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5.3.6 Groundwater Quality

5.3.6.1 Introduction

This subsection describes the approach and applicable regulatory framework for the assessment of the Groundwater Quality Valued Component (VC). Issues pertaining to the Groundwater Quality VC were identified and potential Project-related effects on the Groundwater Quality VC were assessed by using applicable regulatory, cultural, and scientific information and applying best practice analyses. Much of the groundwater quality effects assessment is based on information in the groundwater flow effects assessment. Some sections of the latter assessment are duplicated here for ease of reference.

5.3.6.1.1 Applicable Guidelines and Regulations

Although Canadian federal legislation does not directly regulate groundwater quality, the following federal legislation indirectly addresses groundwater issues with respect to the proposed Blackwater Gold Project (the Project):

- *Canadian Environmental Assessment Act* (*CEA Act*) (Government of Canada, 1992). The Project is a reviewable project, as defined by *CEA Act*, and groundwater issues, including groundwater flow, must be assessed under the *CEA Act*;
- *Canadian Environmental Protection Act, 1999* (*CEPA*) (Government of Canada, 1999). The *CEPA* regulates surface water chemical or physical quality, flow conditions, or water depth near the Project, which may be impacted by Project-related activities pertaining to groundwater flow;
- *Fisheries Act* (Government of Canada, 1985). The *Fisheries Act* regulates surface water chemical or physical quality, flow conditions, water depth, or benthic or riparian area conditions near the Project, which may be impacted by Project-related effects on groundwater flow; and
- *Species at Risk Act* (*SARA*) (Government of Canada, 2002). *SARA* regulates surface water chemical or physical quality, flow conditions, water depth, or benthic or riparian area conditions near the Project, which may be impacted by Project-related effects to groundwater flow.

While groundwater quality is not directly regulated by British Columbia (BC) provincial legislation, groundwater quality is indirectly regulated under the following provincial acts and regulations:

- BC *Environmental Assessment Act* (BC *EAA*) (Government of BC, 2002). The Project is a reviewable project, as defined by this legislation, which requires groundwater issues (including groundwater flow) to be assessed according to BC *EAA* assessments;
- *Mines Act* (Government of BC, 1996c). This legislation pertains to all mines that operate in BC;

- *Environment and Land Use Act* (Government of BC, 1996b). This legislation empowers Land Use Committees to ensure the preservation and maintenance of the natural environment, including groundwater, in administrating BC land use and resource development;
- *Environmental Management Act* (Government of BC, 2003), including the *Contaminated Sites Regulation* (Government of BC, 1996a), *Hazardous Waste Regulation* (Government of BC, 1988), and *Waste Discharge Regulation* (Government of BC, 2004b). This legislation regulates the chemical quