Baseline Report). These materials include ore, waste rock, water treatment plant solids (i.e., sludge), tailings, tailings paste backfill and various site characterization materials including overburden, construction and road (cut and fill) materials. The results of this study are presented in Appendix 5-B and summarized below.

5.6.1 Sample Selection

The Brucejack Property contains a wide range of rock types, with 24 unique rock lithologies identified by Pretivm geologists from drill core. Mapping within the Brucejack area shows many of these rock types are intensely altered and, in addition to a diverse range of mineral assemblages, adds to the difficultly in relating logged drill core to stratigraphic sequences. Pretivm developed a geological model to relate these logged lithologies to seven model units that best categorize the rock composition (Table 5.6-1). Sample material is classified as one of the seven geological model units based on geochemical assay results (i.e., Ti/V) and/or its proximity to intensely silicified rocks located within the central part of the deposit.

Proposed Brucejack mine plans describe the year-to-year development of the mine, from the Construction phase to Closure phase, using the generalized nomenclature shown in Table 5.6-1. The same classification scheme was applied to the ML/ARD program such that geochemical results and proposed management and monitoring plans may be readily applied to mine operations activities.

Figure 5.5-1
Brucejack Property
Diamond Drillhole Plan

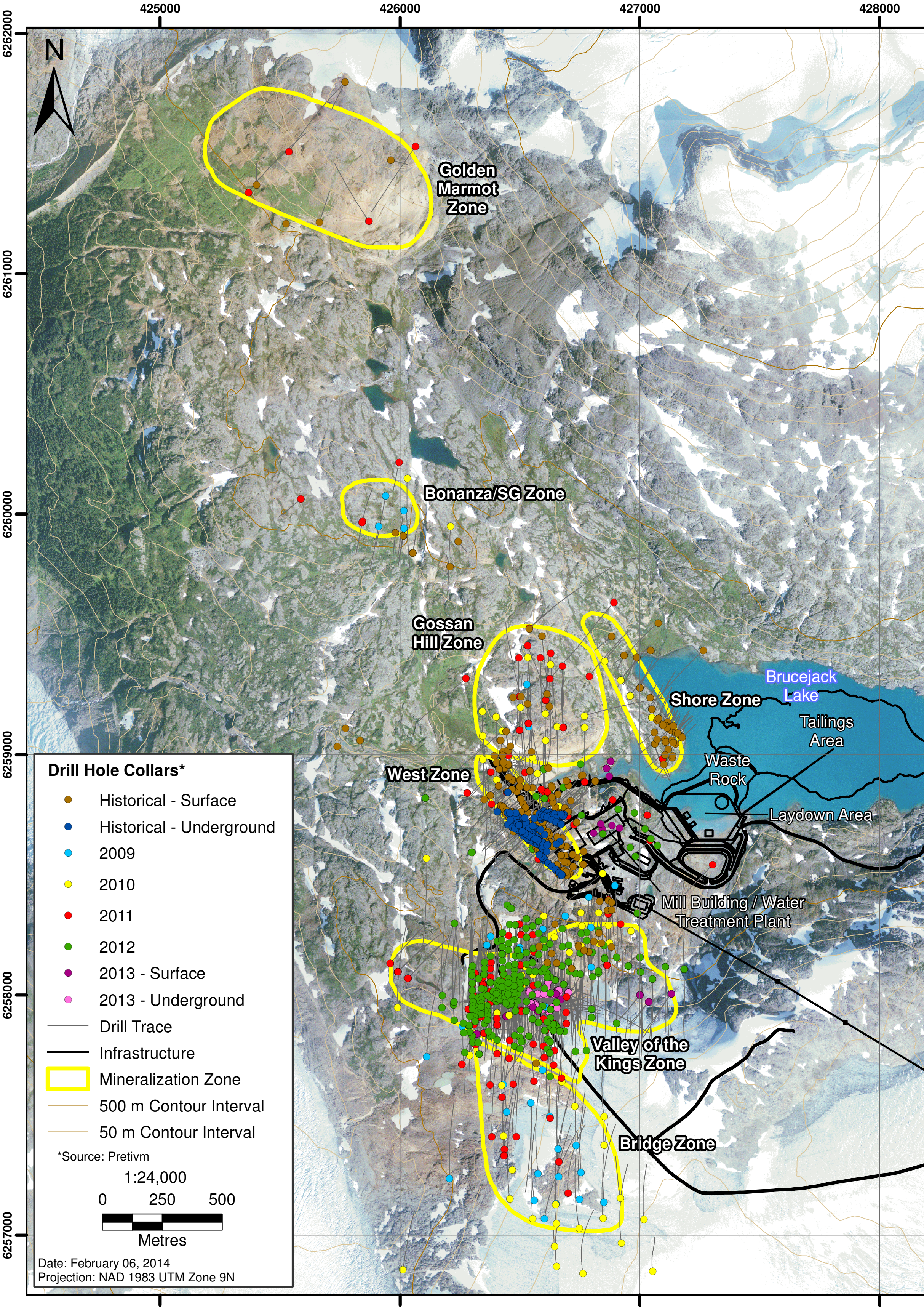


Table 5.6-1. Description of Pretivm Geological Model Units

Model Unit	Description	Sulphides
P2	Megacrystic, plagioclase, K-feldspar and hornblende phyric flow.	Pyrite with minor sphalerite and trace chalcopyrite
Fragmental	Hornblende and/or feldspar phyric latite to andesite fragmental volcanic rocks and subordinate flows with minor ash and lapilli tuff.	Pyrite with minor sphalerite and trace chalcopyrite
Conglomerate	Heterolithic boulder to course cobble conglomerate with sandstone.	Pyrite with minor sphalerite and trace chalcopyrite
Silicified Cap	Silicified rocks; typically poorly sorted heterolithic conglomerate, lesser sandstone and local mudstone; commonly includes rhyolite fragments.	Pyrite with minor sphalerite and trace chalcopyrite
Volcanic Sedimentary Facies (VSF)	Volcanically derived siltstone and sandstone with minor arenite and pebble conglomerate.	Pyrite with minor sphalerite and trace chalcopyrite
Office P1	Hornblende, feldspar phyric latite flows.	Pyrite with minor sphalerite and trace chalcopyrite
Bridge P1	Hornblende, feldspar phyric latite flows. Same general rock type as Office P1 but with a different age and geochemical signature.	Pyrite with minor sphalerite and trace chalcopyrite

The Brucejack property consists of a planned underground mine operation, whereby ore extraction from the underground workings will occur for a period of 18 years. A total of 20.7 Mt of rock will be excavated from the underground workings, of which the majority will be processed on-site by crushing, grinding, sulphide flotation and gravity concentration (Figure 5.6-1). Gold doré will be produced on-site from the gravity concentrate while the flotation concentrate will be trucked off-site for further processing.

Approximately 2.62 Mt (62%) of the waste rock produced will be returned to the underground and the remaining 1.58 Mt (38%) will be deposited in Brucejack Lake, predominantly during the Construction phase (Figure 5.6-1). These numbers from the 2014 Feasibility Study Update (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC) differ from the more conservative numbers (larger total volume produced over a longer mine life and smaller proportion stored underground) from the 2013 Feasibility Study (Tetra Tech 2013) that were used in the effects assessment. The excavation of 4.2 Mt of waste rock includes material from all seven geological model units (Figure 5.6-2). Ranked in order of decreasing contribution to the waste rock volume produced by underground mine operations, the units are: Volcanic Sedimentary Facies (VSF) – Fragmental – Conglomerate – Bridge P1 – Office P1 – Silicified Cap – P2. Each geological model unit was shown to contain many unique rock types and, to aid in identifying possible lithology-based trends, the 24 logged lithologies were reorganized into nine generalized lithology groups: felsic volcanics, metasediments, conglomerate, andesite, mafic volcanics, porphyry, siliceous rocks, granitoids and metavolcanics (as described in Appendix 5-B, Brucejack Environmental Assessment ML/ARD Baseline Report).

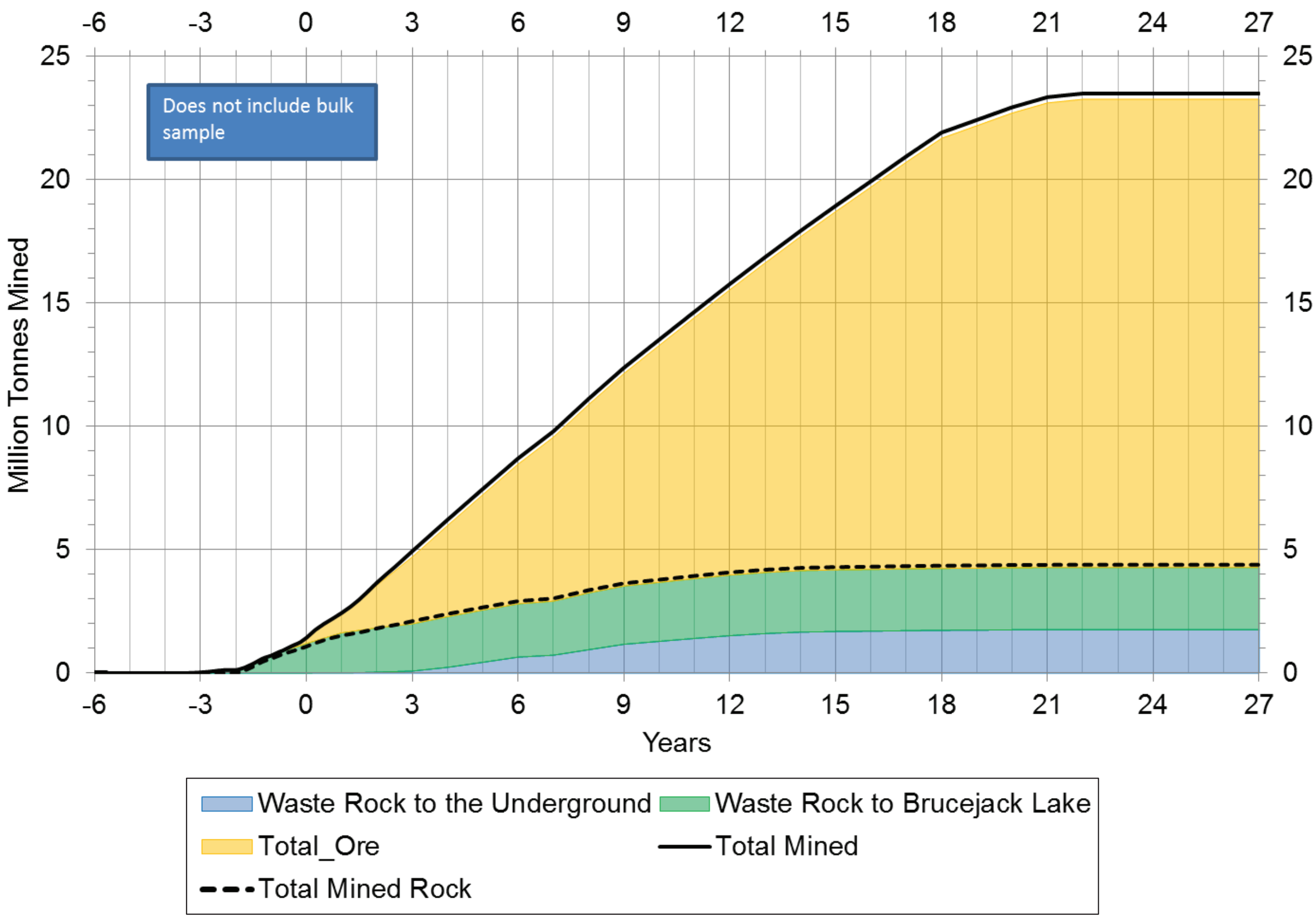
Approximately 7.12 Mt (45%) of the total produced flotation tailings will be deposited in the underground workings as paste backfill. The remaining tailings (8.63 Mt or 55%) will be piped as fluidized tailings to the bottom of Brucejack Lake. These numbers from the 2014 Feasibility Study Update (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC) differ from the more conservative numbers (greater total volume produced over a longer mine life) from the 2013 Feasibility Study (Tetra Tech 2013) that were used in the effects assessment.

5.6.2 Waste Rock

Waste rock samples selected for the ML/ARD baseline characterization were submitted for static testing, shake flask extraction (SFE) tests, and kinetic testing.

Figure 5.6-1

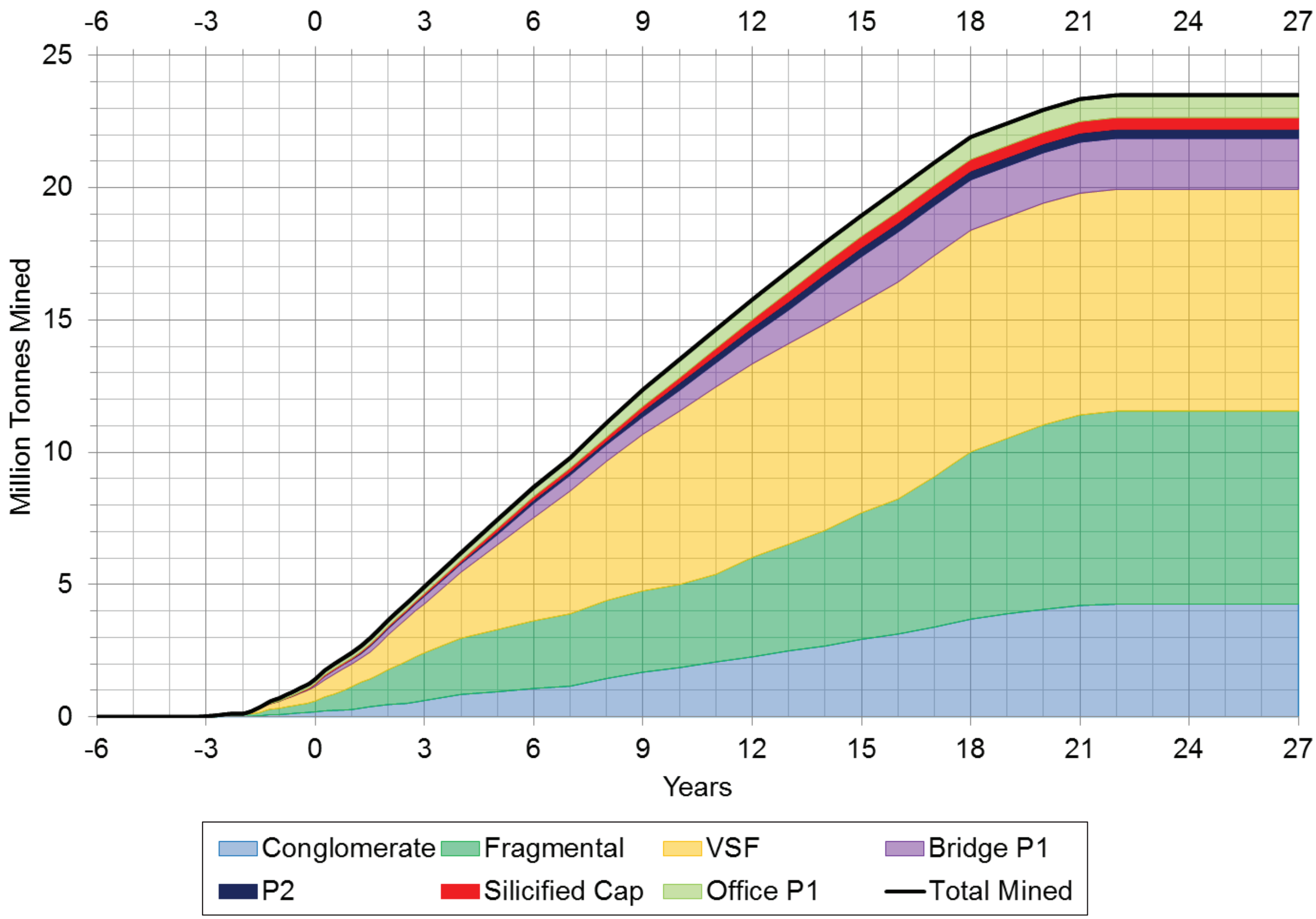
Total Ore and Waste Rock Amounts from Brucejack Underground Workings



Source: BGC Engineering Inc.

Figure 5.6-2

Contributions from Geological Model Units to Total Generated Waste Rock



Source: BGC Engineering Inc.

5.6.2.1 Static Testing

A large number (N=428) of collected waste rock samples were submitted for Acid-Base Accounting (ABA) and elemental composition tests. A frequency analysis was performed on selected parameters from these tests to characterize their population distribution and statistical variation. Notably, all seven geological model units were included in this static sample suite (Table 5.6.2), in addition to materials from the nine generalized lithology groupings (Section 5.6.1).

Table 5.6-2. Composition of Static Test Samples Submitted for ML/ARD Characterization

Model Unit	N_{tot}	N_{lith}	Major Lithology Groupings
Conglomerate	61	9	Conglomerate (25), Felsic Volcanics (13), Andesite (11)
Fragmental	128	9	Andesite (46), Felsic Volcanics (35)
(VSF)	180	8	Meta-sediments (68), Felsic Volcanics (56), Andesite (19)
Bridge P1	17	4	Porphyry (12)
P2	20	5	Porphyry (7), Conglomerate (5)
Silicified Cap	6	2	Felsic Volcanics (3), Siliceous Rocks (3)
Office P1	16	2	Porphyry (15)

Notes:
N_{tot} = number of static test samples.
N_{lith} = number of generalized lithology groupings.

<u>Acid-Base Accounting</u>

Frequency analyses of Neutralization Potential Ratio (NPR) values of waste rock samples from the various geological model units show that Office P1 is the only unit that contains predominantly (84%) non-potentially acid generating (non-PAG) waste rock (NPR greater than 2). The waste rock from the other geological model units is characterized as predominantly (77% to 100%) PAG material (NPR ≤ 2).

The VSF, Fragmental, and Conglomerate units account for 84.8% of the total generated waste rock and contain 76.5 to 85.0% PAG material. The three geological model units also constitute the majority of waste rock destined for Brucejack Lake (87.6%) and returned as backfill to the underground mine (86.7%).

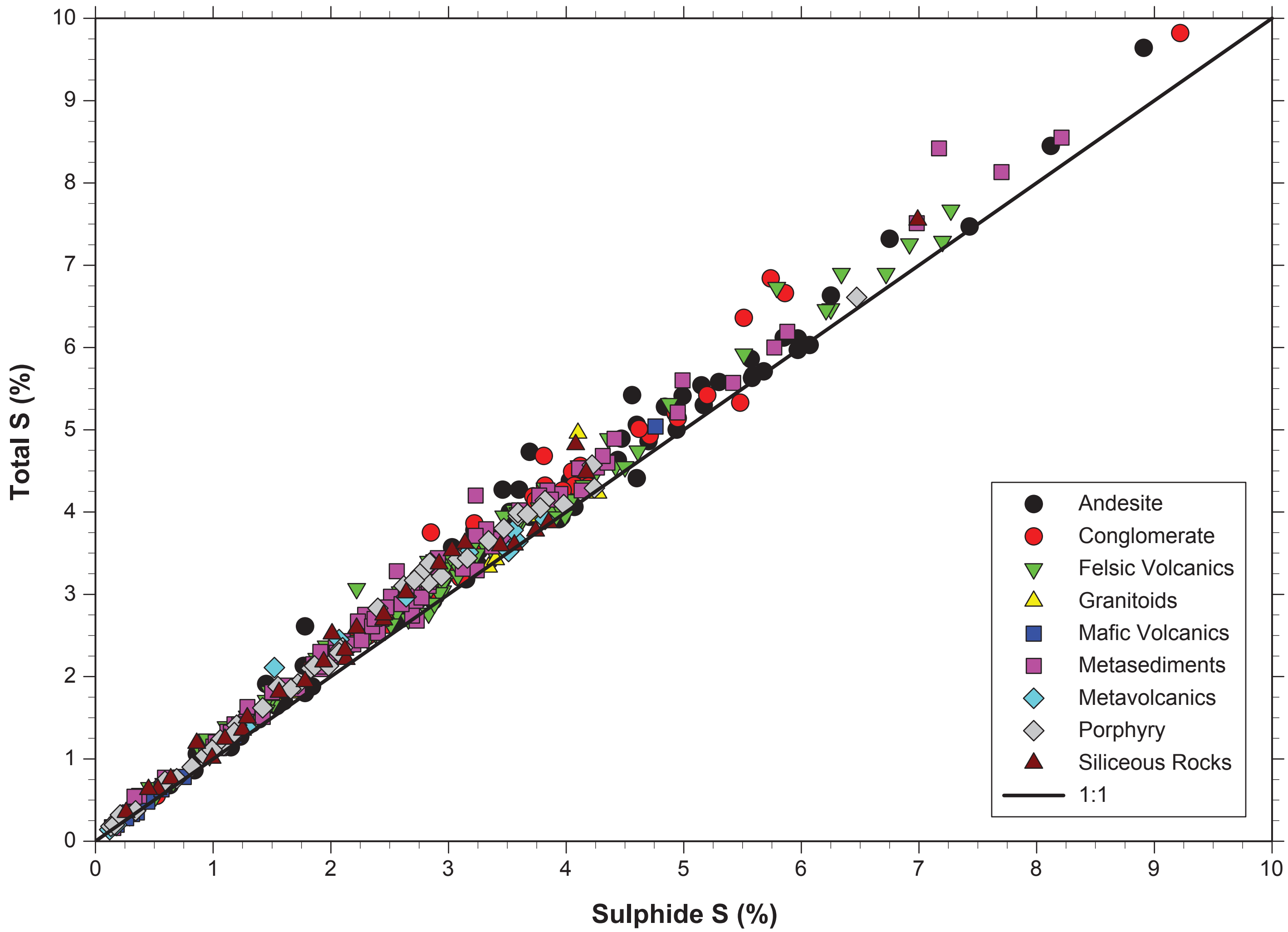
In general, paste pH values are circumneutral to alkaline and closely related to the presence of carbonates. Sulphide is the main sulphur species (greater than 90%) and sulphate-S and insoluble-S make up a relatively small component of the total-S content of most samples (Figure 5.6-3). The presence of highly insoluble sulphate minerals (barite, anglesite) or elemental S (S^o) is suggested as likely contributors to those select scenarios of high insoluble-S amounts (12 to 20%).

A comparison between Sobek Neutralization Potential (Sobek NP) and Carbonate Neutralization Potential (CaNP) values indicates carbonates are the main NP contributors in Brucejack waste rock. Iron carbonates have been identified by mineralogical analyses and are suggested to contribute to higher observed CaNP values, relative to Sobek NP values, in several logged lithologies (andesite, porphyry). Comparison of median NPR and Net Neutralization Potential (NNP) values indicates Office P1 is the only geological model unit with a significant excess of NP.

Similar to frequency analyses, plots of NP against Acid Potential (AP) values show that most of the samples are characterized as PAG material (Figure 5.6-4). In regards to lithology groups, all rock types are dominantly PAG material (66 to 92%) with the exception of mafic volcanics that are dominantly (83%) non-PAG material. Comparable results and trends from the seven geological model units and nine lithological groups indicate there is considerable overlap between ABA parameters. The absence of a clear distinction between these groupings makes it difficult to propose recommendations for waste segregation based on ABA testing and parameter values specific for lithology groups or geological model units.

Figure 5.6-3

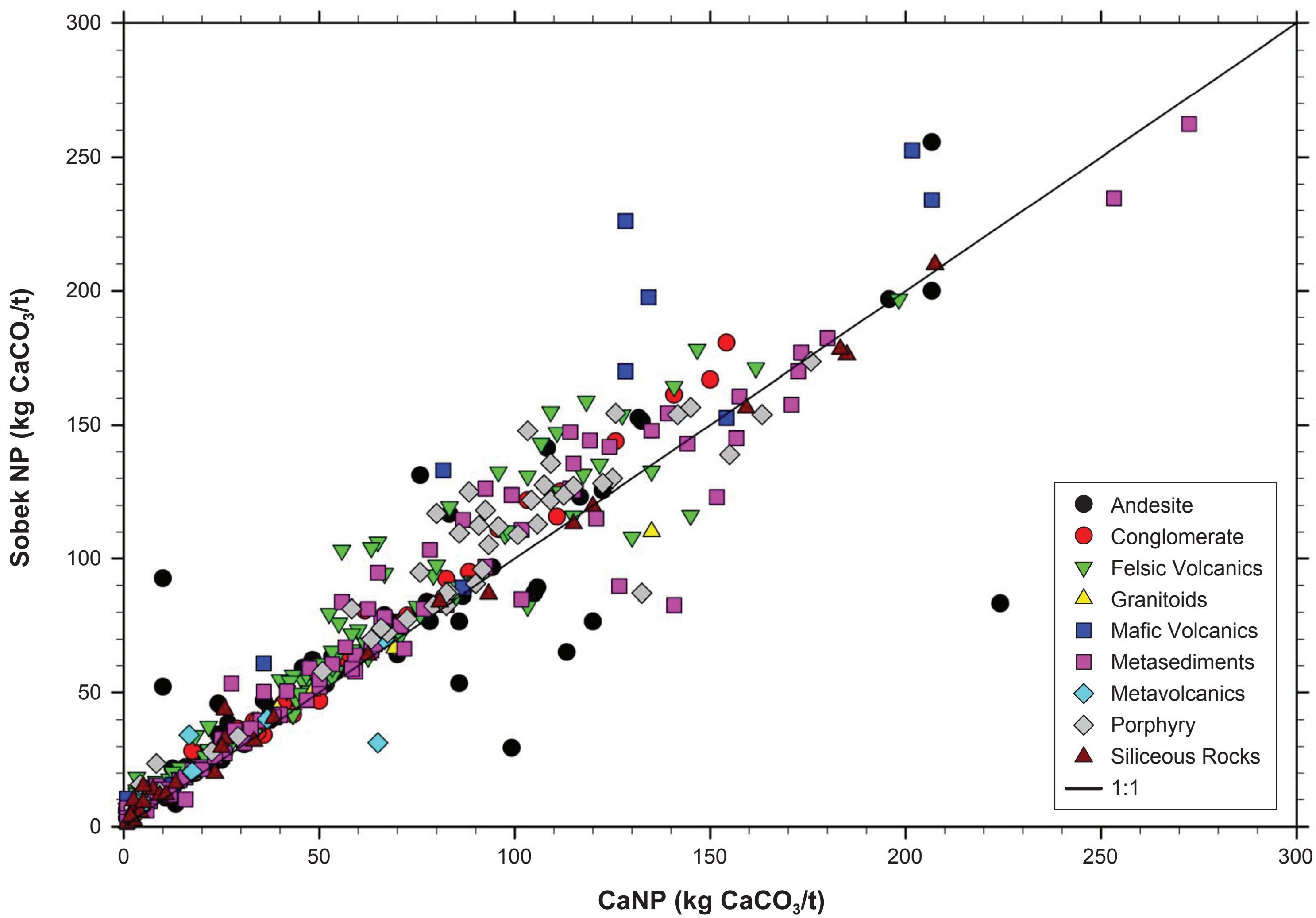
Comparison of Total-S (%) versus Sulphide-S (%) from Waste Rock Samples



Source: BGC Engineering Inc.

Figure 5.6-4

Comparison of Sobek NP Values versus CaNP Values from Waste Rock Samples



Source: BGC Engineering Inc.

Frequency analyses of selected metal concentrations (As, Cd, Cu, Pb, Zn) of waste rock samples from the various geological model units show the highest metal concentrations generally occur in the Silicified Cap and irregularly in the VSF and Conglomerate units. Office P1 and P2 have the lowest metal concentrations.

The total elemental concentrations of waste rock from geological model units and lithology groups were compared to concentrations in non-mineralized rock (i.e., continental crust). Geological model units and lithology groups were considered to have a significant elemental enrichment if the median values of the elemental concentrations in waste rock were 10 times higher than continental crust values. Significant enrichment was noted for Ag, As, Cd, Mo, Pb, Sb, Se, and Zn in waste rock from most geological model units and from most lithology groups. Similar to frequency analyses results pertaining to Silicified Cap units, the siliceous rock lithology (including siliceous veins and breccias) present the highest metal enrichment for several metals (Ag, Sb, Cd, and Mo).

5.6.2.2 Shake Flask Extractions

Shake flask extracts provide an estimate of the soluble constituents of waste rock that may be released with waste rock deposition in Brucejack Lake. Shake flask tests were conducted on 47 waste rock samples from the Project, representing the seven geological model units. Shake flask test results for only three of the 47 tested waste rock samples showed elevated metal concentrations (greater than 1% of total metal content). Considering the reported metal content of waste rock, As, Sb, Ag, and Cd may be a concern for metal leaching when waste rock is exposed to water.

5.6.2.3 Kinetic Testing

Several kinetic tests, including humidity cells, subaqueous columns and field barrels, were conducted to investigate the weathering and metal leaching of waste materials. Optimal weathering conditions are simulated in humidity cells, whereas subaqueous conditions of proposed waste disposal strategies are simulated in the column experiments. The impact of equilibrium-controlled secondary mineral reactions on drainage chemistries is assessed with field barrels. Generally, a distinction can be made between the initial leaching of solutes at the beginning of the kinetic test (initial 3 to 5 weeks) and the final leaching at the end of the kinetic test (final 5 to 10 weeks).

<u>Humidity Cells</u>

A total of 36 humidity cells were implemented and leachate data were collected from test periods ranging from 26 to 61 weeks. Leachates from the Fragmental and Silicified Cap units have the lowest average pH, as some of these humidity cells produced acidic pHs within months of test initiation. For all other geological model units the average pH is circumneutral. Relative elevated metal concentrations of As, Cd, Cu, Pb, Se and Zn are often observed in Fragmental and Silicified Cap leachates. The (final) leaching rates of Fe, Cd, Cu, Pb, and Zn are highest in the Fragmental and Silicified Cap humidity cells. Oxyanions (As, Sb, and Se) show a different leaching behavior than transition metals, as they are more mobile at neutral pH conditions.

Leaching rates of SO_4, Al, Sb, As, Mo, and Se generally show a decreasing trend over the duration of the humidity cell test (initial rates are greater than final rates). An opposite trend is observed for Cd, Co, Cu, Fe, Pb, and Zn.

The shortest lag times (less than 15 years) in the humidity cell tests are estimated for waste rock from the Fragmental (3 of 10 HCs), VSF (2 of 13 HCs), Silicified Cap (1 of 2 HCs) and Conglomerate (1 of 3 HCs) units. These geological units correspond to andesite (2 of 6 HCs), felsic volcanics (3 of 7 HCs), siliceous rock (1 of 6 HCs) and conglomerate/arenite (1 of 1 HCs). Materials with the shortest lag times typically have paste pH values below 7, very low NP values (5 to 15 kg $CaCO_3$/t) and high sulphide-S values (3 to 8%), and are expected to weather readily and quickly.

Subaqueous Columns

Material from the geological model units representing the largest expected waste rock volumes (according to current mine plans) were used in the two subaqueous columns (Fragmental [andesite] and VSF [felsic volcanics]). Leachate results from these columns show several metals with elevated concentrations (As, Sb, Mo, Se, and Zn), based on median values.

Estimated lag times from the two subaqueous columns are highly variable (274 and 71 years). However, these estimates are based on sulphate concentrations that have not yet reached their final values. Therefore, considering that the column tests are ongoing and have not yet attained equilibrium, these estimated lag times should be interpreted with caution.

Field Barrels

Eight field barrels were constructed using five (of seven) geological model lithologies; Fragmental, VSF, P2, and Bridge P1. Among those elements with stable or decreasing leachate concentrations trends, As and Se are the only solutes with concentration values above maximum CCME guidelines and are considered parameters of concern (POCs). The metals Cu, Cd, and Zn also show increasing trends and are considered to be likely POCs for waste rock drainage in unsaturated conditions.

5.6.3 Flotation Tailings, Sludge, Paste, and Ore

Over the operating life of mine, 16.55 Mt of ore will be extracted from underground operations and will produce 15.76 Mt of flotation tailings. From these flotation tailings, approximately 7.12 Mt (45%) will be returned as paste backfill to the underground and 8.63 Mt (55%) will be conveyed to Brucejack Lake as fluidized tailings. These numbers from the 2014 Feasibility Study Update (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC) differ from the more conservative numbers (greater total volume produced over a longer mine life) from the 2013 Feasibility Study (Tetra Tech 2013) that were used in the effects assessment.

Sludge will be produced from the interim (or Construction phase) water treatment plant as well as the Operation phase water treatment plant. Sludge samples submitted as part of the ML/ARD baseline program are representative of the detrital component of future sludge materials. The remaining content (i.e., secondary precipitates) is specific to the treatment method used in the water treatment plant and samples will be taken at the operational onset of either water treatment plant. These details can be found in the ML/ARD Management Plan (Section 29.10). Similar to waste rock, tailings, sludge, paste and ore material were submitted for static and kinetic testing.

5.6.3.1 Static Testing

Acid-Base Accounting

In contrast to the ore and sludge, the acidifying potential of the tailings and uncemented paste is insignificant (AP is greater than 2 kg $CaCO_3$/t). The Sobek NP of these samples varies between 60 and 90 kg $CaCO_3$/t, with the exception of high-grade ore and cemented paste materials that show the highest neutralization potential (165 kg $CaCO_3$/t) and the highest carbonate contents. Ore and sludge materials are the only samples with NPR values smaller than 2 and are characterized as PAG materials, whereas tailings samples and paste samples are non-PAG materials.

Elemental Composition

The elemental composition of ore, tailings, sludge and paste shows enrichments of Ag, As, Cd, Mo, Sb, Mn, and possibly Se, relative to non-mineralized rock. Cu and Zn are only selectively enriched in the ore and sludge materials, whereas Cr and Ni present enriched elemental abundances in tailings and paste materials only. Sludge material presents maximum values of Cd, Pb and Zn, relative to other materials.

5.6.3.2 Shake Flask Extractions

The tailings, raw paste and sludge samples have circumneutral pH values (pH ~ 7.5) while the ore samples have alkaline pH values (pH 8.5 to 9.0). The cemented paste sample had a high pH value (pH 11), which may be attributed to the addition of a thickener to cure tailings materials. The alkalinity of sample extracts follows a similar trend as pH, whereby tailings, raw paste, and sludge samples have similar alkalinities, and ore and cemented paste samples present higher and the highest (respectively) measured alkalinity values. Sulphate concentrations are low (24 to 86 mg/L) for most samples, with the exception of a 1.5 times to 5 times higher value from the cemented paste sample (114 mg/L) and up to 24 times higher values for sludge. The higher sulphate in cemented paste may be a result of gypsum dissolution, which may have formed during the tailings curing process and supported by higher sulphate-S values from ABA results. Sludge samples present modest sulphate-S values (~ 10% of total S) and its significantly finer grain-size may result in a higher reactivity (sulphate from sulphide dissolution).

5.6.3.3 Kinetic Testing

Humidity Cells

The tailings material was tested in two humidity cells (T1 and T2). Parameters of concern in the leachates from these humidity cells are identified as As, Sb, Mo, and Se. The concentrations of these oxyanions maintain relatively high values throughout the test and during the final phase when concentrations generally approach constant values. Similarly, leachate rates from oxyanions (As, Sb, Mo, and Se) are the highest for both initial and final phases, in addition to Al and Fe.

Comparable to tailings, static test results show an extremely low AP. It is evident from these kinetic tests that tailings-AP will be depleted prior to the exhaustion of its neutralization potential. As such, tailings material used in humidity cell tests is not likely to generate ARD conditions.

Subaqueous Columns

The tailings material was tested in two subaqueous columns (Column 3 and 5). Similar to the leachate chemistry from tailings in the humidity cells, concentrations of As, Sb, Mo, and Se are often elevated in the leachate from the columns. Estimated lag times of subaqueous columns are such that they will never generate ARD conditions, which is comparable to results from humidity cell tests bearing tailings material.

5.6.4 Site Characterization Materials

A site characterization program was designed to assess the ML/ARD characteristics of surface materials at (1) the plant site (plant foundation, overburden and roads in the surrounding mine area); (2) the proposed air strip (Bowser Aerodrome); (3) the access road connecting Wildfire Camp to the Brucejack camp; (4) the proposed quarry site (Figures 5.6-5 to 5.6-7; also Drawings 3 to 5 in BGC Engineering Inc. [2014a] report).

Forty samples were taken from the plant site area (Figure 5.6-6) and results from static testing present a wide range of ABA characteristics. Sulphide-S concentrations vary from below detection (less than 0.01%) to 13.6 % and median values of 0.29%. NP also varies significantly, with values varying from below detection (less than 0.5 kg $CaCO_3$/t) to 168 kg $CaCO_3$/t. This high variability in NP and AP contributed to a large range in NPR values, from 0.6 to 998. Paste pH values are generally between 7.5 and 9.5, with the exception of a few lithologies. Arenite, latite flow and intermediate volcanic assemblages present frequent occurrences of acidic paste pH values (pH 4.0 to 6.5), which may be attributed to the absence of carbonates and significant sulphate values. Most samples showing acidic paste pHs were obtained from overburden material.

From these results, 23 (of the 40) samples from the plant site present NPR values less than 2.0 and are characterized as PAG material. Distinct trends between NPR values and lithology were not observed; however, results suggest that caution should be exercised when removing weathered overburden materials.

The majority of access road samples (Figure 5.6-7) have NPR values greater than 2.0 and are generally considered non-PAG materials. Shale material poses the greatest risk to ARD as over half of the samples show NPR values below 2.0. Samples taken from the aerodrome and quarry are characterized as non-PAG, which is likely attributed to low sulphide-S values and high buffering capacities.

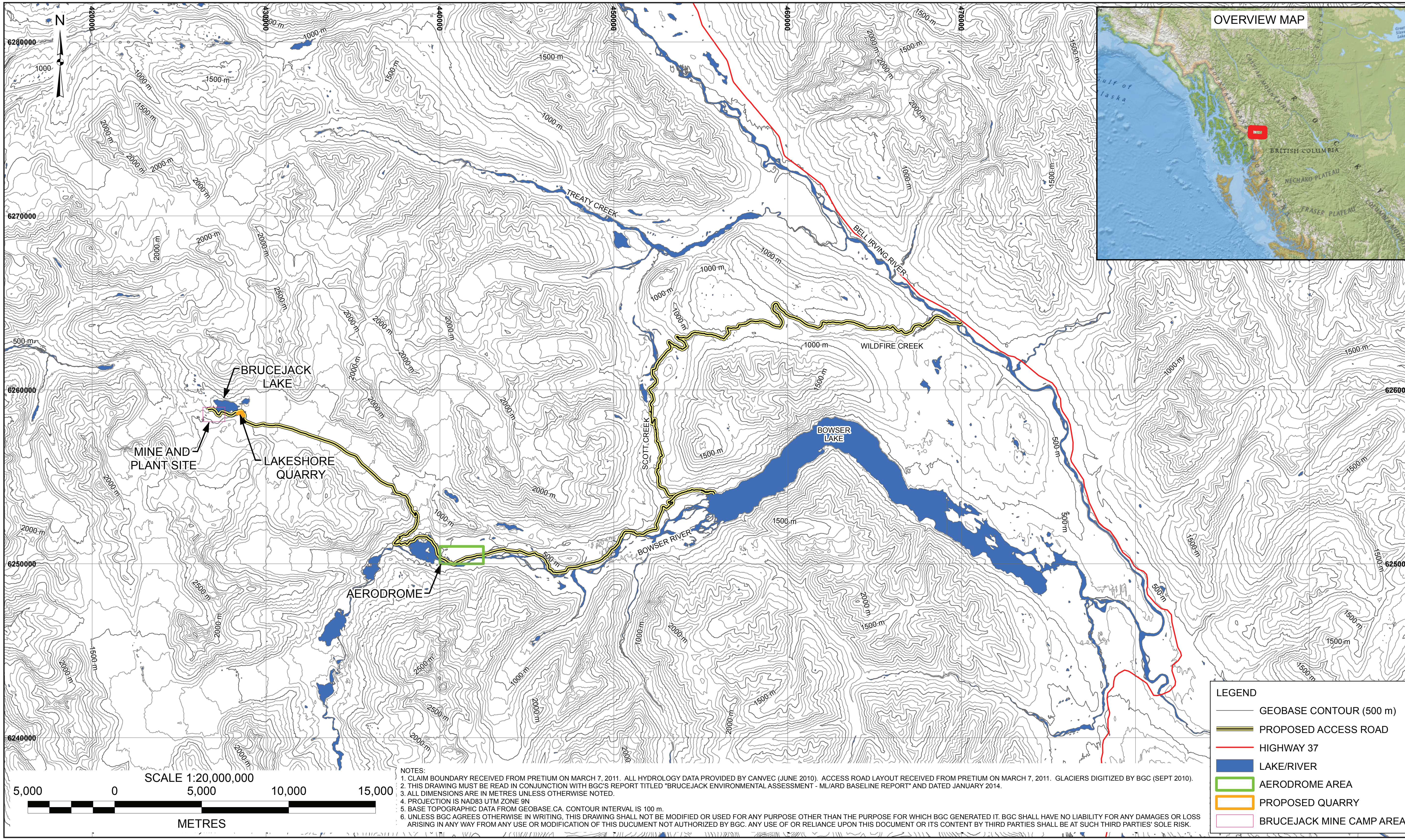
The metals As, Ag, Hg, and Sb are found at high concentrations in almost all lithologies sampled. The metals Mo, Pb, Zn, Cd, and Mo are found at moderate to high concentrations in many samples while exceedances of Cr and Ni were generally limited to sedimentary assemblages (i.e., sandstone, mudstone, and shale).

5.6.5 Main Conclusions

The main conclusions of the geochemical characterization of the materials affected by the planned mining activities can be summarized as follows:

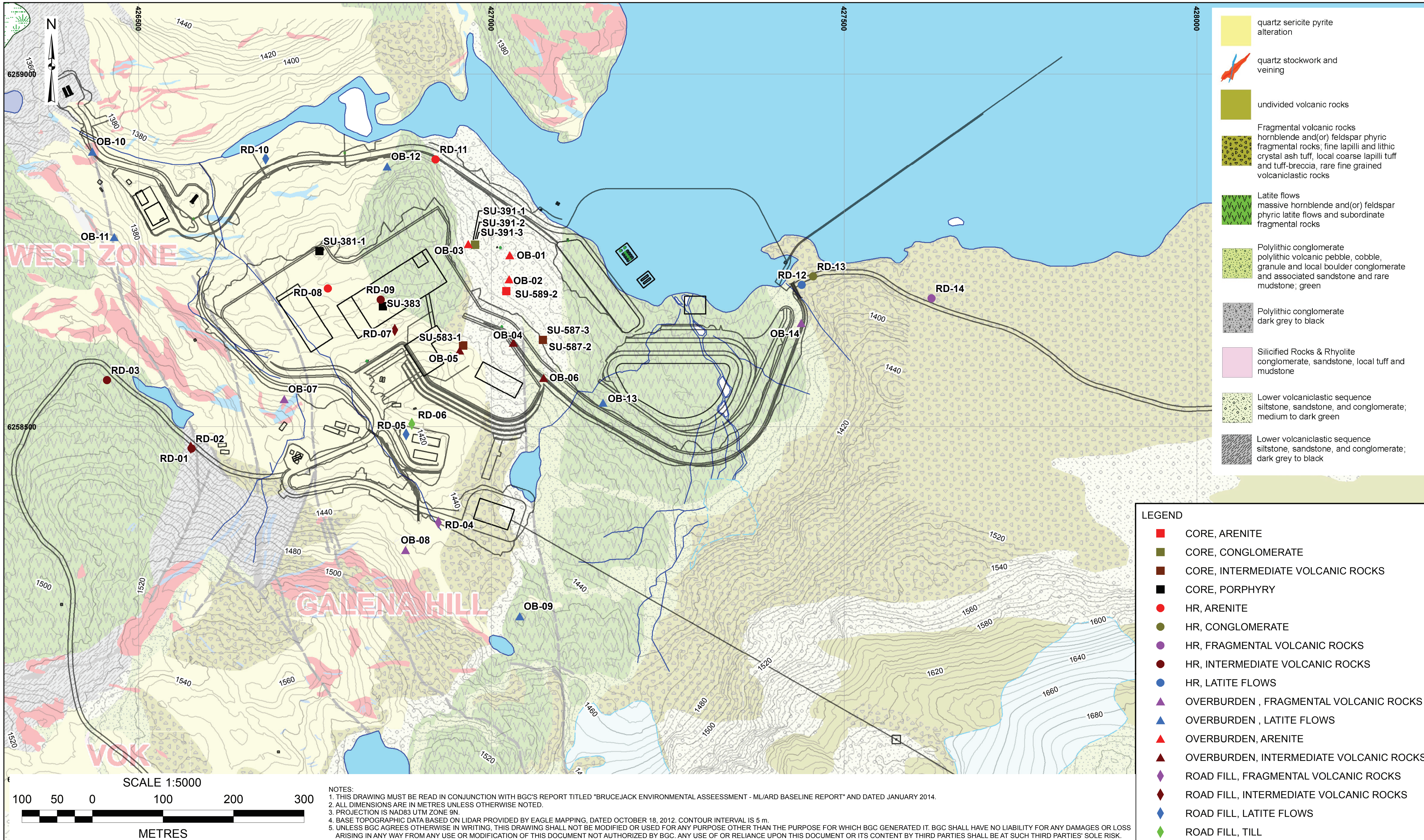
- The ABA assessments of waste rock according to both geological model units and lithology groupings show that the majority of waste rock at the Project is PAG material, with the exception of one geological model unit and one lithological group. Specifically:
  - the Office P1 unit contains predominantly non-PAG rock, as per results from frequency analyses conducted on waste rock static tests; and
  - mafic volcanics are generally non-PAG material, as 83% of samples submitted for static testing present NPR values greater than 2.
- The VSF, Fragmental, and Conglomerate units account for 85% of the total generated waste rock and contain 77 to 85% PAG material. These three geological model units constitute 87 and 88% of the waste rock destined for the underground mine and Brucejack Lake, respectively.
- Due to the absence of a clear distinction in ABA characteristics between lithology groups or geological units, it is difficult to propose recommendations for waste rock segregation.
- Materials with the shortest lag times (less than 15 years) typically have paste pH values below 7, very low NP values (5 to 15 kg $CaCO_3$/t), and high sulphide-S values (3 to 8%) and weather readily and quickly.
- The elements As, Cd, Cu, Pb, Se, and Zn are considered POCs, based on leachate concentrations from humidity cells and field barrels containing waste rock.
- Ore and sludge samples are characterized as PAG materials, whereas tailings and paste samples are considered non-PAG materials.
- Compared to non-mineralized rock, Ag, As, Cd, Mo, Pb, Sb, Mn and possibly Se are enriched in the ore, tailings paste and sludge. Cu and Zn are enriched in ore and ore and sludge (respectively). Cr and Ni are enriched in tailings and paste. Sludge contains the highest enrichments of Cd, Pb, and Zn (relative to tailings, paste, and ore).
- The concentrations of dissolved Sb, As, Mo, and Se in the shake flask extracts of ore, tailings, paste, and sludge are relatively high and may be of concern when tailings are discharged into Brucejack Lake. Sludge material presents the highest concentrations of Ag and Cd and may be of concern during lake deposition.
- Tailings in the humidity cells and subaqueous column tests are not expected to generate ARD.

Figure 5.6-5
Overview of Location of Brucejack Site Characterization Samples



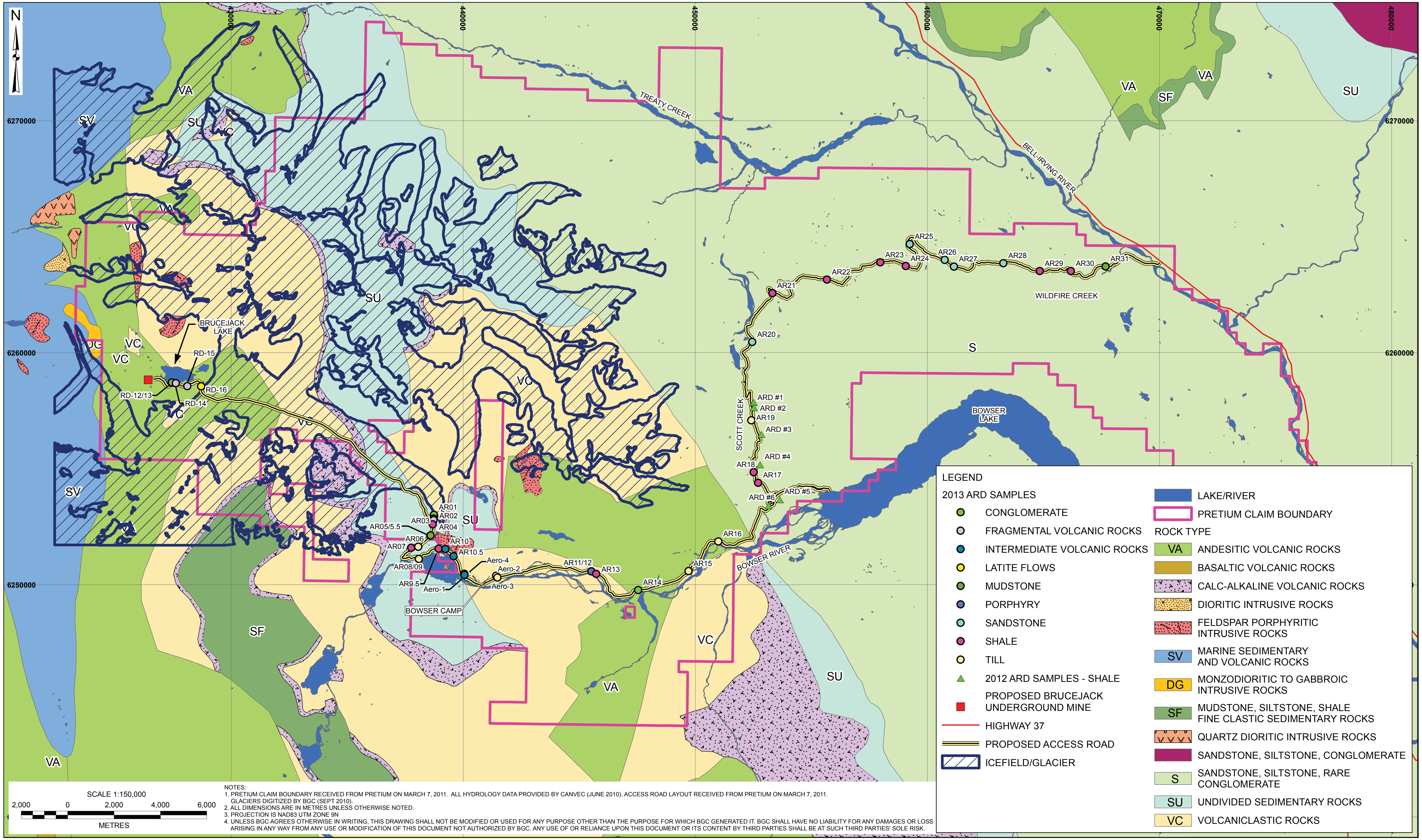
Source: BGC Engineering Inc. (2014).

Figure 5.6-6
Location of Brucejack Plant-Site Samples



Source: BGC Engineering Inc. (2014).

Figure 5.6-7
Location of Site Characterization Samples along Access Road and Aerodrome



Source: BGC Engineering Inc. (2014).

- POCs in the leachates from humidity cells and subaqueous columns bearing tailings are As, Sb, Mo, and Se.
- Almost 60% of the site characterization samples collected from the mine site are PAG material.
- All aerodrome and quarry samples and the majority of access road samples are non-PAG material. Shale material along the access road poses the greatest risk to ARD as over half of the shale samples are characterized as PAG material.

5.7 CONSTRUCTION

5.7.1 Construction Overview

Pretivm has developed a comprehensive Project Execution Plan (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC) that includes consideration of health, safety, environmental, and security issues; management procedures; Project scheduling and reporting; allocation of responsibilities; risk management; engineering; procurement; contract management; waste management; equipment supply; maintenance and operation; and communication and commissioning.

As part of the Project Execution Plan, Pretivm will design and construct the Project to meet the requirements of applicable BC and Canadian environmental and safety standards and practices. Pretivm will develop and implement a fully-integrated health, safety, and environmental (HSE) program. Pretivm and its contractors will be responsible for providing leadership and committing to the highest HSE standards and values.

HSE practices will be developed by using a high level of communication, motivation, and involvement including alignment with site contractors on topics such as safety training, occupational health and hygiene, hazard and risk awareness, safe systems of work, and job safety analysis. The Project team will incorporate HSE as key criterion in the design, constructability, and operability of each facility and major area.

Pretivm already has a suite of written plans and procedures in place for site activities related to the current exploration program. These plans will form the basis of new plans to be in place for the Construction phase, including the construction management plan, and which will be further modified throughout the life of the Project to address Operation phase and Closure phase activities.

There will be two main facets to the Construction phase of the Project: development of the underground mine, and development of on-site and off-site surface facilities. The exploration road will be used for access and will require upgrades.

Figure 5.7-1 illustrates a conceptual Project construction schedule. Note that the years indicated on this figure are construction years rather than calendar years.

5.7.2 Pre-production Underground Development

Pre-production underground development will occur over an approximately 24-month timeframe before commercial production is achieved. Development drive ore produced during this period will be hauled directly to a lined surface stockpile (Figure 5.1-2) pending commissioning of the conveyor system. Crushing of this early ore will be performed on surface at the pre-production ore storage pad once the mill is operational. The stockpile will contain a maximum of about 280,000 m^3 of ore. The stockpile will be benched, with 6 m-high and 5-m-wide benches and 2:1 slopes. Geotechnical assessment of the ore storage stockpile/waste rock transfer site is being completed in the summer of 2014 and will provide information on foundation conditions including foundation angle and soil properties, a feasibility level geotechnical stability assessment including preliminary factor of safety, and a conceptual plan for any proposed instrumentation or monitoring.

Figure 5.7-1. Conceptual Construction Schedule

The development strategy targets the VOK upper block as the first priority, followed by the more distant middle and lower blocks to sustain production. Development and construction of significant underground mine infrastructure including the declines, 1,330 Level workshop area, and crusher will be accomplished in parallel with the development of the VOK orebody.

The upper elevations of the West Zone and the VOK Zone bulk sample area on the 1,345 Level are currently accessible via the existing West Zone portal. The infrastructure development program will utilize this existing development, effectively developing the mine from the bulk sample access drive.

Development of the West Zone will be deferred until the second half of the mine life, given the significantly lower-grade of mineralization.

The first stopes will be extracted between the 1,200 Level and 1,350 Level of the VOK Zone. Figure 5.7-2 illustrates the extent of development required for the main stope production between the 1,200 and 1,380 levels. Total development of 12,728 lateral metres and 947 vertical metres is planned in the first 24 months. Up to 627 m/month of development advance will be required at the peak activity level with an average rate of 460 m/month and 605 m/month in years -2 and -1 respectively.

Critical path pre-production activities include:

- access development to the top and bottom of the crusher chamber, excavation and support of the crusher chamber, and installation of the crusher;
- decline development to the 1,200 Level, development of the 1,200 Level, and continuation of ventilation raise VR1 from 1,200 to 1,350 to establish a ventilation circuit in the lower part of the mine;
- twin decline development from surface and underground to allow the installation of the portal structure, main ventilation fans and underground conveyor system;
- excavation and construction of the sump, maintenance workshops, magazine, fuel bay, and other ancillary installations;
- development of 1,200, 1,230, 1,350 and 1,380 levels including ventilation raise VR3 to allow commencement of stoping.

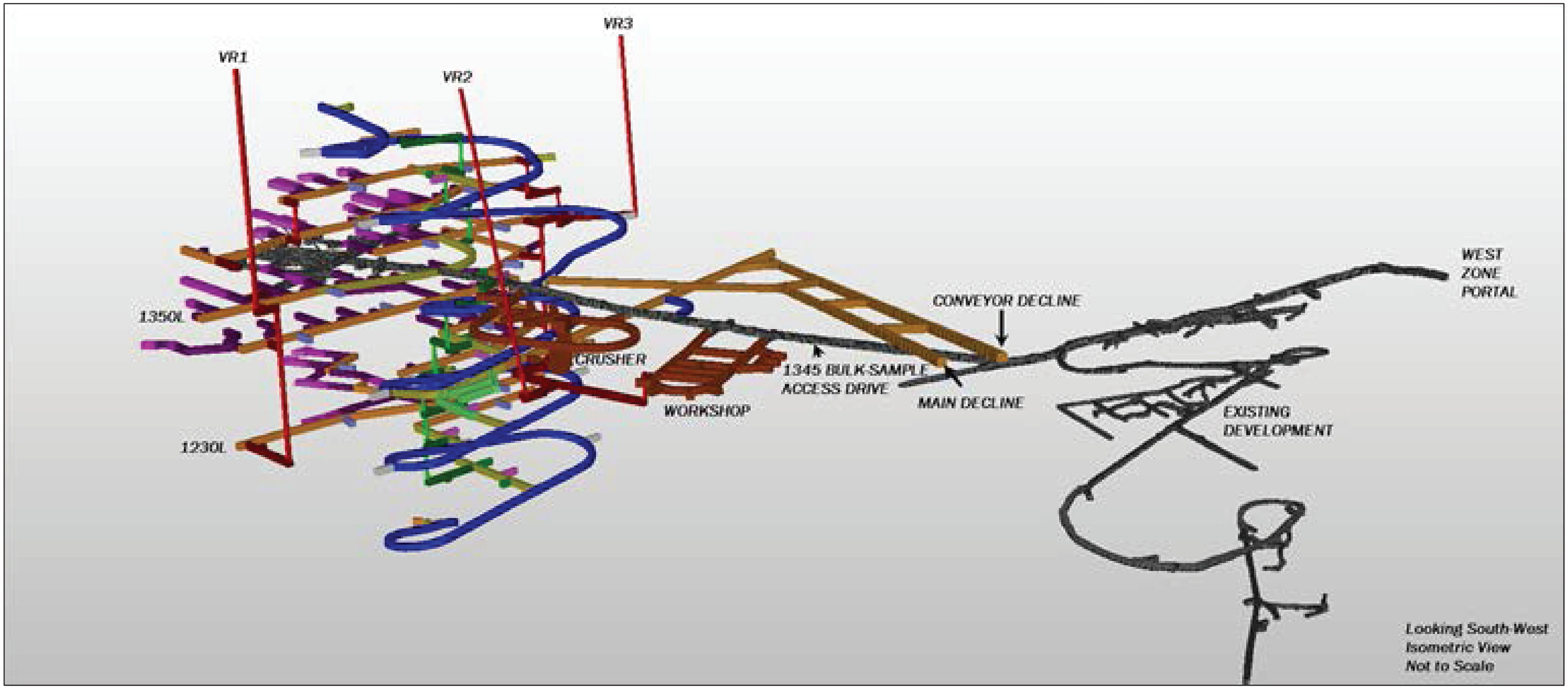
5.7.3 Pre-production Underground Development Equipment

During the pre-production phase, over 14,000 m of lateral development will be completed to meet the ramp-up production schedule. Development during this period will average approximately 600 m/month. The mobile equipment required underground to accomplish this development will include:

- 4 two-boom mining jumbos;
- 4 fourteen tonne load-haul-dump (LHD) vehicles;
- 4 forty tonne haulage trucks;
- 2 bolters;
- 1 cable bolter;
- 2 shotcrete sprayers;
- 1 in-the-hole (ITH) long hole drill;
- 2 scissor lifts;
- 2 explosives loaders; and
- 2 transmixers.

Figure 5.7-2

Extent of Mine Development at the Main Onset of VOK Stoping



Source: Tetra Tech .

Horsepower ratings and expected hours of use of pre-production mine equipment are discussed in Chapter 7, Air Quality Predictive Study.

5.7.4 Construction of On-site and Off-site Surface Facilities

Concurrent with the pre-production development of the underground mine, Pretivm will develop on-site and off-site surface facilities. Figure 5.7-1 illustrates the relative schedule for the development of these facilities. On-site facilities and activities will include:

- construction of a mine water treatment plant in the vicinity of the existing exploration mine water treatment plant location. This plant is to be operational before pre-production development of the underground mine proceeds;
- development of the surface water management system, including contact and non-contact water ditches and the contact water pond; and implementation of erosion prevention and sediment control measures;
- overburden salvage, given that there are no developed soils on the Brucejack Mine Site;
- development of the lined waste rock storage facility;
- expansion of the current exploration camp facilities to accommodate the construction workforce, including an additional dry, bunkhouse and kitchen, and sewage and administration facilities;
- development of the underground portal and related facilities such as the crushed ore conveyor;
- grading of the mine site area;
- construction of the mill, truck shop, substation and generator buildings;
- surface infrastructure installations, including fuel storage facility; and
- construction of the tailings pipeline.

Pad development for such facilities as the portal, truck shop, permanent camp, mill building, and substation will entail a general earthworks program, including rock cuts. The design criteria for allowable slopes are shown in Table 5.7-1. Overburden will be moved by conventional excavator and truck as the site is not conducive to scraper work. Rock cuts will be ripped if possible, and if not, will be blasted. Rock will be loaded on trucks for transport. The highest cuts will be at the south end of the mill pad (approximately 25 m) and along the haulage road (approximately 33 m). Both of these high slopes are assumed to be in rock and will be benched per the criteria in Table 5.7-1. The approximate 33-m cut is higher than the maximum benched rock cut criteria of 30 m, and therefore additional geotechnical recommendations will be sought in detailed design. Geotechnical recommendations may include remedial measures such as rock bolts or retaining wall.

The highest fills (approximately 19 m) will be on the west side of the mill pad. Since the height is over the 15 m maximum fill height cited in Table 5.7-1, a retaining wall will be constructed in this location.

At this time, all rock to be excavated for surface installations is assumed to be PAG. Acid generating waste rock and PAG waste rock will be disposed under water in Brucejack Lake. Non-PAG rock will be laid over the submerged waste rock as required to provide a dump surface and causeway, and to develop the laydown area. Where rock quality is suitable, excavated rock may be used locally as fill. A quarry will be developed in non-PAG rock about 1,600 m east of the mill building on the south side of Brucejack Lake to provide additional construction fill and laydown surfacing where required, as described in Section 5.12.20.

Table 5.7-1. Cut and Fill Slope Angles

Item	Material	Maximum Height (m)	Maximum Slope	Comments
Fill Slope	Structural fill	15	2H:1V	
Fill Slope	Rock fill	15	2H:1V	
Fill Slope	General Fill	5	2H:1V	
Fill Slope	General Fill	15	2.5H:1V	
Cut Slope	Overburden	5	2H:1V	May have to flatten below the water table and/or provide drainage.
Cut Slope	Overburden	10	2.5H:1V	May have to flatten below the water table and/or provide drainage.
Cut Slope	Rock – unbenched	15	0.5H:1V	Spot bolting and scaling may be required based on field engineer's review.
Cut Slope	Rock - benched	30 (see comments)	see comments	6 m bench height, 5 m bench width, 75° bench face angle; spot bolting and scaling may be required based on field engineer's review.

Notes:
All cut and fill slopes to be reviewed in the field by the field engineer.
All cut slopes in rock greater than 15 m in height must be approved by a geotechnical engineer.

Soil and overburden salvage and storage are described in Chapter 11, Terrain and Soils Predictive Study, and the Soil Management Plan is described in Section 29.13.

Equipment, supplies and personnel for the mine site construction will be transported over the Knipple Glacier from the Knipple Transfer Area. The equipment to be used to transport supplies over the glacier will have a maximum capacity of about 36 tonnes (t). Equipment and mill components will be delivered in pieces weighing 36 t or less and assembled on site.

Off-site facilities and activities will include:

- upgrades to the existing 73-km exploration access road to accommodate mine traffic. The upgrades will include minor re-alignments of the sharper curves, reductions of the steeper grades, short sections of double lanes for pull out areas, widening in areas of reduced visibility, and additional surfacing of some sections; however, it is not anticipated that any upgrades to stream crossings will be required. The upgraded exploration access road will be referred to as the Brucejack Access Road throughout the Application for an Environmental Assessment Certificate/Environmental Impact Statement (Application/EIS);
- upgrade of the existing overgrown airstrip in the Bowser River Valley. The upgraded aerodrome will have a longer and wider runway than the original Newhawk airstrip and will have an improved runway surface, runway, taxiway and edge lighting. The upgraded aerodrome will be referred to as the Bowser Aerodrome throughout the Application/EIS;
- construction of the Knipple Transfer Area near the base of the Knipple Glacier; and
- construction of the Brucejack Transmission Line, including right of way clearing, installation of towers and stringing of the conductors.

5.7.5 Surface Construction Equipment

A wide range of equipment will be required for site preparation, facilities construction, and access road improvements during the Construction period. A conceptual list of this equipment is provided in Table 5.7-2.

Table 5.7-2. Conceptual List of Equipment Required for Surface Facilities Construction

Item	Number Required
Equipment New to the Project	
30 t CAT 730 Haul Trucks	6
Dozer CAT D8T	6
Loaders CAT 988H	4
Grader CAT 14M	4
Drills Atlas ROC L8	3
Excavators CAT 374D	4
Back Hoe CAT 450F	4
Mobile Heavy Crane LTM 1160 (160t)	1
Mobile Cranes LTC 1045 (45t)	2
Mobile light Cranes LTM 1035 (35t)	2
Pickers	3
Man Lifts (Genie)	5
Welding Units	5
Pickup trucks	24
Quads	20
Telehandler CAT TL1255C	3
Buses	5
Water Truck	2
Fuel Truck	2
Ambulance	2
Fire Truck	2
Snowmobiles	14
Generators	4
Compressors	6
Husky	4
Equipment Currently on Site and Retained for Construction	
Printoh Beast Snowcat	2
Bobcat UTV 3400XL	1
T140 Bobcat	1
Hitachi 200 Zaxis excavator	1
Marooka 2200	1
Marooka 800	1
Marooka 4000	1
Cat D6K LGP Dozer	1
Hitachi 200 Zaxis Excavator	1
Pisten Bully 600 Polar	2

(continued)

Table 5.7-2. Conceptual List of Equipment Required for Surface Facilities Construction (completed)

Item	Number Required
Equipment Currently on Site and Retained for Construction (cont'd)	
Caterpillar D8T	1
All-Track AT80	1
Foremost Chieftain C	1
Formost Nodwell 110	1
ATV – Canam	4
ATV - Polaris Ranger	4
ATV - John Deer Gator	1
ATV - Canam Side by side	1
Snowmobiles - Skidoo Skandik	6
Snowmobiles - Skidoo Summit	2
Kubota RTV 1140	1

Further information on the equipment can be found in Chapter 7, Air Quality Predictive Study.

5.8 MINE DEVELOPMENT AND OPERATIONS

5.8.1 Overview

Commercial operation will commence after two seasons of construction. The Operation phase is expected to last about 18 years. When the mine ceases operation, there will be a Closure phase (see Section 5.15) followed by a Post-closure phase (Section 5.15.2).

The proposed underground mine design supports the extraction of 2,700 tonnes per day (t/d) of ore through a combination of long hole open stoping (LHOS) and longitudinal LHOS (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC). Paste backfill is integral to the mine plan to maximize both orebody recovery and mining productivity. Modern trackless mobile equipment will be employed in the majority of mining activities.

A main decline from a surface portal in close proximity to the mill building will be used to access the mine. A second decline, parallel to the main access decline, will be dedicated to conveying crushed ore via a conveyor, transferring to a second conveyor feeding the mill. The West Zone portal will be used as the primary access during the initial development phase until the main decline is completed.

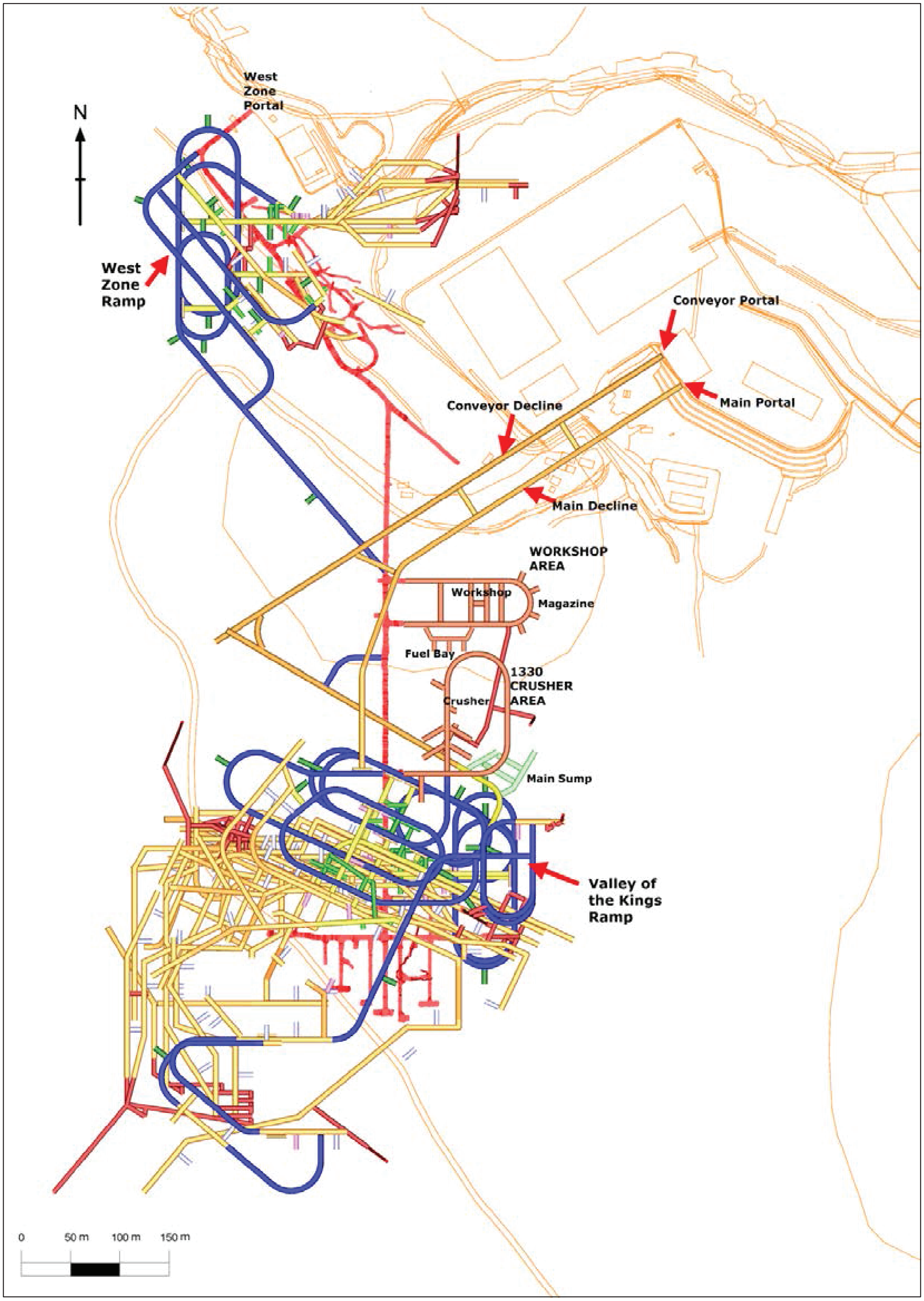
Figure 5.8-1 illustrates the general development arrangement.

A fleet of LHD vehicles and trucks will be used for material loading and transport from the various underground working areas through an internal ramp system that will connect all levels to the centrally located crusher.

Permanent fans will provide ventilation by forcing air down the declines, through the internal ramps, and exhausting via dedicated raises that will connect the various working levels to surface in each zone. The primary fans will be located at each of the main surface portals (excluding the West Zone portal), and complemented by booster fans located in the exhaust raises, in a push-pull configuration. An electric mine air heating system will be used, with a propane system available for supplemental heat during cold periods and as back-up.

Figure 5.8-1

Mine Access and Development Infrastructure



Source: Tetra Tech .

A pre-production development program that attains approximately 660 m/month of advance will be required to establish the mine infrastructure and provide access to the initial stoping levels during the first 2 years of underground activity. Ongoing development, to sustain 2,700 t/d of ore production, will average approximately 420 m/month during the first 12 years of production, and then decrease considerably in the latter years of mine life following completion of West Zone infrastructure development.

Major underground infrastructure will include the crusher, conveyors, ventilation raises, fans, heating system, pumping stations, a maintenance facility, electrical substations, fuelling facility, explosives magazines, refuge stations, mine communications, and other ancillary installations.

5.8.2 Mine Design

5.8.2.1 Geotechnical Assessment

Ground control was a key consideration in the design of the mine and development of operating plans. Geotechnical designs and recommendations, to be consolidated in the ground control management plan for the underground workings (see Appendix 5-I, Brucejack Project Ground Control Management Plan Outline), were based on the results of site investigations and geotechnical assessments, which included rock mass characterization, structural geology interpretations, excavation and pillar stability analyses, and ground support design (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC). The full ground control management plan will be included in the *Mines Act* permit application. This plan is expected to evolve over time with operating experience and will therefore be considered a “living” document. The text throughout Sections 5.8 and 5.8.2.1 specifically provides at a general or conceptual level much of the information to be included in the plan.

Geotechnical site investigations completed to support the underground rock mechanics assessments included: geotechnical drilling and logging, oriented drill core measurements, borehole televiewer surveys, laboratory testing of rock core samples, and installation of borehole instrumentation to measure groundwater pressures. Geotechnical mapping of the dewatered historic underground workings was completed to provide structural geology information; the geotechnical performance of excavations in the existing mine was also reviewed.

The rock mass properties determined from these investigations are summarized in Table 5.8-1.

Table 5.8-1. Rock Mass Properties

Unit	UCS (MPa)	GSI*	Unit Weight** (kN/m^3)	m_i	m_b	S	Em (GPa)
VOK Fault Zone	89	60	26.3	12	1.110	0.0023	5.13
VOK Weathered Rock Zone	50	63	28.6	17	1.879	0.0037	0.77
VOK Domain 1	116	72	27.2	17	3.211	0.0144	9.76
VOK Domain 2		70	27.1	19	3.186	0.0106	9.02
VOK Domain 3	73	85	27.3	26	10.647	0.103	14.37
WZ Fault Zone	77	57	26.3	12	0.928	0.0015	4.27
WZ Weathered Rock Zone	37	62	28.6	17	1.771	0.0032	0.73
WZ Fresh Rock	116	85	27.3	21	8.599	0.103	16.77

Notes:
UCS = unconfined compressive strength.
** GSI = geological strength index. GSI are calculated from median rock mass parameters for each unit, where GSI = RMR ‘76.*
*** Unit weights are based on average results of specific gravity testing when possible.*
The Hoek-Brown failure criteria were estimated assuming a disturbance factor ('D') of 0.8 for all units.
The Hoek-Brown curves were derived using a sigma3 maximum for a tunnel depth of 650 m.

Stope Design Criteria

Rock mechanics analyses were completed to estimate achievable spans for the proposed mine openings. Stope stability analyses for the observed lower quartile ("conservative," Q' = 10) and median ("base case," Q' = 40) rock masses were completed. The recommended maximum unsupported hydraulic radii vary from 1.9 to 3.1 for the backs and from 6.2 to 11.0 for the hanging walls, for the conservative and base case designs, respectively. The recommended maximum supported hydraulic radii vary from 4.1 to 5.6 for the backs and from 10.0 to 14.5 for the hanging walls, for the conservative and base case designs, respectively (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC).

A preliminary MAP3D numerical model developed for the VOK Zone shows stress concentration and yielding proximal to the dense stope clusters in the middle of the VOK Zone, indicative of potential instability in the stope hanging walls and footwalls. This modelling indicates some potential for increased dilution. Cable bolts could be installed into the hanging walls of dense stoping blocks to "tie" the hanging wall together until backfill is placed, to help reduce this dilution (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC).

Stand-off Distances

Minimum stand-off distances between excavations of 10, 25, and 50 m are recommended for the raises, ramps, and underground crusher, respectively. The recommended stope stand-off distance from all hanging wall drives is 25 m. The proposed portal decline will be twinned, with a recommended minimum pillar thickness of approximately 10 m between the two excavations (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC).

Rib Pillars

The rib pillars between cross-cuts were designed to be in waste and will not be recovered, but are considered temporary based on the short-term lifespan required for access to a given stope. The minimum recommended pillar width to height ratio for cross-cut rib pillars for the "base case" stope design is 1.1:1.0, and 3.3:1.0 for the "conservative case" stope design. If cross-cuts are developed within the weathered zone, the recommended rib pillar width to height ratio is 1.7:1 (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC).

The rib pillars between the open stoping blocks are intended to give temporary support to the mining block until the primary stopes are backfilled and the pillar can be recovered in the form of a secondary stope. Using the pillar stability graph method developed by Hudyma (1988) and tributary loading theory, the minimum recommended secondary stope span (rib pillar thickness) to primary stope span for the "base case" stope design is 1:1 for sublevel intervals of 30 m (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC).

Sill Pillars

The current design sill pillar thickness is 30 m. The numerical modelling analysis shows some relaxation in larger stope hanging walls, and stress concentrations in sill pillars within areas of the mine with denser stoping. The model shows that the bottom-up sequence concentrates stress in both VOK Zone sill pillars. Yielding is likely to occur prior to recovering the entire sill pillar, and therefore achievable sill pillar recovery may be less than 100% (Appendix 5-A, Feasibility Study and Technical Report on the Brucejack Project, Stewart, BC). The West Zone sill pillar is interpreted to be stable except for stress concentration in the sill pillar abutments. Stress concentration in pillar abutments is common in mines using centre-out sequencing, and does not necessarily indicate stability problems prior to full extraction of the sill pillar.

Ground Support Requirements

The structural stability of the proposed excavations was analyzed using an empirical design chart after Grimstad and Barton (1993) and Unwedge© (Rocscience Inc. 2003) to develop minimum ground support recommendations. Ground support analyses for primary (permanent "man-entry") and secondary (temporary "development") headings were conducted in each structural domain to develop relevant ground support recommendations, shown in Table 5.8-2 (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC).

Table 5.8-2. Ground Support Recommendations

Opening Type	Cross Section (w x h, m)		Ground Support Type	Length (m)	Spacing (m)	Shotcrete Estimate (%)	Additional Notes
Main access decline, ramps, and other haulage routes	6 x 5.5	Back	Fully-grouted #7 Dywidag	2.4	1.8 x 1.8	10	
		Walls	Fully-grouted #7 Dywidag	1.8	1.8 x 1.8	10	
Level development	5 x 5.5	Back	Swellex Pm12	1.8	1.8 x 1.8	10	Fully-grouted #7 Dywidag can be used in direct substitution of Pm12 when desired for operational efficiency.
		Walls	Swellex Pm12	1.8	1.8 x 1.8	10	
Intersections	Includes 6 x 5, 5 x 5, three-way, four-way, and herringbone layouts	Back	Pre-support: fully-grouted #7 Dywidag	2.4	1.8 x 1.8	10	Welded wire mesh should be installed on the back and upper portion of each wall for all intersections with an effective span greater than 6 m. Strap consumption estimate: 25% of pillars; 3 straps per pillar
		Back	Long support: Coupled fully-grouted #7 Dywidag or cable bolts	5.0	2.4 x 2.4	10	
		Walls	Fully-grouted #7 Dywidag	1.8	1.8 x 1.8	10	
Full-width undercuts	5 m high x 6 m wide pilot	Back	Long support: Bulbed cable bolts	6	2.4 x 2.4	n/a	All support must be installed prior to slashing.
		Walls	-			n/a	
	15 m wide full undercut (post-slash)	Back	Swellex Pm12	2.4	1.8 x 1.8	25	All support except for shotcrete must be installed as each lateral slash is developed (prior to full width exposure)
		Walls	Swellex Pm12	2.4	1.8 x 1.8	100	
Portal		Back	Fully-grouted #7 Dywidag	1.8	0.8 x 0.8	100	1 m spaced steel sets in first 30 m and 100% coverage with minimum 50 mm thick steel-fibre reinforced shotcrete throughout the length of the portal
		Walls	Fully-grouted #7 Dywidag	1.8	1.8 x 1.8		
Raises	3 m x 3 m cross-section	All	Fully-grouted #7 Dywidag	1,2	0.8 x 0.8	50	Staggered spacing. Reduced support may be feasible if man-access is not permitted.

All developments through the Brucejack Fault Zone will require support with fully grouted #7 Dywidag bolts on a 1.5 m square pattern. Full coverage (sill to sill) of welded wire mesh and 75 mm of fibre-reinforced shotcrete is also recommended. Stopes will be excavated in isolation and backfilled prior to any other production openings within the fault zone. The rock mass within the fault zone is not competent enough to form adequate rib or sill pillar strength between stopes. In each case, stopes will be constrained to either the host or fault disturbed rock.

The finalized raise locations will avoid fault-disturbed rock, and minimize intersection of weathered rock. The recommended pillar thickness between a raise and nearby development or production openings, including the decline access ramp, is 10 m.

The underground crusher excavation was designed for a factor of safety of 2.0, as the excavation must remain operable for the life of the mine. Support will include:

- Primary support consisting of galvanized, resin-grouted rebar (or an equivalent) and welded wire mesh (or fibre-reinforced shotcrete). The purpose of these elements is to support and retain material between the cable bolt plates and to provide a shell of near-surface support. In addition, confining surface support (e.g., steel or heavy gauge mesh straps) will be used for all noses and benches within the excavation to reduce the potential for unravelling. Fibre-reinforced shotcrete will be used when infrastructure will make rehabilitation impractical.
- Secondary support consisting of cable bolts in the back and walls of the excavation. The purpose of these elements is to support larger wedges and increase long-term stability of the excavation.

The crusher chamber excavation will be completed in stages from the top heading to allow sequential support installation and minimize the dimensions of unsupported spans. A minimum radial standoff distance of 50 m will be maintained to prevent stress interaction between the crusher and development or production openings. This standoff distance will also apply to offset from major structures (i.e., the Brucejack Fault Zone).

Further recommendations have been provided for the other mine infrastructure, the crown pillar and portals (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC).

5.8.2.2 Access and Ramp Infrastructure

The new main access decline will join the main surface portal to the crusher area on the 1,335 Level (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC). A main cross-over drive on the 1,335 Level will join the main decline to the two independent ramps servicing the VOK Zone and West Zone.

The internal ramps will connect all levels of the mine. The West Zone portal will be used for underground access until the completion of the twin declines and portal construction.

The southern ramp (VOK ramp), which will service the VOK and Galena Hill zones, and the northern ramp (West Zone ramp), which will service the West Zone, were both designed in a race-track configuration for improved safety, haulage efficiency, and to minimize wear on mobile equipment.

The VOK ramp will be developed up and down from the bulk-sample access development on the 1,345 Level. The West Zone ramp will be developed up and down from the main cross-over drive on the 1,345 Level.

The use of an independent ramp for each zone, as opposed to a single ramp servicing both zones, was selected in the interest of access and capital efficiency, given that the West Zone ramp will not be required until mid-way through the mine life.

For ease of entry and exit, ramps were designed with a 25 m turning radius and a 15% gradient, levelling out to a 5% gradient in proximity to a level access intersection. Passing bays were incorporated where required, typically at the level access. Figure 5.8-2 shows the ramp system for both zones in perspective view.

5.8.2.3 Level Development

Sublevels will be accessed from the ramps on a 30 m vertical interval that is defined by the planned stoping heights. Footwall and hanging wall drives will be set back a minimum of 22.5 m from the ore contact, whereas ramp development will be set back a minimum 50 m from the ore contact. This arrangement addresses long-term geotechnical stability requirements and provides adequate space for the placement of a fresh air raise and other ancillary services between the ramp and level development.

The vent raises will be used as exhaust raises. Figure 5.8-3 illustrates the VOK Zone sublevel arrangement in long section.

Level development will follow the general strike of the various lenses, providing access to the mineralized zones in a manner that facilitates transverse mining where stope thickness is greater than 15 m. Level development will generally be in the hanging wall, with hanging wall drives typically including excavations for sumps, refuges, transformers, remucks, paste fill line, and raise accesses.

Stope access crosscuts will be on 15-m spacing, with the exception of those levels where sill extraction or near-surface weathered ore will be recovered in smaller units that are designed on 10-m spacing. Figure 5.8-4 illustrates typical level development requirements.

Development design considered equipment size, services, and required activity. Development design parameters are summarized in Table 5.8-3. Figure 5.8-5 and Figure 5.8-6 illustrate standard designs for hanging wall drives and the main decline, respectively.

5.8.2.4 Stope Design

AMC Mining Consultants (Canada) Ltd. (AMC) used the MSO module from the Datamine Studio 3 mine planning software package to produce conceptual stope shapes. Key design parameters used in MSO are summarized in Table 5.8-4.The conceptual stope shapes were refined as necessary in order to minimize the amount of planned dilution and to meet practical mining constraints.

Individual areas meeting cut-off grade were evaluated against access development costs to determine economic viability, before including them in the mineral reserves. The life of mine plan includes 1,058 stopes in the VOK Zone and 138 stopes in the West Zone. Figures 5.8-7 and 5.8-8 are long-section views showing stope shapes generated by the MSO process.

Life of mine development requirements are shown in Table 5.8-5.

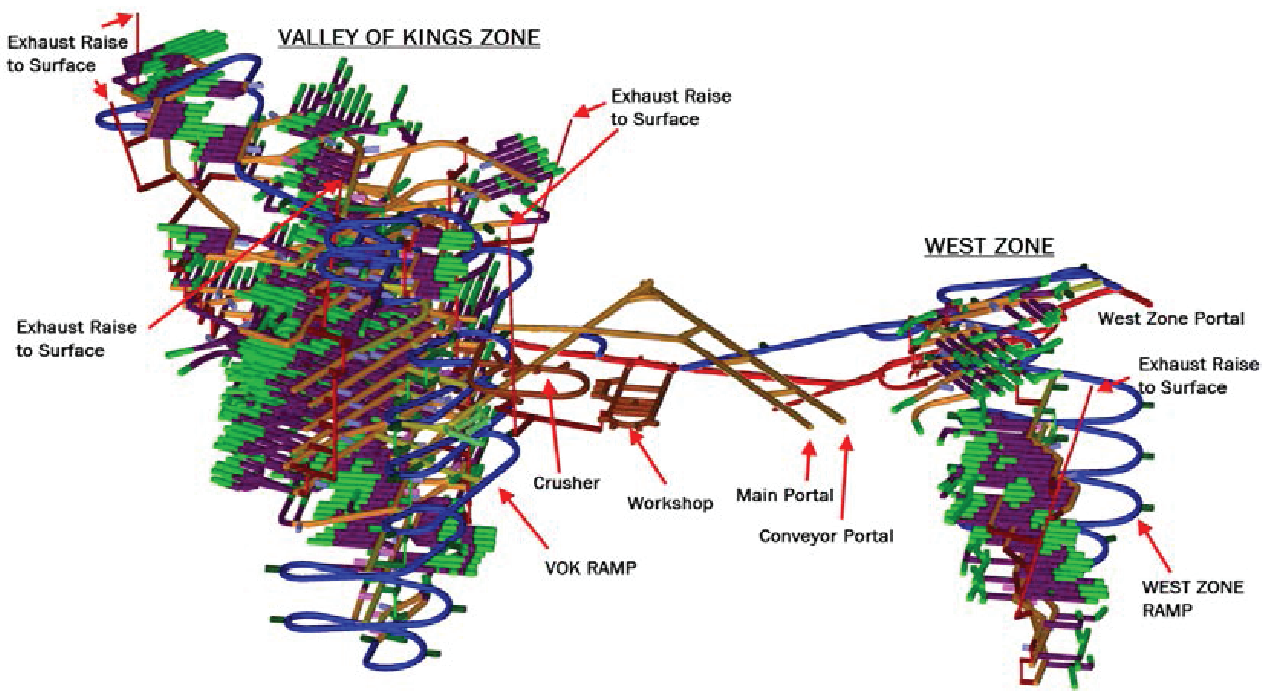
5.8.2.5 Stope Cycle

The primary mining method will be transverse LHOS based on a standard primary/secondary sequence. No permanent pillars will be required and maximum ore extraction will be targeted.

The hanging wall drives will be completed and a through ventilation circuit will be established before mining begins between any two levels.

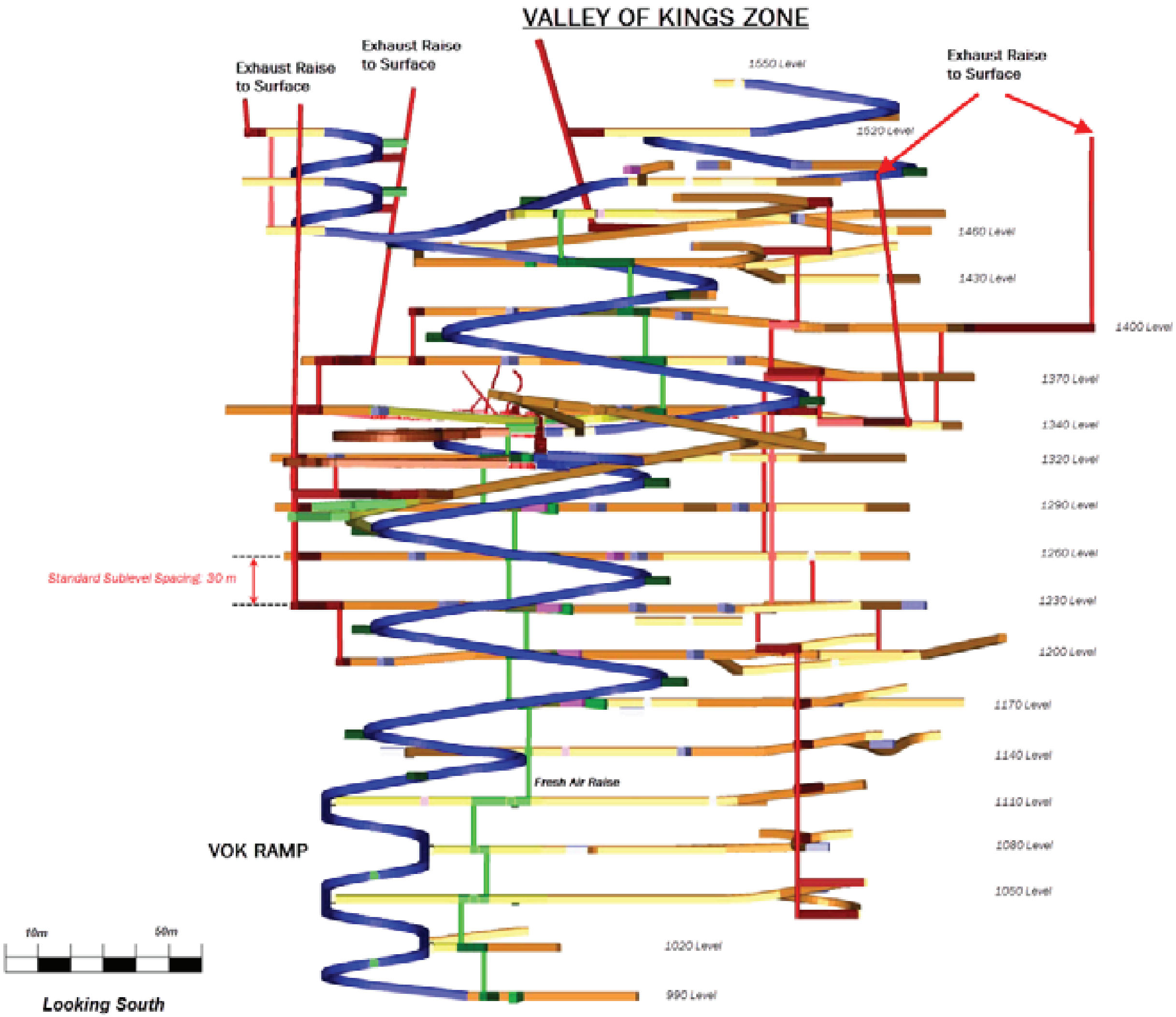
Figure 5.8-2

Brucejack Twin Declines and Ramp System



Source: Tetra Tech .

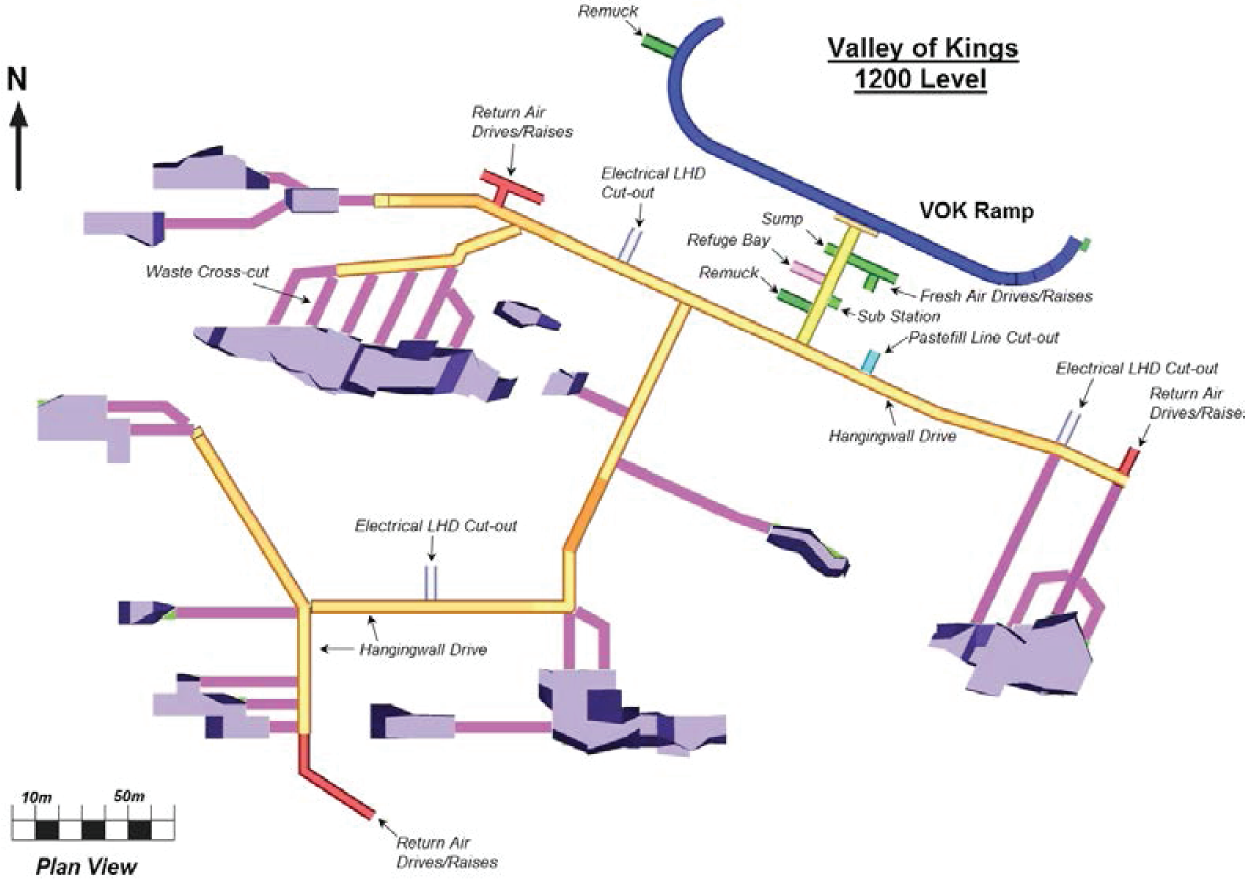
Figure 5.8-3
VOK Zone Sublevel Arrangement - Long Section



Source: Tetra Tech .

Figure 5.8-4

Typical Level Plan
- 1,270 Level in the VOK Zone



Source: Tetra Tech .

Table 5.8-3. Development Design Parameters

Parameter	Lateral																		Vertical		
	Remuck	Hanging Wall Drive	Access Drive	Electric LHD Cut-out	Ramp	Return Air Drive	Decline Cross-over Drive	Conveyor Decline	Main Access Decline	Infrastructure Drive	Drainage Cut-out	Waste Cross-out	MainCross-over Drive	Refuge Bay Cut-out	Ore Cross-cut	Fresh Air Drive	Return Air Drive	Pastefill Line Drive	Alimak Raise	Return Air Raise	Fresh Air Raise
Width (m)	6.0	5.0	6.0	5.0	6.0	5.0	6.0	6.0	6.0	5.0	5.0	5.0	6.0	5.0	6.0	5.0	5.0	5.0	3.0	3.0	3.0
Height/Length (m)	5.5	5.5	5.5	5.5	5.5	5.5	5.5	3.0	5.5	5.5	5.5	5.0	5.5	5.5	5.0	5.5	5.5	5.5	3.0	3.0	3.0
Arch (m)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0
Max Gradient (%)	2	15	2	2	15	2	5	15	15	2	2	2	15	2	2	2	2	2			

Source: Tetra Tech (2014).

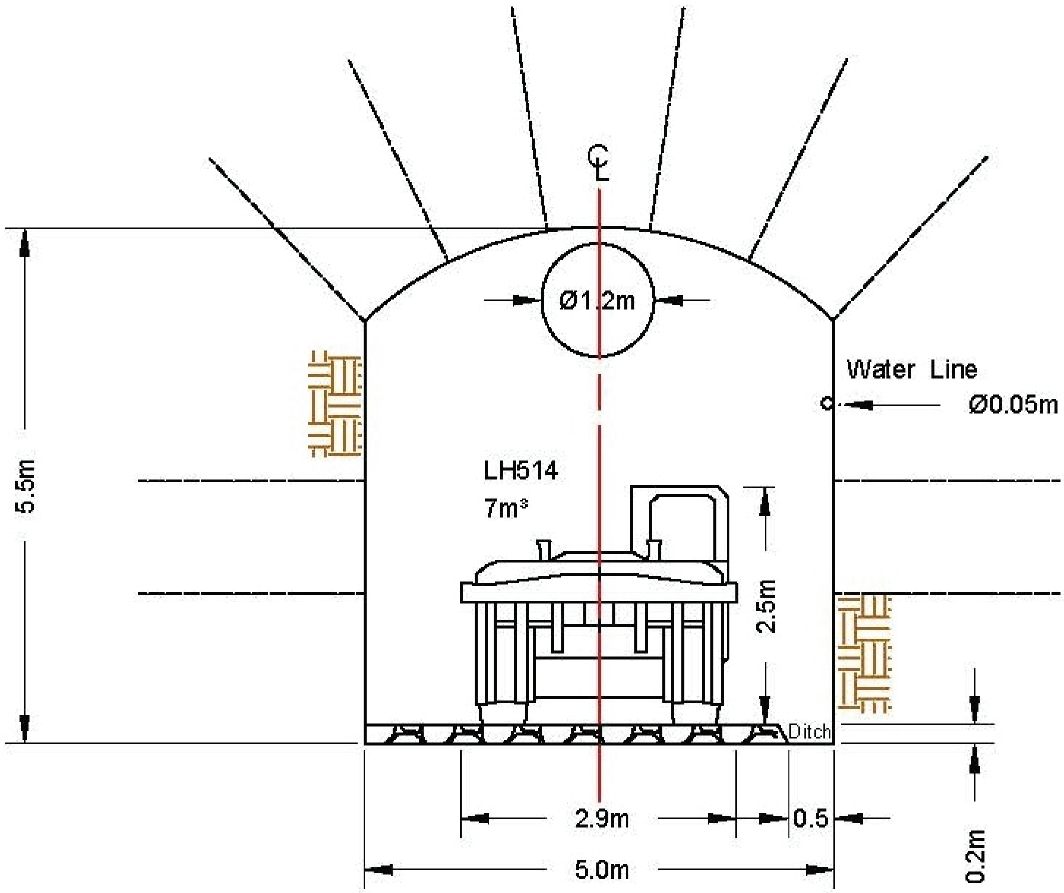
Table 5.8-4. Stope Design Parameters

Parameter	Unit	VOK Zone			West Zone		
		Standard	Weathered*	Sill Pillar	Standard	Weathered*	Sill Pillar
NSR Cut-off	$/t	180	180	180	180	180	180
Level Spacing	m	30	30	30	30	30	30
Stope Span	m	15	10	10	15	10	10
Minimum Mining Width	m	3	3	3	3	3	3
Minimum Waste Pillar Width	m	5	5	5	5	5	5
Minimum Footwall Dip	degrees	60	60	60	60	60	60
Minimum Hanging Wall Dip	degrees	60	60	60	60	60	60

** Refers to stoping in weathered material immediately below the surface crown pillar. Weathered material extends 10 to 50 m below surface.*

Figure 5.8-5

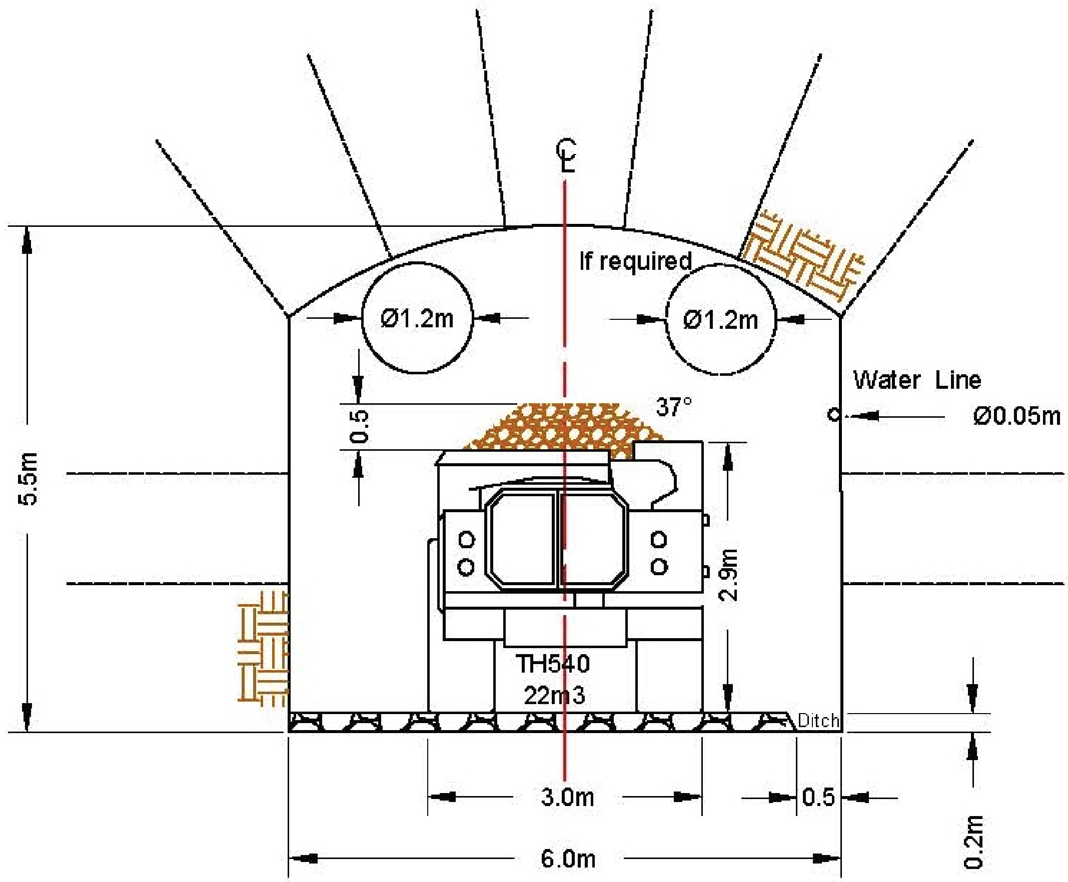
Standard Design
- Hanging Wall Drive



Source: Tetra Tech (2013)

Figure 5.8-6

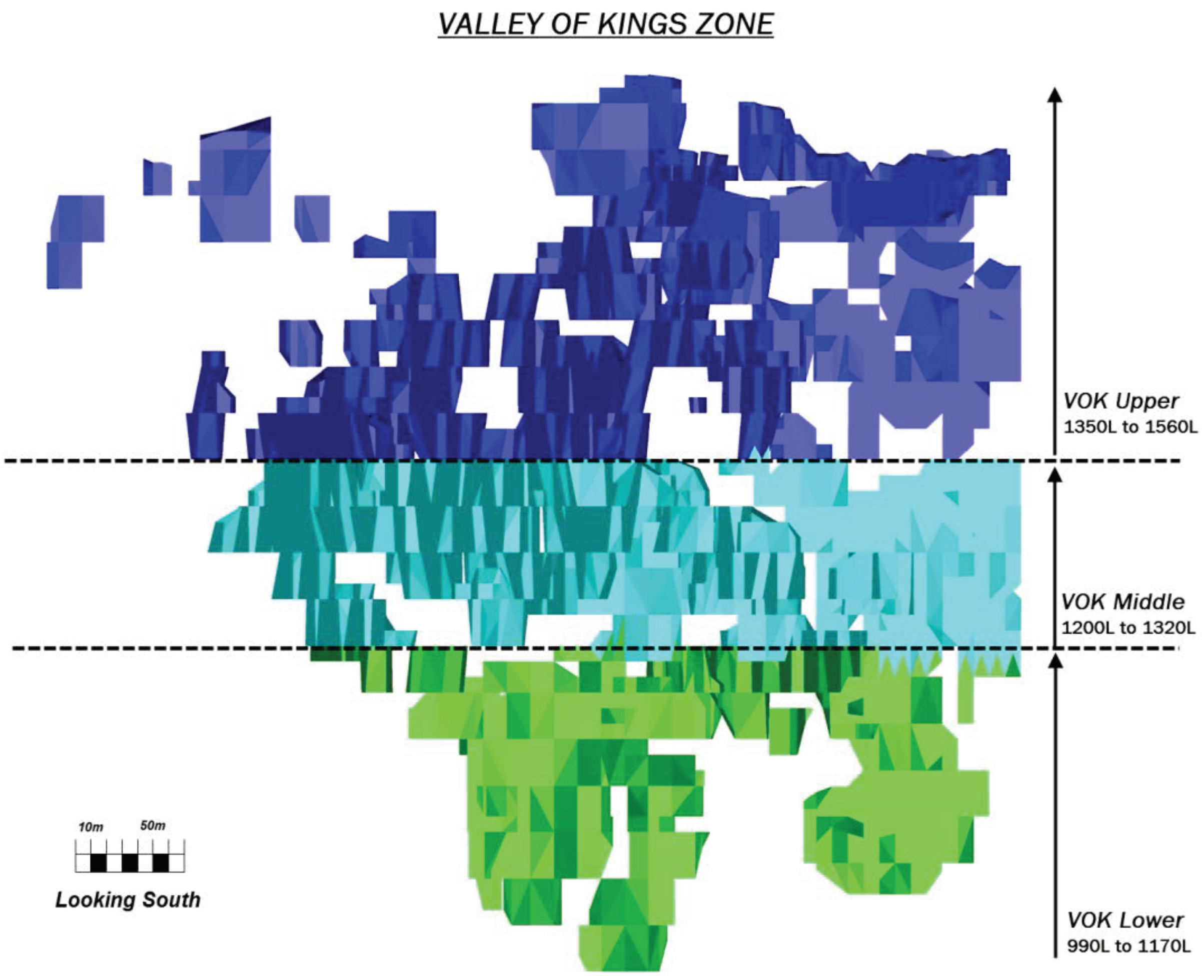
Standard Design - Main Decline



Source: Tetra Tech (2013)

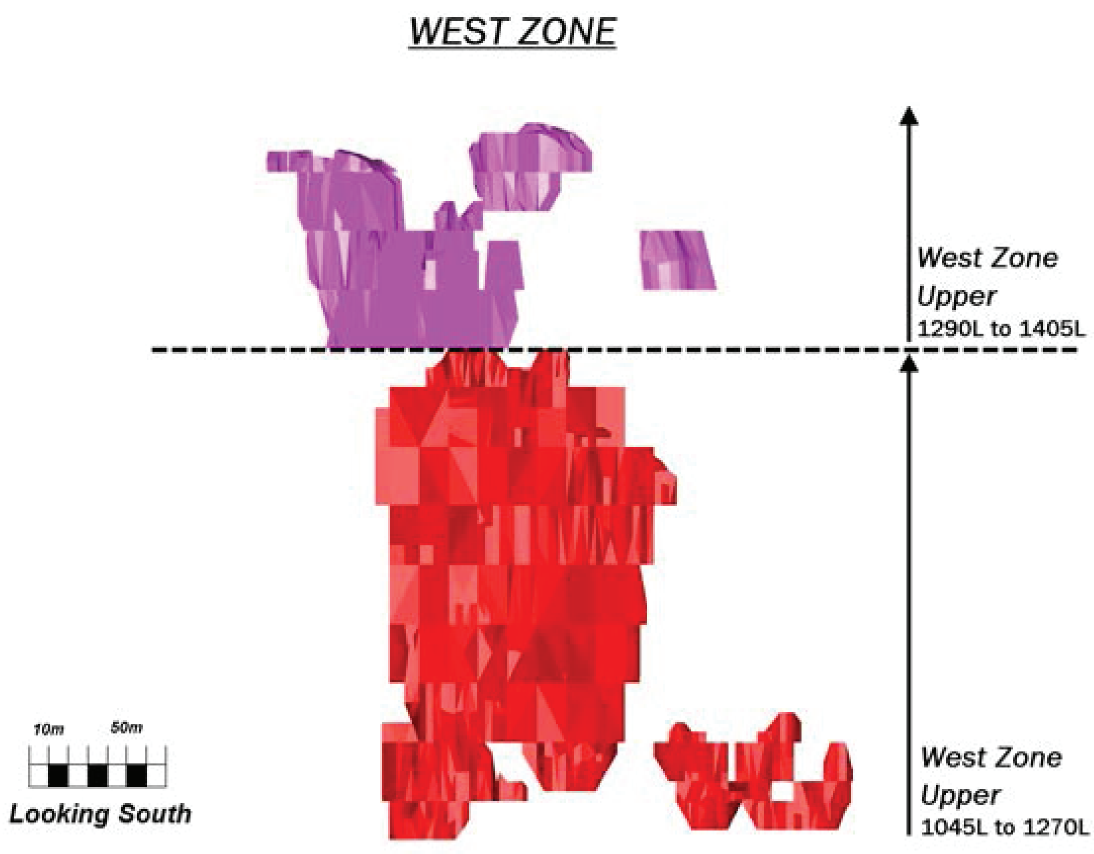
Figure 5.8-7

Mineable Stope Shapes - VOK Zone



Source: Tetra Tech .

Figure 5.8-8
Mineable Stop Shapes - West Zone



Source: Tetra Tech .

Table 5.8-5. Life of Mine Development Requirements

Year	Development	
	Lateral (metres equivalent)	Vertical (m)
-2	5,469	117
-1	7,259	831
1	5,467	0
2	5,292	110
3	5,224	262
4	5,179	144
5	5,139	75
6	5,030	170
7	5,001	34
8	4,684	21
9	5,199	65
10	4,472	97
11	5,063	371
12	4,610	90
13	1,926	0
14	1,360	0
15	1,457	0
16	1,612	0
17	944	0
18	132	0
Total	**80,518**	**2,386**

A cross-cut will be driven from the hanging wall drive, through the centre of the stope, to the far ore contact on the undercut and overcut levels. The undercut level will have already been developed if stoping has progressed beyond the block starting level.

Cross-cuts on both levels will be cable-bolted from the central access to pre-support the roof prior to full-width slashing of the entire stope footprint. Slashing to the adjacent stope boundaries will expose paste fill walls in the case of secondary stope extraction.

Full width slashing will permit parallel production hole drilling across the entire width of the stope, and will reduce the potential for ore in stope corners to fail to break to design due to inadequate free face or poor explosives distribution. Ore recovery will be higher than a fan drilling alternative (necessary in the absence of full-width slashing). Parallel hole drilling is also simpler and leads to fewer drilling errors. Given the significant value of Brucejack ore, high recovery was an overriding criterion in the design.

Once the stope footprint is slashed out, a 750-mm pilot hole will be drilled in the slot raise location. Production drilling will commence in the raise and slot area, followed by the production rings as drilling progresses towards the near ore contact.

The raise and slot will generally be opened in five firings or less. Production blasting and mucking will proceed cyclically until the stope is depleted and all ore has been mucked out. Transverse LHOS is a non-entry method, with remote mucking of blasted ore required once the drawpoint brow is open to the extent where the operator may be exposed to uncontrolled sloughing from the stope cavity.

The empty stope will be remotely surveyed with cavity monitoring equipment. A barricade will be constructed in the drawpoint and the stope backfilled to just below the floor elevation of the top level. Crushed aggregate or run of mine waste rock may be spread over the fill surface to reduce backfill dilution and increase trafficability of mucking equipment for the next lift of the stope.

The mining of sills and other areas, where top access is not available, will proceed in a similar manner; however, raise development and production drilling will be performed via uppers drilling from the bottom level. Figure 5.8-9 illustrates the typical LHOS design.

Longitudinal LHOS will also be employed at the Project, although significantly less ore tonnage will be recovered by this method in comparison to transverse LHOS. The longitudinal method will be used in areas of the orebody where the thickness of mineralization is less than 15 m, to avoid excessive access waste development. In contrast to transverse LHOS, mining will progress along the strike of the orebody to a common access point.

The overcut and undercut will be slashed to the footwall and hanging wall contacts. In all other respects, the stope cycle will be similar to transverse LHOS.

5.8.2.6 Stope Sequence

The mining sequence in any lens of a given block will begin with the extraction of the primary stopes on the first (lowest) level. Wherever possible, the first primary stope will be located near the middle of the lens to begin the development of a pattern of stope extraction that moves outwards to the extremities of the lens while progressing upwards towards the top. This approach generally promotes a favourable redistribution of ground stress, although many smaller lenses in the Brucejack orebody are either too irregular in shape or of insufficient dimensions to properly develop this sequence.

When the adjacent primary stopes from the level above have been filled and the paste has cured, secondary stoping will commence. Figure 5.8-10 illustrates typical sequencing for the more massive lenses at the Property.

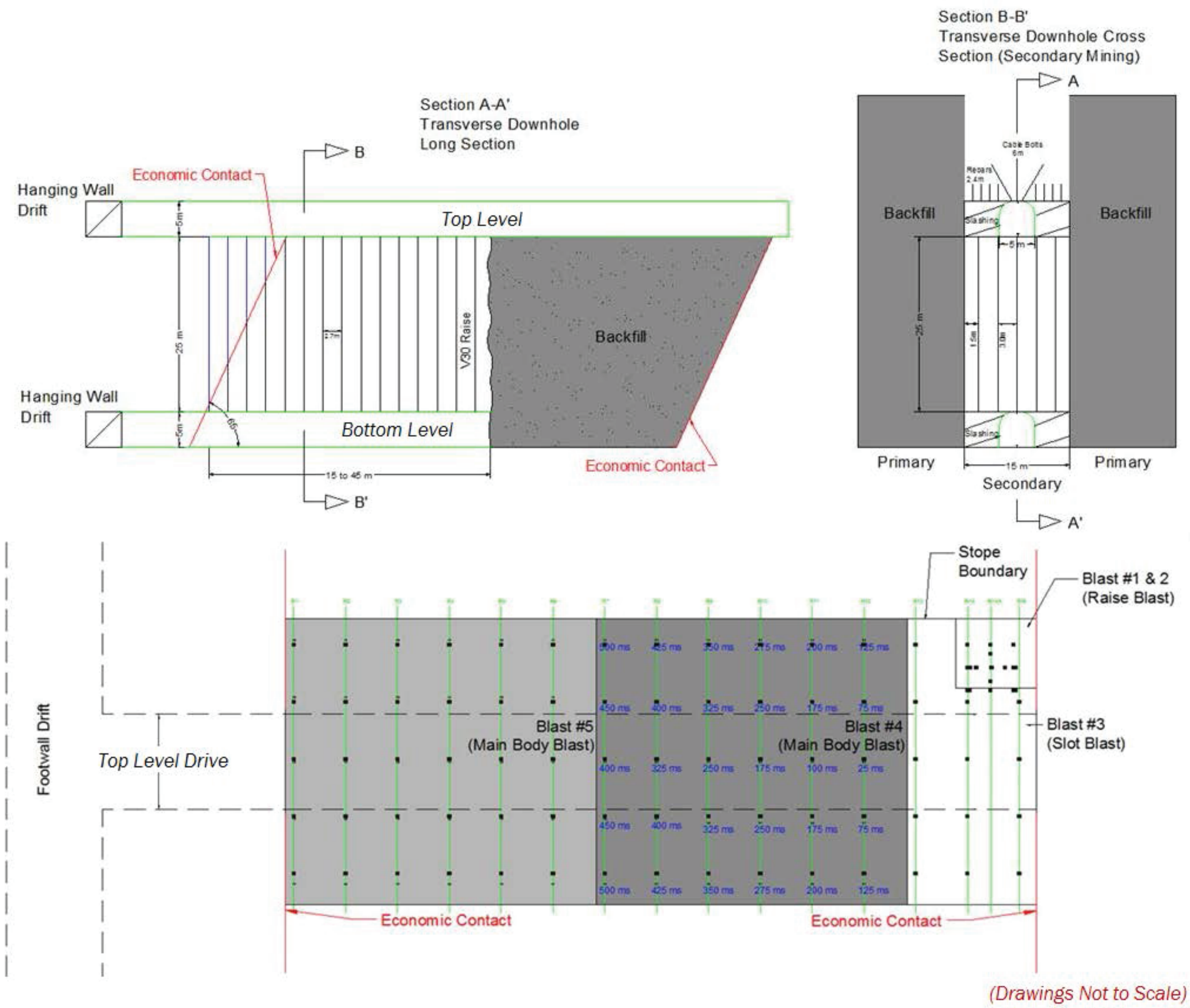
5.8.2.7 Blasting

Bulk emulsion will be used for blasting. Non-electric detonators will be used for lateral development while electric programmable detonators will be used for stoping operations. Blast holes will be stemmed with 10 to 19 mm crushed rock aggregate.

The stope drill patterns will describe the slot raise, slot, and drill patterns for the transverse and longitudinal down-hole and up-hole stopes. The blasting sequence will begin with the slot raise, followed by opening of the slot and eventual blasting of full rings into the growing void.

For development loading, two face charger modules (that can be mounted on the back of a tractor) will be used to load as many as six rounds per day. For loading uphole and downhole stopes with emulsion, one boom loading unit will be used at full production.

Figure 5.8-9
Typical LHOS Design



Source: Tetra Tech (2013)

Source: Tetra Tech (2013)

AMC developed detailed drill patterns and blasting sequences for various stope and raise configurations, including slot raises, transverse up-hole and down-hole stopes, longitudinal up-hole and down-hole stopes, and lateral development (AMC 2013). Figure 5.8-11 illustrates a typical drill ring pattern, in this case for a down-hole stope. Figure 5.8-12 illustrates typical main ring blast timing for a transverse down-hole stope.

The longitudinal stopes will use the same slot raise pattern and similar slot patterns as the transverse stopes. Ring drilling may be employed rather than parallel hole drilling and the stope walls will follow the natural boundary of the ore body. This will cause the stope drill design to have more complex geometric shapes and drill patterns, in contrast to transverse stopes. Regardless of the stope shape and drill pattern, the designed powder factor ranges from 0.35 to 0.50 kg/t for all of the stope types. Timing of blasts will vary for all geometries. The typical size of each of the transverse down-hole stope blasts will be:

- total raise blast size 300 m^3 (Blasts #1 and #2 combined);
- slot blast size 2,000 m^3 (Blast #3);
- main body blast size 6,100 m^3 (Blast #4); and
- main body blast size 6,100 m^3 (Blast #5).

The overall design powder factors for the transverse down-hole and up-hole stopes are 0.48 kg/t and 0.39 kg/t, respectively.

Lateral development will use bulk emulsion and non-electric detonators to create drifts typically sized to 5.5 m high by 6.0 m wide, using a typical drill depth of about 4.3 m. The overall powder factor using bulk emulsion for the lateral development design is 1.02 kg/t. Figure 5.8-13 illustrates typical drill layout and blast timing for lateral development.

5.8.2.8 Backfilling

The primary means of backfilling at the Project will be paste fill, generated from unclassified mill tailings mixed with adequate cementitious binder, to meet the strength requirements of re-exposure. Regular strength paste fill is commonly required where there will be re-exposure of vertical stope walls.

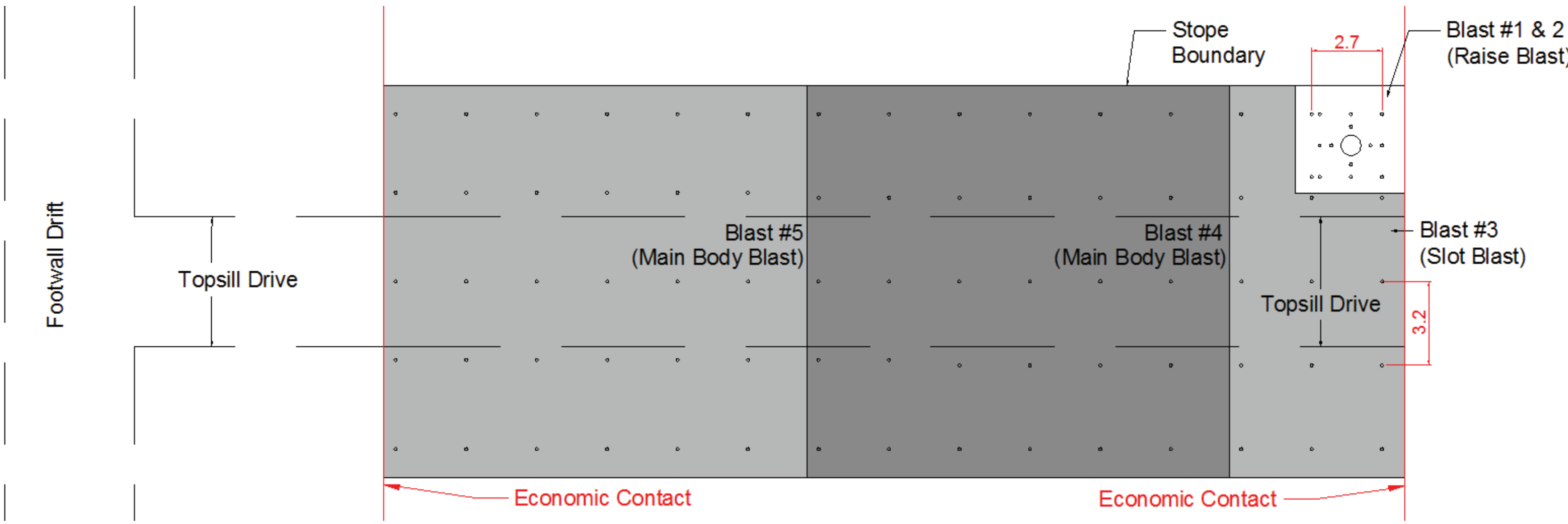
Stopes that will not be re-exposed by adjacent mining may be backfilled with unconsolidated waste and/or by paste fill with sufficient binder to remove any risk of future liquefaction (low-strength paste fill). High-strength paste fill will be required in the lower portion of all primary and secondary stopes that will be undercut by sill extraction from below. Estimates of volumes of paste backfill required are 122,000 m^3 of high strength paste, 3,701,000 m^3 of regular paste and 1,192,000 m^3 of low-strength paste. The amount of binder required to create these volumes is estimated at 258,000 t.

Waste rock will consume stope voids that might otherwise receive mill tailings in the form of low strength paste fill. Table 5.8-6 tabulates the volumes of waste to be generated from milled ore and development headings, and the destination of these volumes over time. Over the life of the mine, 62% of development waste and 45% of tailings generated from milled ore will be placed back underground. The balance will be disposed of in Brucejack Lake (see Section 5.11.1).

The approach developed for paste fill distribution is a dual pumping system. This will optimize the pumping capacity and minimize wear on the paste pumps. A positive displacement pump in the paste fill plant will provide paste to all of the West Zone (WST-U and WST-L) and the lower zones of the VOK (below the 1,330 Level). The paste plant pump will also feed a booster pump located near the crusher station at the bottom of the conveyor ramp, and near to the main entrance to the VOK Zone area on the 1,330 Level. This booster pump will pump paste up to the Galena Zone and the upper VOK Zone (1,330 Level and above).

Figure 5.8-11

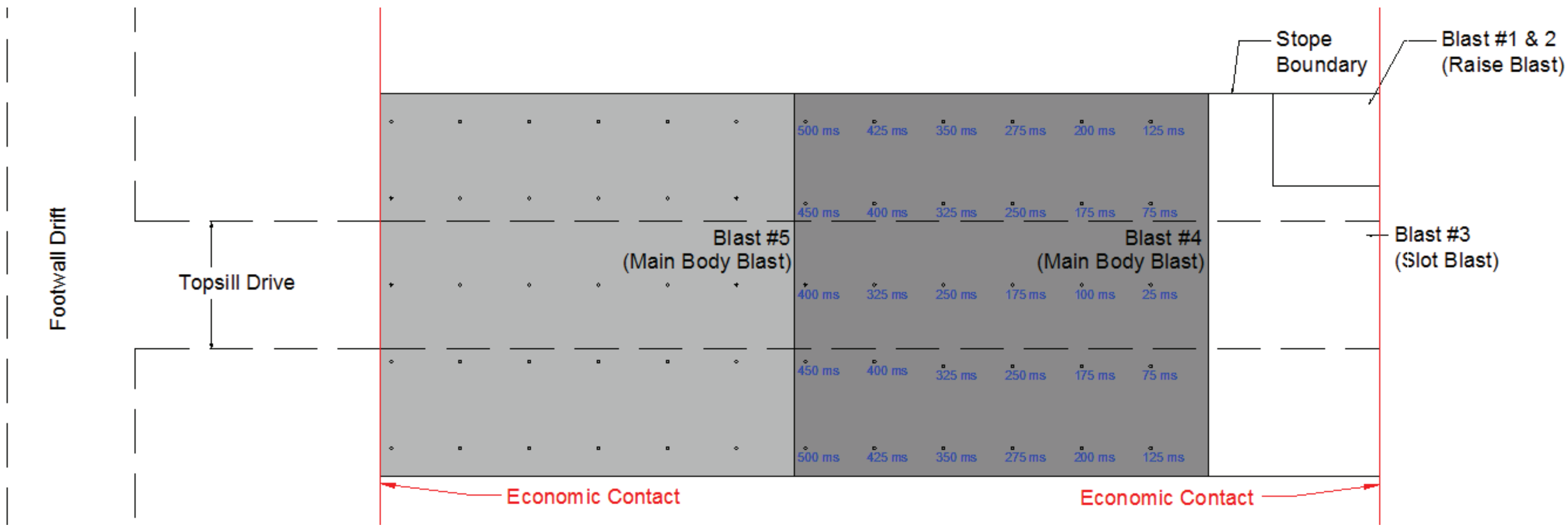
Main Body Drill Ring Pattern for Down-hole Stope (Primary Mining)



Source: AMC Consultants, 2013.

Figure 5.8-12

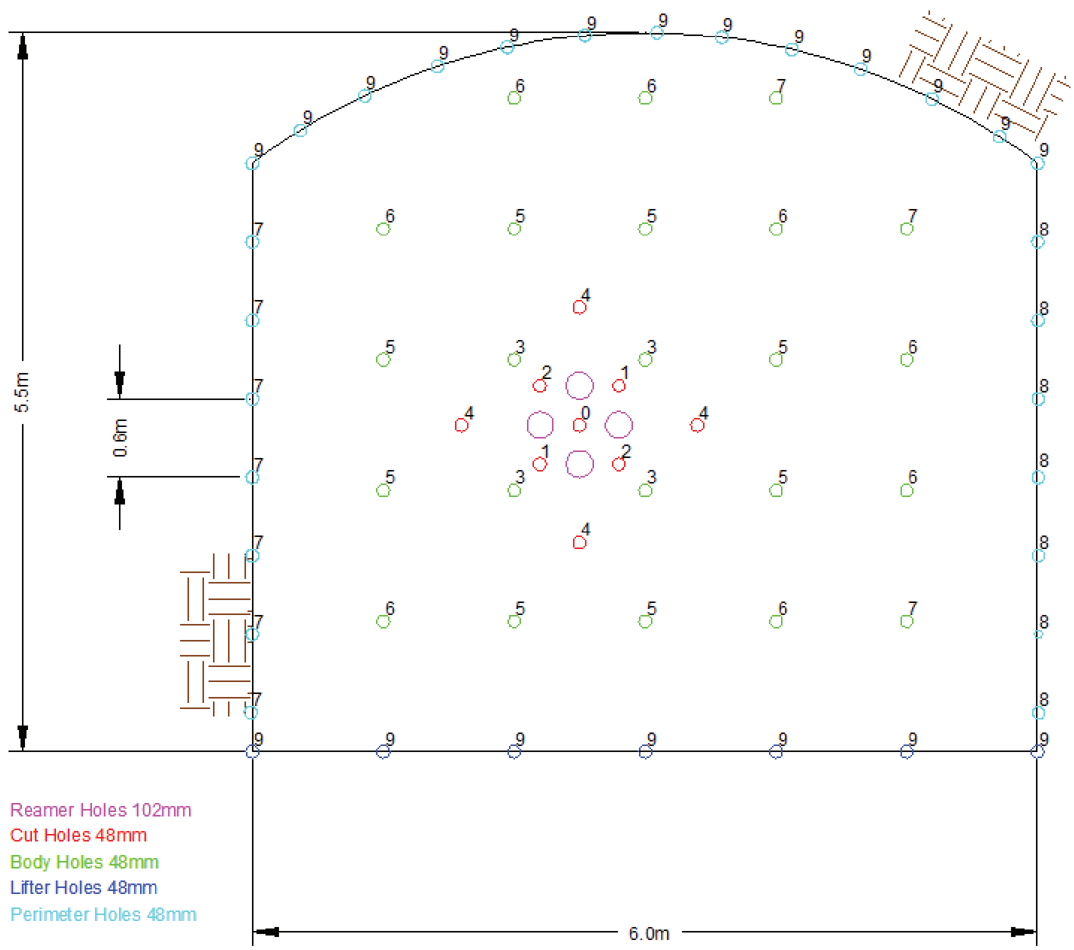
Main Ring Blast Timing for Transverse Down-hole Stope



Source: AMC Consultants, 2013.

Figure 5.8-13

Lateral Development – Drill Layout and Blast Timing



Source: AMC Consultants, 2013.

Table 5.8-6. Life of Mine Backfilling – Waste Rock and Mill Tailings

Year	Ore Tonnes ('000 t)	Total Tailings ('000 t)	Waste Rock ('000 t)	Waste Rock Fill Volume (m^3)	Paste Fill Volume (m^3)	Tailings Underground ('000 t)
-2	0	0	324	0	0	0
-1	81	0	343	0	0	0
1	839	876	303	0	332	471
2	929	884	274	42	281	399
3	979	932	315	59	276	392
4	984	936	282	91	257	365
5	988	941	316	90	241	342
6	999	951	286	91	247	350
7	986	939	213	73	258	366
8	996	948	230	75	252	358
9	994	946	321	89	259	369
10	987	940	315	99	277	393
11	985	938	292	8	231	327
12	993	945	179	62	261	371
13	986	939	32	11	346	491
14	981	934	40	14	386	548
15	991	943	52	18	372	5292
16	908	864	46	16	337	478
17	663	632	31	11	274	389
18	281	267	3	1	129	184
Total	**16,550**	**15,775**	**4,198**	**934**	**5,016**	**7,123**

5.8.2.9 Potential for Surface Subsidence at the Brucejack Gold Mine Project

BGC Engineering Inc. (2013) conducted a preliminary review of the site specific conditions and factors affecting the potential for subsidence at the Project. This review indicated a very low probability that significant subsidence will occur. This conclusion was based primarily on the following facts:

- Because the overburden is thin (less than 5 m) and generally has a low clay content, dewatering of the Project area is not anticipated to cause consolidation and subsidence in the overburden.
- The rock mass at the Project is classified as Good to Very Good and Medium Strong to Strong, using industry standard classification systems. Rock of this quality around the periphery of an excavation limits the failure of overlying strata, resulting in a lower likelihood and severity of subsidence.
- The Brucejack deposits are steeply-dipping vein-type deposits. The principal risks for the safety of people and property located at surface above vein-type deposits is often concentrated above crown pillars and represents a relatively limited zone of influence at surface.
- The proposed mine footprint, while substantial, is not on the scale of other vein-type mining districts where significant subsidence has typically been recorded (e.g., tens to hundreds of hectares vs. thousands to tens of thousands of hectares).

- The proposed mining method of LHOS with complete backfilling will significantly reduce post-mining void volumes. Most often subsidence occurring as a result of stope mining techniques is limited to the hanging wall side of underlying stopes. In many cases, the degree of surface subsidence that occurs from stope mining is both isolated and relatively minor. Complete mine backfilling further reduces subsidence potential, often to virtually undetectable levels.
- To improve near-surface stability conditions at the Project, a minimum recommended crown pillar thickness of 15 m has been determined using a number of industry standard geotechnical methods and techniques. The crown pillars are also to be supported with cable bolts to assist with enhancing stability conditions and preventing the onset of subsidence mechanisms.

Notwithstanding the above, the presence of a number of significant regional geologic structures in the Project area may negatively influence rock mass stability and increase the potential for mining induced subsidence. Continuous subsidence monitoring and further study of these structures will improve the level of understanding with respect to this potential.

5.8.3 Mine Production Schedule

Full 2,700 t/d production will effectively be achieved in Year 2, the fourth year of Project activity.

Figure 5.8-14 illustrates the ramp-up to full production tonnage as the various blocks are brought into production.

Table 5.8-7 provides a summary of projected life of mine production tonnes and grade.

5.8.4 Underground Infrastructure

5.8.4.1 Mine Dewatering

Mine dewatering must accommodate groundwater inflows from the VOK Zone workings, the West Zone workings, and inflows from drills and other operating equipment. Average annual Inflows to the underground workings for best estimate parameters are estimated to range from 3,800 m^3/d (start of construction) up to 6,500 m^3/d (Year 8 for development of the West Zone) and then to decline to about 5,200 m^3/d by end of operations. Average annual flow over life of mine is simulated to be 4,900 m^3/d.

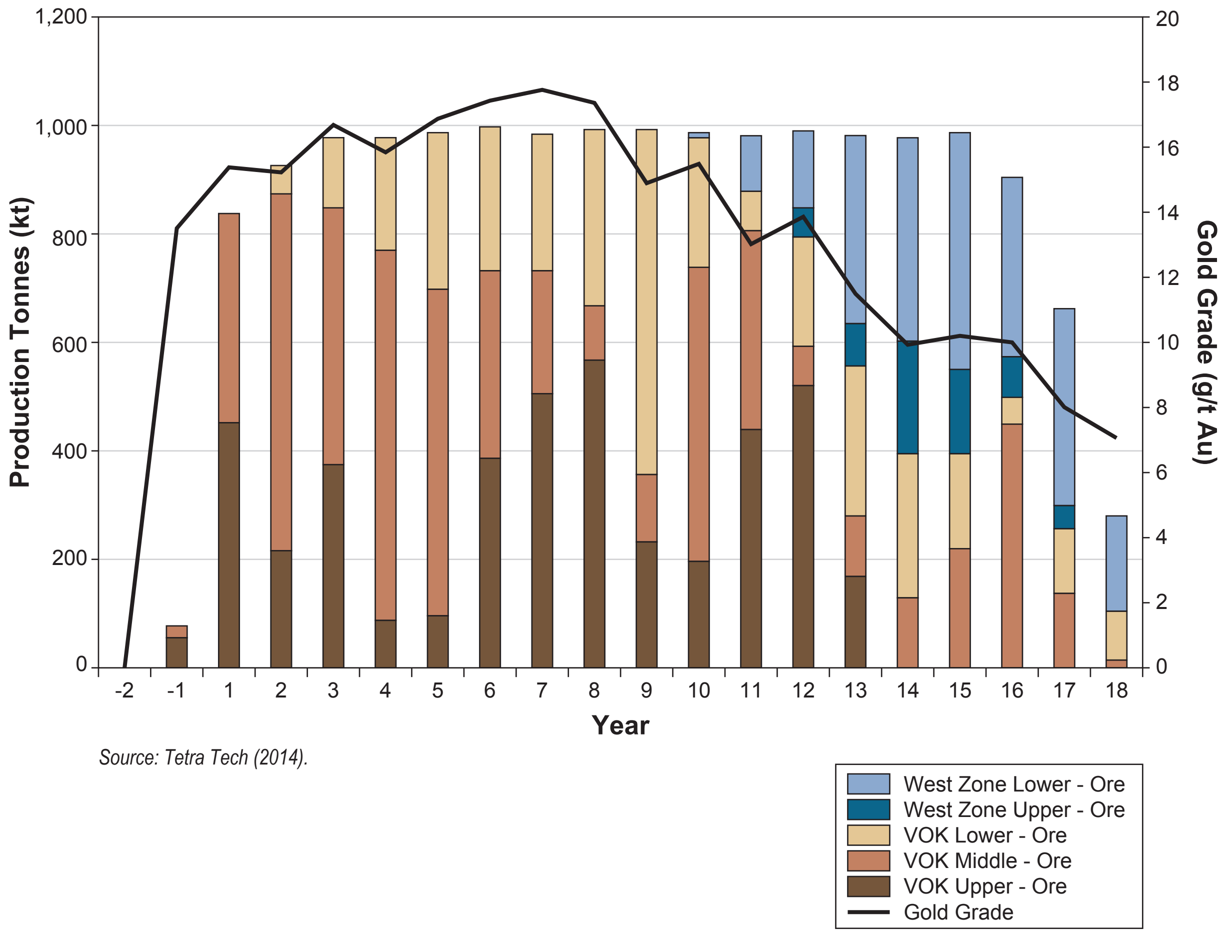
Mine dewatering will be handled by a combination of submersible and horizontal centrifugal pumps located throughout the West Zone and VOK Zone working levels. The pumps will handle mine water via multiple lifts throughout the mine to minimize pump size and power. Lift stations will be designed with consistent vertical intervals of 60 m to maintain similar pump head characteristics. This reduces the number of different pump sizes required, which will simplify maintenance. Each pump station will have 100% redundancy such that the loss of any single pump will not disable the system.

Waste water from all of the underground dewatering sumps will report to the VOK Zone 1,330 Level sump through a network of boreholes and pressure piping, before leaving the mine and reporting at the surface 1,400 Level water treatment plant.

It is assumed that the pumps will not be running full time, but will cycle as required. For this reason, pump capacity was designed to be larger than the inflow, such that the maximum required operation, relative to time, is limited to 80% or less for any pump. The pipe capacity was sized in a similar manner.

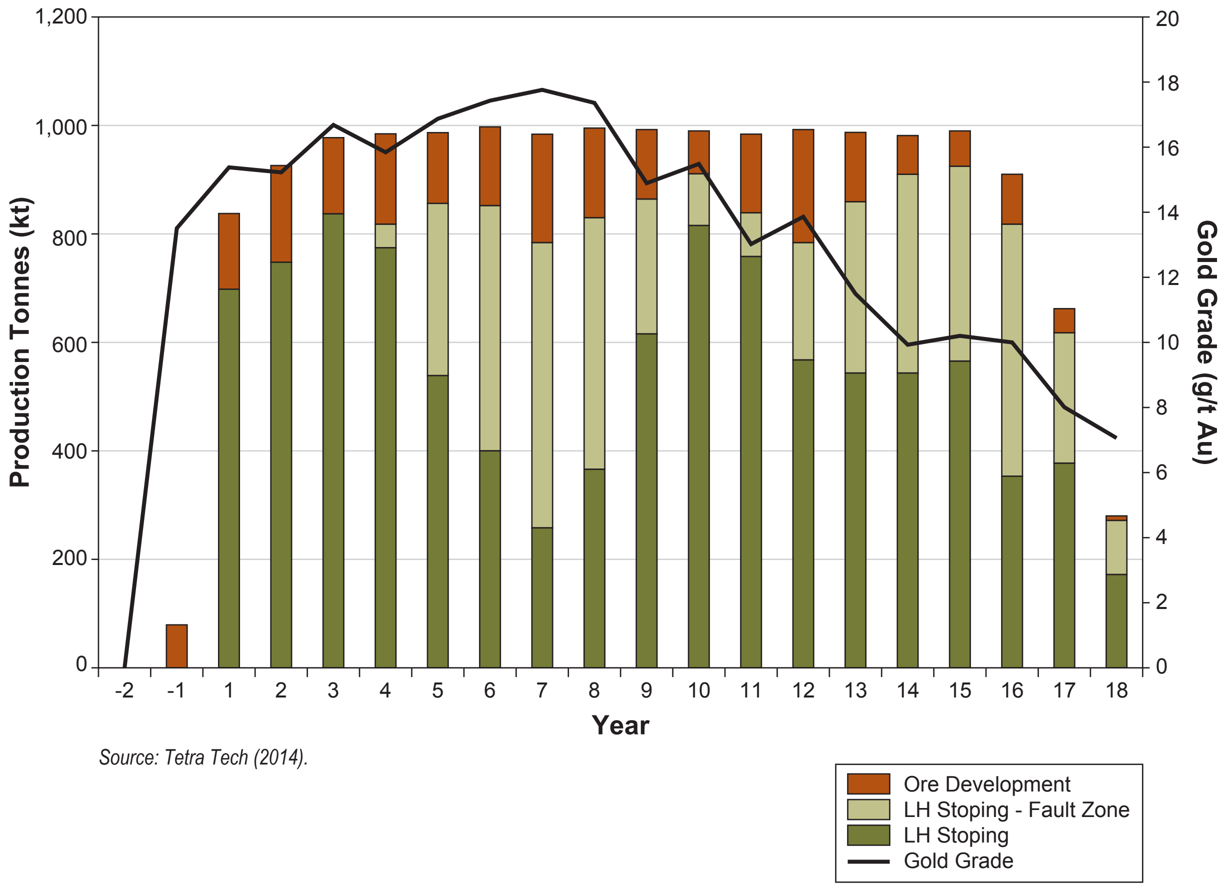
Figure 5.8-15 shows the projected life of mine split of production by development, slashing, and stoping.

Figure 5.8-14
Life of Mine Production Schedule by Mining Block



Source: Tetra Tech (2014).

Figure 5.8-15
LOM Production Schedule by Activity



Source: Tetra Tech (2014).

Table 5.8-7. Life of Mine Tonnes and Grades

Year	Ore (Mt)	Au (g/t)	Ag (g/t)	NSR ($/t)
-2	0	0	0	0
-1	81	13.6	11.5	451
1	839	15.4	11.7	521
2	929	15.3	11.7	516
3	979	16.8	12.8	574
4	984	15.9	9.9	539
5	988	16.9	11.0	579
6	999	17.5	10.6	601
7	986	17.8	11.8	612
8	996	17.5	11.7	600
9	994	14.9	10.2	507
10	987	15.5	11.2	525
11	984	13.0	29.3	444
12	993	13.9	69.2	497
13	986	11.6	102.8	430
14	981	9.9	151.9	393
15	991	10.2	158.7	407
16	908	10.4	104.1	376
17	993	8.0	254.7	375
18	281	7.1	271.9	350
Total	**16,550**	**14.1**	**57.7**	**500**

** Waste rock is assumed to be PAG.*

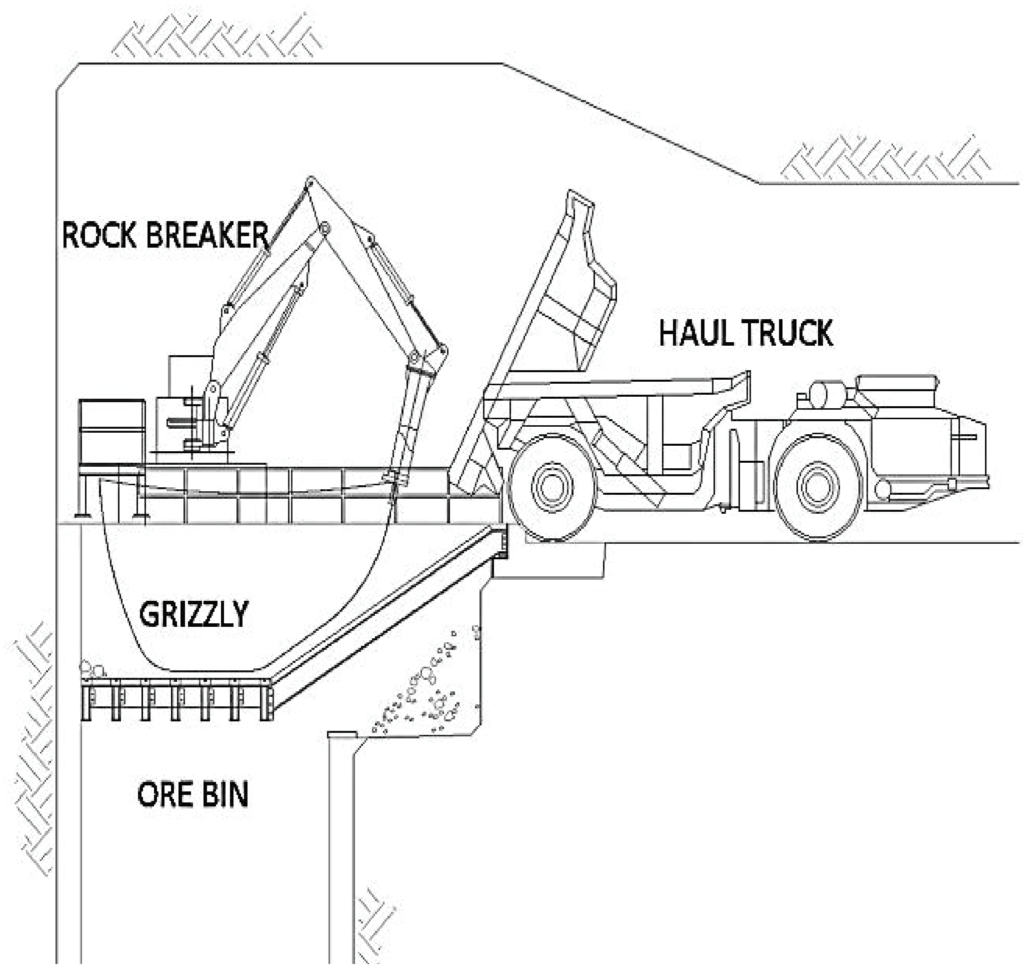
5.8.4.2 Ore Handling

Run of mine material will be transported underground by truck from the West Zone and VOK Zone areas and deposited into the ore storage bays or directly onto the scalping grizzly (see Figure 5.8-16). Material stockpiled in the 2,500 t capacity storage bays will be scooped and deposited onto the scalping grizzly by an electric LHD vehicle. At the scalping grizzly, material smaller than 500 mm will fall through to the ore bin and larger material will be broken down by a hydraulic rock breaker stationed above the grizzly screen.

As shown in Figure 5.8-17, the 500 t capacity ore bin will feed material down through a hopper at the bottom of the bin to a vibratory feeder. This vibratory feeder will contain a grizzly screen that will transport large material to a jaw crusher and allow fines (less than 64 mm) to fall through and down the fines chute to the transfer conveyor. The jaw crusher will reduce the larger material down to 80% passing 120 to 150 mm in size and drop this product down the fines chute to the transfer belt conveyor.

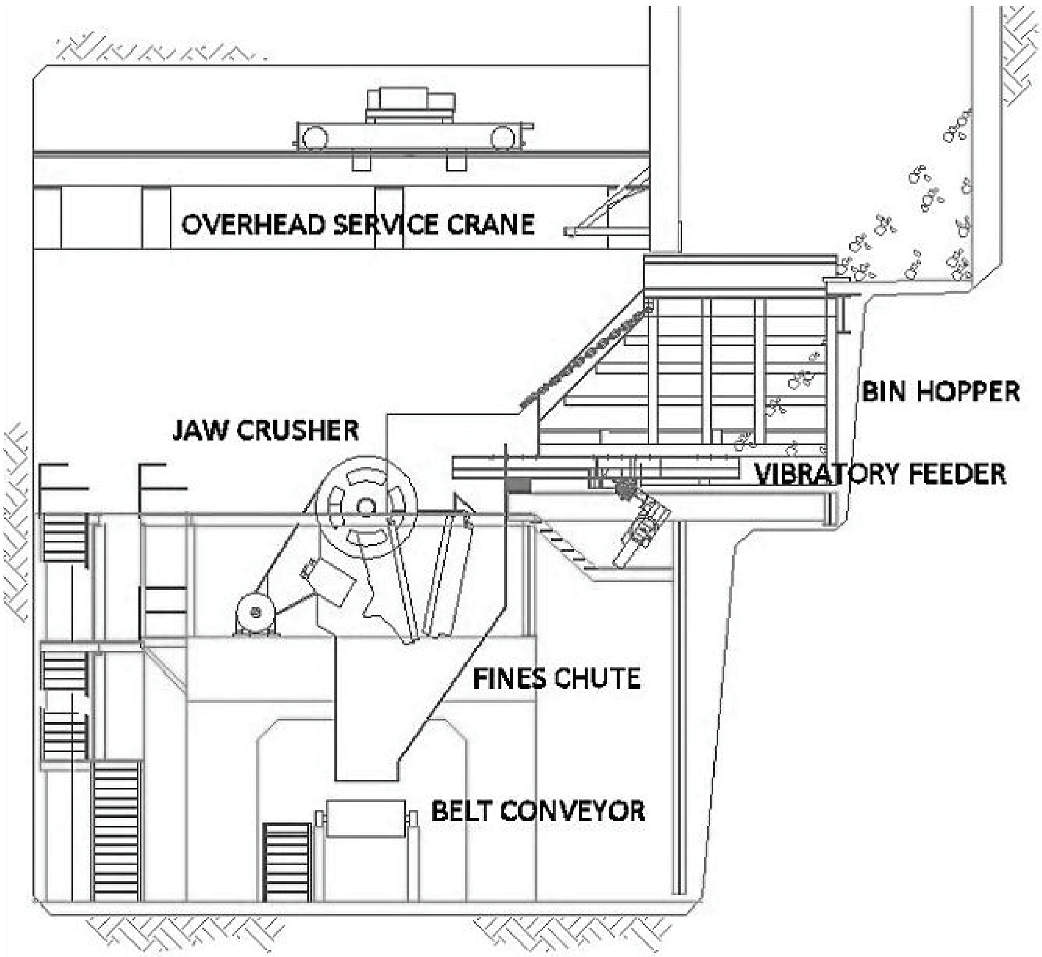
The 42 inch (107 cm)-wide belting on the transfer conveyor will carry material from the crushing area to the main conveyor at a speed of about 1 m/s and will be positioned at a 90° angle to the main conveyor. A magnet will remove any tramp iron.

Figure 5.8-16
Crusher Tipping



Source: Tetra Tech (2013)

Figure 5.8-17
Crusher



Source: Tetra Tech (2013)

The main conveyor will move at a rate of about 1 m/s transporting approximately 225 t/hour of ore up the decline tunnel to the transfer tower at the portal. The main conveyor will exit the decline tunnel through the portal structure where the drive unit will be located. The ore will continue on from the portal to the transfer tower and then by conveyor to the mill through an enclosed, heated, rectangular gallery. The combined length of the two conveyors will be about 800 m. The gallery structure will be elevated, continuing from the portal structure to the feed surge bin located inside the mill building, allowing for traffic underneath.

5.8.4.3 Ventilation

The ventilation system was designed to meet the requirement of the *Health, Safety and Reclamation Code for Mines in British Columbia – 2008* (BC MEMPR 2008), which requires a minimum of 0.06 m^3/s of ventilating air for each kilowatt of power of diesel powered equipment operating. The design is based on a “push” configuration, with permanent surface fans located at the portal of the twin declines.

The VOK Zone and West Zone mining areas will be supplied with fresh air from a connection to the twin declines and each area will have at least one exhaust return air raise to surface.

The underground crusher and workshop will have a dedicated return air raise to prevent the introduction of dust and other contaminants into production areas. The volume of air flowing through the crusher and workshop areas will be controlled with a combination of fans and regulation.

Figure 5.8-18 shows an isometric view of the Brucejack ventilation system.

All work areas in the mine not supplied with flow-through fresh air will be ventilated using auxiliary systems. These areas are typically headings under development. The most effective means for providing airflow to areas without primary airflow is typically with small diameter (up to 1,400 mm) axial fans combined with low leakage and flexible ducting.

During access and level development, distances up to 800 m will be ventilated using auxiliary systems. The peak auxiliary airflow for development activity will be required to dilute the emissions of one 40-t truck and one 14-t loader, amounting to 38 m^3/s of auxiliary airflow.

Modelling indicates that two ducts will be required in this situation. Each duct will have two 55-kW fans bolted together in series. The duct size will be 1,200 mm in diameter, which will supply 38 m^3/s up to a distance of 850 m. This arrangement will allow for adequate overhead clearance for a fully-loaded 40-t truck.

An allowance of 10 m^3/s was made for each active drawpoint for dust, blast fume, and diesel exhaust clearance. Modelling indicates that a single-stage 55-kW fan, with 900 mm diameter low-resistance, low-leakage ducting will supply the required airflow to a distance of at least 400 m. An increase of ducting size to 1,100 mm will be employed for stopes that require a longer forcing distance-up to 750 m.

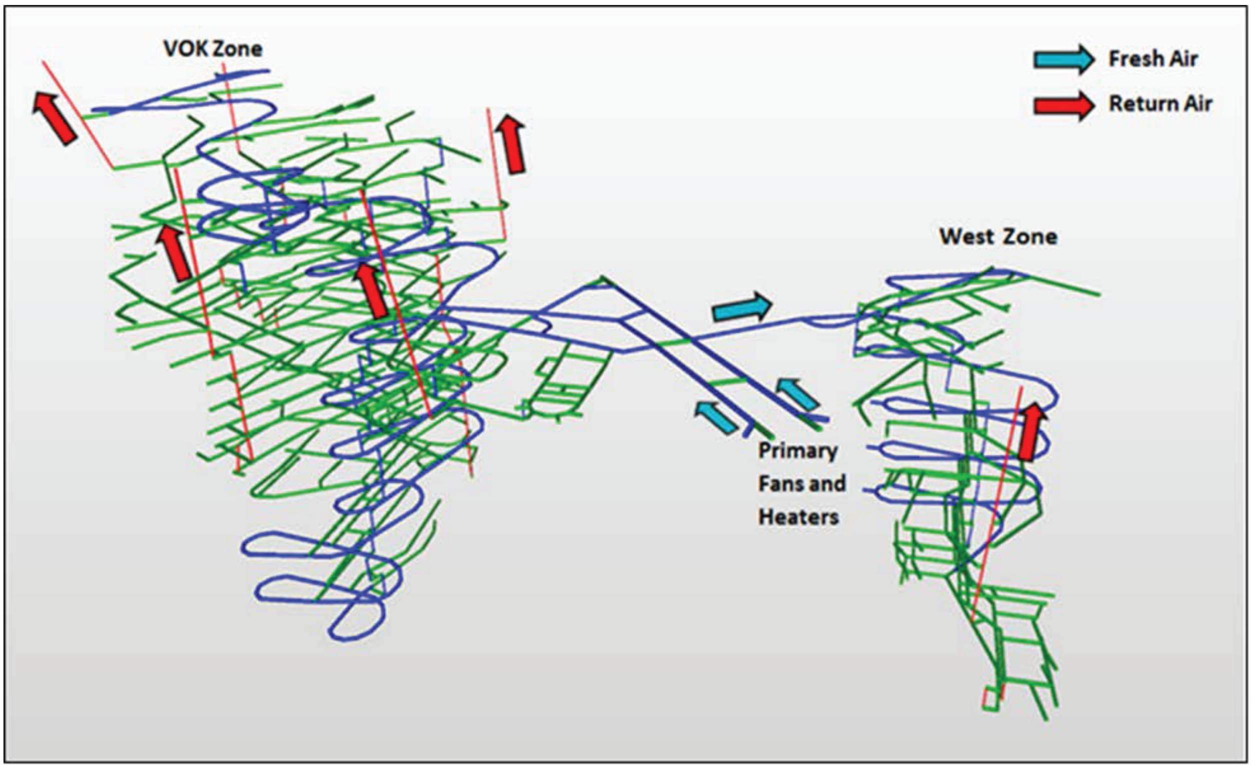
Table 5.8-8 summarizes the specifications of the primary fan.

An automatic stench gas warning system will be installed on the supply side of the surface vehicle portal and conveyor portal. When fired, this system will release stench gas into the main fresh air system allowing the gas to permeate rapidly throughout the mine workings. Once stench gas is released, underground mine personnel would report immediately to the nearest mine refuge station or surface, whichever is closer.

The primary purposes of fire doors are to prevent noxious gases from reaching workers should they be trapped underground and to prevent fire from spreading as much as possible.

Figure 5.8-18

Brucejack Ventilation System - Looking West



Source: Tetra Tech .

Table 5.8-8. Primary Fan Specifications

Description	Specification
Duty	Two each @ 170 m^3/s @ 1,200 Pa
Fan diameter	2.84 m
Type	Horizontal mount axial mine fan
Configuration	There will be two forcing fans, each connected with ducting to the main access decline and conveyor decline
Voltage	4,160 V
Fan motor	266 kW to 710 rpm, variable frequency drive capability

Fire doors will be required to isolate the following areas:

- workshop;
- fuel bay;
- crusher tipple; and
- conveyor decline.

Portal doors will also be designed to meet fire door criteria.

5.8.4.4 Underground Electrical Demand and Distribution

The maximum underground connected electrical load to support full production and development activities will be approximately 9 MW, inclusive of ventilation and heating. A propane direct-fired system will supplement the electric heating system.

Ventilation and heating, mobile equipment, and dewatering are the main consumers of power. The maximum running load is estimated to be 4.8 MW and will occur when full production levels are achieved. As the mine is developed deeper, the dewatering power demand will increase due to a higher lifting head and increased inflows. As development activity and production decrease, the power requirements will also reduce.

Electrical power will be supplied to the portal building by four separate 4,160-V feeder circuits from the site main substation. Two feeders (2 x 3 conductor, 500 MCM each) will supply power to the 4,160-V distribution equipment located at the portal building. The other two feeders (2 x 3 conductor, 350 MCM each) will continue on through the portals to the underground access declines, one feeder in the main access decline and one in the conveyor decline.

The portal building 4,160-V switchgear will incorporate two main incoming circuit breakers, a tie circuit breaker and suitable feeder circuit breakers. These will supply power to two ,2500-kVA electric heater units supply transformers, two 350-horsepower fan drives, a 300-horsepower conveyor drive, and other auxiliary equipment via a 300-kVA delta-wye step-down transformer with a 5 A continuous rated neutral grounding resistor. A 600 V, 600 A motor control center will be supplied by the step-down transformer to distribute power to various small horsepower motors and a lighting panel located at the portal building.

Each 4,160-V decline feeder will terminate at respective substations located at the 1,298 crusher level and 1,330 (truck dump) level. A tie circuit will connect the two underground fused switch assemblies to allow for a redundant power feed system from either underground feeder. A step down transformer located at the 1298 level substation will provide 600 Volt supply to various electrical loads including the crusher, conveyors, main sump, lighting, etc.

Additional 4,160 V-feeders (three conductors, 500 MCM each), supplied from fused disconnects at the 1,290 and 1,330 level to both the VOK Zone and West Zone working levels, will provide power to portable substations to be used for development, pumping, ventilation, lighting, etc.

5.8.4.5 Compressed Air

Compressed air will be supplied by local area compressors. The underground maintenance and service bay area will have a dedicated compressor permanently installed, with air lines from the air receiver routed to convenient locations in the area.

In addition to the permanent compressors, several smaller, portable compressors will be available.

All mobile drilling equipment, including jumbos, long-hole drills, bolters, and cable bolters will be equipped with on-board compressors. ITH drilling equipment will have portable adjacent compressors to meet their elevated pressure requirements.

5.8.4.6 Service Water Supply

Service water for drilling and dust control will be supplied via a 10 cm (4 inch) steel line at the portal. The line will continue through the main decline ramp to the underground workings. Pressure reducing valves will be supplied at the 1,320, 1,220, and 1,120 levels to reduce the supply pressure below 689 kPa (100 psig).

Two lift stations will be required to supply service water to the higher-working levels. Water holding tanks will be positioned at the 1,390 and 1,480 levels. The 1,390 Level tank will be fed by the main header pressure in the decline ramp. An automated valve will control the tank level and a booster pump will feed working levels from the 1,390 Level up to the 1,480 Level. A tank positioned on the 1,480 Level will supply another booster pump to feed service water to the higher levels in the same fashion.

5.8.4.7 Fueling and Lubrication

A fuel bay area will be located on the 1,320 infrastructure level between two automatic fire doors. The doors will be connected to a fire detection system that will close the doors if a fire is detected. A foam fire suppression system will be located inside the fuel bay area and will consist of a storage tank, piping, valving, detectors, and alarms.

The fuel bay area will include a main drift and three bays. A 20,000-L fuel storage tank and a fuel delivery pumping system will be located in one of the bays located inside the fuel bay area.

The fuel storage tank will be filled from a fuel delivery truck coming from surface. A sump pit in another of the side bays will contain a sump pump and removable grating cover. The sump pump will report any collected water to the shop sump.

The third side bay will be used for oil and grease.

Vehicles requiring re-fueling or oil and greasing will enter the fuel bay area from the west and exit to the east.

5.8.4.8 Workshop and Stores

The main maintenance area will be located on surface. All major scheduled preventive maintenance and rebuilds will take place in the surface shop. Two small service bays will be located underground to complete low level maintenance such as lubrication and small repairs. The service bays will have finished concrete floors, monorail hoists, tire storage, lube storage and the capacity to make hydraulic hoses.

The service area will be equipped with a stationary compressor and airlines to power air tools and provide compressed air as needed. A welding plug will also be sited in this area.

A warehouse and small office will also be located near the underground service bay area.

5.8.4.9 Explosives Magazine

Two bays will be provided for the storage of bulk emulsions, each containing 24,000 L storage tank and a storage area. The entrance to the bays will be controlled with a rollup door and a man-door. The length of each bay will be approximately 12.8 m.

A powder bay will be designated for the storage of all other explosive products (other than the bulk emulsion and the detonators) on wooden shelves. A concrete wall with a steel door will separate this bay from the rest of the mine works.

A fourth bay will be designated for the storage of detonators on wooden shelves. A concrete wall with a steel door will separate this bay from the rest of the mine works.

5.8.4.10 Refuge Stations

A refuge station will be located between the two decline tunnels at the mine works. The station will accommodate 40 people and will be equipped with an airlock entrance, a battery back-up electrical system, an air conditioning unit, a carbon dioxide/carbon monoxide scrubbing unit, cache of oxygen-type cylinders, and an emergency supply of first aid, food, water, and oxygen candles.

The refuge station will be located in a bay off a drift and will be separated from the drift by a concrete wall. Access to the station will be through an airlock system.

This refuge station will also serve as a lunchroom.

Additional refuge will be provided by five 12-person, mobile, self-sufficient rescue chambers. These chambers will be independent of a compressed air supply, with appropriate provisions for safe refuge. They will be located in areas where a secondary egress is not, or has not yet been established, and will be sited relative to the active working areas in order to be within the average walking pace duration of a personal self-rescuer device.

5.8.4.11 Portal Structure

A portal structure will be constructed at the access to the underground decline tunnels. The structure will span the area between both decline tunnels and will house the mine air heaters and ventilation fans, the conveyor drive motor and mechanism, and an electrical substation. The main decline conveyor will exit from the tunnel to a transfer tower to the conveyor to the mill building. Access into the portal structure will be via one of four overhead doors.

The portal structure was designed to be built up against the pad excavation high wall and will be required to resist roof snow loads with pressures up to 400 kg/m^3. The roof was designed with 6:12 and 7:12 pitches to better shed snow. A ridgeline roof split will also help initiate snow movement from the roof.

A monorail located in the ceiling of the portal structure will allow for removal of the mine air fan motor and components.

5.8.4.12 Underground Communications

The underground wireless network infrastructure will consist of:

- Voice over Internet Protocol (VoIP) MinePhones;
- cap lamps; and
- asset and personnel tracking;

Radio communications will be established underground by virtue of a wireless digital, Local Area Network (LAN) protocol WiFi compatible system. The backbone of the network will comprise of gigabit network switches connected by a composite cable that runs fiber and power to each device. Each switch will also house up to two wireless radios, giving pervasive wireless coverage along travel ways. This will also provide the ability to make continuous VoIP telephone calls from the portal to the face, and complete asset and personnel tracking. The system will also have redundancy to keep it running in the event that the fiber gets damaged.

The network system “Head End Unit” will reside in the portal indoor substation. The two network backbone cables will branch out through the portals into the underground access declines—one in the main access decline and one in the conveyor decline. Amplifiers will be spaced out between ultra-high frequency coax cable segments at no more than 350-m spacing. A communications cable will also branch out at drifts as necessary, with “end-of-line” termination antennae as required.

Personnel tracking will be accomplished using a radio frequency identification tag system. An integrated communications cap lamp will contain the radio frequency identification tag.

Vehicles will also contain radio frequency identification tags and ultra-high frequency radios. The system will be integrated into MineDash, a browser-based tracking and reporting application, allowing operators and mine controllers to monitor, track and allocate personnel and resources.

Movement of personnel, vehicles, and other assets will be monitored throughout the mine. Having the ability to ensure that mine staff are accounted for in an emergency will increase safety and speed the provision of help to any injured personnel.

A programmable logic controller (PLC) system will be used for fixed plant monitoring and control. The PLC system processor (main rack) will reside in the portal indoor substation. Remote PLC racks placed near equipment (as necessary) will monitor and control the underground systems, including, but not limited to:

- rock box levels;
- crusher;
- conveying equipment;
- tramp metal magnet;
- substations;
- sumps and pumps;
- ventilation doors;
- fuel delivery;
- traffic control; and
- air quality and quantity.

The PLC system will be tied to the mill and control room on surface using a wireless antenna to bridge the underground network and the control room networks together.

5.8.5 Production Equipment

During the Operation phase the rate of development will average about 420 m/month. The equipment required to achieve this rate of development as well as the proposed 2,700 t/d of ore production is shown in Table 5.8-9. Required support equipment is shown in Table 5.8-10.

Table 5.8-9. Underground Development and Production Equipment

Description	Availability (%)	Utilization (%)		Quantity
		Peak	Average	
Two boom mining jumbo	86	64	53	3
LHD, 14 t (diesel;(development)	80	76	59	3
LHD, 14 t (electric; production)	80	85	73	5
Haulage truck, 40 t	85	90	72	6
Bolter	76	82	58	3
Cable bolter	71	90	68	1
Top hammer long hole drill	66	66	58	3
ITH long hole drill	66	88	59	2
100-kW generator set for electric LHD tramming	93	73	54	2
Explosives loader, diesel, emulsion (production)	93	20	15	2
Shotcrete sprayer	87	53	27	2
Transmixer	87	57	30	2

Table 5.8-10. Support Equipment

Description	Availability (%)	Utilization (%)	Quantity
Personnel carrier, 22 person capacity, diesel, underground	93	22	3
Scissor lift truck, diesel	87	39	2
Lubrication service truck, diesel	93	36	1
Boom truck, diesel	93	18	1
Explosives truck, diesel, emulsion (transport)	93	15	1
Tractor	93	22	11
Utility vehicle	93	22	19
Telehandler, diesel	87	34	1
Wheel loader with tire handler	93	11	1
Motor grader (tracks and wheels)	88	16	1
500 cubic feet per minute portable compressor	93	59	2

Horsepower ratings and expected hours of use of mine equipment are discussed in Chapter 7, Air Quality Predictive Study.

5.9 MINERAL PROCESSING

5.9.1 Introduction

The Brucejack mineralization typically consists of quartz-carbonate-adularia, gold-silver bearing veins, stockwork and breccia zones, along with broad zones of disseminated mineralization. Gold and silver are the major economical metals contained in the mineralization. There is a significant portion of gold and silver present in the form of nugget or metallic gold and silver.

The proposed concentrator, to be located near the conveyor portal, will use conventional gold and silver processing at a nominal rate of 2,700 t/d with an equipment availability of 92% (365 days a year). The concentrator will produce gold-silver doré from the gold and silver recovered by gravity concentration and smelting at the mine site. A gold-silver bearing flotation concentrate will also be produced, which will be shipped off site and sold.

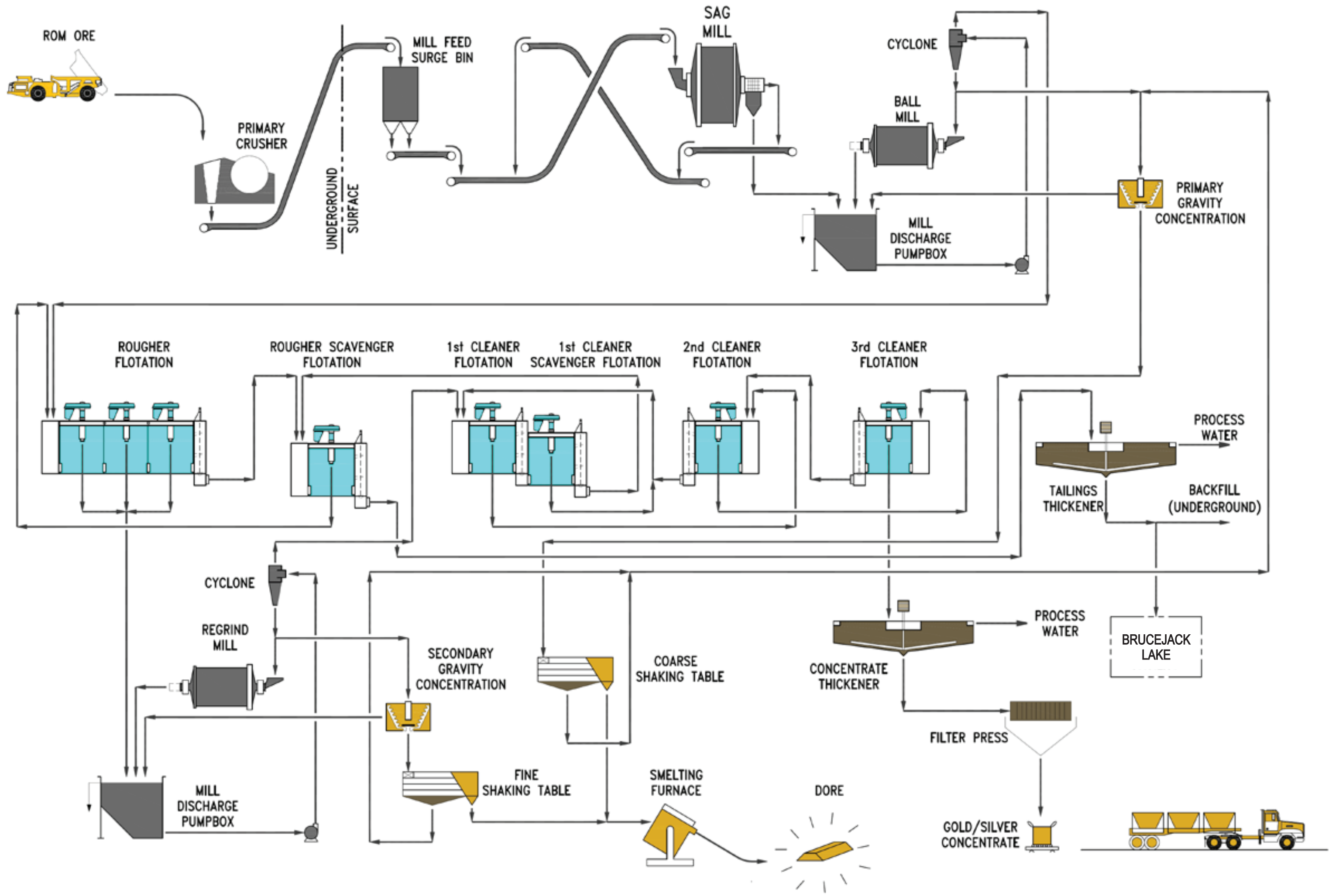
The concentrator and associated facilities will be constructed and operated in a manner consistent with the *Mines Act* (1996d) and its *Health, Safety and Reclamation Code for Mines in British Columbia* (BC MEMPR 2008).

5.9.2 Summary

The process flowsheet (Figure 5.9-1) developed for the Brucejack mineralization is a combination of conventional bulk sulphide flotation and gravity concentration to recover gold and silver. The process plant will produce a gold-silver bearing flotation concentrate and gold-silver doré from melting the gravity concentrate produced from the gravity concentration circuits. Based on the life of mine average, the process plant is estimated to produce approximately 5,600 kg of gold and 1,900 kg of silver as doré and 44,000 t of gold-silver bearing flotation concentrate per year from the mill feed, grading 14.1 g/t gold and 57.7 g/t silver. The estimated gold recoveries to the doré and flotation concentrate are 43.3% and 53.4%, respectively, totalling 96.7%. The estimated silver recoveries reporting to the doré and flotation concentrate are 3.5% and 86.5%, respectively, totalling 90%. The life of mine average gold and silver contents of the flotation concentrate are anticipated to be approximately 157 g/t gold and 1,000 g/t silver. The flotation concentrate will be shipped off site to a smelter for further treatment to recover the gold and silver. The process will consist of:

- primary crushing underground;
- a conveying system for crushed ore;
- a surge bin with a live capacity of 2,500 t on surface;
- primary grinding circuit integrated with gravity concentration;
- rougher/scavenger flotation;
- bulk flotation concentrate regrinding and gravity concentration;
- cleaner flotation;
- gravity concentrate smelting to produce doré;
- flotation concentrate dewatering, bagging, and load out; and
- tailings thickening and transport to the paste plant or mixing plant for disposal.

Figure 5.9-1
Simplified Process Flowsheet



Source: Tetra Tech (2013).

A portion of the flotation tailings will be used to make paste for backfilling the excavated stopes in the underground mine, and the balance will be stored in Brucejack Lake. The water from the thickener overflows will be recycled as process make-up water. Treated water from the water treatment plant will be used for mill cooling, gland seal service, reagent preparation, and make-up water.

5.9.3 Primary Crusher and Mill Feed Surge Bin

The run-of-mine ore will be trucked from the underground mine to the underground primary crushing facility. The jaw crusher feed will be less than 500 mm. The jaw crusher will reduce the run of mine ore to 80% passing 120 to 150 mm. A rock breaker will be installed to break any oversize rocks ahead of the jaw crusher.

Pre-production ore will be stockpiled at the pre-production ore storage and waste rock transfer storage area. Once the mine is in production, stockpiled ore will be backhauled underground to the crushing plant.

During the Operation phase the primary crusher product will be transported by a conveyor system from the underground primary crushing facility to the 2,500-t SAG mill feed surge bin located in the mill building on surface. The primary crushing and conveying facilities, including each of the crushed ore transfer points, will be equipped with a dust collection system or water spray to control fugitive dust generated during crushing and conveyor loading. The crushing and conveying system will be controlled from the process central control room, located in the mill building.

5.9.4 Mill Building

The mill building will be located on a pad adjacent to the underground portal (Figure 5.1-2) and will have a footprint of about 137 m by 63.5 m.

The mill building will be a pre-engineered steel building with insulated roof. It will be supported on a concrete spread footing with concrete grade walls along its perimeter. The building floor will be a concrete slab-on-grade, and will be sloped towards sumps for cleanup operation. Heavy equipment with dynamic loads housed in the mill building will be supported on a concrete foundation isolated from other building components.

The building will house the following facilities:

- grinding/regrinding/flotation/thickening;
- gold room;
- concentrate dewatering, storage, and loadout;
- water treatment plant;
- paste backfill plant and cement storage;
- potable water treatment plant;
- mill mechanical and electrical maintenance shops;
- storage room;
- electrical room;
- control room ;
- offices, including administration offices; and
- assay and metallurgical lab.

Interior steel platforms on multiple levels will be provided to support process equipment and to meet ongoing operation and maintenance needs.

Electric power will be supplied to the mill building by overhead lines from the nearby substation and emergency diesel generators.

5.9.5 Primary Grinding, Classification, and Primary Gravity Concentration

The primary grinding circuit will consist of a SAG mill and a ball mill in a closed circuit with classifying hydrocyclones and a pair of centrifugal gravity concentrators. The primary grind size will be 80% passing approximately 90 micron. The tailings of the centrifugal concentrators will be sent to the SAG mill discharge pumpbox (cyclone feed pumpbox). Grinding will be conducted as a wet process at a nominal feed rate of 122 t/hour of ore.

The gravity concentration process will recover nugget gold particles from the ball mill discharge. Tailings from gravity concentration will return to the hydrocyclone feed pump box by pumping. The gravity concentrate will be pumped to the gold room for further upgrading by tabling. Tailings from the tabling will be further processed by a centrifugal concentrator in the gold room. The concentrate produced from the centrifugal concentrator will be recycled back to the tabling circuit while the tailings will be pumped to the feed well of the centrifugal gravity concentrators located in the grinding circuit. The concentrate from the tabling circuit will be further upgraded by smelting. The gravity concentration circuit will have a security enclosure and CCTV cameras; access will be restricted to authorized personnel only.

5.9.6 Rougher and Scavenger Flotation

The pulp from the grinding circuit will be subjected to conventional flotation to recover the free gold, silver, and their bearing minerals from the materials being processed. The feed rate for the flotation circuit will be 122 t/hour of ore. Flotation reagents, including potassium amyl xanthate (PAX) as collector and methyl isobutyl carbinol (MIBC) as frother, will be added to the flotation circuits. The mass recovery of the rougher concentrate will be approximately 20% of the flotation feed. The concentrates produced from the rougher flotation circuit will be sent to the regrind circuit and subsequently to the cleaner flotation circuit. The rougher flotation tailings will be further processed by scavenger flotation, along with the tailings from the first cleaner flotation circuit. The scavenger concentrate will be returned to the preceding rougher flotation head. Rougher and scavenger flotation will be carried out at the natural pH level (without slurry pH adjustment). The tailings from the flotation circuit will be discharged to the tailings thickener.

The flotation concentrate from the rougher flotation circuit will be forwarded to the regrinding circuit. Steel balls will be added into the mills on a batch basis as grinding media.

5.9.7 Slimes Flotation

An additional flotation circuit consisting of two 3 m^3 flotation cells will be included in the circuit to handle slime material that is generated in the underground workings. This material will enter the circuit at approximately 30% solids. The reagents PAX and MIBC will be added to enhance flotation recovery. The concentrate recovered in this circuit will be pumped to the head of the first cleaner flotation circuit. The tailings from the circuit will report to the rougher scavenger tailings pump box for disposal.

5.9.8 Cleaner Flotation

The reground concentrates will undergo three stages of cleaning by flotation in order to produce a final gold-silver bearing concentrate. The reagents used in the primary bulk flotation circuits will also be added to the three stages of cleaner flotation to float the target minerals. The cleaner flotation processes will be carried out at the natural slurry pH level as well.

5.9.9 Concentrate Handling

The concentrate from the third cleaner flotation will be thickened to about 60% solids, filtered in a tower type press filter to about 10 to 12% moisture, and bagged in 2-t bags prior to being transported to off-site smelters in shipping containers.

5.9.10 Gravity Concentrate Upgrading

The gravity concentrates produced from the primary grinding circuit and the regrinding circuit will be upgraded by conventional tabling followed by smelting to produce gold-silver doré. Upgrading will be conducted in a secure facility with security entrances and 24-hour CCTV surveillance. Operations in the secured gold room will be conducted during day-shift only, and access to the gold room will be restricted to authorized personnel only.

5.9.11 Reagent Handling and Storage

The concentration process will use a number of reagents, including flocculants, and anti-scalants. The transportation, storage, use, and disposal of these chemicals will be subject to management plans, including the hazardous materials and waste management plans.

PAX and MIBC will be added to the flotation process slurry stream to modify the chemical and physical characteristics of mineral particle surfaces, and to enhance the recovery of the valuable mineral particles into the concentrate products. Flocculant will be used as a settling aid for the flotation concentrate and tailings thickening. Anti-scalant will be added as required to protect pipelines and process equipment. Hydrated lime will be used to prepare an alkaline solution for scrubbing.

PAX will be shipped to the mine site in solid form. The reagent will be diluted to 10% solution strength in a mixing tank, and stored in a 1.50-m-diameter by 1.50-m-high holding tank. The solution will be added to the various addition points by metering pumps. Freshwater will be used to make up the required solution strength.

MIBC will be shipped to the plant as liquid in bulk tankers. The reagent will be stored in a holding tank and pumped in undiluted form to the points of addition using metering pumps.

Solid flocculant will be used for the Project. The flocculant will be prepared in the standard manner in a wetting and mixing system to a dilute solution of less than 0.2% solution strength. The solution will be stored a holding tank prior to being pumped by metering pumps to the thickener feed wells.

Anti-scalant chemicals will be delivered in liquid form and added to the process water tank as required to minimize scale build-up in the water pipelines and process equipment. This reagent will be added in undiluted form.

A mixing, holding, and dosing system will be provided to occasionally test any new reagents that may improve the metallurgical performance for better metal recovery. These reagents will be handled in accordance with Material Safety Data Sheet requirements, and any unused test reagents will be returned to the suppliers for disposal.

To ensure containment in the event of an accidental spill, the reagent preparation and storage facility will be located within a containment area designed to accommodate 110% of the content of the largest tank. The storage tanks will be equipped with level indicators and instrumentation to ensure that spills do not occur during normal operation. Appropriate ventilation, fire and safety protection, and Material Safety Data Sheet stations will be provided in the area.

Each reagent line and addition point will be labelled in accordance with Workplace Hazardous Materials Information Systems standards. All operational personnel will receive Workplace Hazardous Materials Information Systems training, along with additional training for the safe handling and use of the reagents. A Hazardous Materials Management Plan is outlined in Section 29.7.

5.9.12 Plant Control

A distributed control system using PLCs will provide equipment interlocking, process monitoring and control functions, supervisory control, and an expert control system (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC). The system will generate production reports, provide data and malfunction analyses, and produce a log of all process upsets. All process alarms and events will be logged by the system.

Using the operator workstations in the main process plant, it will be possible to monitor the entire plant site process operations, view alarms, and control equipment within the plant. Supervisory workstations will be provided in the offices of the plant superintendent and the mill maintenance superintendent.

A dedicated security system will be installed with multiple CCTV cameras in the gold room to monitor operations and security. The system will connect with the overall site security monitoring systems in the plant control room and the offices of the plant superintendent and security.

5.10 WATER MANAGEMENT

Water management will be a critical component of the Project design in this high runoff environment. The most likely avenue for transport of contaminants into the natural environment will be through surface or groundwater. As such, Pretivm has developed a water management plan (Appendix 5-C, Brucejack Project Environmental Assessment – Water Management Plan; see also Section 29.19, Water Management Plan) that applies to all mining activities undertaken during all phases of the Project.

Strategies for water management include:

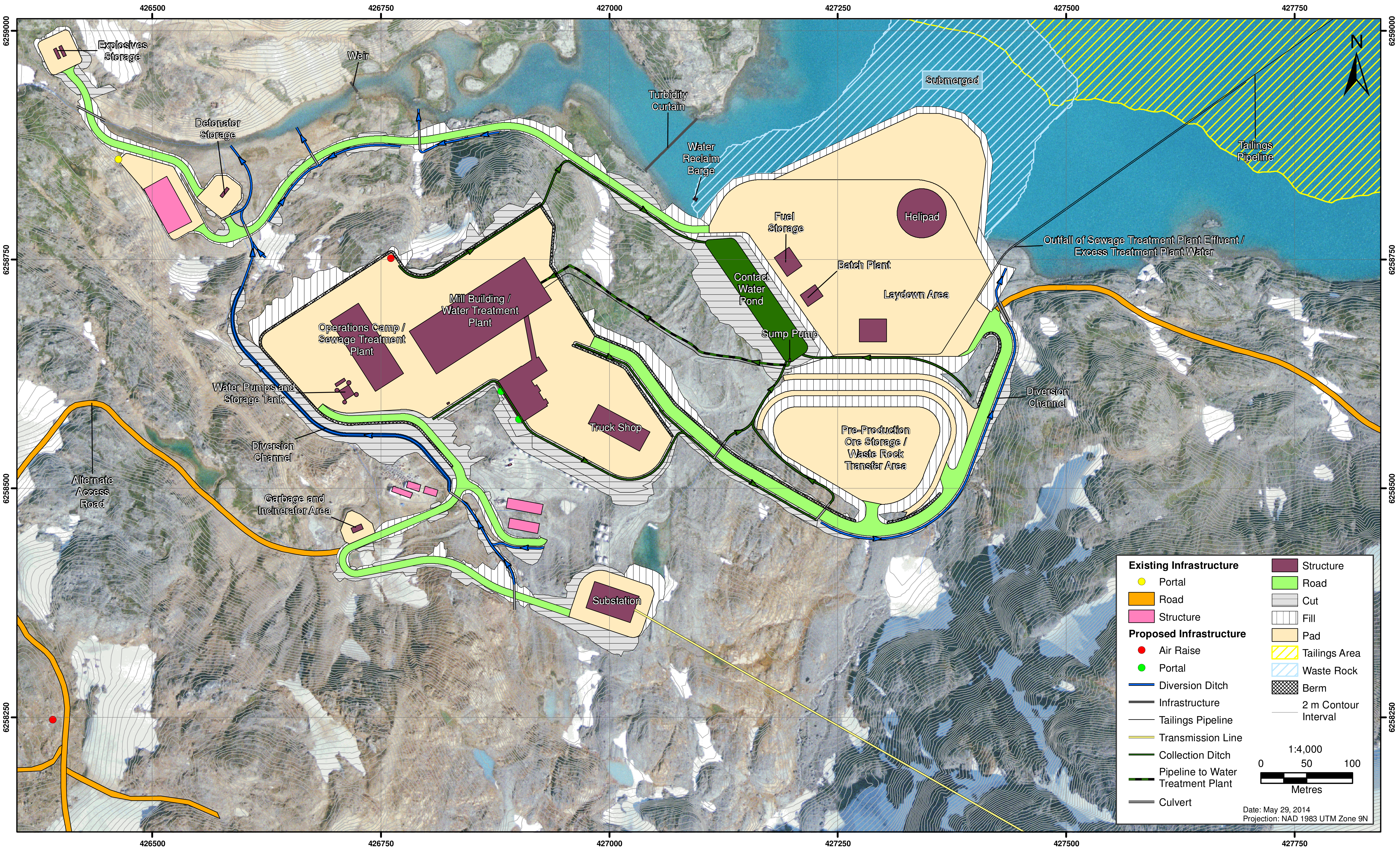
- protecting disturbed areas from water erosion, and collecting surface water from disturbed areas and treating it to meet discharge standards prior to release (contact water collection and treatment);
- minimizing the use of freshwater through recycling of water whenever possible;
- monitoring the composition of release water and treating it to remove or control contaminants as required to meet discharge standards; and
- constructing diversion channels around the mine surface development area to direct undisturbed runoff away from surface activities at this location.

5.10.1 Construction Phase Water Management

During the Construction phase, water management will include the following:

- Freshwater diversion channels will be constructed around the plant site (Figure 5.10-1). Diversions will be required for the Brucejack Camp, laydown area, and garbage and incinerator area. The diverted water will either discharge to Brucejack Lake or downstream of the lake into Brucejack Creek.

Figure 5.10-1
Freshwater Diversion and Contact Water Collection Systems



- Groundwater from the underground workings will be pumped to a water treatment plant and treated before being discharged into Brucejack Lake. The water treatment plant will have a capacity of 400 m^3/hour.
- Runoff from the plant site excavation and from the ore stockpile will be captured by a perimeter ditch system, diverted to a contact water pond, and pumped to the water treatment plants for treatment prior to release to Brucejack Lake.
- Waste rock suspected to be PAG will be deposited in Brucejack Lake to create the laydown area. Therefore, sufficient water cover over the waste rock deposits must be maintained to limit exposure to air. Reclamation material stockpiles will be seeded and silt fences will be installed around the perimeter of any stockpiles to prevent erosion during construction.
- A 450-person camp will be required for the Construction phase. An effluent rate of 104 m^3/d is assumed. A sewage treatment plant will be constructed to handle this effluent with the treated effluent discharged to Brucejack Creek downstream of Brucejack Lake during construction (and into the lake during operations).

5.10.2 Operation Phase Water Management

During the Operation phase, water management will include the following:

- Approximately 45% of the tailings will be deposited underground as paste backfill, while 55% will be discharged sub-aqueous at a maximum depth of 80 m in Brucejack Lake.
- Reclaim from the lake will be required, as there will be periods when the groundwater inflows are predicted to be less than the process requirement.
- Tailings will either be diverted to the paste backfill plant or diluted and sent to Brucejack Lake, but never concurrently. A constant flow is required through the pipeline at all times to keep the deposit at the end of the outfall fluidized; however, the tailings line to the lake will only be operational about 50% of the time. Therefore, when the thickened tailings are used in the backfill plant, flow will be maintained with fluidizing water, which will be sourced from excess treated underground seepage water and reclaim water from the surface of Brucejack Lake.
- Seepage water from the underground mine will be sent directly to a water treatment plant located in the mill building for treatment. Priority of use for this treated water will be:
  - the process plant;
  - fluidization water when excess amounts remain after process plant requirements; and
  - excess treated groundwater will be discharged to Brucejack Lake at times when the tailings slurry is also being discharged, as there is no on-site storage for the treated water.
- Given a settled dry density of 1.46 t/m^3 and a slurry consisting of 65% solids by weight, the paste backfill will exude some water during the curing phase (Appendix 5-C, Brucejack Project Environmental Assessment – Water Management Plan). This additional water is assumed to be pumped out with the groundwater seepage water and sent to treatment.
- Freshwater diversion channels will divert surface runoff around the surface infrastructure and temporary waste rock storage areas (Figure 5.10-1). The diverted water will either discharge to Brucejack Lake or downstream of the lake into Brucejack Creek (Camp Creek diversion).
- Contact water from the mill building and portal site and upper laydown area where the waste rock transfer and pre-production ore will be stored will be captured by a perimeter ditch system, directed to the contact water pond, and pumped to the water treatment plant for treatment prior to release to Brucejack Lake or use in process.

- Potable water will be obtained from wells, with subsequent treatment as required before piping to end users at the camp and other facilities (see Section 5.10.6.3). Studies to locate a suitable location for a potable water well(s) to supply the mine site requirements are underway.

Additional information on water management is provided in the following sections related to contact water management, freshwater diversions, process water requirements, and sources of water supply.

The Water Management Plan (Section 29.19; Appendix 5-C, Brucejack Project Environmental Assessment – Water Management Plan) lays out monitoring commitments related to water management. These commitments are important for meeting Pretivm's obligations under the *Environmental Management Act* (2003) and *Fisheries Act* (1996d), including the Metal Mining Effluent Regulations (SOR/2002-222), and any related permits. The application of these statutes to the Project is discussed in more detail in Chapter 13, Assessment of Potential Surface Water Quality Effects.

5.10.3 Freshwater Diversion Channels

Freshwater diversion channels will be constructed to the west of the operations camp and the south and east sides of the laydown area (Figure 5.10-1). Specifications are provided in Table 5.10-1. Culverts have been designed so that the hydraulic grade line does not overtop the roads.

Table 5.10-1. Freshwater Diversion Channel Specifications

Ditch	Q_{100} (m^3/s)	Q_{200} (m^3/s)	Ditch Shape	Water Depth for Q_{100} (m)	Freeboard (m)	Water Depth for Q_{200} (m)	Freeboard (m)	Capacity of Full Channel (no freeboard) (m^3/s)
East Diversion Ditch	4.8	5.3	Trapezoidal: Bottom Width 2.5 m. 2:1 side slopes. 0.5% min. grade. Geotextile under Riprap. Minimum 1 m deep.	0.90	0.10	0.95	0.05	5.9
West Diversion Ditch	4.6	5.0	Trapezoidal: Bottom Width 2.5 m. 2:1 side slopes. 0.5% min. grade. Geotextile under Riprap. Minimum 1 m deep.	0.88	0.12	0.92	0.08	5.9

A geotextile liner will be used as necessary with riprap to prevent erosion damage to the channel if the scour velocity is exceeded. The channels will discharge directly to natural drainages or Brucejack Lake.

Side slope materials for both freshwater diversions and contact water ditches will be bedrock, stable natural ground or compacted fill materials and will not exceed three metres except for one location south of the mill pad that may require a higher side slope. Geotechnical recommendations will be followed, such as maximum slope angles, rock bolting, and shotcrete. The stability of side slopes will further be addressed by lining protection (riprap or high-density polyethylene [HDPE] lining as warranted by flow velocities).

5.10.4 Contact Water

There are three expected sources of contact water during the Construction and Operation phases:

- the upper laydown area that will be used for waste rock transfer and pre-production ore storage;
- the mill building and portal site which requires cuts into bedrock, some of which is currently assumed to be PAG material; and

- groundwater seepage to the underground mine tunnels.

Runoff from the former two sources will be managed by collection, storage, and treatment. The contact water ditches are described in Table 5.10-2.

Table 5.10-2. Contact Water Ditch Specifications

Ditch	Q_{100} (m^3/s)	Q_{200} (m^3/s)	Ditch Shape	Water Depth for Q_{100} (m)	Freeboard (m)	Water Depth for Q_{200} (m)	Freeboard (m)	Capacity of Full Ditch (no freeboard) (m^3/s)
Largest Contact Water Ditch	1.2	1.3	Trapezoidal: Bottom Width 1.0 m. 2:1 side slopes. 0.5% min. grade. HDPE Lined. Minimum 1 m deep.	0.50	0.30	0.64	0.36	3.55
Typical Contact Water Ditch	0.75	0.83	V-Ditch: 2:1 side slopes. 0.5% min. grade. HDPE Lined. Minimum 1 m deep.	0.69	0.31	0.71	0.29	2.106

The contact water ditches will direct contact water to an HDPE-lined contact water pond sized to contain runoff from the 24-hour, 200-year return period rainfall event plus snowmelt (about 33,000 m^3). Pond specifications are summarized below:

- water depth for 200-year storm plus snow melt event = 4.9 m;
- internal side slope = 3H:1V;
- external side slope = 2H:1V maximum;
- width = 45 m;
- length = 150 m;
- water volume = 48,700 m^3;
- freeboard = 3 m; and
- distance from bottom of pond to top of freeboard = 7.9 m.

The constructed components of the pond impoundment will be founded on bedrock with the exception of a small area in the north corner. Construction will start with the installation of sediment control measures such as diversion ditches and silt fences, followed by stripping of any topsoil and overburden, excavation of bedrock by ripping or drilling and blasting with removal to Brucejack Lake, and installation of a cushion layer of 30 mm minus rock and the HDPE liner. The pond liner will minimize seepage and as a result, any seepage is expected to be negligible. Embankment fill will be comprised of non-PAG rock from the quarry. Lower elevations will be 500 mm minus rock fill while the top metre of fill will be 19 mm minus processed rock structural fill. Voids in the rock fill will be filled with structural fill by vibratory compaction. A feasibility-level geotechnical assessment will be completed in the summer of 2014 to confirm that the current design meets acceptable standards. The Canadian Dam Association, Dam Safety Guidelines will be considered if appropriate. In addition to the information provided above, the geotechnical assessment will include the following components:

- description of embankment heights, slopes, and method of construction;
- foundation conditions including foundation angle and soil properties;

- stability assessment;
- conceptual plan for any proposed instrumentation or monitoring; and
- a geohazard assessment.

The contained runoff will be pumped to the water treatment plant for treatment prior to release into Brucejack Lake or use in process. The pump will be housed in a heated enclosure.

The contained runoff will be pumped to the water treatment plant (see Section 5.12.16) at a maximum rate of 200 m^3/hour. A high-density polyethylene (HDPE) geomembrane liner will be placed under the:

- contact water collection pond;
- pre-production ore storage and waste rock transfer storage areas; and
- sections of the collection ditch founded either in fill or fractured bedrock.

A 300 mm-thick (minimum) cushion layer of 30 mm minus granular material (less than 10% passing 0.75 mm) will be placed under the liner. Appropriate armouring will be placed over the liner to protect it from erosion and damage by equipment used to clean out the ditches and pond.

Sludge from the pond will be excavated from time to time and transported to the tailings thickener for discharge to either the paste plant or lake with tailings.

Average groundwater seepage into the underground workings is expected to vary from approximately 160 to 260 m^3/hour throughout the life of the mine (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC). This water will be sent to the water treatment plant for treatment (see Section 5.12.16) before being sent to the process plant, where its use will be maximized in the process. During periods when tailings are being directed to the paste plant, excess treated groundwater will be used as fluidizing water and discharged to Brucejack Lake at depth as described in Section 5.11.2. During periods when tailings are being directed to Brucejack Lake, excess treated groundwater will be discharged directly to Brucejack Lake.

5.10.5 Process Water Requirements

The average water requirement for the Brucejack process plant will be 3,134 m^3/d, based on a mill throughput of 2,700 t/d. This water is required for the tailings slurry to the lake, the underground paste backfill, the concentrate slurry, and minor evaporative losses within the plant.

Approximately 47% of the tailings will be deposited underground as paste backfill, while 53% will be discharged to the bottom of Brucejack Lake at a maximum depth of 80 m. Additional details of the subaqueous deposition plan are provided in Section 5.11.2. Thickened tailings will either be diverted to the paste backfill plant or diluted and sent to Brucejack Lake, but never concurrently. A constant flow is required through the pipeline at all times to keep the deposit at the end of the outfall fluidized; however, the tailings will be directed to the pipeline about 50% of the time. Therefore, when the thickened tailings are used in the backfill plant, flow will be maintained with fluidizing water, which will preferentially be sourced from treated excess underground seepage water, or reclaim water from the surface of Brucejack Lake. The average fluidizing water requirement will be 3,447 m^3/d.

5.10.6 Water Supply

Two separate water supply systems will be provided to support the operations for the ore processing—one freshwater supply system, and one process water supply system. Separate systems will be provided for potable water for the mill building and camps.

5.10.6.1 Freshwater Supply System

Freshwater will be supplied to a fresh/fire water storage tank. Freshwater will be sourced from:

- treated underground seepage water; and
- reclaim from the lake.

Reclaim from the lake will be required because there are periods when the groundwater inflows are predicted to be less than the process requirement.

Freshwater will primarily be used for:

- fire water for emergency use;
- cooling water for mill motors and mill lubrication systems;
- gland water for the slurry pumps;
- reagent make-up; and
- process water make-up.

The fresh/fire water tank will be equipped with a standpipe, which will ensure that the tank is always holding at least a two-hour supply of fire water.

5.10.6.2 Process Water Supply System

The overflow solutions from the concentrate thickener and tailings thickener will be reused in the process circuit. The balance of the process water will be supplied from the water treatment plant, which will treat water from the mine (underground water) and water collected from the plant site, or from Brucejack Lake, as required. All process water required will be distributed to the process plant from an approximately 8.0-m-diameter by 8.0-m-high process water tank (Appendix 5-A, Brucejack Environmental Assessment ML/ARD Baseline Report).

5.10.6.3 Potable Water Treatment Plants

There will be three potable water supply systems — one located in the mill/administration complex to service the mill building and camp, a second at the Knipple Transfer Area, and a third during the construction stage for the Tide Staging Area. Potable water will be supplied from wells or surface water, as appropriate for each site, and will be treated to achieve the necessary quality for human consumption.

The mine camp water requirements will be approximately 104 m^3/d during Construction (and less during Operation), based on an average usage rate of 230 L/d per person and a camp population of up to 450 people.

The existing exploration camp has an ozone/UV potable water treatment package sized to service 180 people. This camp will be used during the construction period in addition to the new camp.

5.10.7 Water Balance Model

A water balance model for the Project was constructed using a monthly time-step (Appendix 5-C, Brucejack Project Environmental Assessment – Water Management Plan) for Construction, Operation, and Closure. An average annual flow of 2,472 m^3/hour at hydrometric station BJL-H1, located about 800 m downstream of the mouth of Brucejack Lake, has been estimated over the life of the mine, which is an average increase of about 6% above existing conditions (2,324 m^3/hour). The increase in flow results from the introduction of tailings slurry water and the displacement of water by the deposition of tailings and waste rock. In the water balance model, outflows from Brucejack Lake are assumed to be of suitable water quality for discharge to Brucejack Creek following treatment of the underground mine and surface contact water.

The following assumptions were used as input to the water balance model:

- a final tailings settled dry density of 1.6 t/m^3 for the lake deposition and of 1.46 t/m^3 for the underground mine deposition;
- a solids specific gravity of 2.68 is assumed for tailings and 2.71 for paste backfill;
- a nominal mill throughput of 2,700 t/d with:
  - 219 t/d (8.1% of total production) sent to an off-site facility as concentrate for secondary processing in a slurry of 88% solids by weight (30 m^3/d of slurry water);
  - 1,307 t/d (48.4% of total production) will be deposited at depth in Brucejack Lake in a slurry of 35% solids by weight (2,427 m^3/d of slurry water); and
  - 1,245 t/d (43.5% of total production including 5 to 6% bonder) will be deposited in the underground mine in a backfill paste of 65% solids by weight (670 m^3/d of slurry water).
- an average mill loss of about 7 m^3/d;
- an average annual precipitation of 1,900 to 2,034 mm and potential lake evaporation and sublimation losses of approximately 167 mm; and
- annual average runoff of about 1,820 mm from undisturbed ground.

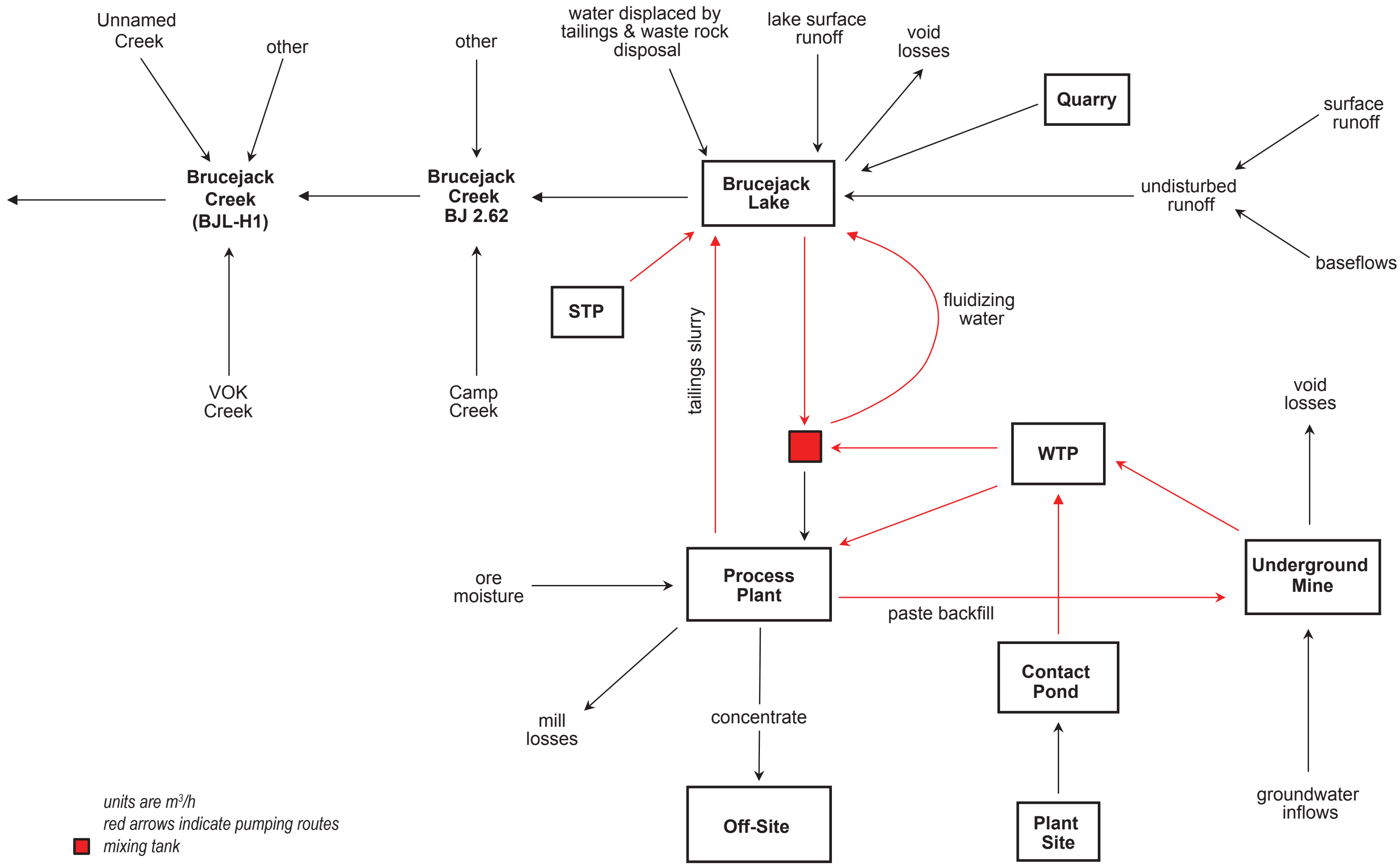
A water balance schematic for the mine during operations is shown in Figure 5.10-2. Values used are average flows (m^3/hour) over the life of mine and account for the annual variations in ore production. Estimates of precipitation, evaporation, stream flows, groundwater discharge/recharge, and hydraulic conductivity, as well as information sources and uncertainty estimates, measurement standards or collection protocols, and assumptions built into the data, are described in Chapters 9 (Hydrogeology Predictive Study) and 13 (Assessment of Potential Surface Water Quality Effects) which also consider climatic variability and data uncertainty. Chapter 13 further discusses the water balance that is also described in Appendix 5-C, Brucejack Project Environmental Assessment – Water Management Plan, which also includes water balance models for Construction and Closure. The following items should be noted in Figure 5.10-2.

- The model accounts for the displacement of lake water resulting from tailings and waste rock deposition.
- Numerical groundwater modelling of the site indicates that during mine operations, the natural groundwater flow pattern will be altered and a cone of depression will form around the underground workings, as seepage water is pumped from the underground and used in process. In response, the baseflow inputs to Brucejack Lake and downstream tributaries will also be altered during this period. The undisturbed runoff value in the flow schematic accounts for these reduced baseflows.

The underground workings will be flooded at closure to minimize development of acid rock drainage and associated leaching of metals. The adits will be sealed to allow the mine workings to flood above the elevation of the historical Newhawk adit level. It is assumed that outflows from Brucejack Lake will be of suitable water quality for discharge to Brucejack Creek following mine closure.

Figure 5.10-2
Brucejack Lake Water Balance Model Schematic - Operations

ERM



units are m³/h
red arrows indicate pumping routes
mixing tank

Source: BGC Engineering Inc.

5.11 WASTE MANAGEMENT

Waste streams for the Project will include waste rock, tailings, and hazardous and non-hazardous waste from shops, laboratories, camps, and offices. Waste management for hazardous and non-hazardous wastes will involve the segregation of waste into appropriate management streams. Project waste collection and disposal facilities will include an incinerator at the Brucejack Mine Site, waste collection areas for recyclable and hazardous wastes, and processes will be in place for sewage effluent and sludge disposal.

Project waste management procedures will be consistent with the requirements of the *Environmental Management Act* (2003) and its associated regulations.

5.11.1 Waste Rock

Stopes will be filled with development waste rock wherever possible, but both initial pre-development waste rock from the Construction stage and the first year of production, and some waste rock generated by ongoing stope development during the production stage will be hauled to surface for subaqueous disposal in Brucejack Lake. Waste rock excavated from the surface infrastructure areas to create development sites will also be disposed subaqueously in the lake.

Approximately 5.7 Mt of waste rock, assumed to be PAG, will be produced throughout the mine life, with about 4.2 Mt coming from the underground operations and the rest from construction of the surface pads and access roads. About 3.1 Mt of this rock will be deposited in Brucejack Lake. These numbers from the 2014 Feasibility Study Update (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC) differ from the more conservative numbers (larger volume deposited in Brucejack Lake over a longer time period) from the 2013 Feasibility Study (Tetra Tech 2013) that were used in the effects assessment. A Waste Rock Management Plan has been developed to minimize potential adverse environmental effects from disposal of waste rock (see Section 29.18); this plan is complemented by an ML/ARD Management Plan (Section 29.10).

5.11.1.1 Waste Rock Characterization

Waste rock characterization is described in detail in Section 5.6.2. The main conclusions of the ML/ARD baseline study with regards to waste rock can be summarized as follows:

- The ABA assessments of waste rock according to geological model units and lithology groupings both show that the majority of waste rock at Brucejack is PAG material, with the exception of one geological model unit and one lithological group. Specifically:
  - the Office P1 unit contains predominantly non-PAG rock, as per results from frequency analyses conducted on waste rock static tests; and
  - mafic volcanics are generally non-PAG material, as 83% of samples submitted for static testing present NPR values greater than 2.
- The VSF, Fragmental, and Conglomerate units account for 85% of the total generated waste rock and contain 77 to 85% PAG material. These three geological model units constitute 87 and 88% of the waste rock destined for the underground mine and Brucejack Lake, respectively.
- Due to the absence of a clear distinction in ABA characteristics between lithology groups or geological units, it is difficult to propose recommendations for waste rock segregation.
- Materials with the shortest lag times (less than 15 years) typically have paste pH values below 7, very low NP values (5 to 15 kg CaCO3/t) and high sulphide-S values (3 to 8%) and weather readily and quickly.

- The elements As, Cd, Cu, Pb, Se, and Zn are considered POCs, based on leachate concentrations from humidity cells and field barrels containing waste rock.
- Subaqueous columns with waste rock material present elevated leachate concentrations of As, Sb, Mo, Se, and Zn, which may be a concern under more reducing conditions and/or circumneutral pH conditions.
- Almost 60% of the site characterization samples collected from the mine site are PAG material.

5.11.1.2 Historical Waste Rock Management

Newhawk Gold Mines Ltd. (Newhawk) previously disposed of waste rock in Brucejack Lake as part of site remediation work undertaken in 1999, following advanced exploration work at the site. A report completed by CANMET (CANMET 2005) indicates that approximately 61,000 m^3 of material was placed in the lake “from a causeway-like pad, with the waste rock placed in berms and then dozed over the side in the lake… Once all the waste rock was placed on the causeway, a backhoe lowered the surface approximately 1 m below the height of the lake” (CANMET 2005). Rinse pH tests performed during the disposal efforts found that 11% of the waste rock samples tested had a rinse pH ranging from 3 to 4.5, 34% were pH 4.5 to 7, 28% were pH 7 to 8, and 27% were pH 8 to 9 (CANMET 2005). The report indicates though that “changes in water quality in Brucejack Lake and Brucejack Creek during and following waste rock disposal were relatively minor in nature” (CANMET 2005).

In addition to the waste rock deposited in Brucejack Lake by Newhawk, Pretivm has deposited into the lake waste rock produced during its bulk sample program in 2012 and 2013. This deposition and its effects on water quality are discussed in Chapter 13, Assessment of Potential Surface Water Quality Effects.

5.11.1.3 Waste Rock Schedule

Waste rock from the Project will be generated from two sources at the Project site: general construction activities during mine site construction; and mining activities throughout the life of the mine. The total amount of waste rock is estimated at about 5.7 Mt.

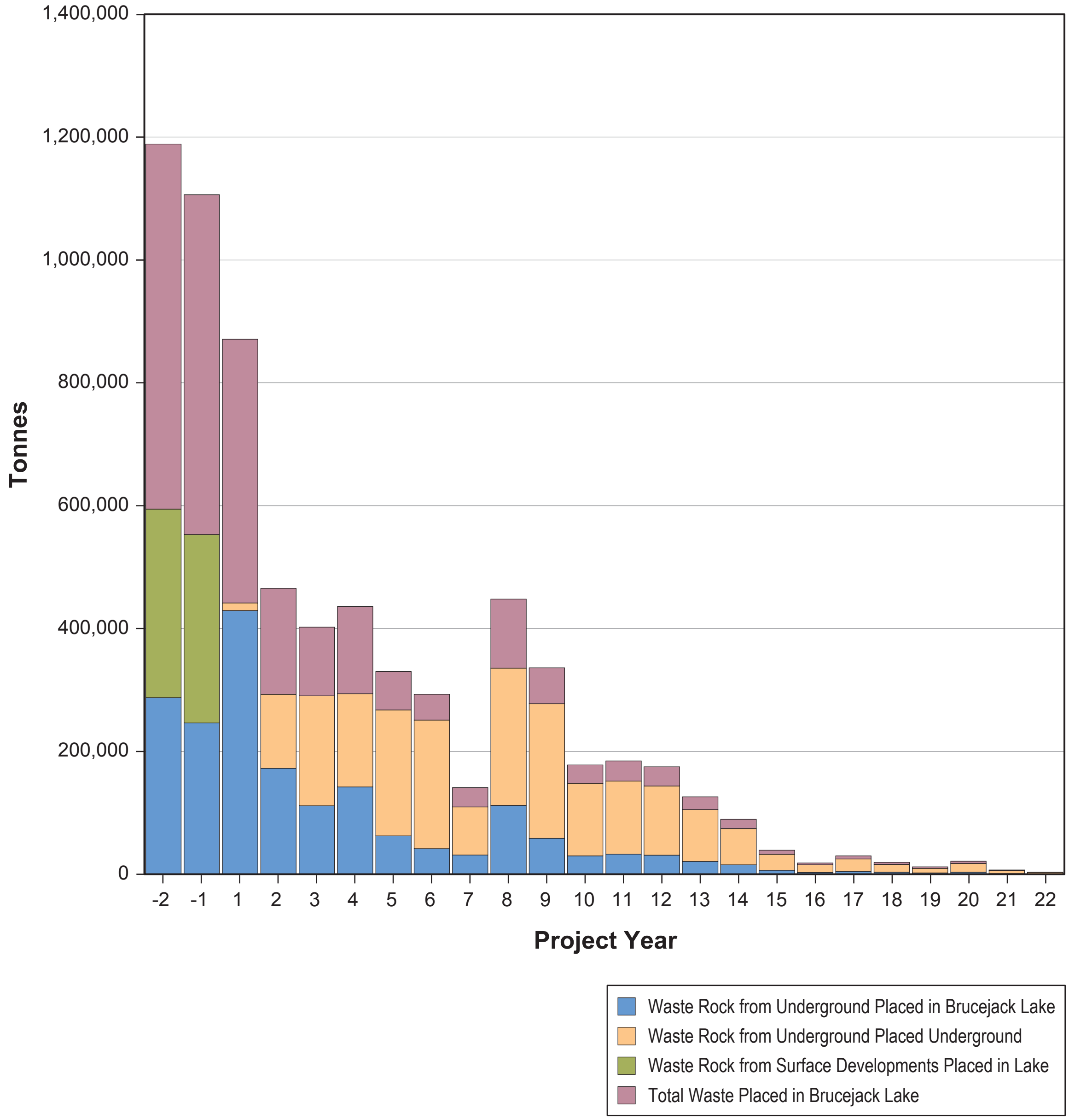
<u>Construction</u>

It is anticipated that construction of the surface facilities at the Brucejack Mine Site will produce approximately 0.7 Mm^3 of excess waste rock, most of which is assumed to be PAG. This waste rock will be hauled to Brucejack Lake for disposal and to create the construction laydown area (Figure 5.1-2). In addition, it is estimated that about 0.67 million tonnes of PAG development rock will be produced from the underground mine during the construction stage (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC). Pre-production waste rock from underground will be stored temporarily on surface about 400 m east of the portal (Figure 5.1-2). It will later be transported from the storage area to the lake for disposal.

<u>Operation</u>

Approximately 4.2 Mt of waste rock, assumed to be PAG, will be produced by the underground mining throughout the operating period (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC). Initially, almost all underground waste rock will be hauled to the surface for disposal in the lake. Over time, as appropriate voids become available underground, much of this rock will be used as backfill. About 37%, or 1.58 Mt, of waste rock generated from mining activities will be disposed of in the lake. The volume of waste rock hauled to the lake will decrease over time (Figure 5.11-1).

Figure 5.11-1
Waste Rock Disposal by Year



5.11.1.4 Deposition in Brucejack Lake

Waste rock that is not deposited underground will be deposited in Brucejack Lake where a water cover will be maintained over the waste rock to prevent acid generation. Similar to the waste rock deposition completed by Newhawk and recently by Pretivm as part of its bulk sample program, it is anticipated that the waste rock pile will be constructed by advancing a platform or causeway, or series of platforms or causeways, of not PAG rock out into the lake. Waste rock will be end dumped from haul trucks onto the platform/causeway and then, either a dozer will be used to push it over the side or an excavator will be used to cast it over the side (Appendix 5-D, Geotechnical Stability of Waste Rock Deposition in Brucejack Lake) to ensure a minimum 1-m depth of submersion.

Overwater geophysical surveys indicated that Brucejack Lake reaches depths of up to 70 m in the area proposed for waste rock disposal and that the lake bottom sediments are typically up to 15 m thick, with thicker deposits up to 30 m thick located near the shoreline and in the deeper areas of the lake (Appendix 5-D, Geotechnical Stability of Waste Rock Deposition in Brucejack Lake). At depth, the sediments primarily consist of low plastic silts to high plastic clays, whereas closer to shore they can be classified as silty sand to sandy silt. The fine grained sediments typically display low undrained shear strengths. However, as a result of the sampling method, samples could only be collected from the surface of the lake bottom. Therefore, it is likely that the samples represent the softest and weakest sediments from this area, and it is possible that denser and stronger sediments may be present below the surface of the lake bottom (Appendix 5-D, Geotechnical Stability of Waste Rock Deposition in Brucejack Lake).

For planning purposes it is assumed that the submerged waste rock pile will have an overall slope of ranging from 1.5:1 to 2H:1V due to lateral spreading failures (Appendix 5-D, Geotechnical Stability of Waste Rock Deposition in Brucejack Lake). Two-dimensional, limit equilibrium stability analyses were completed based on the waste rock pile layouts, and the results of the geophysical surveys and laboratory testing. The stability analyses indicate that, under drained loading, the waste rock pile will have a factor of safety ranging from 1.09 to 1.28 when applying strength estimates to the lake bottom sediments based on the results of laboratory testing. However, when applying possible lower bound strength estimates based on values from literature, the factor of safety ranges from 0.95 to 1.05 (Appendix 5-D).

These results are, however, based on the assumption that soft, weak lake-bottom sediments extend all the way down to bedrock. It is considered possible that denser and stronger sediments may be present below the surface of the lake bottom (Appendix 5-D, Geotechnical Stability of Waste Rock Deposition in Brucejack Lake). Further investigations, consisting of drilling and sampling will be conducted to confirm this assumption.

The stability analyses also indicate that, under undrained loading, the waste rock pile will have a factor of safety below 1 and will be inherently unstable (Appendix 5-D, Geotechnical Stability of Waste Rock Deposition in Brucejack Lake). Rapid advancement of waste rock over the sediments may result in undrained loading. Based on the waste rock deposition schedule, the annual volume of PAG waste rock to be disposed in Brucejack Lake will be greatest from Years -2 to 1. Following this period, the annual volume of waste rock disposed of in Brucejack Lake will decrease. Therefore, Years -2 to 1 are likely when the advancement rate of waste rock out into the lake will be the highest and is the period of time when instability near the face should be expected. Undrained loading may also occur following Year 1, but the advancement rate of the waste rock pile will likely be reduced so instabilities may be less frequent.

The results of the analyses demonstrate that the overall stability of the waste rock pile can be expected to vary significantly depending on the slope geometry, shear strength of the lake bottom sediments, and loading conditions (Appendix 5-D, Geotechnical Stability of Waste Rock Deposition in Brucejack Lake). The estimated factors of safety are generally lower than those typically applied to subaerial waste rock piles. However, this situation is not unexpected given that the waste rock pile will be developed by end dumping and pushing material into a subaqueous environment that contains soft, plastic sediments. To utilize this dumping method at Brucejack Lake, safe operating procedures will be put in place, and instabilities near the advancing crest will be anticipated throughout the development of the waste rock pile and construction laydown pad. Deformations due to creep will also be anticipated over the long term. To minimize undrained loading of the lake bottom sediments, active dumping areas will be maintained sufficiently large to reduce the crest advancement rate as much as possible. Based on the waste rock deposition schedule, it is anticipated that it will be possible to maintain a crest advancement rate of less than 1 m/d. Haul trucks will also maintain a minimum distance of 10 m from the active crest when dumping their loads. This minimum distance will be re-evaluated as operational, site-specific experience is gained. The dumping platform will also be monitored throughout the life of the mine to assess whether it is safe for personnel and equipment to be operating in this area. Safe working procedures will be developed specifically for this area and visual monitoring for signs of deformation will be completed continuously while work is actively being conducted on the waste rock pile.

Instrumentation, such as wireline extensometers, will be installed to help facilitate deformation monitoring if deemed necessary. Advancement of the crest line will also be limited to prevent waste rock from being built out onto the lake bottom sediments too quickly.

A maximum crest advancement rate of 1 m per day is predicted and will be re-evaluated with experience. Care will be taken to sequence the deposition of waste rock and tailings in order to avoid geotechnical instability. Most of the waste rock deposition in the lake will take place during pre-production and the first year of operation when the tailings mound will be remote from the waste rock deposition area. Once the tailings mound approaches the proximity of the waste rock, any additional waste rock placement will be conducted away from the tailings to avoid adverse effects on waste rock pile stability. Figure 5.11-2 provides cross-sections of the waste rock pile over time, showing its relationship with the tailings deposit.

Waste rock will be dumped at the waste rock transfer storage area (Figure 5.1-2) during poor weather conditions, due to the limited traction capabilities of the underground trucks and a haul road grade of approximately 5.2%. Underground trucks will haul waste rock directly to the Brucejack Lake waste rock dump when weather conditions permit. Snow removal and clearly marked paths will be maintained on the dumping platform for safety during construction in the winter.

Subaqueous deposition is expected to proceed, as needed, throughout the year. Deposition was successfully achieved over the 2012/2013 winter period during Pretivm's bulk sample program. The relatively continuous waste rock placement activities were sufficient to keep an ice-free area open throughout the winter. If required during Construction or Operation, an aerator could be installed in Brucejack Lake to provide an ice-free area of the lake to allow for waste rock deposition year-round.

Overburden salvaged during the Construction and Operation phases will be managed as described in Section 29.13, Soils Management Plan.

5.11.2 Tailings

5.11.2.1 Overview

The Project is expected to create about 15.8 Mt of flotation tailings over the life of the mine (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC). A Tailings Management Plan has been developed to minimize potential adverse environmental effects of tailings disposal and can be found in Section 29.15. Approximately 7.1 Mt of the flotation tailings will be used in paste backfill in the underground workings, while the rest will be deposited in Brucejack Lake (Figure 5.11-3).

Figure 5.11-2
Cross-sections of Tailings and Waste Rock Pile in Brucejack Lake Over Time

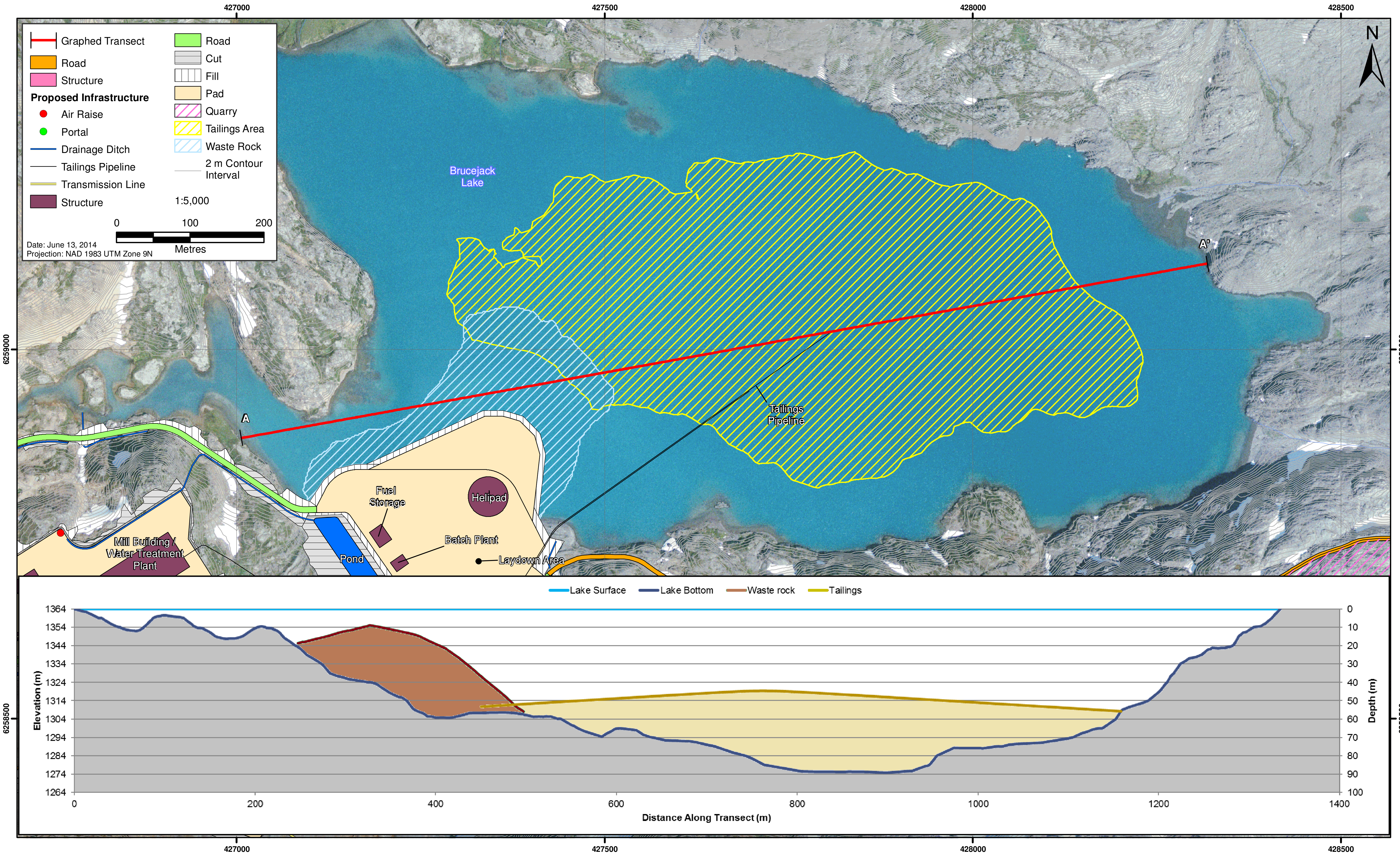
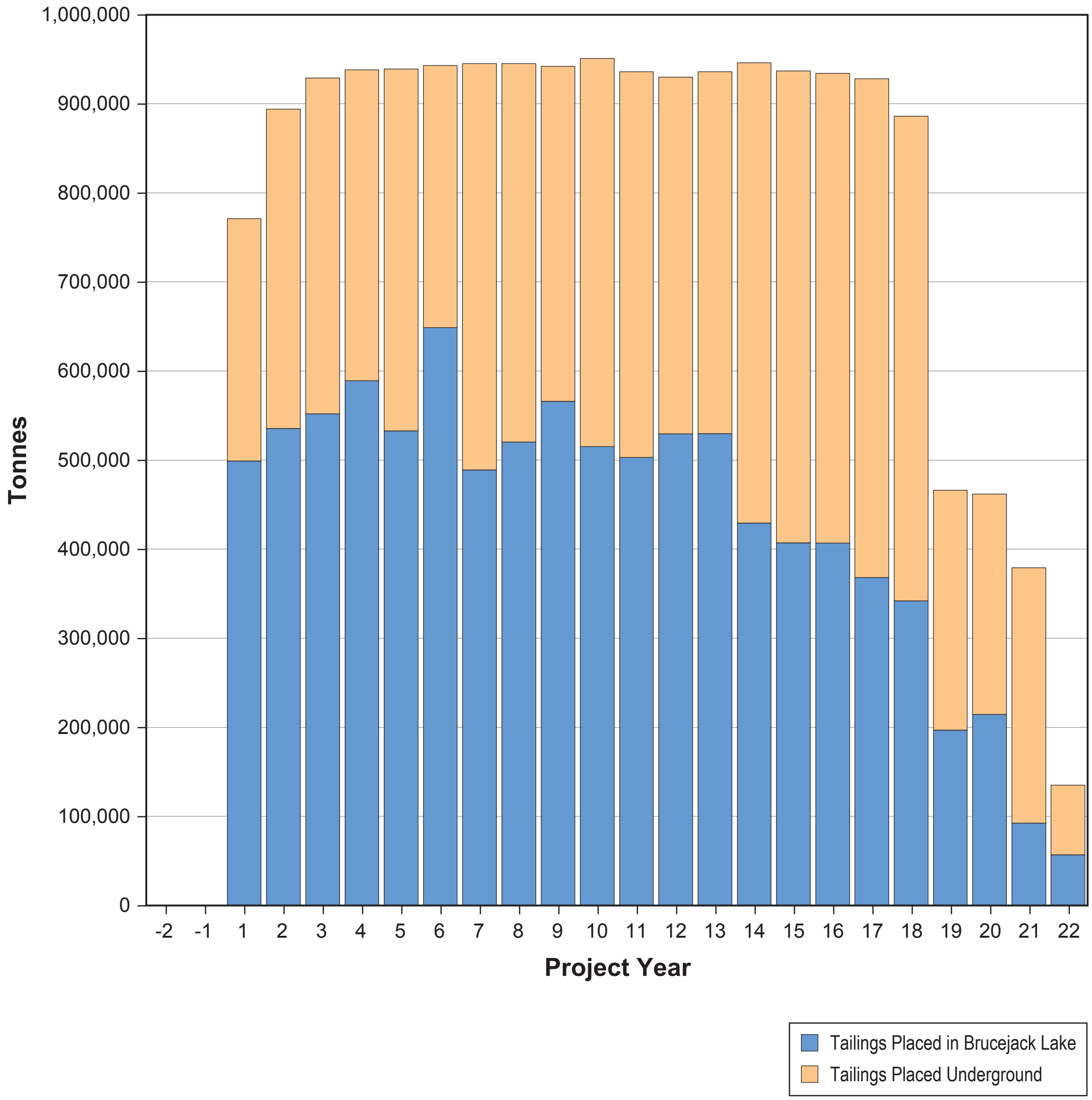


Figure 5.11-3

Tailings Disposal by Year

ERM



The total volume of tailings and the proportion of those tailings directed to Brucejack Lake will be lower than estimated for the effects assessment in this Application since that assessment used figures from an older and more conservative feasibility study (Tetra Tech 2013) The tailings are not anticipated to be acid generating based on acid base accounting test work (Appendix 5-B, Brucejack Environmental Assessment ML/ARD Baseline Report).

Two options for disposal of tailings in Brucejack Lake are being considered. The option of disposal in Brucejack Lake using a fluidized mound of tailings over the outfall located deep in the lake as a means of reducing potential release of fine sediments is described in the following discussion. A second option in which thickened tailings would be discharged at depth into the lake is currently under investigation.

A pair of tailings discharge pipelines to Brucejack Lake will be located along the south side of the lake. The pipelines overland will be trenched and backfilled in most locations to protect the pipes. The pipelines will also have a continuous downward slope from the mill building to the lake shore to permit the line to drain during shutdowns.

The diluted slurry will be pumped through a 254-mm outside diameter (181-mm inside diameter) HDPE pipe overland some 1,150 m and 510 m underwater on the lake bed (Appendix 5-E, Brucejack Lake Tailings System Design). At the lake shore the pipe will split into two parallel pipes, one of which will discharge at a depth of 80 m, near the bottom of the lake, and the other at a depth of 60 m. Prior to tailings discharge, a small quantity of coarse sand or gravel will be placed at the terminus of each of the outfalls. Through Operation, tailings solids will accumulate over and further cover the discharge point, acting as a filter intercepting the majority of fine tailings particles in a manner similar to a sand filter. This feature will reduce the likelihood of suspended solids entering the upper layers of the lake's water column and subsequently discharging into Brucejack Creek, potentially in violation of strict receiving water quality regulations.

There will be a flow through the pipeline at all times to maintain a fluidized state in pathways in the deposit at the end of the outfall. When the thickened tailings are used in the backfill plant, water will be directed through the tailings discharge system to maintain the fluidized state.

The footprint of the tailings at the end of 18 years of operation will cover most of the lake bottom (Figure 5.11-4), to a depth below the lake surface of approximately 48 to 59 m at its edge and a depth below the lake surface of 44 m at the apex of the deposition cone.

5.11.2.2 Brucejack Lake

Brucejack Lake has a surface area of about 782,000 m^2 and a volume of about 30.4 Mm^3. The maximum depth is about 85 m, confined to a relatively small area. The bathymetry or topography of the lake bed is shown in Figure 5.11-5.

Water flows into the lake from multiple sources and the flow rate varies during the course of the year. Brucejack Lake discharges into Brucejack Creek, the outlet at the west end of the lake. The highest flow rate occurs during freshet around June or July each year.

Baseline surveys show that the lake turns over twice per year due to seasonal heating or cooling which causes the lake surface temperature to pass through 4°C, the temperature of maximum density of freshwater. There was concern that during lake turn over, fine sediment being discharged on the lake bottom could be transported upward toward the surface resulting in elevated suspended solids concentrations in the surface layer and at the outlet. To address this concern, a one dimensional numerical model simulating thermal and wind-driven convection was developed (Lorax 2013). Results of the simulation predict that suspended solids concentrations should not exceed the regulated limit at the discharge from Brucejack Lake.

Figure 5.11-4
Surface Extent of the Tailings Mound at Various Periods

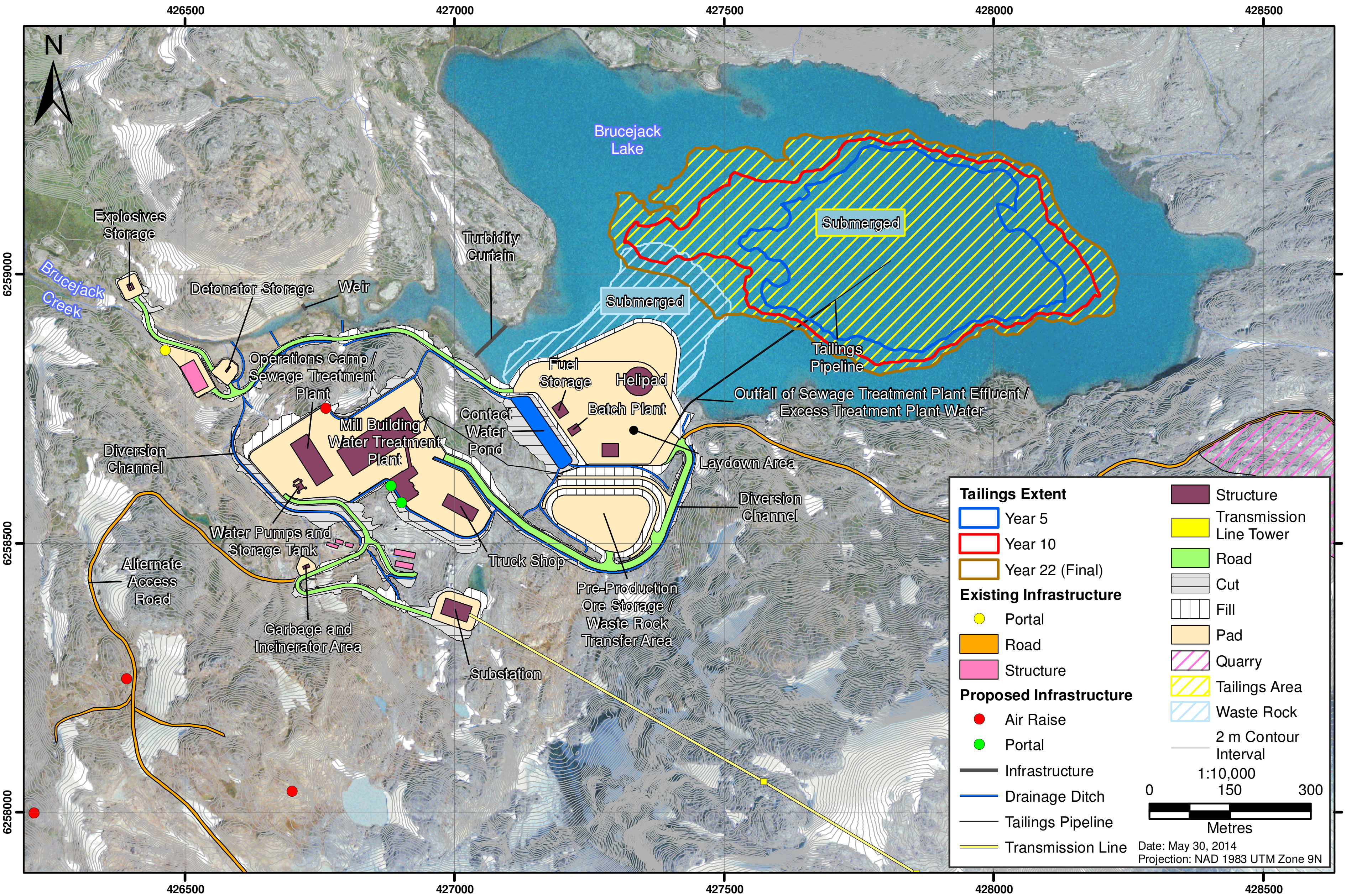
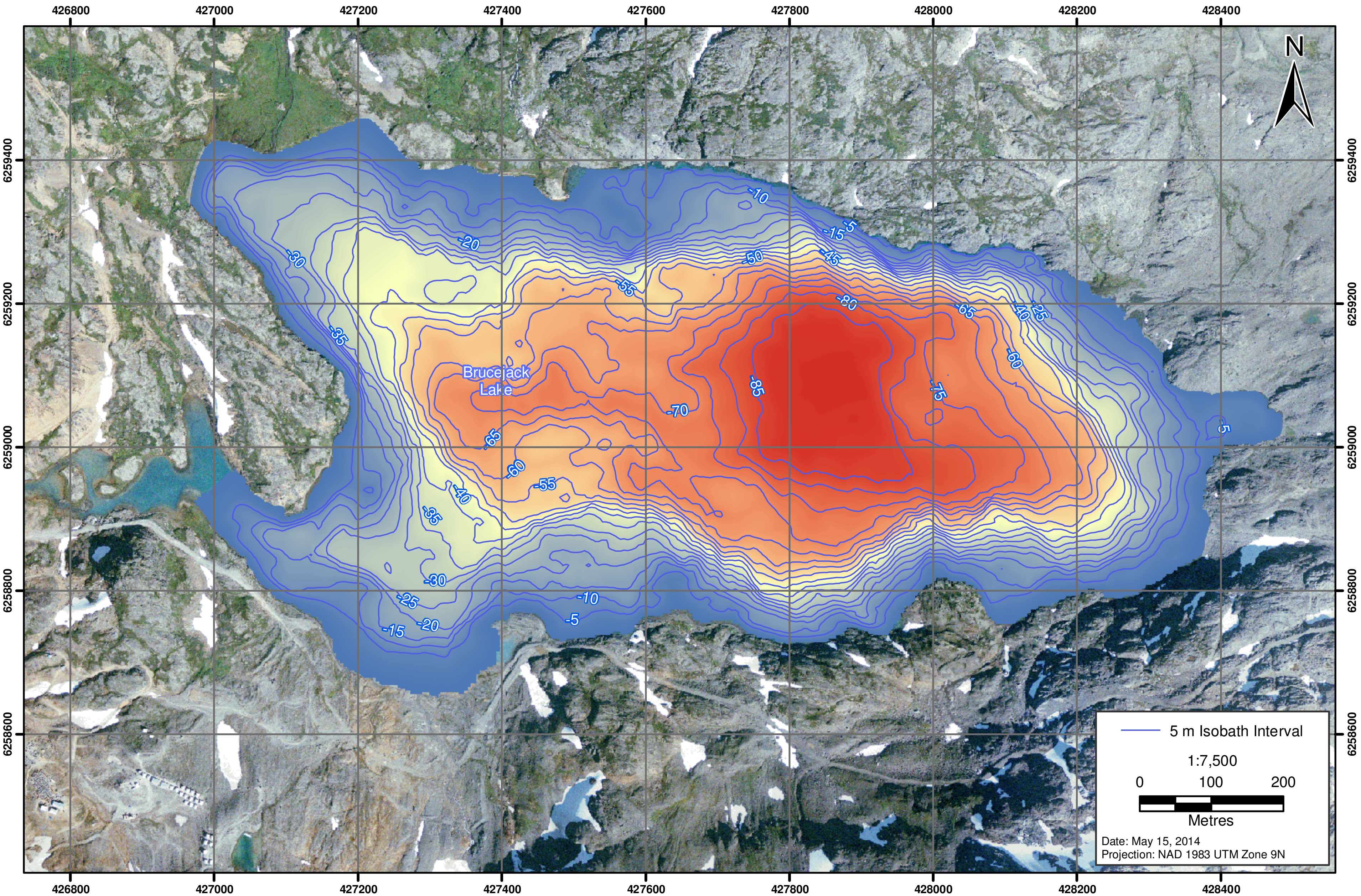


Figure 5.11-5
Brucejack Lake Bathymetry 2013



5.11.2.3 Tailings Characterization

Tailings characterization with regards to ML/ARD is discussed in detail in Section 5.6.3. The test work shows that the tailings will be non-PAG (Appendix 5-B, Brucejack Environmental Assessment ML/ARD Baseline Report). The tailings particle size distribution is fine with a median particle size less than 25 µm (Appendix 5-B). The particle size distribution is shown below in Figure 5.11-6.

5.11.2.4 Mixing Tank

The tailings discharged from the flotation cells will be directed to a thickener in the mill building in order to provide a desirable feed to the paste backfill plant at a maximum design throughput of 124 t/hour of solids at a concentration of 40 to 65% w/w. Tailings destined for discharge to Brucejack Lake will then be diluted in an agitated mixing tank to approximately 35% solids w/w (this dilution will ensure efficient operation of the agitator, pump, and pipeline while keeping the deposit at the lake bed fluidized. Total flow in the outfall will be approximately 320 m^3/hour (velocity of approximately 3.4 m/s). At the relatively low concentrations that will be present in the outfall, the tailings slurry will exhibit Newtonian rather than Bingham Plastic behaviour; that is, head loss can be predicted based on the viscosity alone and is independent of the very small yield stress (Appendix 5-E, Brucejack Lake Tailings System Design).

Dilution of thickener underflow will be accomplished by using an approximately 2-m-diameter by 3-m-tall agitated mixing tank with a double-pitched blade turbine impeller driven by a 5-horsepower motor. This configuration will provide the appropriate degree of dilution, ensure that air is purged from the slurry, and provide a liquid level by which the dilution water flow can be controlled. Two pumps, one operating and one on standby, will be located downstream of the mixing tank to provide pressure when required to transport the tailings slurry through the pipeline and the outfalls.

5.11.2.5 Tailings Pipeline

The mixing tank and discharge pumps will be located in the mill building. The pipeline alignment and profile is shown in Figure 5.11-7. Twin pipelines will run from inside the mill building to the lake shore at slopes between 0.3 and 15% (Appendix 5-E, Brucejack Lake Tailings System Design). The overland pipeline route will be approximately 640 m long. There will be manual isolation valves located in the mill building to manually switch between the two pipelines. The primary pipeline will discharge at a depth of 80 m with a total length of about 1,150 m, with about 510 m underwater. The secondary pipeline will discharge at a depth of 60 m with a total length of about 1,040 m, with about 400 m underwater.

The pipelines are designed to slope continuously downward from the mill building to their discharge points in the lake. This configuration is desirable to promote complete drainage in the event that no water is available to maintain pipeline flow. The maximum slope of 15% upstream of flatter sections will prevent a settled solid bed from sliding into the flatter section on emergency shutdown. The pipeline overland will be contained in a trench with grating for protection or trenched and backfilled in most sections. The pipeline will be installed in a culvert at road crossings. The route is close to an avalanche risk area near the lake and will be properly protected and supported. The pipeline will be insulated but not heat traced to protect against freezing. Heat tracing is not required as the heat generation due to friction (head losses) in the pipeline will be sufficient to prevent freezing of the lines.

The subaqueous pipelines (or outfalls) will extend from the shore to the two discharge depths. The outfalls will be laid on the lakebed and stabilized with rock bolts and/or concrete ballast weights. Ballasting is required to prevent the pipe from floating (HDPE is slightly buoyant) when discharging clear water and in the event that a significant volume of air enters the outfall if air release valves malfunction.

Figure 5.11-6

Tailings Particle Size Distibution

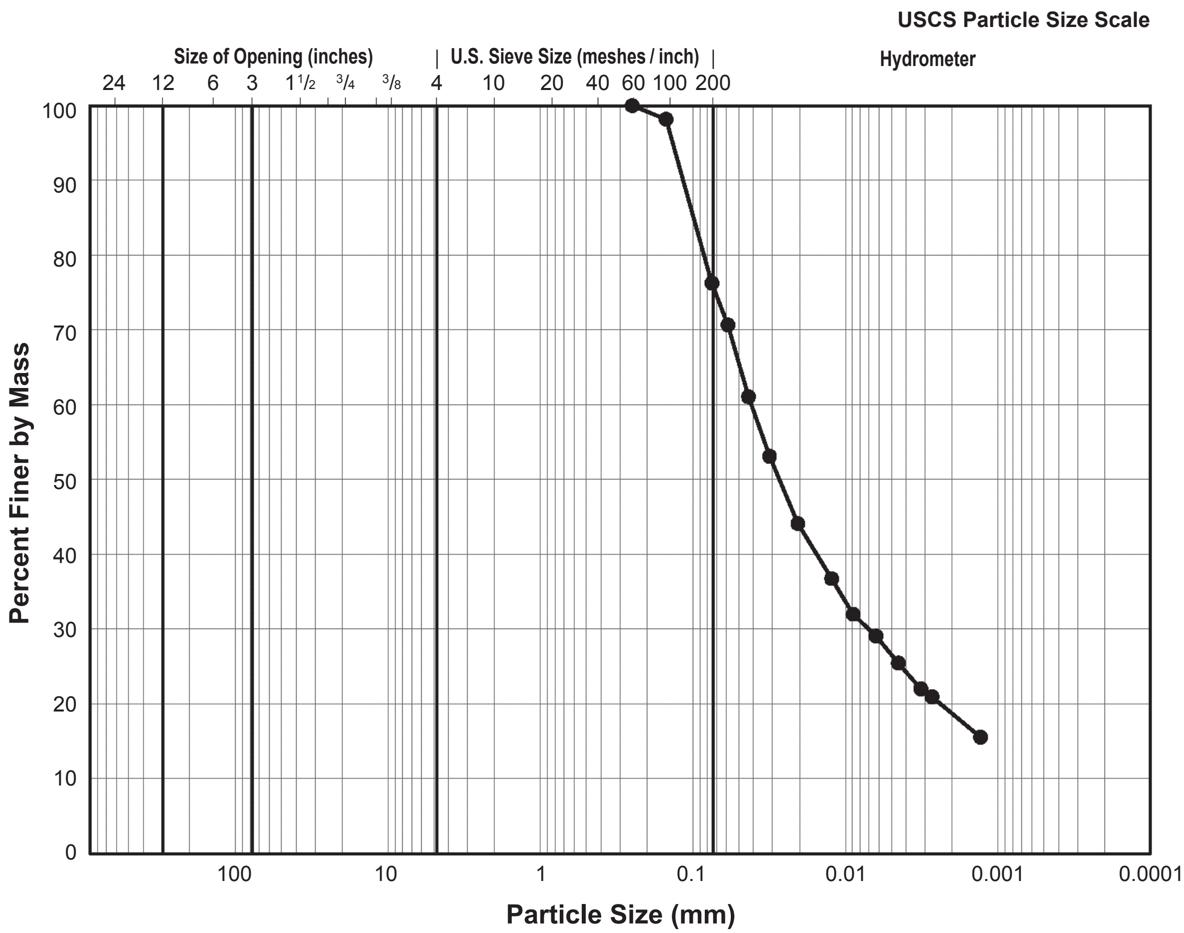
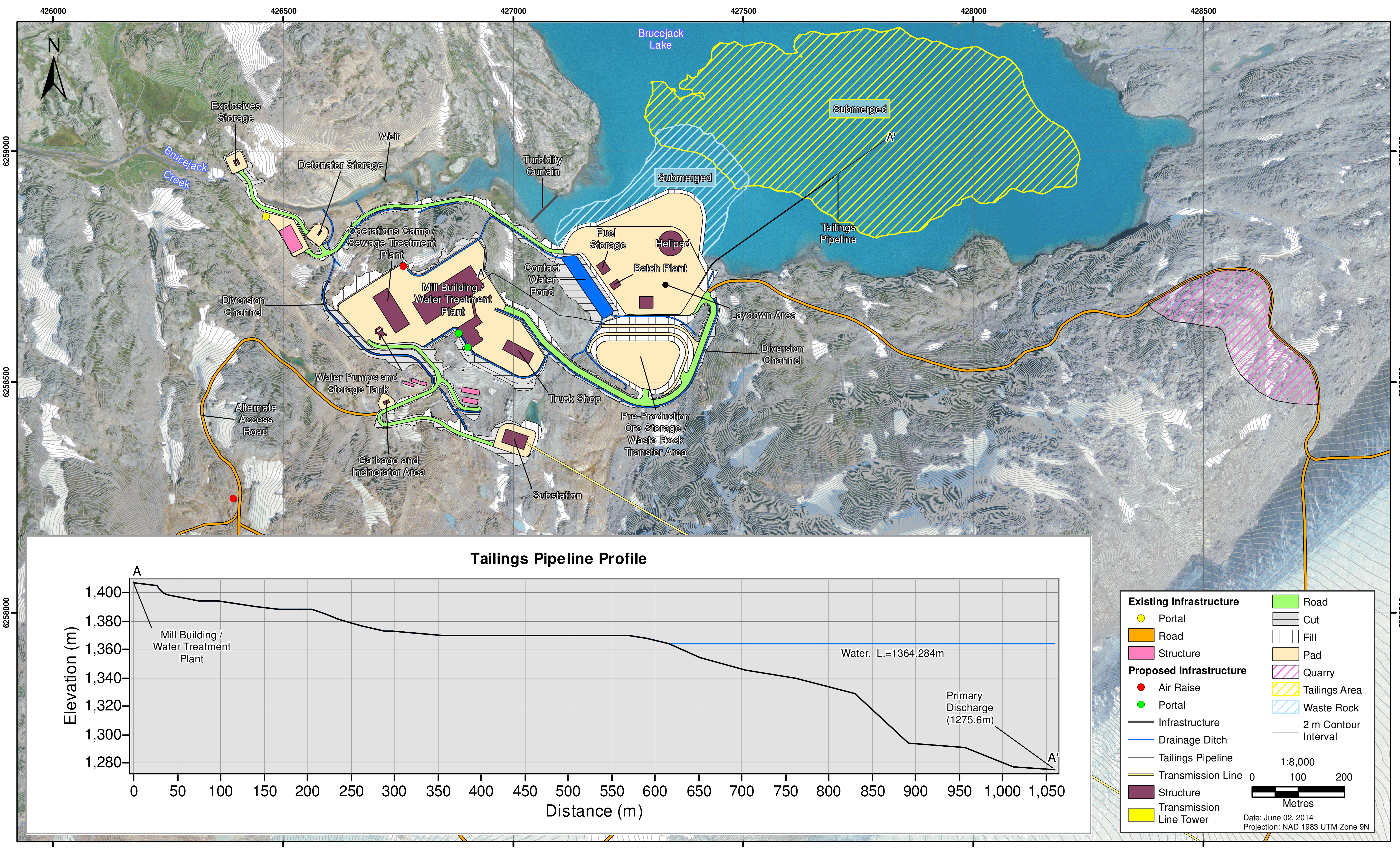


Figure 5.11-7
Plan and Profile of Tailings Discharge Pipelines



Concrete ballast weights (or collars) will be precast, each in two pieces and bolted together clamping the pipe between them. The outfalls, complete with the attached weights, may be launched and sunk as one piece or individually.

5.11.2.6 Air Valves

A significant volume of air introduced to the submerged pipeline could potentially interfere with flow or float sections of the pipeline. At start-up, the overland portion of the line will be full of air and it is this volume which must be vented off by air valves. Combination air / vacuum valves will be strategically located along the overland section of the tailings pipelines to prevent air entering the underwater sections of the pipelines. The valves will primarily vent air during start-up and permit air to enter the overland portion of the pipeline at shut-down.

5.11.2.7 Deposit over the Pipeline Terminus

Coarse sand or gravel will be placed over the pipeline terminus to initiate accumulation of tailings solids. After the terminus of the outfall is adequately buried, flow conditions will be transformed from an energetic turbulent discharge to slow, laminar flow through a locally fluidized medium (Appendix 5-E, Brucejack Lake Tailings System Design). Flow within the tailings deposit will be complex because the entire range of mechanical properties of a solid/liquid mixture will come into play. At the end of the pipe and in the region in close proximity to it, the deposit will be fluidized, meaning the particles will be supported by fluid forces. At relatively large horizontal distances from the discharge point, the tailings deposit will settle and consolidate over time.

The substantial accumulation of solids over the terminus (ultimately 40 m thick) will capture fine solids, acting in a manner similar to a sand filter, and prevent their transport by momentum toward the upper layers of the lake. The deposit will remain locally fluidized by the flow discharged from the outfall. The deposit at the outfall terminus will quickly bury the deepest section of the outfall and thicken over time. As a result an increasing back pressure will be imposed at the end of the outfall. From experience in other projects, it has been found that the head loss imposed by the fluidized deposit is approximately 1 m for each m of deposit thickness. The static head available from the elevation of the mill above the lake will balance this back pressure until the deposit exceeds approximately 30 m in thickness. As the deposit thickens, additional head will be provided by centrifugal slurry pumps.

As slurry is discharged, the mound will increase in size: particles will be transported upward to the apex through the mound and then flow radially outward and settle out over the flanks of the mound. Growth of the deposit, approximately as a cone, may cause over-steepening on the upper flanks which will ultimately result in slope failure. Slope failure has been observed as the dominant mechanism in maintaining the angle of repose of the deposit at other similar installations.

5.11.2.8 Experience at Other Operations with Similar Disposal Method

The use of a filter mound over a tailings discharge pipe terminus has been tested elsewhere (Appendix 5-E, Brucejack Lake Tailings System Design). The approach was first tested at Newmont's Minahasa Gold Mine in North Sulawesi, Indonesia in the early 1990s. It proved highly successful in achieving its goal of containing fine tailings particles. Earlier it was noted at the Island Copper Mine on Vancouver Island that the tailings discharge to Rupert Inlet could continue when the outfall was buried beneath settled tailings.

There has been a good deal of qualitative observational data collected at CMP in Chile. At this site it was not the intention to discharge tailings beneath a deposit, but probably due to the discharge of out of specification coarse material a deposit did form over the ends of two separate outfalls over a

15-year period. Both outfalls discharged on a moderate subsea slope, permitting material coarser than a few millimetres to accumulate over the end of the pipe.

5.11.2.9 Operation

During normal operation, the level in the mixing tank will be maintained by the addition of dilution water; the flow rate and solids concentration from the thickener underflow will not be controlled.

The discharge pump variable frequency drive will be controlled by a signal from the flow meter to maintain the velocity in the pipeline above 2.5 m/s. Approximately 50% of the time, the thickener underflow will be directed to the paste back-fill plant. When this occurs, level in the mixing tank will be maintained by an automatic increase in dilution water flow. Velocity in the pipeline will be maintained above 2.5 m/s by varying the pump speed.

There will be two centrifugal slurry pumps to discharge the tailings, one duty and one standby at any time. The piping configuration will be such that either pump will be able to deliver tailings slurry to either pipeline by opening and closing appropriate valves

Detailed procedures will ensure proper operation and preservation of the system during start-up and shut down.

5.11.2.10 Switching Outfalls

The intent is to use the primary discharge pipeline, discharging at 80 m below the lake surface. The secondary pipeline will be employed in the event that excess back pressure occurs in the primary pipeline. The pump head, that is the discharge pressure in the pipeline, will be calculated in the PLC and displayed in the control room. The PLC will be programmed to alert the control room operators to switch over the pipeline if the pump approaches its maximum permissible discharge head. For switch over, the primary pipeline will first be flushed with water for approximately 10 minutes. The tank and the discharge pipeline will flush fully in that time. The pipelines will be manually switched by swinging the isolation valves and allowing flow to the secondary pipeline. The system will not require the pump being shut down, but the pump will require a much lower head as the pipeline length will decrease and the deposit will have to build back up at the new terminus.

The system is designed to offer operational flexibility. Once the secondary pipeline is operating, the primary pipeline can be shortened by cutting the pipeline to discharge at a depth of 40 m. It will then be ready to for use in the event that the secondary pipeline imposes an excessive back pressure on the pumps. The same procedure will be used: flush the line, swing the isolation valves, and re-start the primary pipeline.

5.11.3 Air Emissions

Air emissions will include particulate matter, NO_x, SO_x, and greenhouse gas emissions from fuel combustion by surface and underground equipment and vehicles, and diesel generators when in use. Overall annual fuel consumption is expected to be in the order of 4.7 million L for the mine site and Knipple Transfer Area combined. The electrical induction furnace emissions may include particulates and SO_x Fugitive dust emissions will occur due to vehicle traffic along the access road, but will be limited at the Brucejack Mine Site as a substantial amount of vehicle traffic will occur in the underground. Waste rock and tailings will be stored sub-aqueously (minimizing the need to stockpile material), and blasting and crushing will primarily occur underground, which will limit the potential for fugitive emissions from these sources. Additional air emissions will occur from the waste incinerator at the mine site that will primarily dispose of food waste and packaging as well as other domestic camp waste.

Air emissions, their sources, potential effects and proposed mitigation are discussed in more detail in Chapter 7, Air Quality Predictive Study.

Pretivm will implement an Air Quality Management Plan (see Section 29.2) to ensure that the levels of air emissions generated by Project activities meet the regulatory requirements of the Canada and BC Ambient Air Quality Objectives.

Adverse effects from air emissions and fugitive dust will be minimized through the implementation of mitigation measures such as:

- the use of diesel equipment that at a minimum meets the BC *Mines Act* (1996d), regulations, codes or orders;
- the use of electric equipment may be used where feasible;
- the use of appropriate emissions control equipment;
- the use of low-sulphur diesel fuel;
- preventative maintenance to ensure optimum performance of light-duty vehicles, diesel mining equipment, and incinerator;
- use of dust collection systems at the crushers and conveyor transfer points;
- controlling conveyor speed to limit dust lifting;
- application of dust suppressants, particularly water, on the aerodrome and roadways as required;
- the implementation of a recycling programs, which may reduce CO_2 emissions; and
- the segregation of waste prior to incineration to minimize toxic air emissions.

Instrumentation to monitor emissions quality of stationary emission sources. The use of electricity as primary source of power during Operation, as opposed to on-site generators, will also have a substantial impact on reducing Project-related air emissions.

5.11.4 Hazardous Waste

Pretivm is already registered as a hazardous waste generator for waste oil and batteries, and has procedures in place for the storage and handling of these materials. The registration will be amended as needed for additional materials during construction and operations. Existing procedures will be revised for hazardous waste management and spill response (see Hazardous Waste Management Plan, Section 29.7, and Spill Prevention and Response Plan, Section 29.14) during the Construction phase and adopted through time to accommodate the Operation and Closure phases. These procedures will be defined in the Project procedures and include compliance, auditing, and reporting requirements. Procedures will be established regarding the safe handling, storage, and disposal of batteries, fuels, oil, and hazardous materials. Hazardous materials may be generated in the shops, laboratories, mill facilities, substation, generators, and camps. Table 5.11-1 lists many of the hazardous materials that can be anticipated on site. Maximum volumes of these materials are estimated at:

- batteries: about 1,000 various sizes of batteries/year;
- fuels: about 500 L/year;
- engine oils: about 4,000 L/year;
- gear lubricant: about 1,000 L/year;
- hydraulic fluid: about 100 L/year;
- grease: about 100 L/year.

Table 5.11-1. Typical Dangerous Goods and Hazardous Materials on Site by Project Phase

Product	Phase			
	Construction	Operation	Closure	Post-closure
Diesel fuel	Used throughout; stored at the Brucejack Mine Site in 205-L barrels, double-wall tanks, or fabric bladders with secondary containment	Used throughout; stored at the main fuel storage facility at the Brucejack Mine Site, as well as the Knipple Transfer Area and underground maintenance shops, in either double-wall tanks or within secondary containment	Used in decreasing amounts as components are decommissioned; stored at the main fuel storage facility at the Brucejack Mine Site, as well as the Knipple Transfer Area in either double-wall tanks or with secondary containment	Use in small quantities within vehicles associated with monitoring, no onsite storage
Gasoline	Used throughout; stored at the Brucejack Mine Site in 205-L barrels with secondary containment	Used throughout; stored at the main fuel storage facility at the Brucejack Mine Site, as well as the Knipple Transfer Area and underground maintenance shops, in either double-wall tanks or with secondary containment	Used in decreasing amounts as components are decommissioned; stored at the main fuel storage facility at the Brucejack Mine Site, as well as the Knipple Transfer Area and underground maintenance shops, in either double-wall tanks or with secondary containment	Use in small quantities within vehicles associated with monitoring, no onsite storage
Lubricating oil	Used throughout; stored at the Brucejack Mine Site in 205-L barrels with secondary containment	Used throughout; stored at maintenance shops in bulk tanks with secondary containment	Used in decreasing amounts as components are decommissioned; stored at maintenance shops in bulk tanks with secondary containment	Use in small quantities within vehicles associated with monitoring, no onsite storage
Lubricants, greases	Used throughout; stored at the Brucejack Mine Site in tubes, pails, and drums with secondary containment	Used throughout; stored at maintenance shops in bulk tanks with secondary containment	Used in decreasing amounts as components are decommissioned; stored at maintenance shops in bulk tanks with secondary containment	Use in small quantities within vehicles associated with monitoring, no onsite storage
Ethylene glycol	Used throughout; stored at the Brucejack Mine Site in 205-L barrels with secondary containment	Used throughout; stored at maintenance shops in 205-L barrels with secondary containment	Used in decreasing amounts as components are decommissioned; stored at maintenance shops in 205-L barrels with secondary containment	Not required
Hydraulic fluid	Used throughout; stored at the Brucejack Mine Site in 205-L barrels with secondary containment	Used throughout; stored at maintenance shops in 205-L barrels with secondary containment	Used in decreasing amounts as components are decommissioned; stored at maintenance shops in 205-L barrels with secondary containment	Not required
Batteries	Used throughout; stored at the Brucejack Mine Site and maintenance shops on pallets with secondary containment	Used throughout; stored at the Mine Site and maintenance shops on pallets with secondary containment	Used in decreasing amounts as components are decommissioned; stored at maintenance shops on pallets with secondary containment	Use within vehicles or equipment associated with monitoring no onsite storage
Solvents	Used and stored at the maintenance shops; stored in 205-L barrels with secondary containment	Used and stored at the maintenance shops; stored in 205-L barrels with secondary containment	Used in decreasing amounts as components are decommissioned; stored at maintenance shops in 205-L barrels with secondary containment	Not required

(continued)

Table 5.11-1. Typical Dangerous Goods and Hazardous Materials on Site by Project Phase (completed)

Product	Phase			
	Construction	Operation	Closure	Post-closure
Lime	Used at temporary and permanent water treatment plant; stored in large bulk bags at each plant and otherwise in bulk	Used at water treatment plant; stored in large bulk bags at each plant and otherwise in bulk	Used in decreasing amounts as water treatment plant is decommissioned; stored in large bulk bags at each plant and otherwise in bulk	Not required
Flocculent	Used at temporary and permanent water treatment plant; stored in 25-kg bags at each plant and otherwise in bulk	Used at water treatment plant and process plant; stored in bulk	Used in decreasing amounts as water treatment plant is decommissioned; stored in bulk	Not required
Surfactant	Not required	Used at process plant; stored in bulk	Not required	Not required
Propane	Used at camps and other temporary and permanent facilities for space heating; stored in portable and permanent tanks/cylinders	Used at camps for kitchens and other facilities for space heating, for heating mine air during cold periods; stored in portable and permanent tanks/cylinders	Used in decreasing amounts for camps and other facilities for space heating; stored in portable and permanent tanks/cylinders	Not required
Domestic cleaning products	Stored and used primarily at camps and kitchens for cleaning	Used primarily at camps, offices and kitchens for cleaning	Used primarily at camps and kitchens for cleaning	Not required
Laboratory chemicals	Preservatives for environmental samples; stored in 1-L to 5-L containers	Preservatives for environmental samples, reagents for laboratory analyses; stored in 1-L to 5-L containers	Preservatives for environmental samples; stored in 1-L to 5-L containers	Used as preservatives for environmental samples; no onsite storage
Process Plant reagents	Not required	Will include lime, potassium amyl xanthate (PAX), methyl isobutyl carbinol (MIBC), antiscalant and flux (possibly borax ($Na_2B_4O_2$), sodium nitrate ($NaNO_3$), silica (SiO_2), and fluorspar (CaF_2)). Dry reagents will be stored in bulk bags up to 1 tonne in size, liquids in tanks	Not required	Not required
H_2SO_4	Used in water treatment lab assay; stored in framed totes at the water treatment plant	Used in water treatment lab assay; stored in framed totes at the water treatment plant	Used in water treatment lab assay; stored in framed totes at the water treatment plant	Not required
Water treatment sludge (treatment by-product)	Stored temporarily in the contact water pond or an engineered cell prior to the mill being available to produce tailings for co-disposal in Brucejack Lake	Stored in a tank in the mill building and added to the tailings stream for subaqueous disposal in Brucejack Lake	Processed through a filter press to dry and removed off-site to a licenced facility	Not required

These materials will be anticipated in advance and segregated, inventoried, and tracked in accordance with federal and provincial legislation and regulations such as the federal *Transportation of Dangerous Goods Act* (1992). Hazardous waste will be labelled and stored in appropriate containers for shipment to approved off-site disposal facilities. Storage facilities for hazardous wastes will be inspected regularly for leaks or non-compliance with policies, plans, and procedures. Inspections will be recorded in a systematic manner and such records will be filed with the Mine Manager. Designated storage sites will be provided at the mill building, truck shop, underground shop, construction and operations camps, and Knipple Transfer Area.

5.11.5 Non-hazardous Waste Management

Waste will be recycled to the extent feasible. Waste collection areas will have provisions to segregate waste according to disposal methods and facilities to address spillages, fire, and wildlife attraction. Kitchen, camp, and office wastes will be incinerated and the ash added to the paste backfill. Specific procedures (Waste Management Plan, see Section 29.17) and separate secure storage areas will be designated at the mill building, truck shop, construction and operations camps, and Knipple Transfer Area for waste prior to recycling or removal from the site. Solid waste will be recycled or disposed off-site at a licensed facility.

5.11.6 Sewage

Sewage management for the Project will be consistent with the requirements of the *Environmental Management Act* (2003) and its Municipal Wastewater Regulation (BC Reg. 87/2012). The existing exploration site sewage treatment plant, which is sized for a camp population of 300, but registered for 210, will have additional unit(s) added for the construction camp population of 450 and subsequent operations camp size of 330 persons (Figure 5.1-2). There will be a holding tank underground and sewage will be trucked to the main sewage treatment plant as requiured. The mill building will have a sewage lift station inside and a heat-traced pipeline to the camp sewage treatment plant. The truck shop will have a sewage lift station inside and a heat-traced holding tank outside. A truck will transfer sewage from the holding tank to the sewage treatment plant at the camp. Effluent from the sewage treatment plant will be of appropriate quality for direct discharge to Brucejack Lake. It will be directed to the lake through a pipeline that will run parallel to the tailings discharge pipeline. Sludge from the plant will be incinerated and the ash added to the paste backfill, or hauled offsite for disposal at a licensed facility.

The Knipple Transfer Area and Tide Staging Area camps will have septic systems with tanks and drainfields.

5.12 ANCILLARY INFRASTRUCTURE

Ancillary surface infrastructure to be constructed in the vicinity of the mine will include the truck shop, substation, helipad, fuel storage facility, concrete batch plant, explosives storage area, and camp. The mine dry, first aid facility, assay and metallurgical labs, water treatment plant, administrative offices, and warehouse will be centralized in the mill building to reduce the overall Project footprint.

5.12.1 Mine Site Geohazards

Mine site facilities are all located away from avalanche paths and areas with the exception of some sections of the site access roads, the incinerator, and the pre-production ore storage and diversion channel area. Areas subject to avalanche risk will have appropriate mitigation to minimize the risk. Short slopes that currently exist (ranging from 10 to 40 m in height), or will be created during construction, may be expected to affect other facility areas; however the hazard and consequences would normally be assessed on a site specific basis during Construction and Operation (Appendix 5-H, Brucejack Project Avalanche Hazard Assessment).

5.12.2 Internal Site Roads and Pad Areas

Internal site roads will connect various on-site facility pad areas. Internal site roads will be 8.0 m wide to accommodate two opposing lanes for unconstrained two-way traffic. They will be crowned gravel roads with ditch drainage, and will include a safety berm where required. See Figure 5.1-2 for internal site road locations.

A haul road will be constructed for underground trucks to travel from the underground mine south portal to the pre-production ore/waste rock transfer storage area, or the Brucejack Lake waste rock dump. Waste rock will be dumped at the waste rock transfer storage area during poor weather conditions, due to the limited traction capabilities of the underground trucks and a haul road grade of approximately 5.2%. Underground trucks will haul waste rock directly to the Brucejack Lake waste rock dump when weather conditions permit.

The pre-production ore/waste rock transfer storage area will have 2:1 slopes up to 6 m high with a bench between. The total height above the laydown area will be up to 14 m.

The frequency of the standard axle load and subgrade modulus have been considered in the design of all road and gravel surfacing structures. Subgrade was assumed to be either rock or good soil. Road travelling surfaces, safety berms, and drainage channels will be regularly maintained.

The proposed development consists of several pad areas for the following:

- mill building and Brucejack Camp;
- portal and truck shop;
- substation;
- garbage and incinerator;
- batch plant
- fuel tank;
- laydown;
- pre-production ore/waste rock transfer storage area;
- detonator storage; and
- explosives storage.

In addition, a pad area will be developed for the Knipple Transfer Area.

Earthworks, including rock blasting, will be required to create the pads. It is assumed that there will be PAG rock in the mill pad cut. Drainage from this area will be collected and treated. Rock excavated from this area is proposed to be deposited as subaqueous fill in the lower laydown area or into Brucejack Lake. The pads will be finished with a gravel surface, and will drain to ditches. Despite the mountainous terrain, only minor retaining walls are proposed at this time.

During pad design, consideration was given to optimizing operations, providing sound structural foundation bearing capacity, and minimizing earthworks operations. Proposed pad and road areas were three-dimensionally designed and modelled to obtain approximate final grades. Cut-and-fill volumes were then derived using computer software, and verified by model and cross-section checks. The cut-and-fill volumes accounted for topsoil removal as well as shrinkage and swell factors.

The site will be positively drained at all times. Existing drainage courses will be preserved as much as possible as this typically leads to the most economical drainage design. Any minor drainage systems will be designed for the 200-year storm event, and the site will always have a major storm outlet route to prevent any area flooding. Ditch design is discussed in Section 5.10.3.

Contact water from most of the mine surface facilities area, including from potential PAG runoff areas, will be collected and directed to a contact water pond. Water contained in the contact water pond will be pumped to the mine water treatment plant for treatment prior to use or discharge

A sediment control plan will be implemented to minimize the release of sediment from disturbed areas.

5.12.3 Camp

The current exploration camp includes a kitchen and dormitories, and can accommodate 210 people. Two dormitories will be demolished to allow for construction of the new mill pad, reducing the current camp capacity to 120. The new permanent camp (Figure 5.1-2) will accommodate 400 people with a combination of single and multi-person dormitories and will include an additional kitchen, recreation and exercise facilities, camp offices, and sewage treatment. The new camp and remaining exploration camp will have a combined capacity of 450 people during the Construction phase. Once the Construction phase is complete, the permanent camp will be refurbished for use during Operation.

The new camp will consist of multi-storey modular buildings constructed of wood framing with insulated metal-clad walls and roof. Roofs will be designed to minimize snow accumulation.

A second camp will be constructed at the Knipple Transfer Area to accommodate staff for road maintenance and for short visitor stays in the event of adverse weather conditions that prevent the transportation of personnel to the mine site. The existing Bowser Camp, located adjacent to the proposed aerodrome site, will be decommissioned once the Knipple Transfer Area camp is available.

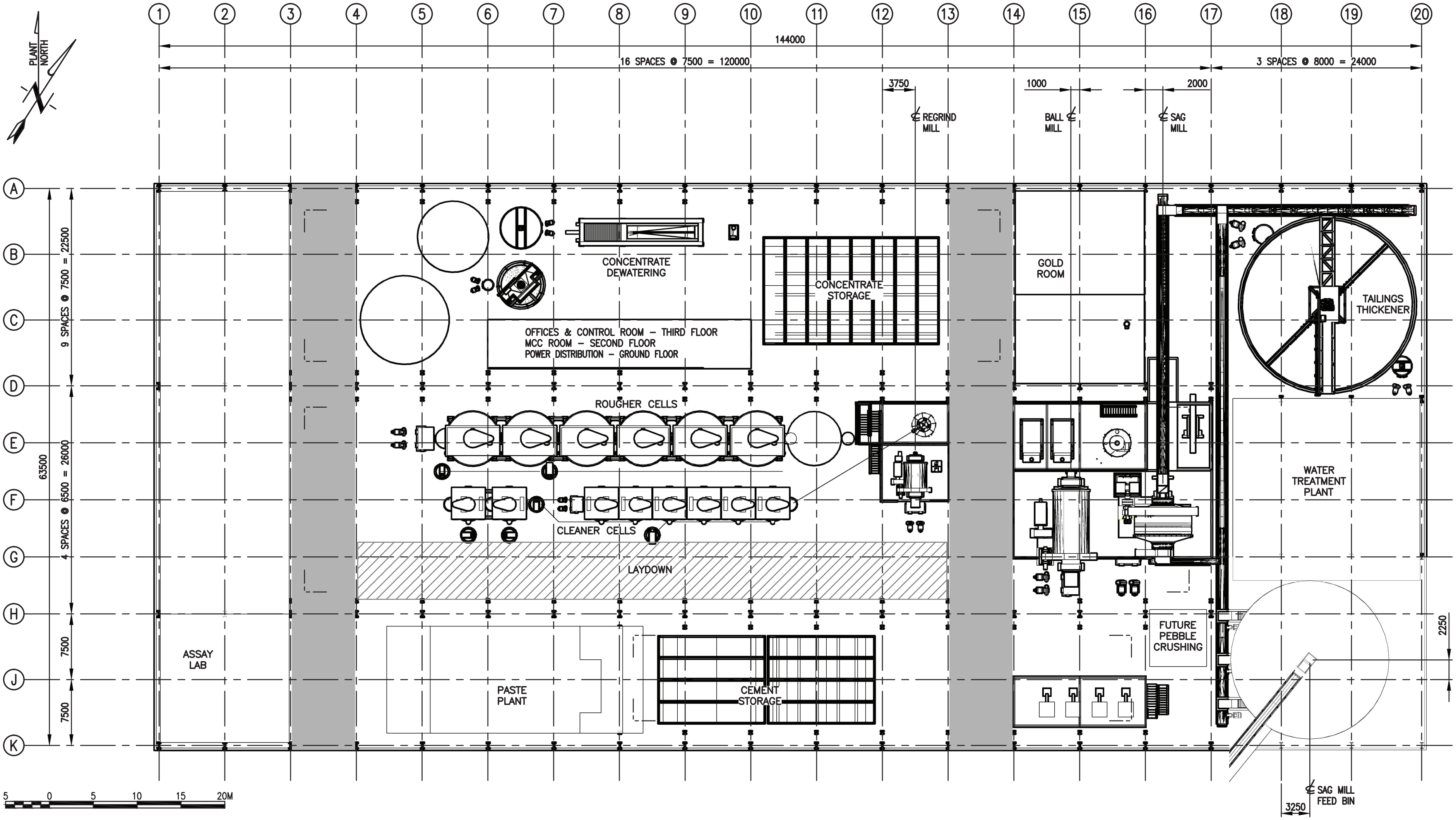
5.12.4 Assay and Metallurgical Laboratories

The assay and metallurgical laboratories will be incorporated in the mill building (Figure 5.12-1) and will house all necessary laboratory equipment for metallurgical grade testing and control. Typical analytical equipment include:

- sample preparation equipment including crushers, pulverizers, screens, and blending tools;
- fire assay related furnaces and devices;
- atomic absorption spectrophotometer;
- ICP-mass spectrometer for environmental sample analysis;
- weigh scales; and
- Leco furnace.

The metallurgical laboratory will undertake all the necessary test work to monitor metallurgical performance and, more importantly, to improve process flowsheet unit operations and efficiencies. The laboratory will be equipped with laboratory crushers and ball mills, particle size analysis sieves, bench scale flotation cells, centrifugal gravity concentrators, leach units, filtering devices, balances, and pH meters. Personal protection devices and items will be provided to protect the lab workers. The laboratories will be equipped with all appropriate HVAC and chemical disposal equipment as needed. The facility floor will be reinforced as needed to accommodate specialized equipment.

Figure 5.12-1
Mill Building Plan



Source: Tetra Tech (2014).

5.12.5 Warehouse Facility

The warehouse facility located within the truck shop structure will house a mill shop, electrical and instrumentation shop, mechanical room, and tool crib.

5.12.6 Mine Dry

The mine dry will be constructed as part of the camp to accommodate 400 people, each with individual lockers and hanging baskets. The wicket and lamp rooms will be located in the camp adjacent to the dry where underground personnel will be picked up by underground vehicles and transported to and from the underground mine.

5.12.7 Truck Shop

The truck shop will be a standalone pre-engineered steel building with insulated roof and walls to be located about 60 m east of the portal. It will have a footprint of about 80 m by 24 m and will include five bays for both surface and underground vehicles, a welding bay, wash bay, emergency vehicle bays, first aid and emergency equipment storage, shop warehouse, mechanical room, electrical room, and washrooms. Sumps and trenches will be constructed to collect waste water during maintenance operations. A floor hardener will be applied to concrete surface on high-traffic areas. Steel inserts will be embedded into the concrete in areas where tracked vehicles will be driven. A 5-t overhead crane will service this facility.

5.12.8 First Aid

The first aid and emergency response facility will be incorporated in the truck shop and will include parking for a fire truck and an ambulance. A helicopter pad will be located close to the facility for any medical evacuation requirements.

5.12.9 Administration Office

The administration office will be constructed on the second floor of the mill building.

5.12.10 Fuel Handing, Transportation, and Storage

Fuel handing, transportation, and storage facilities and activities will be consistent with the Health, Safety and Reclamation Code (BC MEMPR 2008); the Ministry of Water, Land and Air Protection's publication, *A Field Guide to Fuel Handling, Transportation and Storage* (BC MWLAP 2002); and, for storage facilities with greater than 100,000 L of fuel at a single location, with the *Environmental Management Act* (2003) Petroleum Storage and Distribution Facilities Storm Water Regulation (BC Reg. 168/94).

The transportation, storage and handling of fuels required for the Project at the Construction, Operation, Closure, and Post-closure phases will be addressed by the Hazardous Materials Management Plan (Section 29.7), which will be modified as required over the life of the Project. Fuel will be stored at the Knipple Transfer Area, at the mine laydown area, and in an underground storage tank to service the mine fleet. Minor quantities of aviation fuel may be stored in drums at the Bowser Aerodrome.

Fuel storage areas will have impermeable liners with the capacity of 110% of the largest storage tank. Oil/water separators will be provided to treat overflows from the containment area.

Diesel fuel will be delivered by commercial tankers to the Knipple Transfer Area where it will be offloaded to a single 50,000-L double-walled steel tank. From there it will be transferred to double-walled tanks mounted on a tracked vehicle or other vehicle specifically equipped for transport over the glacier to the Brucejack Mine Site fuel storage facility.

Smoking will be prohibited in the vicinity of the fuel storage areas and measures will be implemented to prevent sparks that could ignite fuel or fumes. Fire extinguishers and other fire-fighting equipment will be strategically located adjacent to the fuel storage areas.

Fuel levels in tanks will be measured and records of deliveries and dispensing compared as part of a regular capacity audit.

5.12.10.1 Mine Area Surface Fuel Storage

Diesel fuel primarily for mobile equipment will be stored in four 50,000-L double-walled tanks located at the upper laydown area (Figure 5.1-2). It will occupy an area of about 500 m^2. The storage is estimated for a 10-day capacity, including allowance for auxiliary equipment. The fuelling station will include a receiving pump, a strainer and delivery pumps, and filters. Procedures for transportation, storage, and distribution of fuel will be developed as part of a Hazardous Materials Management Plan (see Section 29.7). The fuelling station will include containment with an impervious membrane under gravel to collect any spillage. It will have a capacity of 110% of the largest tank and be equipped with an oil/water separator.

Diesel fuel for the back-up generators will be stored in two 75,000-L double-walled tanks to be located at the substation. Like the fuelling station, this fuel storage area will include containment with an impervious membrane under gravel to collect any spillage. It will have a capacity of 110% of the largest tank and be equipped with an oil/water separator.

One 5,000-L double-walled diesel fuel batch tank will be located on the surface above the vicinity of the underground fuel storage, and will serve to fill the 20,000-L underground mine tank by gravity.

Aviation fuel for helicopters will be stored in one 5,000-L double-walled fuel tank located adjacent to the helicopter landing pad at the mine laydown area.

Gasoline for mobile equipment will be stored in one 5,000-L double-walled fuel tank located adjacent to the diesel fuel tanks.

Propane will be used for heating of mine air and for the camp kitchen. Propane for mine air heating will be stored in two 114,000-L tanks to be located between the portals and connected by buried pipeline to the heaters at the portals. Three 5,000-L propane tanks will be located adjacent to the permanent camp facilities.

5.12.10.2 Underground Fuel Storage

A fuel bay area will be located on the 1,320 infrastructure level and will include a 20,000-L fuel storage tank. Fuel will be transported underground by truck to refill the storage tank as required.

5.12.10.3 Knipple Transfer Area Fuel Storage

The Knipple Transfer Area will include a fuel dispensing system with facilities for diesel, gasoline, and aviation fuel. The fuel storage tanks will be double-walled type to minimize risks due to leaks. An additional diesel fuel tank will supply the camp generators.

5.12.11 Explosives Storage and Use

Explosives transportation, storage, and use will be consistent with the requirements of the federal *Explosives Act* (1985a), *Transportation of Dangerous Goods Act* (1992), and the provincial *Health, Safety and Reclamation Code for Mines in British Columbia* (BC MEMPR 2008). The Hazardous Materials

Management Plan (Section 29.7), to be developed prior to Construction, will guide the safe transportation, storage, use, and disposal of explosives at the site throughout the life of the Project.

During the Construction phase, the existing exploration explosives magazines will continue to be used for the development of the underground works. Contractors completing the earthworks for pad construction for the mill building, water treatment building, camp facilities, and related excavations will supply, and acquire permits for, temporary explosives magazines. Similarly, contractors undertaking any required blasting for access road upgrades will supply and permit temporary explosives magazines.

Additional small explosives and cap magazines will be required near the Knipple Transfer Area and the Bowser Aerodrome for ongoing avalanche control work throughout the life of the Project. These explosives will be used solely be licensed technicians for avalanche control purposes.

At the mine, explosives consumption at full production is estimated to be 2.7 t/d of bulk emulsion, or about 80 t/month at full production. This emulsion will be delivered to the mine in nine custom-made ISO tanks, each with a capacity of 6,000 L or 7 t. These tanks will be filled at the supplier's plant and delivered to the Knipple Transfer Area by highway truck. There they will be transferred to tracked vehicles or other vehicles specifically equipped for glacier travel for transportation to the mine. A boom truck will transport the full tanks to the emulsion bays. The two emulsion bays will each contain a 24,000-L storage tank and a storage area. The entrance to the bays will be controlled with a rollup door and a man-door. The bays will be located so that a fire or detonation in the magazine will not impede egress from the mine. The bays will also be located near an exhaust raise separate from the main ventilation system. Emulsion pumps will be used to transfer from the full tank to the empty one in the bay.

Cap and powder magazines with approximate dimensions of 6 m by 3 m will be excavated underground for the storage of packaged explosives (cartridged emulsion, primers, and boosters), detonating cord, non-electric detonators, and electric detonators on wooden shelves. The maximum volume of packaged explosives to be stored would be about 5 t at any time, although normal volumes would be closer to the weekly consumption of about 2 t plus a small margin of surplus. A concrete block wall with a steel door will separate these bays from the rest of the mine works. These magazines will also be located near the dedicated exhaust raise and separated from the main egress routes. Approximately 300 caps and 300 primers will be required daily. The maximum quantity to be stored in the cap magazine will be about 5,000 caps. These products will be transported by the supplier to the Knipple Transfer Area for transfer to appropriate vehicles for glacier travel, similar to bulk emulsion. Once on site, these products will be delivered to the underground magazines by an underground utility vehicle.

Two pre-fabricated shipping container-type structures will be used for packaged explosives storage on the surface and will be locked at all times to prevent unauthorized access. This storage facility will be located about 500 m north-northwest of the water treatment plant building, 835 m from the camp, and about 30 m from Brucejack Creek (Figure 5.1-2). The magazines will be sited and constructed to meet both federal and provincial regulatory requirements. Access to the explosives storage will be by road. The magazines will be heated as required to ensure that the explosives do not freeze.

A pre-fabricated shipping container-type structure on surface will house the detonator magazine storage and will be locked at all times to prevent unauthorized access. Access to the detonator magazine storage will be by road, and the facility will be controlled by a locked gate.

Neither the surface explosives nor detonator magazines will be located in avalanche or geohazard areas. Records will be maintained of all explosives delivered to the magazines and the explosives will only be removed by authorized persons who will sign out approved volumes. These records will be available to confirm and track explosives consumption.

Potential accidents and malfunctions with regards to explosives are discussed in Chapter 31, Accidents and Malfunctions.

5.12.12 Concentrate Storage

A press filter within the mill building will be used to reduce the moisture content of the concentrate to about 10 to 12%. The filter cake will be bagged in 2-t bags and stacked in the mill building prior to being loaded into containers for shipping. The bagging and containerizing will reduce spillage and dusting concerns once the concentrate leaves the plant. The plant will provide sufficient on-site storage capacity for up to 10 days of production. Additional secured storage will also be provided at the Knipple Transfer Area.

The concentrate storage area will have a concrete floor with a sump. Material collected in the sump from wash downs will be returned to the concentrate thickener underflow.

5.12.13 Concentrate Transportation

There are two options being considered for transportation of concentrate, depending upon market conditions. Regardless of which option is used, the concentrate will be loaded in 2-t bags for shipment from the Brucejack Mine Site. The bags will be transported in containers via properly equipped vehicles over the glacier to the Knipple Transfer Area. The containers will be unloaded and transferred to standard 42-tonne highway B-train flat-decks for shipment to smelters. On average, up to six concentrate shipments will be made on a daily basis. It is expected that the maximum number of concentrate trucks on a daily basis will be less than 10.

It is currently assumed that the concentrate will be shipped to the Horne Smelter in Noranda, Québec. This facility receives concentrate via rail in open-top gondola railcars. Concentrate will be shipped from the Knipple Transfer Area via the Brucejack Access Road, Highway 37, and then Highway 16 to Terrace, a one-way distance of about 310 km. The concentrate bags will be received in Terrace, inventoried, and loaded into railcars. The estimated transit time from Terrace to the Horne Smelter is 13 days.

The second option for concentrate transportation is to direct the flat deck trucks from the Knipple Transfer Area to Highway 37, thence along Highway 37A to Stewart where the concentrate will be offloaded for transfer to deep sea freighters for shipment to offshore smelters. Total one-way distance travelled by each truck originating from the Project to Stewart will be 175 km on the access road, Highway 37, and Highway 37A.

5.12.14 Power Supply

A BC Hydro 138-kV overhead power line will supply power to the Project site (see Section 5.13.2). The overall power requirements for the Project will be approximately 20 MW.

The main site power will be stepped down from 138 kV to 4.16 kV via two 15/20/25 MVA oil-filled transformers, complete with neutral grounding resistors, located in the main substation yard. The yard will be fenced. Each transformer will be capable of carrying the entire site load. A pre-fabricated electrical house, containing 5-kV class switchgears, will distribute power to various points on the site.

Within the mill, large loads will be powered at 4.16 kV. Smaller loads will be powered at 600 V via switchgear and motor control centres. Variable frequency drives and soft starters will be employed strategically to optimize process and energy performance.

Approximately 1.2 km of 4.16-kV single wood-pole overhead power lines will be constructed to provide power to outlying buildings such as the batch plant, fuel storage, etc.

The emergency power strategy will employ two elements:

- Four existing 500-kW, 600-V diesel generators will be installed at the main substation and will connect to the main power distribution bus. Although the primary function of these units is to power critical loads underground and in the mill, select critical loads throughout the site can be powered as well.
- An additional 500-kW, 600-V diesel generator will be purchased for construction activities and then re-deployed as a dedicated back-up power supply for the permanent camp.
- Two new 1,250-kW, 4,160-V diesel generators will be purchased for construction power and will also be installed at the main substation and connected to the main power distribution bus to further augment emergency power supply.

A dedicated power system programmable logic controller (PLC) will be included in the electrical house. This PLC will connect to the 4.16-kV and 600-V switchgear as well as mine heating systems using fiber optic communication.

The power system PLC will perform two important functions:

- load optimization/load shedding to ensure line limits are not exceeded, while maximizing electricity use for mine heating; and
- power control during emergency power operations to ensure correct sequencing and operations of critical loads.

5.12.15 Communications

A complete site-wide telecommunications system will be installed in two phases. The first phase will include the base installation of the communication system during the Construction phase. The second phase will allow for expansion of the system to include the operating plant. Major subsystems will include:

- a VoIP telephone system for buildings, camps, and offices;
- satellite communications for critical voice and data needs;
- Ethernet cabling for site infrastructure and wireless internet access;
- very-high frequency two-way radio system with eight public channels;
- four remotely located very-high frequency repeaters; and
- satellite TV and Internet for the 450-person camp at the mill site and the 30-person camp at the Knipple Transfer Area, including a wireless access tower for communications to the Knipple Transfer Area and airport location.

A pre-manufactured trailer will be used as a central equipment enclosure (CEE) to house all communications equipment for both phases. The CEE will include all HVAC equipment and an uninterruptable power supply. The site telecommunications will be linked to the site fibre optic backbone via the CEE. A separate existing satellite communications system will be provided and will be isolated in a separate building from the CEE cabinet. This system will handle emergency off-site contact in the unlikely event that the CEE and its vital equipment are compromised.

5.12.16 Treatment Plant for Underground Mine and Surface Water

The operations mine water treatment plant will be located in the mill building. It will treat underground inflows and surface water from the contact water collection pond.

The proposed treatment process is described in the following section and shown schematically in Plate 5.12-1 (Veolia 2013). The raw water will be pumped to two parallel precipitation reactor chains whose purpose will be to precipitate dissolved metals present in the raw water. To do so, the water pH will be increased to 9 to 10 using sodium hydroxide. Hydrex 3288, a ferric chloride-based coagulant, will be added to the water upstream. The ferric chloride will react to form a ferric hydroxide floc which will adsorb part of the dissolved metals by co-precipitation and capture fine solids, while the high pH will favour the precipitation of most metals as hydroxide. The pH will be adjusted to optimize metal removal depending on the exact composition of the water.

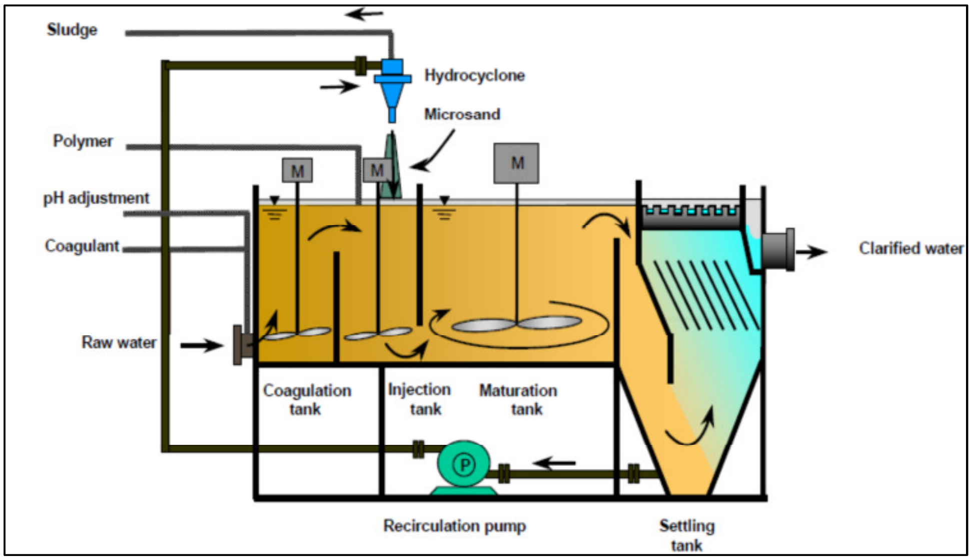


Plate 5.12-1. Schematic of the Proposed Water Treatment Process (Veolia).

A portion of sludge from the clarifier will be recycled in the precipitation reactor to improve the reaction at low temperature and minimize scaling.

The proposed clarifiers are designed to remove suspended solids present in the raw water as well as produced metal hydroxides from the precipitation step. Sand-ballasted settling is a high-rate coagulation/flocculation/sedimentation process that utilizes microsand as a seed for floc formation. The microsand will provide a surface area that enhances flocculation and act as a ballast or weight. The resulting floc will settle quickly, with high overflow rates and short detention times. The use of microsand will also permit the unit to perform well under dramatically changing flow rates without impacting final effluent quality.

The slurry from the precipitation step will flow to a coagulation chamber where the reaction will be completed. The water will then flow into the maturation tank where Hydrex 6105, an anionic polymeric flocculant, and microsand will be added to initiate floc formation. These additives serve as a "seed" for floc formation and development in the next process step. In this tank, a mixer will provide ideal conditions for bridging between the microsand and the destabilised suspended solids. From this tank, the fully formed ballasted floc will enter a settling tank equipped with a lamella, which will provide the rapid and effective removal of the microsand/sludge floc. The clarified water will exit the system via a series of collection troughs or weirs.

The sand-sludge mixture will settle to the bottom of the clarifier. Scrapers will force the sludge collected at the bottom of the clarifier into a center cone from which it will be continuously withdrawn and pumped in a hydrocyclone where sludge and microsand will be separated by centrifugal force. After separation, the higher density microsand will be discharged from the bottom of the hydrocyclone and injected into the process for re-use. The lighter density sludge will then be sent to a tank. From this tank, a portion of the sludge will sent to the metal precipitation reactors upstream to act as seeds to help the precipitation, optimize reagent usage and increase the sludge solid content, while the balance will be sent to the sludge dewatering process. The pH of effluent water will be adjusted with hydrochloric acid prior to discharge to Brucejack Lake or the mill. Discharge water that is not required for mill process or paste plant operation will be transported in a pipe that will follow the tailings discharge pipeline alignment to the lake.

The excess sludge from both clarifiers will be sent to a sludge retention tank. A cationic polymer will be added in order to ease dewatering of this slurry. The sludge will then be pumped to a filter press to increase the solid content.

The treatment plant will include the necessary chemical feeding systems, storage tanks, agitators, dosing pumps, clarifiers, filters, pumps, and precipitate collection and discharge systems. There will be a small laboratory to test influent and effluent water quality, including at least colour, pH, turbidity and temperature.

During the Construction phase, water treatment will be accomplished using a temporary treatment plant that was installed in 2014 to treat water produced from the exploration/bulk sample work. This temporary plant will have a footprint of about 16 m by 20 m and will have a capacity of about 140 m^3/hour based on worst case inflow turbidity levels. If required, the unit capacity can be increased to over 200 m^3/hour depending on inflow turbidity levels. If inflows exceed this capacity, a second train will be added to supplement the first train. The plant is located near the exploration portal. This treatment plant will be used until the new, permanent water treatment plant is constructed and operational. The temporary plant will be removed once the operation of the new water treatment plant has stabilized. The operation phase capacity of the new water treatment plant will be 400 m^3/hour.

Sludge from the water treatment plant will be stored in a tank in the mill building until it can be added to the tailings stream and pumped to Brucejack Lake for secure long term disposal.

Reagent Preparation and Consumption

Sodium hydroxide will be used to increase the pH in the process. Sodium hydroxide will be received in bulk containers of 1 m^3 at 50% concentration. About one and a half totes will be needed per day of operation, depending on the exact operating conditions.

Hydrex 3255, a ferric chloride based coagulant, will be received in containers of 1 m^3 at 13.5% concentration as iron. One tote will be needed per day of operation, depending on the exact operating conditions.

Hydrex 6105, the anionic polymer and the cationic polymer will be received in 25-kg bags and prepared in automatic preparation systems.

Microsand will be supplied in 25-kg bags. The microsand will be added manually to the clarifier as required, probably about twice a week.

Hydrochloric acid or CO_2 will be used to neutralize pH to discharge criteria. Hydrochloric acid will be received in bulk containers of 1 m^3.

All the reagent holding/preparation tanks will be equipped with level detectors and alarm systems. The reagents will be prepared in confined areas. Spoiled reagents will be packaged and returned to the vendors or shipped to a licensed facility for disposal.

5.12.17 Laydown Area

A laydown area will be constructed by filling in a bay on the south shore of Brucejack Lake with rock (Figure 5.1-2). The laydown area will be used for staging of materials for construction of the surface and underground facilities and will also be the location of the helicopter landing pad, fuel storage area, and contact water collection pond.

The laydown area will be constructed with waste rock generated during the development of pads for surface facilities such as the mill building, and from the underground development. Most of this rock will be PAG. PAG rock will only be used to fill to a level of 1 m below the low water level. Non-PAG rock from the quarry will be used to cover the PAG rock to form the travel surface.

The laydown area construction sequence will involve the construction of a causeway around the perimeter of the ultimate laydown area footprint, and then infill of the impounded area behind the causeway. This approach will reduce the likelihood of sediment release to the lake for most of the construction period.

5.12.18 Helicopter Pads

Helicopter landing pads will be provided on the laydown area adjacent to Brucejack Lake and at the Knipple Transfer Area. A level area will also be available for helicopter landings at the Bowser Aerodrome. Landing pads will provide sufficient room for main rotor and tail rotor clearance, will be kept free of loose materials that could be disturbed by rotor wash, and will be kept clear of vehicles and other obstacles.

5.12.19 Operations Mobile Equipment

A wide range of mobile equipment will be required during the Operation phase due to the variety of activities and high snowfall. Table 5.12-1 provides a conceptual list of anticipated equipment requirements for Project surface activities.

Table 5.12-1. Conceptual List of Equipment for Project Surface Activities

Mobile Equipment	Number of Units	Fuel Type
Brucejack Mine Site		
Backhoe loader	2	Diesel
Dump truck	1	Diesel
Forklifts	4	Diesel
Mobile crane – 50 t	1	Diesel
Boom truck -20 t	1	Diesel
Loader F/E	1	Diesel
Ambulance/mine rescue	1	Diesel
Truck - 1/2 tonne	4	Diesel
HDPE fusion machine	1	Diesel
Flatbed truck	1	Diesel
Fire truck	1	Diesel
Forklift (25 t)	1	Diesel
Mechanics truck	1	Diesel

(continued)

Table 5.12-1. Conceptual List of Equipment for Project Surface Activities (completed)

Mobile Equipment	Number of Units	Fuel Type
Brucejack Mine Site (cont'd)		
Welding truck	1	Diesel
Pickup trucks	2	Diesel
Buses - on-site	3	Diesel
Water truck	1	Diesel
Sewage truck	1	Diesel
Foremost Husky 8 tracked hauler	4	Diesel
Tracked snow groomer	5	Diesel
Bobcat utility vehicle	1	Diesel
Track loader	1	Diesel
Excavator	2	Diesel
Tracked material handler	3	Diesel
Dozer	2	Diesel
All terrain carrier	1	Diesel
Articulated tracked vehicle	1	Diesel
Tracked vehicle	1	Diesel
ATVs	10	Diesel
Snowmobiles	8	Diesel
Knipple Transfer Area		
Mobile Crane – 50 t	1	Diesel
Forklift	2	Diesel
Water truck	1	Diesel
Bowser Aerodrome		
Forklift	3	Diesel
Grader	1	Diesel

5.12.20 Quarry

A quarry will be developed in non-PAG rock about 1,300 m east of the mill building southeast of the south end of Brucejack Lake to provide construction fill where required. BGC Engineering Inc. reports that quarry samples show significant carbonate-buffering capacity and low sulphide-S contents (Appendix 5-B, Brucejack Project - Tailings Alternatives Assessment). A crusher will be located at the quarry site. It is estimated that about 740,000 m^3 of non-PAG rock will be excavated from this site and hauled along the access road that follows the south shore of Brucejack Lake to the mine site area. Rock will be mined at the quarry site using conventional drill and blast methods.

BGC Engineering Inc. completed a geotechnical assessment of the quarry site in 2013 to support engineering design of the quarry (BGC Engineering Inc. 2014b). The bedrock at the quarry was mapped as volcanic porphyry consisting of plagioclase-hornblende porphyritic rocks with strong, pervasive silica and hematite alteration. Based on field observations, BGC Engineering Inc. estimated intact strength, geologic strength index, Hoek-Brown material constant, disturbance factor, and rock mass fabric character for the bedrock.

Slope design parameters include an average bench face angle of 65°, a maximum bench height of 15 m, minimum bench widths ranging from 9 to 10 m, and a maximum overall height of 75 m (BGC Engineering Inc. 2014b). The overall angle of the quarry will be controlled by the bench geometry, and will be dependent on the number of benches utilized. Based on the maximum overall slope height considered, overall slope angles will range from 45 to 47°.

Freshwater diversions, contact water collection channels, and a settling pond will be provided to manage erosion and sediment.

5.12.21 Brucejack Lake Outlet Weir

Pretivm will construct a concrete weir across the outlet of Brucejack Lake, at the location shown in Figure 5.1-2. This small structure is intended to allow confident year round monitoring of flows from Brucejack Lake. It is not intended to restrict flows into Brucejack Creek or to increase the storage capacity of Brucejack Lake. The lake outlet stability is assessed in Appendix 5-J, Brucejack Lake Outlet Stability. A full geotechnical assessment of the site and construction plan for the weir will be completed in the summer of 2014.

5.12.22 Turbidity Curtain

To address the possibility that the dumping of waste rock and discharge of tailings into Brucejack Lake may elevate total suspended solids in the lake above acceptable levels, Pretivm will install a turbidity curtain across the width of the lake at a location downstream of the waste rock and tailings disposal areas, as shown conceptually in Figure 5.1-2. The curtain will be attached to a boom that will support the top of the curtain fabric. The boom will be held in place by a cable securely anchored to each side of the lake. Regularly spaced anchor weights may also be used to secure the boom in place to resist movement by wind and ice. The impermeable plastic fabric curtain will be weighted at the bottom to maintain a near-vertical configuration. The fabric will extend from the surface of the lake to a depth of about 10 m above the lake bottom. The objective of the turbidity curtain is to force water flow to the bottom of the lake so that surface turbidity is not permitted to flow out to Brucejack Creek. The turbidity curtain will be in place for both the Construction and Operation phases.

A second turbidity curtain will be installed around the perimeter of the waste rock disposal area to eliminate sediments from entering the water column in the lake as a result waste rock dumping. This turbidity curtain will be cabled to the shore at both ends and will be supported by a floating boom held in place with anchors regularly spaced along its length. Plate 5.12-2 shows an example of a turbidity curtain being used in a similar application for the construction of a jetty.

Plate 5.12-2. Example of a turbidity curtain used for the construction of a jetty.

Spare curtains will be stored onsite to facilitate rapid repair and or replacement of curtains if they become damaged.

5.13 OFF-SITE INFRASTRUCTURE

5.13.1 Project Access and Transportation Corridor

5.13.1.1 Overview

Road access to the Brucejack Mine Site will be via the existing 73-km-long exploration access road from Highway 37 (Figure 5.13-1), which will be upgraded to allow for operational traffic (Appendix 5-G, Brucejack Access Road: Upgrade Prescription). Throughout the remainder of the Application/EIS, the access road will be referred to as the Brucejack Access Road. The Brucejack Access Road begins at about km 216 on Highway 37, crosses the Bell-Irving River on a single-span bridge and follows the valley of Wildfire Creek to Scott Creek drainage, passes Todedada Lake in the Todedada Creek Valley and proceeds over the pass to follow Scott Creek to the Bowser Valley, which it follows to the toe of the Knipple Glacier. A constructed ramp allows tracked vehicles to access the glacier, which is followed for about 12 km to its apex near Brucejack Lake where a further 2 km of road connects with the proposed Brucejack Mine Site.

For the Project, the road will be used to mobilize equipment, personnel, and supplies to the Brucejack Mine Site and to truck concentrate from the Brucejack Mine Site to Highway 37. The Knipple Transfer Area will be constructed near the base of the Knipple Glacier to facilitate the transfer of goods and materials from highway trucks to specialized vehicles for travel on the glacier, and for transfer of concentrate from vehicles equipped for glacier travel to highway trucks for shipment to Terrace.

Five large “Husky 8” tracked vehicles with a maximum payload of 36 t each, or similar equipment, will be available for primary transport of equipment, materials, and flotation concentrate over the Knipple Glacier when conditions are not appropriate for the use of more traditional transport vehicles. Other tracked and wheeled vehicles will also be utilized for smaller loads.

Primary personnel transport over the glacier will be performed with two “Terra Bus” all-terrain 56-passenger buses, or similar equipment. A variety of multi-passenger tracked or wheeled vehicles will also be used.

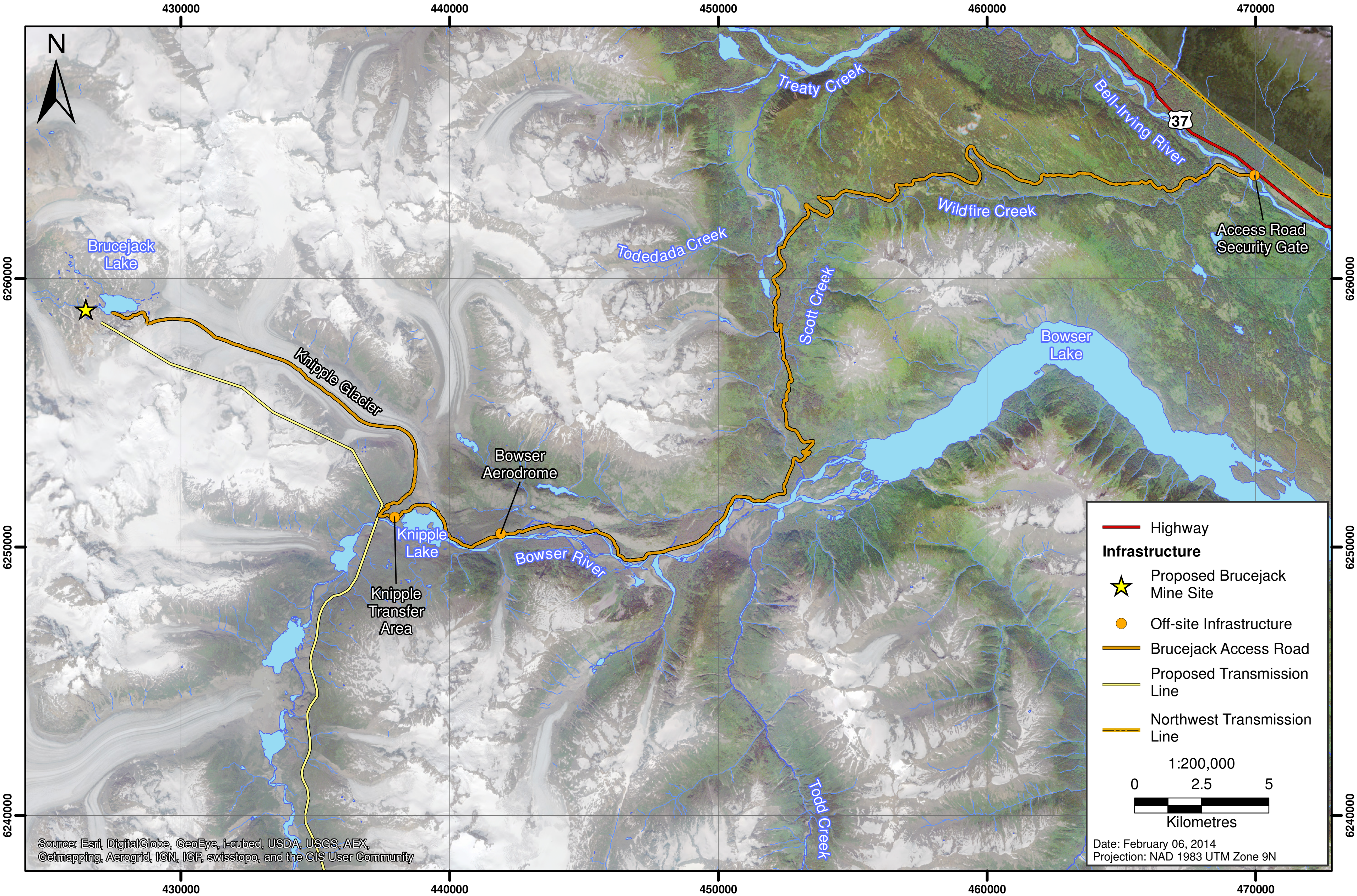
Upon receipt of construction and operations permits, the road will require additional upgrading to increase the speed limit to 40 km/hour and to handle the higher traffic loadings from both construction and operations activities. The work will include widening of the road surface in locations with limited sight distances, minor re-alignments of the sharper curves, and reductions of the steeper grades (Appendix 5-G, Brucejack Access Road: Upgrade Prescription). It is not anticipated that any upgrades to stream crossings will be required. Locations of the more significant upgrades are shown in Figure 5.13-2.

The Brucejack Access Road will have a 5 m stabilized road width and a 40 km/hour design speed. To meet the standards laid out in the Forest Road Engineering Guidebook (BC MOF 2002) the road will have:

- a 95 m minimum stopping site distance;
- a minimum horizontal curve radius of 65 m;
- vertical curve values (K values) of 9.6 for crest curves and 8.5 for sag curves;
- favourable grades of 12% (14% for pitches less than 150 m); and
- adverse grades of 8% (10% for pitches less than 100 m).

Figure 5.13-1
Access Road Alignment

ERM



To address safe two-way traffic along the Brucejack Access Road, in locations with sight distances below the minimum site stopping distance of 95 m (blind vertical and horizontal curves), the road width will be widened to 10 m (double lane).

Specific sections of the Brucejack Access Road have been designated into speed zones to:

- reflect the existing conditions encountered along the road;
- address worker safety and dust control around camps and helicopter laydown areas; and
- ensure a safe travel speed into constricted travel zones such as single lane bridges, and blind vertical and horizontal curves.

A number of geohazards have been identified along the Brucejack Access Road, as show in Table 5.13-1 (Appendix 5-F, Brucejack Project: Geohazard and Risk Assessment). These geohazards will be monitored as necessary and mitigation applied where appropriate.

Table 5.13-1. Geohazard Types Identified along the Brucejack Access Road

Access Road Segment	Road km Reference (+/- 50 m)	Hazard Type
Wildfire Creek (0 to 17 km)	2.3 to 2.7	Debris avalanche
Scott Creek (17 to 35 km)	30 to 31.5	Snow avalanche
	33.8 to 34.2	Debris flow
Bowser River to Knipple Glacier (35 to 59 km)	36.6 to 36.7	Flood
	38.0 to 38.3	Flood
	39.5 to 40.0	Snow avalanche
	41.0 to 45.4	Flood
	43.7 to 44.2	Snow avalanche
	45.2	Snow avalanche
	45.3 to45.4	Rock fall impact
	47.8 to 51.8	Flood
	52.0 to 54.0	Flood
	54.8 to 55.8	Snow avalanche
	55.7 to 56.7	Snow avalanche
	57.7 to 58.0	Rockfall
	57.8 to 59.3	Snow avalanche
	58.7 to 59.0	Rockfall
Brucejack Lake	71.2 to 71.3	Rockfall
	72.1 to 72.5	Rockfall
	71.7 to 73.0	Snow avalanche

5.13.1.2 Knipple Glacier

Twelve km (km 59 to 71) of the Brucejack Access Road, ending 2 km east of the Brucejack Mine Site, as illustrated in Figure 5.13-3, traverses the main arm of the Knipple Glacier. During winter months, the route is a groomed snow surface, but it is an ice surface during the summer months.

The toe of the Knipple Glacier is receding and the top surface of the glacier is melting vertically. Anecdotal reports suggest that the surface has melted some 90 m vertically since the early 1990s.

Figure 5.13-2
Access Road Upgrade Locations

ERM

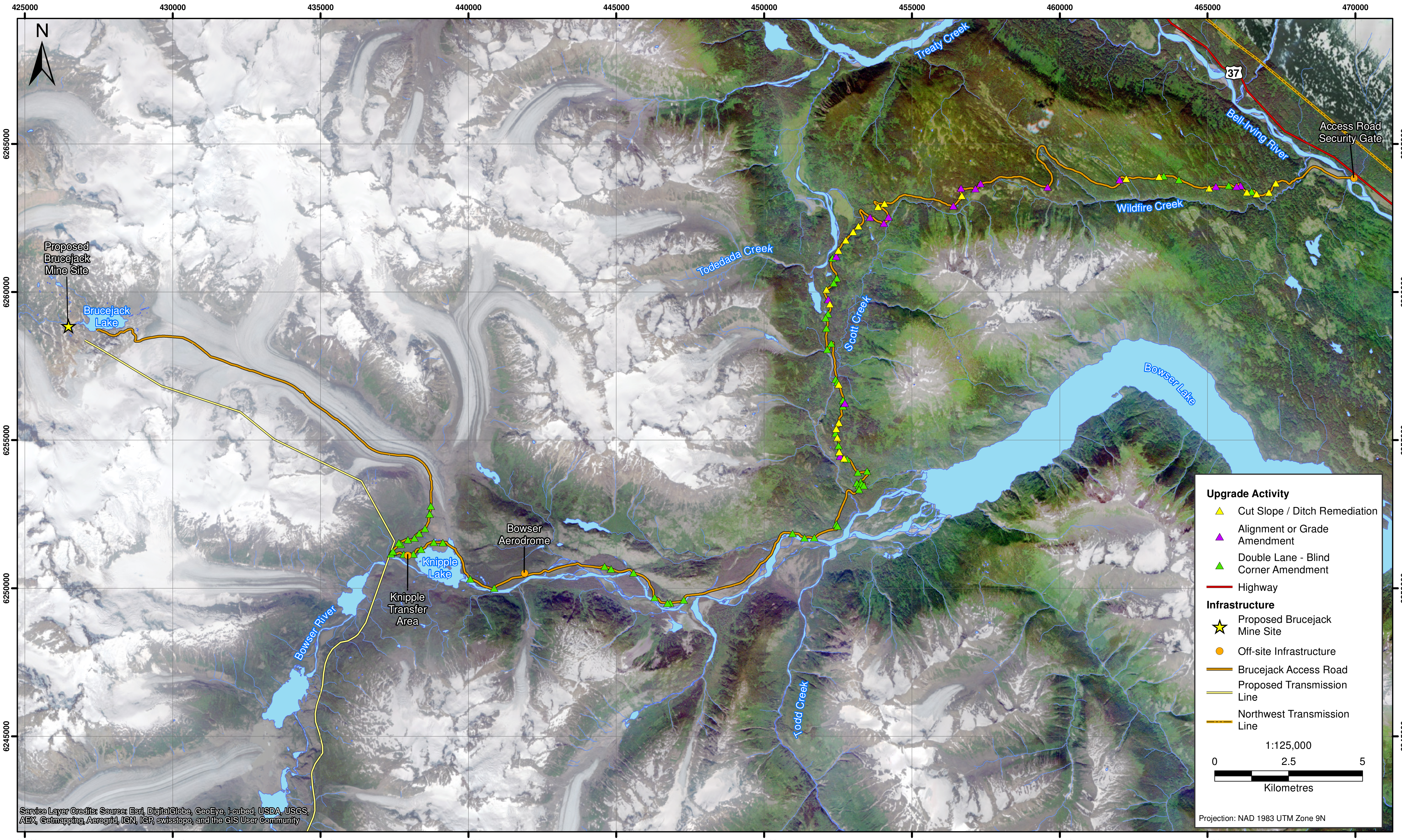
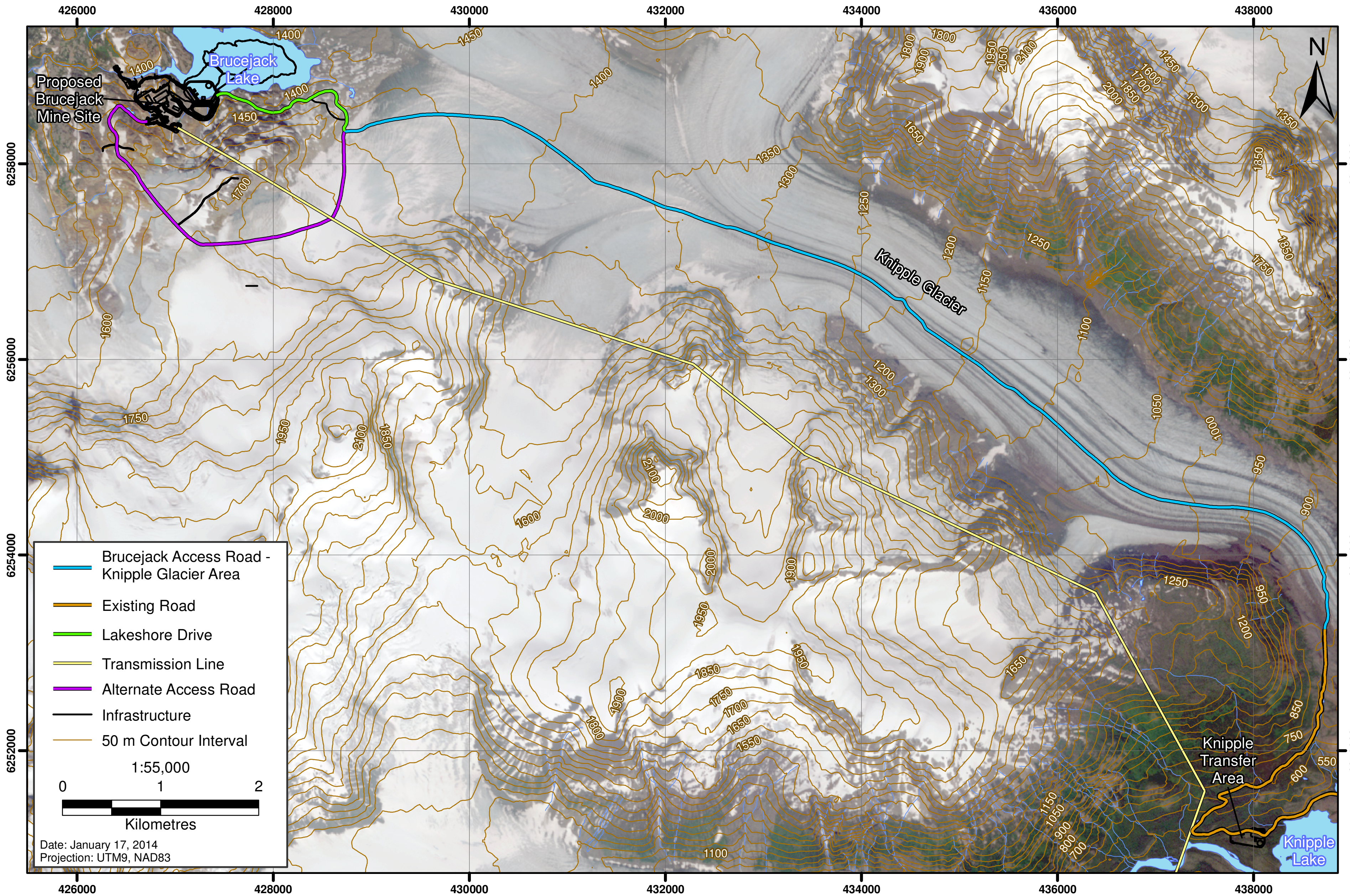


Figure 5.13-3

Brucejack Access Road - Knipple Glacier Area



Due to dropping surface, Pretivm established a new access ramp at km 58.6 of the road. This ramp provides access to the ice. It is expected that this approach will require additional excavation every two years to maintain a safe gradient as the glacier melts further.

During the winter months, the Knipple Glacier is covered in many metres of snow. Pretivm has experience using ski resort-type snow cats to prepare the running surface for other tracked equipment. The snow cats are equipped with blades on the front to distribute the snow across the road surface and break through snow drifts. A hydraulically powered tiller on the rear of the snow cat then mixes the new snow with previous layers, reduces chunks, and beats the air out of the snow. A plastic comb then compresses the snow into a ribbed or "corduroy" running surface. The end result is a snow surface that is dense enough for properly equipped equipment to run on.

The road surface is maintained as high above the ice level as possible with compact snow to maintain a snow running surface well into summer.

Summer maintenance of the Brucejack Access Road on the Knipple Glacier consists mainly of leveling the snow surface as it melts in the warmer months. It is vital to keep running water off the road surface as much as possible to avoid channeling on the road. Excavators are used to channel the water into existing crevasses.

The melting snow exposes the crevasses and mill holes, which pose a hazard to small vehicles and personnel on foot. Avalanche forecasters and mountain safety guides survey the ice conditions daily, marking safe travel areas to avoid the larger ice hazards. Ice bridges are constructed over the larger crevasses from ice harvested in other areas of the glacier.

The road route is checked during the summer months and altered to avoid particularly large hazards as needed. A crevasse survey is completed each summer so that a safe route can be planned for the winter when the hazards are obscured by snow bridging.

The length of road on the south side of Brucejack Lake between the Knipple Glacier and the Brucejack Mine Site is called Lakeshore Drive, and often has high avalanche risks. During times when it is unsafe to travel on Lakeshore Drive, an alternate snow route over the VOK is available. This VOK bypass road traverses around to the south of the Property, eventually meeting up at km 71 of the primary road on the Knipple Glacier. This road is only available in the winter and also provides access to the upper elevations of the Project area for avalanche control measures.

Unlike other glaciers in the area, the Knipple Glacier is generally free from large crevasses that present a hazard to equipment. It does contain many crevasses and mill holes (moulins) that present hazards to all-terrain vehicles or personnel on foot. Seracs, or ice cliffs, are not present along the immediate travel route.

Glacier travel guidelines and glacier emergency response plans have been developed and implemented by Pretivm.

The road route is demarcated with closely spaced bamboo delineators that provide a visual reference for operators at night and in low-visibility weather. Personnel on foot must not wander from the safe zones.

Personnel operating on the glacier receive additional safety training and are issued additional personal protective equipment such as rescue harnesses, avalanche beacons, rope rescue equipment, and avalanche rescue equipment.

5.13.1.3 Operation

During the Operation phase, the road will be maintained throughout the year by road grooming equipment and snow plows. Dust will be controlled by using water sprays as required. The use of alternative dust suppressants will take into consideration potential environmental effects, including attracting wildlife and degrading fish habitat. Regular patrols will be conducted in potential avalanche areas and remotely activated avalanche control measures will be utilized.

Pretivm maintains a locked gate at the intersection with Highway 37 to control access to the road. The gate is staffed at all times and only authorized vehicles are permitted to pass the gate. Project employees will not be permitted to drive personal vehicles on the Brucejack Access Road. Employee transportation to the Project site will be by air to the Bowser Aerodrome, with bus transportation as an alternative for local labour source and as backup for periods when air transport is precluded by inclement weather.

All road users will be required to use radios to regularly report their positions and to cooperate with other traffic to avoid collisions.

5.13.1.4 Traffic

The Brucejack Access Road will be used to deliver all supplies to the mine and to ship concentrates to market. Table 5.13-2 illustrates anticipated traffic volumes during the Operation phase of the mine.

Table 5.13-2. Summary of Anticipated Project-related Traffic between Highway 37 and the Knipple Transfer Area during Operation

Truck Type	Load	Delivery Frequency		Total Annual Trips	Maximum Daily Trips
40-t tandem	Process plant: PAX, MIBC, flux, antiscalant, lime (includes lime used in water treatment plant)	1	Month	12	1
	Water treatment plant: NaOH, coagulant, polymer, acid, microsand	5	Month	60	1
	Grinding balls and liners	5	Month	60	1
	Explosives	1	Month	12	1
	Concentrate	100 to 130	Month	1,200 to 1,500	8
	Cement	30 to 31	Month	366	4
40-ft trailer	Food	1	Weekly	30 to 50	1
20,000-L tanker	Fuel	20 to 25	Month	240 to 280	2
Passenger vehicles	People, vendors, suppliers, expeditors, etc.	1	Daily	365	4
20-t tractor trailer	Maintenance and warehouse supplies	7 to 8	Weekly	350 to 400	2
Total Annual Trips				**2,695 to 3,105**	

Specific truck types will vary based on the type of supplies they carry. The source of the supplies will also vary but it is expected that the majority will originate from population centres including Smithers and Terrace. The majority of supply vehicles will travel Highway 37 between the junction with the Brucejack Access Road and the junction with Highway 16 at Kitwanga. Each truck will complete one round trip in a 12-hour period; travelling one time southbound and one time northbound. Total one-way distance travelled by each truck originating from the Project to Stewart will be 175 km on the Brucejack Access Road, Highway 37, and Highway 37A. Total one-way distance travelled by each truck along the Highway 37 corridor originating from Terrace or Smithers will be about 265 km on Highway 37 and the Brucejack Access Road.

As noted in Section 5.13.1.2, all supplies and materials delivered to the Knipple Transfer Area will be transferred to vehicles designed or equipped for glacier travel for transport over the Knipple Glacier. Estimated traffic over the glacier is shown in Table 5.13.3. Note that the vehicles used to transport concentrate out from the mine will be used to backhaul fuel and other supplies.

Table 5.13-3. Summary of Anticipated Project-related Loads between the Knipple Transfer Area and the Mine during Operation, Assuming Transport by Tracked or Otherwise Appropriately Equipped Vehicles

Load	Delivery Frequency		Total Annual Trips	Maximum Daily Trips
Process plant: PAX, MIBC, flux, flocculant, antiscalant, lime (includes lime used in water treatment plant)	1	Month	12	1
Water treatment plant: NaOH, coagulant, polymer, acid, microsand	5	Month	60	1
Grinding balls and liners	5	Month	60	1
Explosives	1	Month	12	1
Concentrate	110 to 140	Month	1,300 to 1,700	8
Cement	35 to 40	Month	480 to 540	4
Food)	1	Weekly	30 to 50	1
Diesel	20 to 25	Month	240 to 280	2
Personnel	4	Weekly	200 to 210	2
Maintenance and supplies	7 to 8	Weekly	350 to 400	2
Total Annual Trips			**2,744 to 3,324**	**25**

It is anticipated that supply traffic during the Construction phase will be significantly less than traffic during Operation as shown in Table 5.13-4. The maximum number of supply trucks over the Construction phase will be approximately 4 per day. Project-related traffic will also occur along the Granduc Access Road between Stewart and the former Granduc Mine staging area during the Construction phase of the Brucejack Transmission Line. While the majority of the transmission line construction would be helicopter supported, ground vehicles will deliver supplies and personnel to staging areas along the Granduc Access Road, including the Tide Staging Area.

Table 5.13-4. Summary of Anticipated Project-related Traffic between Highway 37 and the Knipple Transfer Area during Construction

Truck Type	Load	Delivery Frequency		Total Annual Trips	Maximum Daily Trips
40-ft trailer or flat bed	Construction equipment 25 t/load	130	Month	1,560	15
20,000-L tanker	Fuel	40 to 50	Month	480 to 560	2
40-ft trailer	Food	1	Weekly	30 to 50	1
50-person bus	Personnel*	n/a	Weekly	n/a	n/a
Passenger vehicle	People, vendors, suppliers, expeditors, etc.	1	Daily	365.00	4
Total Annual Trips				**2,435 to 2,535**	

** Personnel will be delivered to the site by air to the Bowser Aerodrome.*

Project-related traffic during Closure and Post-closure phases is expected to be less than those estimated for the Operation phase.

5.13.2 Transmission Line

The overall power requirements for the Project will be approximately 20 MW. The Project will be powered by electricity from the BC Hydro system. The proposed transmission line route is from the recently constructed Long Lake Hydro Substation to the Project site. An alternative transmission line route from the Northwest Transmission Line, following the Brucejack Access Road, was also considered (Figure 5.13-4; Section 4.4.2, Primary Power Supply), but is less attractive from environmental, technical, and economic perspectives.

Starting at the Long Lake transmission line west of the Hydro Substation, the transmission line will follow the bedrock slopes on the east side of the Salmon Glacier to the terminus of the Knipple Glacier. From the Knipple Glacier, the preferred transmission line will generally follow the upper crest of the bedrock slope south of the glacier to the Project site. Large towers will facilitate spanning the snowfields in the area.

The Granduc Access Road and existing mineral exploration trails will provide access and staging areas for much of the southern portion of the alignment. Staging areas for the portion of the alignment north of the Granduc mill site will be the Tide Staging Area and the Knipple Transfer Area. Most of the tower construction and conductor stringing along the whole route will be by helicopter. It is not expected that new roads will be needed for the transmission line construction.

The route follows bedrock-dominated terrain that is characterized by gentle to moderate slopes, bedrock hummocks, and discrete debris flow/snow avalanche tracks. The high elevation and prolonged snow cover have limited both tree growth and stand density throughout the area. For the portion of the route from the Knipple Glacier to the Project site, a feasible route exists over the bedrock slopes south of the glacier to avoid both the engineering challenges due to glacier movement and the snow avalanches and snow creep prevalent on the slopes north of the glacier. The alignment and transmission structures throughout the route will be located and designed to mitigate potential effects of snow avalanches, snow creep, and debris flows and rockfalls. The long term right-of-way will be 30 m wide for most of the alignment, although a wider right-of-way will be needed in the area above the Knipple Glacier due to the potential swing of the longer spans between towers.

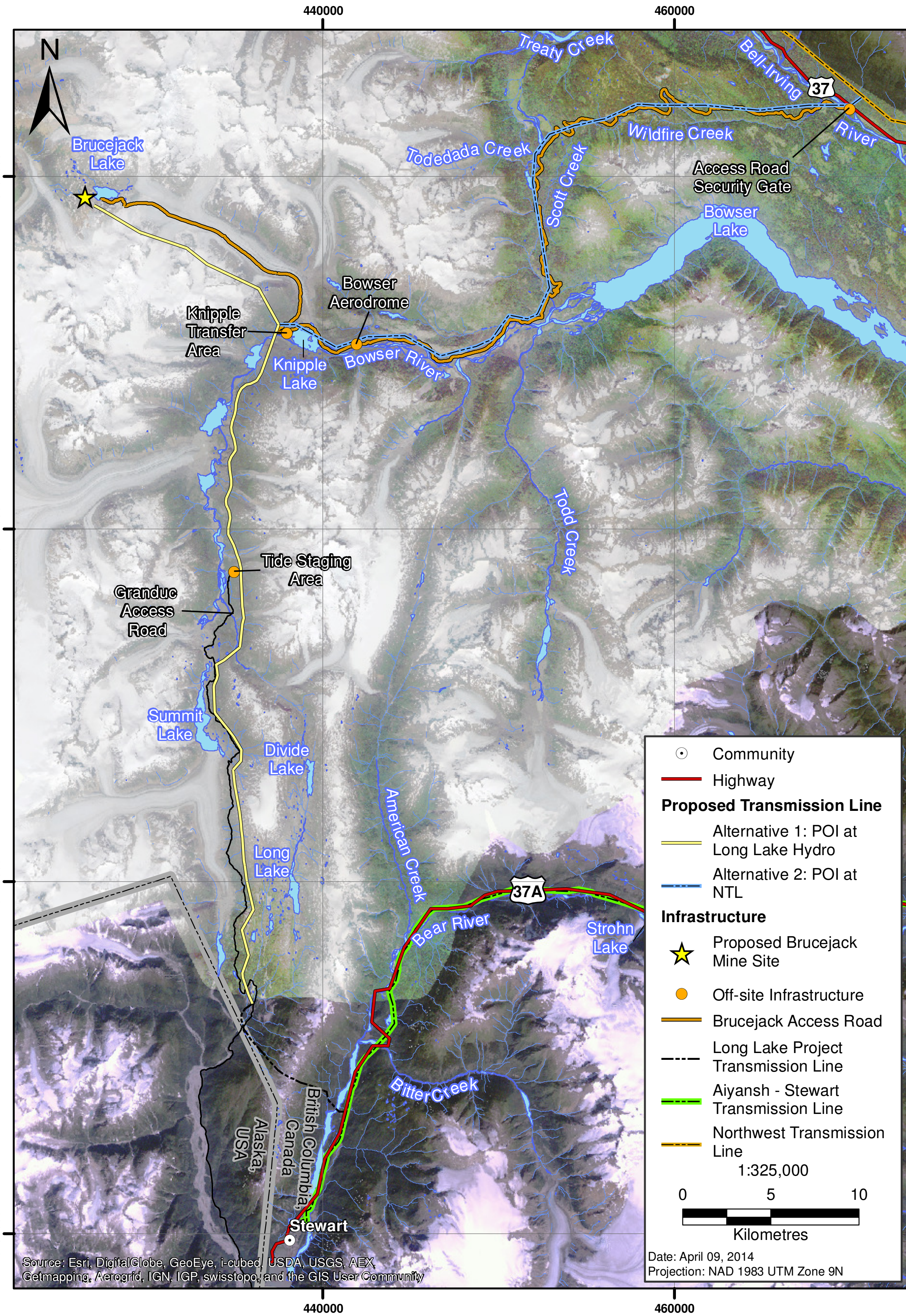
Where the transmission line corridor traverses steeper side slopes it will cross areas prone to snow avalanches and channels that are potentially subject to debris flows, and to a lesser extent, floods and channel avulsion. Rockfall, debris avalanche and rock avalanche hazards also exist within the corridor (Appendix 5-F, Brucejack Project: Geohazard and Risk Assessment). Where technically feasible, tower locations will be selected to avoid these hazards; if avoidance is not possible, tower design or other mitigation measures will be implemented.

Preliminary design criteria for the transmission line include:

- the selection of 138 kV as the operating voltage to eliminate the need for a substation at Long Lake Hydro interconnection;
- the use of two different conductors along the transmission line, selected to accommodate corona effects and the necessary tensile strength for longer spans, with selection of the conductors as part of the detailed design for the transmission line;

Figure 5.13-4

Transmission Line Corridor



- the use of single-steel monopole towers with helicopter placement to lengthen the spans between structures and eliminate the need for an access road or track along the transmission route. Towers will typically be about 25 m in height to provide the necessary ground clearance. Tower locations will utilize local high points in the terrain, and selected to span watercourses and limit potential adverse riparian effects, unless no practicable alternative exists. Mitigation measures will be implemented if there are potential adverse effects of tower locations on streams; and
- limited tree clearing with no removal (trees bucked and left in place along the corridor) where permissible. In riparian areas tree cutting will be limited to topping of taller trees that may interfere with the conductors, with other vegetation being left in place.

5.13.2.1 Transmission Line Construction

The construction of the transmission line from Long Lake to the Brucejack Mine Site will involve the following general steps:

1. Mobilization to site, material delivery, and set-up (camps, material yards, etc.).
2. Tower structure assembly.
3. Site survey to locate structures and establish clearing boundaries.
4. At each tower site:
   - tree clearing at foundation site (if necessary);
   - geotechnical investigation (drilling);
   - rockbolt installation;
   - foundation construction, including concrete placement; and
   - tower installation, including insulators and related hardware.
5. Along entire line:
   - stringing of conductors and optical ground wire;
   - testing and commissioning of transmission components; and
   - testing and commissioning of communication components.

Note that some of the activities in Steps 1, 2, and 4 above can be carried out concurrently.

It is anticipated that about 17 months will be required from the issuance of full construction/ operations permits to completion of commissioning, assuming no significant weather delays.

The construction and maintenance of stream crossings will be consistent with the Fisheries and Oceans Canada's *Pacific Region Operational Statement for Overhead Line Construction* (DFO 2007b) and *Pacific Region Operational Statement for Maintenance of Riparian Vegetation in Existing Rights-of-Way* (DFO 2007a). Watercourse crossings will also be assessed against the *Minor Works and Water Order*, under the *Navigation Protection Act* (1985b). The Wildlife Management and Monitoring Plan (Section 29.21) will guide activities in the vicinity of designated ungulate winter range to avoid potential adverse effects on mountain goats during sensitive periods.

A Licence of Occupation, and eventually a Statutory Right of Way, will be required under the *Land Act* (1996c) for construction and operation of the transmission line. A Licence to Cut under the *Forest Act* (1996b) will be required for right of way clearing. The treed portion of the alignment will occupy about 130 ha; however, disturbance related to tower construction is expected to be limited to about 4 ha.

5.13.2.2 Transmission Line Operations, Maintenance, and Emergency Response

Once constructed, the transmission line will be controlled out of the Brucejack Substation at the Project site with the main switch structure located at the interconnection at the Long Lake Hydro Substation. It is understood that the operation of the Brucejack Substation and Brucejack Transmission Line will very likely be carried out under a joint operating order with BC Hydro, as it is for other industrial customers. The joint operating order will establish the procedures and communication protocols for operation of the Brucejack Substation to protect any transmission line workers and the integrity of the BC Hydro system.

Maintenance of the Brucejack Transmission Line will consist of visual inspections along the transmission line, as well as periodic infrared surveys to look for potential deterioration in splices or other energized components. These inspections and surveys will be complemented with a periodic inspection of the transmission line towers, with climbing inspections to ensure the functionality of all conductors, guy wires, cross arms, and other transmission tower components.

Avalanche mitigation will be required on an ongoing basis during the winter months. An avalanche management plan that includes monitoring and use of explosive charges for controlled avalanche initiation will be developed and implemented throughout the life of the transmission line (see Section 29.4, Avalanche Management Plan). Vegetation management will be implemented to prevent trees from interfering with the conductors. The lack of tree cover along most of the alignment, and typically smaller alpine trees in most areas of tree cover, suggest that a program of limited tree felling every three years should be appropriate.

Emergency response will also be important to manage the risk to the transmission line, with temporary wood poles kept at a central location to facilitate rapid response and restoration in the event of extreme weather damaging the transmission line.

5.13.3 Knipple Transfer Area

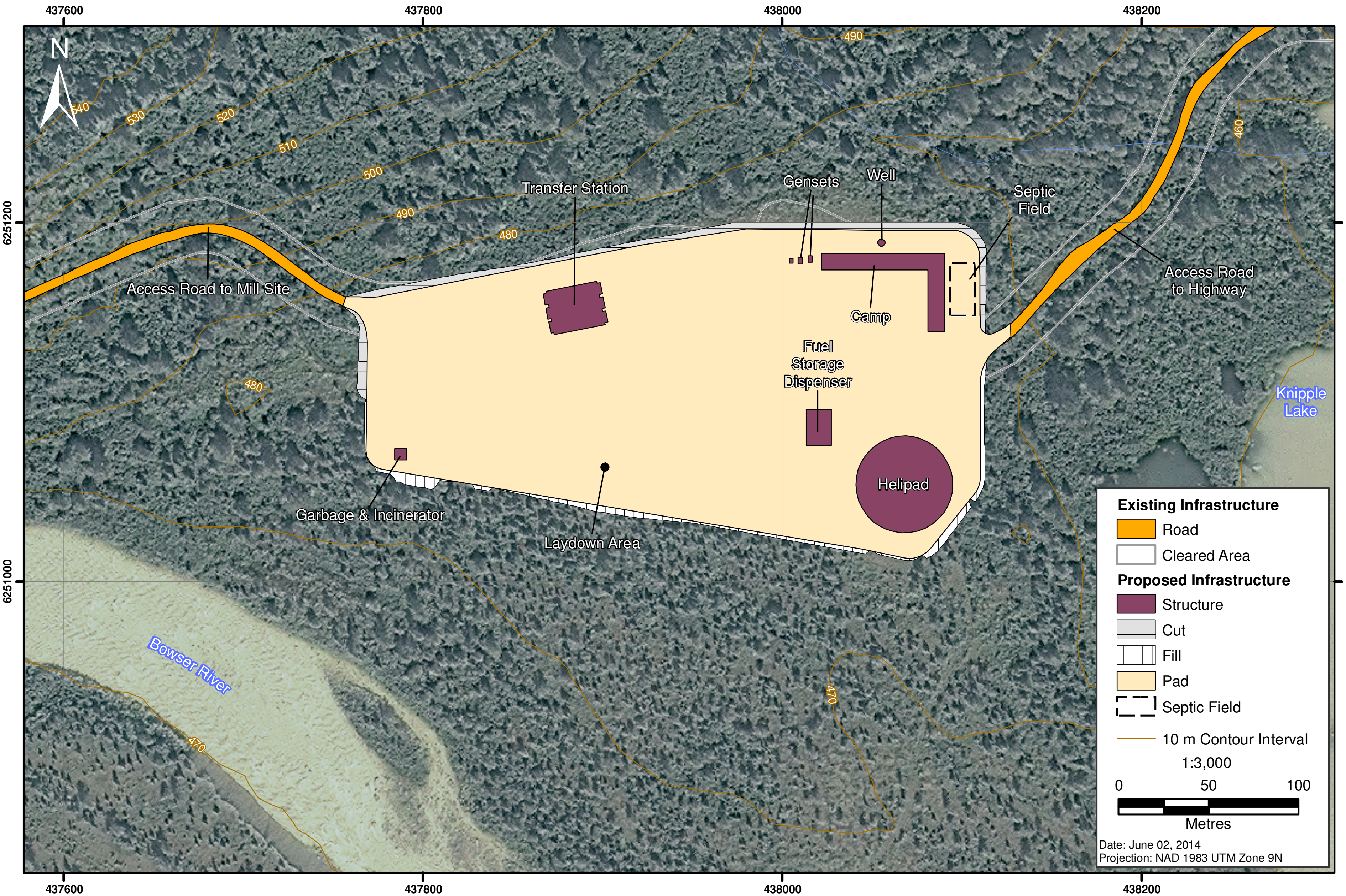
The Knipple Transfer Area facility will be located west of Knipple Lake, about 55 km by road from Highway 37 and 18 km from the Brucejack Mine Site. This location is not subject to geohazards, although there is some risk of avalanche, as discussed in Section 5.14.3. The Knipple Transfer Area will include a camp, maintenance and emergency vehicle building, fuel dispensing system, helipad, and laydown area as shown in Figure 5.13-5. It will occupy a development footprint of about 5 ha. All deliveries to and from the Brucejack Mine Site will report to this facility. Loads from highway-legal trucks will be transferred onto tracked or otherwise properly equipped vehicles that will transport the load across the glacier and to the mill site. Similarly, loads from the mill site will be managed in reverse order.

Transfers will be performed within the maintenance and emergency vehicle building by overhead crane and also outside in the yard with mobile crane and forklift. Equipment and materials may be loose or preferably containerized. Concentrate will be loaded at the mill building site into 2-t bulk bags and then containerized prior to transport down to the Knipple Transfer Area.

Concentrate transported in containers by specialized vehicles from the mill building will be transferred to highway trucks for transportation to market.

Fuel handing, transportation, and storage facilities and activities will be consistent with the Health, Safety and Reclamation Code (BC MEMPR 2008); the Ministry of Water, Land and Air Protection's (2002) publication, *A Field Guide to Fuel Handling, Transportation and Storage*; and, for storage of more than 100,000 L of fuel at a single location, with the Petroleum Storage and Distribution Facilities Storm Water Regulation (BC Reg. 168/94).

Figure 5.13-5
Knipple Transfer Area Facility Layout



The transportation of dangerous goods, such as diesel fuel, will also be consistent with the *Transportation of Dangerous Goods Act* (1992) and the transportation of explosives will be consistent with the *Explosives Act* (1985a). A Hazardous Materials Management Plan will be in place (see Section 29.7).

5.13.3.1 Site Preparation

The Knipple Transfer Area facility will be located along the Brucejack Access Road, approximately 5 km west of the Bowser Aerodrome. It is in a relatively flat terraced area above historical flood levels, and positioned away from an existing creek. Previous activities in the area used this location as a camp. Site preparation will include salvage and storing of surficial growth media, cut and fill, and pad surfacing. Site drainage will include surface drainage to the perimeter and outlet to connect with existing drainage courses.

Construction activities will be guided by construction, erosion and sediment control, hazardous materials, and non-hazardous materials management plans.

5.13.3.2 Camp

The camp will be sized to accommodate 30 people, complete with kitchen, recreation facilities, dormitories, potable water system (two stage), and septic system (tank and drainfield). A fresh/fire water tank will be provided. Offices will be included in the camp to manage the shipping and receiving of goods. A diesel generator with backup will provide power to the camp. A wireless system will be installed for communications.

5.13.3.3 Fuel Storage

Diesel fuel will be delivered by commercial tankers to the Knipple Transfer Area where it will be offloaded to a double-walled 50,000-L tank. From there it will be transferred to a double-walled tank mounted on a tracked or otherwise properly equipped vehicle for transport over the glacier to mine site fuel storage facility.

The Knipple Transfer Area will include a fuel dispensing system with facilities for diesel, gasoline, and aviation fuel. The fuel storage tanks will be double-walled type to minimize risks due to leaks.

An additional diesel fuel tank will supply the camp generators.

5.13.3.4 Maintenance and Emergency Vehicle Building

A two-bay, pre-engineering building, complete with a 5-t overhead crane, will be constructed on this site for use as a maintenance and emergency vehicle building. Limited vehicle maintenance facilities will be included, principally for the glacier travel vehicle fleet.

The building will have a concrete floor with collection sumps and an oil/water separator.

5.13.3.5 Waste Management

The Knipple Transfer Area will have a dedicated area for the management of waste materials generated on site, as well as materials being transported from the Brucejack Mine Site for trans-shipment to off-site disposal facilities. A waste management plan will guide the operation of this area.

5.13.3.6 Temporary Facilities

A metal-covered structure will be constructed at the laydown area to temporarily store equipment during Construction.

5.13.4 Bowser Aerodrome

Regular chartered flights will transport mine personnel to and from the Project site from the point of origin to an aerodrome to be located west of Bowser Lake. In inclement weather conditions where aircraft are unable to fly, personnel will be bused from Terrace to the Knipple Transfer Area. Transport from both the aerodrome and Knipple Transfer Area to / from the Brucejack Mine Site will be by vehicle equipped for glacier travel.

The new aerodrome will be constructed at the site of the historical gravel airstrip, which will be improved and expanded to provide a safe and maintainable facility for the chartered air traffic. The new aerodrome is shown in Figure 5.13-6. A small hill about 450 m west of the proposed aerodrome will be excavated to reduce the impacts of the hill on the take-off approach surface areas.

The site is not subject to the effects of avalanches. While the footprint of the airstrip is subject to flood hazard (Appendix 5-F, Brucejack Project Geohazard and Risk Assessment), alternative sites are not available west of the Bell-Irving River Valley.

The passenger aircraft used in the preliminary design of the aerodrome is the Beechcraft 1900; however, the aerodrome facilities are sized sufficiently to allow DE Havilland Dash 8 turboprops and C-130 Hercules aircraft upon acceptance of the sites by the aircraft operators. The aerodrome will be designated as “Registered,” which will allow service with an approved chartered aircraft without having to meet and comply with all of Transport Canada’s standards and operational requirements. The aerodrome will be designed to allow future “certification” for Beechcraft 1900 aircraft, should Transport Canada regulations change regarding charter flights into registered aerodromes.

The aerodrome will be supported by Instrument Approach Procedures allowing Instrument Flight Rules approaches and departures under suitable meteorological conditions.

The runway, taxiway, and apron surface will be granular and suitable for turbo-prop aircraft. The runway will be 1,524 m long and 30 m wide and oriented magnetically to correspond to the runway designations 07-25. The runway will include a 7.5-m graded area along each runway edge and 60-m-long graded area beyond each runway end. The taxiway will be constructed to a width of 18 m with a 6-m-wide graded area along each edge. The aircraft parking apron has been sized to allow two Dash 8 sized aircraft to manoeuver and park. The overall footprint of the aerodrome will be about 10 ha.

All granular surfaces will be treated for dust reduction and will be maintained to operate year round. A grader, dump trucks, and loaders from the mine or the mine road maintenance crews will be used for aerodrome snow removal and surface re-grading. A self-propelled compaction roller will be available.

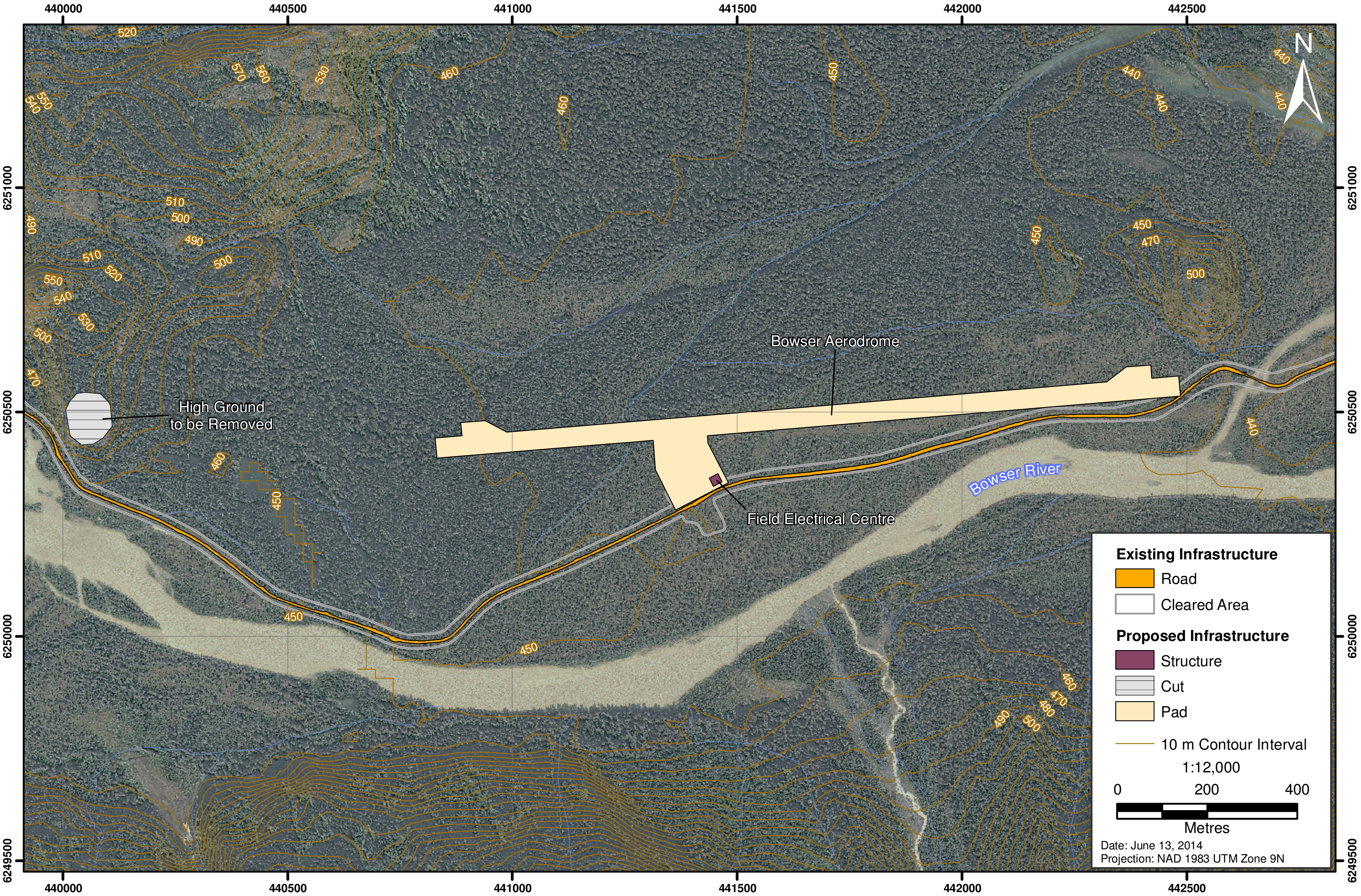
A water tanker/distributer and operator will be available to supplement the chemical dust control measures.

A service pickup truck with equipment for measuring the runway surface friction index will be used to allow the operator to relay the information to pilots.

The aerodrome will include a runway, taxiway, and apron edge lighting. Illuminated signage and wind socks are included to provide pilots with clear directional cues. An Omni Directional Approach Lighting System will guide aircraft on the east approach. The west approach will have Runway End Identifier Lights due to the displaced threshold. Precision Approach Path Indicators will be installed along the edge for both runway approaches to provide the aircraft with visual vertical guidance.

Figure 5.13-6

Bowser Aerodrome



A pre-fabricated ATCO-type trailer Air Terminal Building (ATB) will be located adjacent to the apron. The ATB will be equipped with sufficient windows to view the aerodrome and surrounding area. The building will be mounted on piles to protect it from the possibility of floods. The ATB will contain radio equipment for Pretivm and ground to air communication. It will also be adjacent a weather station and will be equipped to give altimeter readings to the incoming and outgoing pilots. The ATB will be heated and contain washroom facilities. It is expected that all passengers will be loaded from the aircraft directly to a bus and that the ATB will not be sized to contain the passengers. The ATB will support several apron flood lights to illuminate aircraft loading and unloading.

Sewage will be collected in a heated holding tank and trucked to the Knipple Transfer Area treatment plant as required.

A Field Electrical Centre will include an electrical panel to support a lighting system on the airstrip, a generator, and a small (less than 100 L) fuel tank. Operations at the aerodrome will be supported by personnel at the Knipple Transfer Area approximately 3.5 km away along the Brucejack Access Road.

A level area will be available for helicopter landing if required. Small volumes of emergency supplies of jet fuel may be kept in barrels on-site with portable dispensing equipment.

5.13.5 Tide Staging Area

The Tide Staging Area will be located north of the airstrip near the site of the historic Granduc processing plant (Figure 5.13-7). It will be a relatively small cleared area to be used for a short-term transmission line construction camp and storage and staging of equipment and materials for the construction of the Brucejack Transmission Line. There is a history of this area being used to stage equipment and materials for the Project.

The camp will be sized to accommodate up to 90 people. It will use septic tanks and a septic field for sewage management. Potable water will be obtained from a nearby well.

5.14 AVALANCHE HAZARD

Avalanche paths and hazard areas that affect the Project were identified by reviewing topographic relief and vegetation features on maps and aerial photos, as well as available Google Earth™ ortho-imagery and digital elevation models (Appendix 5-H, Brucejack Project Avalanche Hazard Assessment). In addition, field reconnaissance (helicopter overview flights and ground based survey) was completed to complete an Avalanche Hazard Management Plan (Section 29.4) that includes signage, area closures during high risk periods, and blasting to initiate controlled avalanches).

Mine site facilities and access routes are exposed to approximately 15 avalanche paths or areas, and the preliminary transmission line alignment crosses several avalanche paths. Avalanche magnitude and frequency varies depending on location (Alpine Solutions 2013).

5.14.1 Mine Site Avalanche Hazards

The mine site facilities are located away from avalanche paths and areas, with the exception of some sections of the site access roads, and the pre-production ore storage and diversion channel area. Short slopes that currently exist (ranging from 10 to 40 m in height) or will be created during Construction, may be expected to affect other facility areas; however, the hazards and consequences would normally be assessed on a site-specific basis during Construction and Operation.

Table 5.14-1 provides a summary of avalanches reaching the mine site area and Figure 5.14-1 illustrates the approximate hazard locations.

Figure 5.13-7
Tide Staging Area

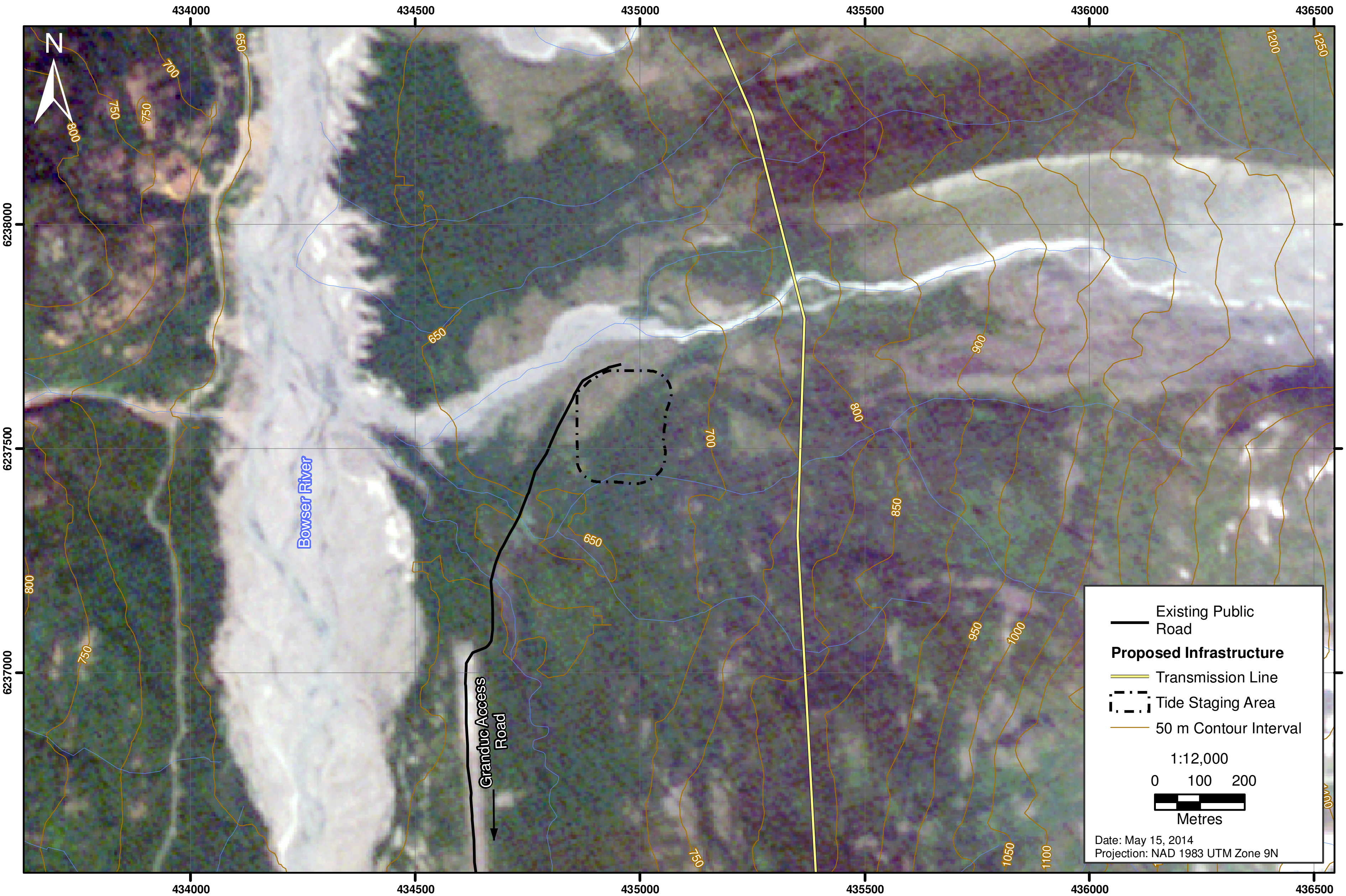


Figure 5.14-1
Mine Site Area Avalanche Hazards

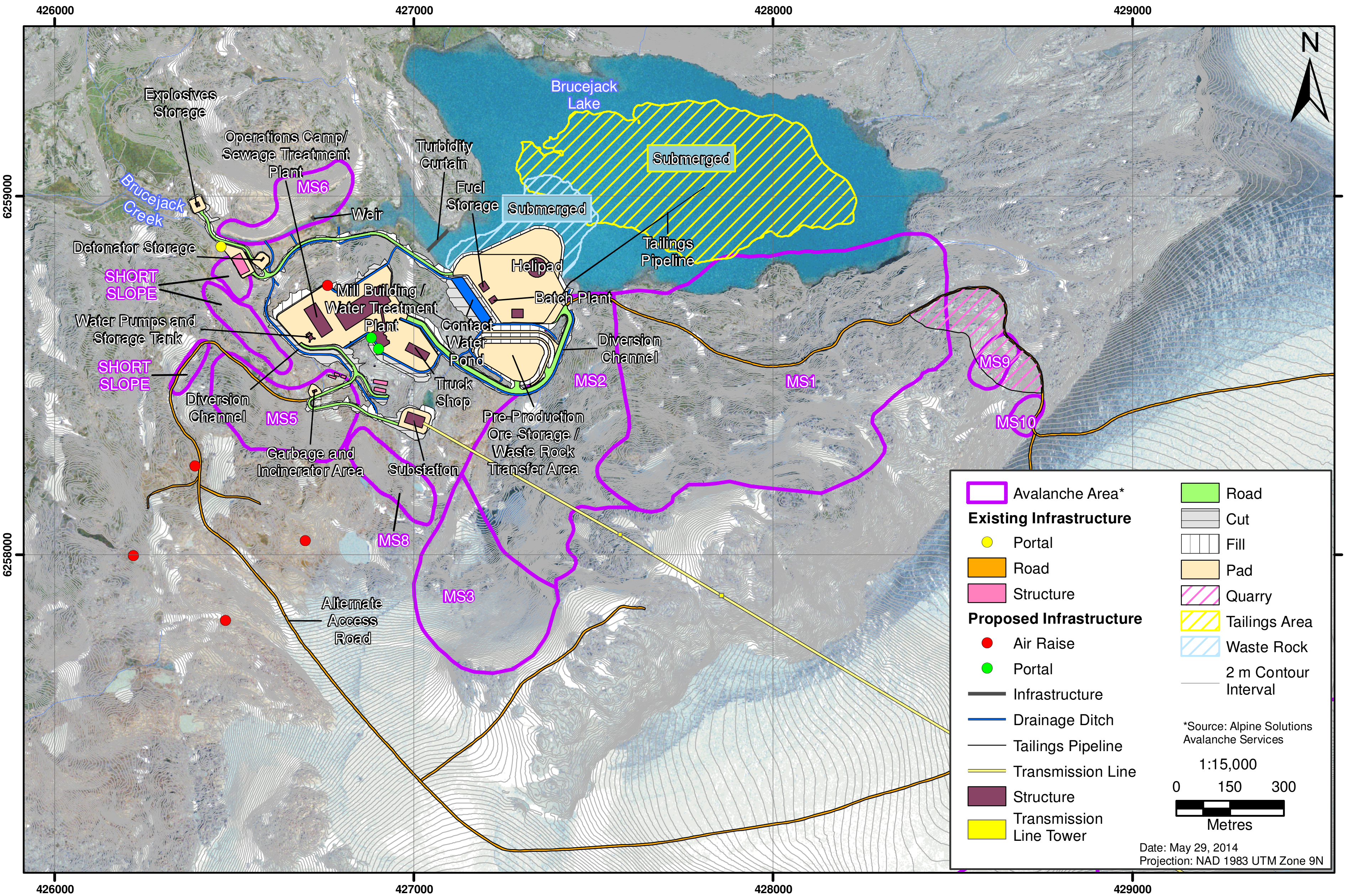


Table 5.14-1. Mine Site Avalanche Hazard Areas

Path or Area ID	Avalanche Atlas Polygon Label	Facility Affected	Facility Position in Path	Length of Facility Affected (m)	Return Frequency		
					Size 2	Size 3	Size 4
Mine Site 2	MS2	Pre-production ore storage and diversion channel area	RZ*	300	-	1:10	-
Mine Site 5	MS5	Site access roads	RZ	800	1:1	1:3	-
Mine Site 5	MS5	Garbage and incinerator area	RZ	20	1:1	1:3	-

** RZ = runout zone.*

Size 2 and 3 avalanches from Path MS5 and Size 2 avalanches from Path MS9 are estimated to reach site access roads annually. Potential consequences include damage to infrastructure and vehicles, and worker injury or fatality if workers are in the runout area when the avalanche occurs.

The pre-production ore storage and diversion channel area is exposed to Size 3 avalanches from Path MS2, approximately once every 10 years. Potential consequences are limited to damage to any vulnerable materials stored in this area during avalanche season, as well as worker injury or fatality if workers are in the runout area when the avalanche occurs. The diversion channel is expected to be buried during avalanche season.

Avalanches up to Size 3 may reach Brucejack Lake from Path MS1, and short steep slopes on the north side of Brucejack Lake may produce avalanches up to Size 3 reaching the lake. If avalanches reach the lake when the surface is not frozen, waves may develop. As a result of the small size and/or slow speed of the avalanches when they reach the lake, these waves are not expected to be destructive.

5.14.2 Access Road Avalanche Hazards

Fourteen avalanche paths or areas are estimated to affect the access road, and two paths approach within 50 m (Table 5.14-2 and Figure 5.14-2; Appendix 5-H, Brucejack Project Avalanche Hazard Assessment).

One area (Path AR8) is potentially affected by ice fall (blocks falling off bluffs above the road). Several avalanche paths on the southwest and northeast side of the Knipple Glacier could affect the road if it is realigned to avoid crevasses. Potential consequences of avalanches reaching the access road include damage to vehicles, occupant injury or fatality, and traffic delays for avalanche debris cleanup. Avalanche path characteristics for the Knipple Glacier segment are expected to change as the glacier changes over time, so this segment will need to be re-assessed regularly.

Areas within Paths AR4, AR8, and KG1 have increased hazard and consequences due to the high frequency of avalanches and ice falls reaching the affected areas, as well as magnitudes large enough to severely damage vehicles, injure occupants, and delay the flow of traffic during storms, when avalanche control is not feasible.

5.14.3 Knipple Transfer Area Avalanches

The Knipple Transfer Area is located at the valley bottom near the confluence of the Salmon and Knipple valleys. Extreme avalanches to Size 4 occurring in Path AR7 (Table 5.14-2) are estimated to reach the west end (approximately 20%) of the Knipple Transfer Area pad with an estimated return period of at least 100 years. Avalanches are not expected to reach the eastern side of the Knipple Transfer Area pad where primary fixed facilities (camp) will be located. Potential consequences of avalanches reaching the site include damage to infrastructure, and injury or fatality for any personnel located in the runout area.

Figure 5.14-2
Access Road Avalanche Hazards

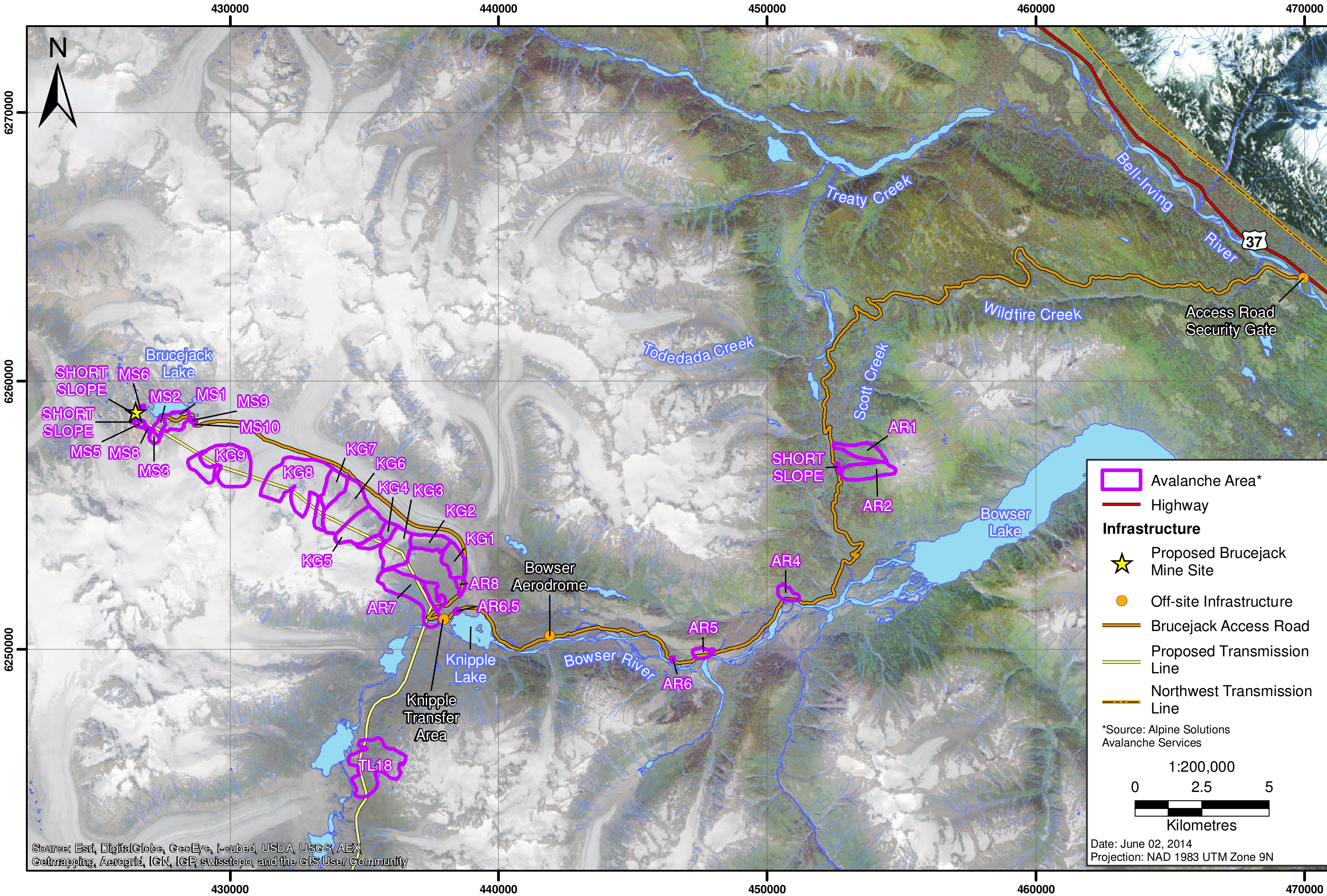


Table 5.14-2. Access Road Avalanche Hazard Areas

Path or Area ID	Avalanche Atlas Polygon Label	Facility Affected	Facility Position in Path	Length of Facility Affected (m)	Return Frequency		
					Size 2	Size 3	Size 4
Access Road 1	AR1	Brucejack Access Road	-	-	-	-	P*
Access Road 2	AR2	Brucejack Access Road	-	-	-	-	P
Access Road 3	AR3	Brucejack Access Road	RZ**				-
Access Road 4	AR4	Brucejack Access Road	RZ	600	1:1	1:3	-
Access Road 5	AR5	Brucejack Access Road	RZ	540	>1:1	1:1	-
Access Road 6	AR6	Brucejack Access Road	RZ	140	>1:1	-	-
Access Road 6.5	AR6.5	Brucejack Access Road	RZ	250	1:1		
Access Road 7	AR7	Brucejack Access Road	RZ	1,000	-	1:3	1:10
Access Road 7	AR7	Knipple Transfer Area (west end only)	RZ	100	-	-	1:100
Access Road 8	AR8	Brucejack Access Road	RZ	700	1:1	1:3	-
Knipple Glacier 1	KG1	Brucejack Access Road	RZ	700	1:1	1:3	-
Mine Site 1	MS1	Brucejack Access Road	RZ	2,000	>1:1	1:1	-
Mine Site 2	MS2	Brucejack Access Road	RZ	300	1:1	1:10	-
Mine Site 5	MS5	Brucejack Access Road	RZ	600	>1:1	1:3	-
Mine Site 9	MS9	Brucejack Access Road	RZ	100	1:3	-	-
Mine Site 10	MS10	Brucejack Access Road	RZ	150	1:3	-	-

** P = Potential to reach access road or facility.*
*** RZ = runout zone.*

5.14.4 Transmission Line

Initial analysis indicates that there are approximately 20 to 25 avalanche paths that affect the proposed transmission line route, although they would only pose a hazard if supporting structures (towers) are built in avalanche paths, or conductors are low enough to the ground. Potential consequences include damage to towers or conductors, and interruption of service to the mine. In addition, worker injury of fatality may occur if the line is built, or if maintenance if undertaken in avalanche hazard areas during avalanche season. The final alignment of the transmission line (including specific structure locations) is expected to be determined following field investigations, through detailed construction level design, and will be assessed further for avalanches at that time.

5.15 CLOSURE AND RECLAMATION

A detailed Closure and Reclamation Plan has been prepared for the Project and is presented in Chapter 30. The Plan has been developed to meet regulatory requirements including the *Mines Act* (1996d) and the Health, Safety and Reclamation Code for Mines in British Columbia (BC MEMPR 2008). The plan is to close all parts of the Project, including the Brucejack Mine Site, the Brucejack Access Road, the Knipple Transfer Area, the Tide Staging Area, the Brucejack Transmission Line, and the Bowser Aerodrome, and to reclaim the disturbed areas, as much as practical, to result in a condition that is stable and is as close to pre-disturbance conditions as possible and practical, minimizing risk to the environment.

Chapter 30, Closure and Reclamation, includes a description of activities that will be carried to close and reclaim each part of the Project. As well, the Closure and Reclamation Plan describes the activities that will be carried out in the event of temporary closure. It will also include a description of progressive reclamation to be carried out during the Operation phase. The costs of closing and reclaiming the different parts of the Project have been developed and are also included in Chapter 30, Closure and Reclamation. The description of monitoring during the Post-closure phase and the costs to carry it out are also included in the Closure and Reclamation Plan. The Closure phase is planned for a two-year period when the greater portion of demolition and reclamation will occur. The Post-closure phase is planned for three years and this is primarily the monitoring period. The goal is to close the permit for the mine at the end of the three year period.

5.15.1 Closure Phase Activities

At the Brucejack Mine Site, the buildings will be removed and taken off-site. The fuels and lubricants will be removed from all equipment and taken off-site for disposal. All surface equipment will be taken off-site. The underground will be allowed to fill with water. The portals will be sealed. The diversion ditches that are no longer required will be backfilled. Diversion of contact water will be directed to Brucejack Lake. The site roads will be ripped. Some soil will have been stockpiled during the Construction phase and this will be spread on the pad surfaces. The soil-covered areas will be reclaimed with native species. Water treatment is not planned following closure as the underground will be allowed to fill. If water treatment is required, the water treatment plant used during Operation will be used.

A similar approach will be taken at the other Project components. The bridges and culverts will be removed along the Brucejack Access Road and the road surface will be ripped in preparation for reclamation. Stockpiled soils will be spread on the surface and the soils re-vegetated with native species. At the Knipple Transfer Area, the camp, maintenance and emergency vehicle building, and other infrastructure will be removed and the disturbed areas reclaimed. At the Bowser Aerodrome, all infrastructures will be removed and reclamation will be carried out. The Brucejack Transmission Line will be dismantled at Closure and the towers and conductors will be removed using helicopter support. The Tide Staging Area will be partially reclaimed once the transmission line is constructed. This area will be used again at the end of the Project as a staging area for transport out of the towers and conductors.

Closure and reclamation has been estimated at $10,707,632.

5.15.2 Post-closure Phase

Monitoring will be carried out during the Post-closure phase. The Brucejack Access Road and Brucejack Mine Site roads will be closed during the Closure phase and, therefore, access will be by helicopter. Monitoring will be carried out at each component of the Project including the Brucejack Mine Site, the Knipple Transfer Area, the Brucejack Access Road, etc. Sites will be checked for surface and slope stability, re-vegetated success, surface water quality, groundwater quality, aquatic resources, and the portal and ventilation seals at the Brucejack Mine Site. The monitoring program has been estimated at $153,900 to be carried out over a three-year period.

5.16 PROJECT WORKFORCE

5.16.1 Construction

The construction contracting strategy and feasibility study cost estimate are based on a “managed open shop” construction program. The schedule is based on a 60-hour work week; crew rotations are planned to be scheduled as three weeks on-site and one week off-site.

Table 5.16-1 illustrates the conceptual mix of types and numbers of jobs anticipated to be required throughout the Construction and Operation phases.

Table 5.16-1. Construction and Operations Workforce

Employment Category	Project Year																			
	Year -2	Year -1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18
A. Mining																				
Management & Tech Services																				
Mine Management																				
Mine Superintendent	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mine Captain	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Safety/Training/First Aid	2	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Operational personnel build-up (Owner/Contractor handover)	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Technical Services																				
Technical Services Manager	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Senior Mine Engineer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mine Engineers	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Mine Planning & Scheduling	0	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Surveyors	3	3	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Mine Technicians	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senior Geologists	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mine Geologists	1	1	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Geological Technicians	2	2	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Secretary	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Diamond Drillers	0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Ground Control Technician	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ground Control Engineer	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Additional hires for availability	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operational personnel build-up (Owner/Contractor handover)	0	12	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

(continued)

Table 5.16-1. Construction and Operations Workforce (continued)

Employment Category	Project Year																			
	Year -2	Year -1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18
A. Mining *(cont'd)*																				
Mine Operations																				
Development Crew																				
Development Shift Supervisors	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Jumbo Operators	13	13	12	12	12	12	12	12	12	12	12	12	12	12	4	4	4	4	4	4
Scoop (LHD) Operators	13	13	12	12	12	12	12	12	12	12	12	12	12	12	4	4	4	4	4	4
Truck Drivers	13	13	8	8	8	8	8	8	8	8	8	8	8	8	4	4	4	4	4	4
Blasters	7	7	8	8	8	8	8	8	8	8	8	8	8	8	4	4	4	4	4	4
Bolters & Ground Support	7	7	8	8	8	8	8	8	8	8	8	8	8	8	4	4	4	4	4	4
Cable Bolter Operators	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
General Labourers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Services Installers	13	13	12	12	12	12	12	12	12	12	12	12	12	12	8	8	8	8	8	4
Additional hires for availability	0	0	12	12	12	12	12	12	12	12	12	12	12	12	8	8	8	8	8	8
Operational personnel build-up (Owner/Contractor handover)	0	22	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Production Crew																				
Production Shift Supervisors	0	0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
LH Drill Operators	0	0	16	16	20	20	20	20	20	20	20	20	20	20	20	20	20	20	16	8
Scoop (LHD) Operators	0	0	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	16	16
Truck Drivers	0	0	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Crusher Operator	0	0	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Crusher labourer	0	0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Blasters	0	0	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Bolters & Ground Support	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
General Labourers	0	0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Services Installers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

(continued)

Table 5.16-1. Construction and Operations Workforce (continued)

	Project Year																			
Employment Category	**Year -2**	**Year -1**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Year 18**
A. Mining *(cont'd)*																				
Mine Operations (cont'd)																				
Production Crew (cont'd)																				
Cable Bolter Operators	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Additional hires for availability	0	0	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	8	8
Operational personnel build-up (Owner/Contractor handover)	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Backfill Crew																				
Backfill Leader	0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Timber men	0	0	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Backfill Plant Operators	0	0	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Maintenance & Logistics																				
Mine Maintenance																				
Maint. & Elect. Superintendent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Master Mechanic	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Maintenance Planner	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mill Wrights	0	4	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Chief Electrician	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Welders	0	4	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Mechanics	8	12	16	20	20	20	20	20	20	20	20	20	20	20	20	20	16	16	12	12
Lead Electrician	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Electrician	8	12	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	12	12
Apprentices	0	4	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	4	4
Labourers	0	4	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Additional hires for availability	0	0	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	8	8
Operational personnel build-up (Owner/Contractor handover)	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

(continued)

Table 5.16-1. Construction and Operations Workforce (continued)

Employment Category	Year -2	Year -1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18
	Project Year																			
A. Mining *(cont'd)*																				
Mine Operations (cont'd)																				
Logistics																				
UG Chief of Logistics	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Grader/Boom truck Operators	3	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
UG Warehouse Manager	0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Labourer/Forklift Operator	0	4	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	4	4
Contractor																				
Alimak Raise Leader	7	8	2	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
Alimak Raise Miner	7	8	2	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
Alimak Raise Mechanic	3	4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
Contractor Manager/Captain	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Construction Superintendent	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Construction Leader	4	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tradesman	0	32	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Owners Construction Superintendent	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Owners Project Control Engineers	0	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Owner Clerk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A. Sub-total Mining	***141***	***300***	***390***	***347***	***351***	***351***	***351***	***351***	***351***	***351***	***351***	***351***	***351***	***351***	***315***	***315***	***308***	***308***	***276***	***264***
B. Processing																				
Process Manager			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Chief Metallurgist			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mill Superintendent			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plant Metallurgist			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

(continued)

Table 5.16-1. Construction and Operations Workforce (continued)

Employment Category	Project Year																			
	Year -2	Year -1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18
B. Processing *(cont'd)*																				
Mill Foreman			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Mill Clerk			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Control Room Operators			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Grinding Operators			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Flotation Operators			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Dewatering Operators			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Gold Room Operators			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
General Labours, incl. Reagent Operators			8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Day Crew			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Maintenance Superintendent			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Maintenance Foremen			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Maintenance Planner			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mechanics			8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Electrician			6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Instrument Technicians			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Welders			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Crane/Equipment Operators			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Apprentices			8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Metallurgical Technician			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Assay Technicians - Senior	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Assay Technicians - Junior	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Sample Prep Labours			8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
B. Sub-Total Processing	***4***	***4***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***

(continued)

Table 5.16-1. Construction and Operations Workforce (continued)

Employment Category	Project Year																			
	Year -2	Year -1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18
C. G&A / Surface Services																				
General Manager			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Human Resources Manager			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Human Resources Coordinator			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Recruiter			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Benefits Adminstrator			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Administrative Assistant (HR)			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Finance Manager			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Accounts Payable/Receivable Clerk			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Payroll Accountant			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cost Accountant			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Junior Accountant			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Purchase Agent			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Buyer			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Expeditor			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Transportation Coordinator			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Freight Coordinator			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
I.T. Technician			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sustainability/Environmental Manager			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Environmental Officer			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Environmental Technician			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Safety Superintendent			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Safety Coordinator			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Safety Supervisor			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

(continued)

Table 5.16-1. Construction and Operations Workforce (continued)

Employment Category	Project Year																			
	Year -2	Year -1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18
C. G&A / Surface Services *(cont'd)*																				
Training Officer			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mine Rescue Coordinator			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Community Relations Coordinator			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Warehouse Supervisor			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Secretary			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
General Clerks			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Warehouse/First Aid			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Security			8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Site Services Manager			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Site Services Foreman			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Electrician-Surface Shops			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Mechanic-Surface Shops			8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Plumber/Pipefitter			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Carpenter-Surface Shops			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Drivers			24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Labourers-Yard/Surface Shops			8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Mine Dry Cleaner			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Camp Supervisor			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Road Maintenance Supervisor			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Clerk			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Transfer Station Supervisor			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mechanic-Offsite			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Airstrip Coordinators			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Operators-Offsite			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

(continued)

Table 5.16-1. Construction and Operations Workforce (completed)

Employment Category	Project Year																			
	Year -2	Year -1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18
C. G&A / Surface Services *(cont'd)*																				
Helpers-Offsite			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Backfill Plant Operators			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Backfill Plant Maintenance Technicians (Shared)			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
WTP Helpers			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Camp Service Men/Women	25	60	51	48	48	48	48	48	48	48	48	48	48	48	45	45	45	45	42	41
C. Sub-Total G&A / Surface Services	***25***	***60***	***194***	***191***	***191***	***191***	***191***	***191***	***191***	***191***	***191***	***191***	***191***	***191***	***188***	***188***	***188***	***188***	***185***	***184***
D. Construction																				
Surface Construction **	10 to 200	135 to 210	80 to 100																	
Service Contractors and Vendor Reps	2 to 20	20 to 30	10 to 30																	
EPCM Team	6 to 15	15 to 20	10 to 20																	
Owners team	10 to 14	14 to 92	10 to 20																	
D. Sub-total Construction	***28 to 249***	***184 to 352***	*********	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***
TOTAL	**198 to 419**	**548 to 716**	**684**	**638**	**642**	**642**	**642**	**642**	**642**	**642**	**642**	**642**	**642**	**642**	**603**	**603**	**596**	**596**	**561**	**548**

** Excluding construction manpower.*
*** Including general labours, mechanics, millwrights, pipe fitters, steelworkers, welders, electricals, instrumentation technicians, plumbers, carpenters, supervisors.*
**** Two to three months for commission.*

5.16.2 Operation

It is proposed that the underground mine workforce will operate with a two week on, two week off rotation, with 11 hour shifts. Table 5.16-1 provides details of the Operation phase workforce. The overall size of the workforce will vary over time depending upon the amount of development work required in the underground workings from about 684 people in the early years, and slowly tapering to a low of 548 people in the final year of operation (Figure 5.16-1). Chapters 19 and 20 discuss the economic and social effects, respectively, of the Project's employment. Note that the job numbers used here, which were estimated for the 2014 feasibility study update, are larger but available for as shorter time span than those used in the economics effects assessment, which were estimated for an earlier feasibility study (Tetra Tech 2013).

5.16.3 Closure and Post-closure

The Closure and Post-closure phases of the Project will provide limited employment opportunities; however, specific estimates are not yet available as Closure is in the distant future

5.17 PROJECT CAPITAL AND OPERATING COSTS

5.17.1 Capital Costs

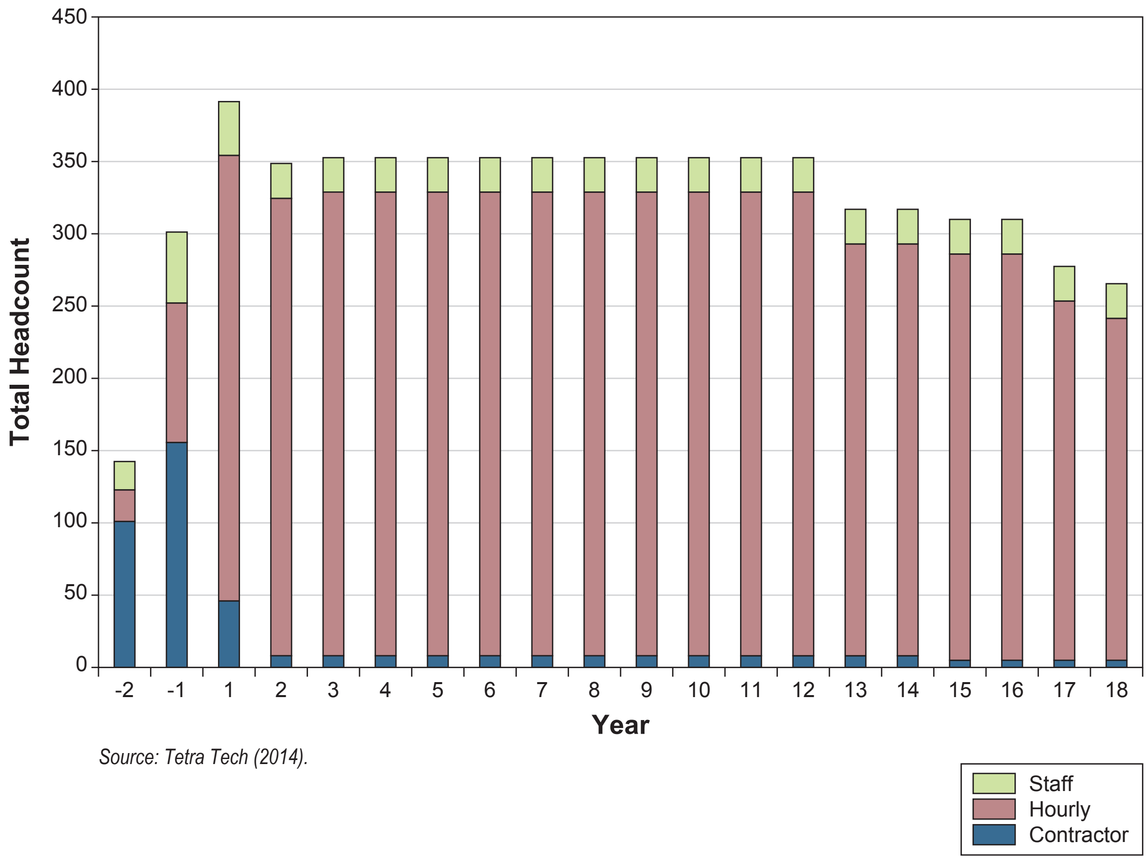
The total estimated initial capital cost for the design, construction, installation, and commissioning of the Project on the whole is $746.9 million, and includes all direct costs, indirect costs, Owner's costs, and contingency (Appendix 5-A, Feasibility Study and Technical Report Update on the Brucejack Project, Stewart, BC). See the Project Benefits section (Section 1.9) and Chapter 19, Assessment of Potential Economic Effects, for further information. A summary breakdown of the initial capital cost is provided in Table 5.17-1.

Table 5.17-1. Summary of Project Initial Capital Cost

Area Description	Capital Cost ($ million)
Direct Costs	
Mine Site	21.5
Mine Underground	179.5
Mine Site Process	53.8
Mine Site Utilities	30.5
Mine Site Facilities	53.5
Mines Site Tailings	3.5
Mine Site Temporary Facilities	33.4
Mine Site (Surface) Mobile Equipment	14.8
Off Site Infrastructure	89.1
Subtotal Direct Costs	**479.4**
Indirect Costs	127.5
Owner's Costs	71.0
Contingencies	69.0
Total Indirect Capital Cost	**748.9**

Note: Numbers may not add correctly due to rounding.

Figure 5.16-1
Underground Workforce Distribution by Year



Source: Tetra Tech (2014).

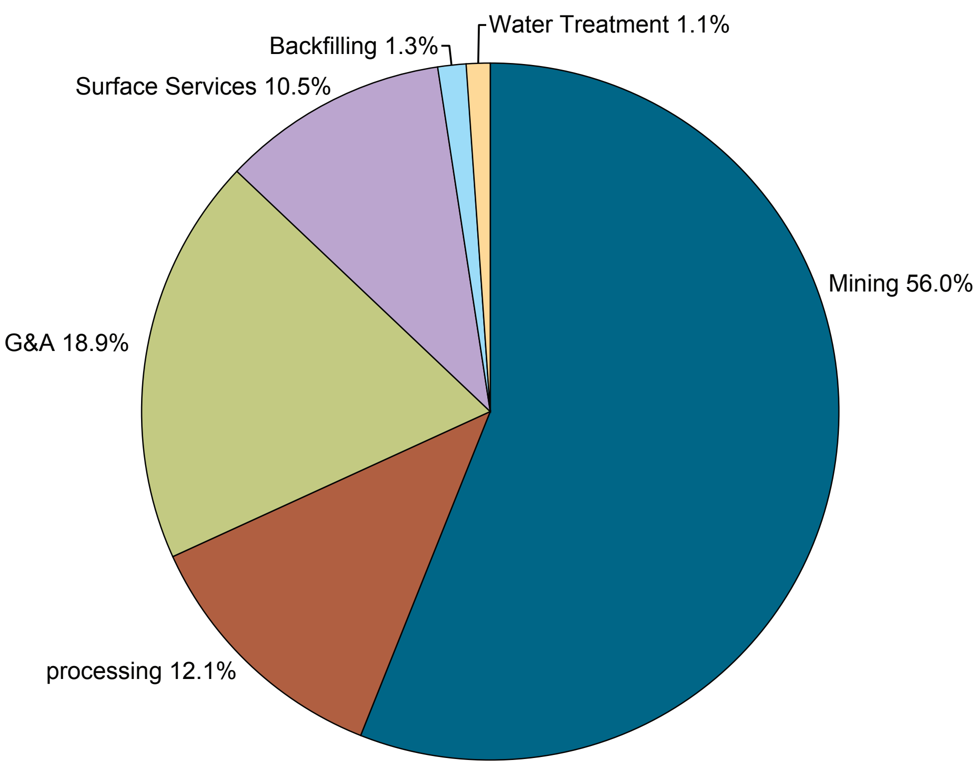
5.17.2 Operating Costs

The life of mine average operating cost for the Project is estimated at $163.05/t of ore milled, which includes costs for:

- mining;
- ore processing;
- general and administrative ;
- surface services;
- backfill, including paste preparation; and
- water treatment.

A total of 593 personnel are projected to be required for the Project.

Figure 5.17-1 provides a summary of the overall operating cost.



Source: Tetra Tech (2013).

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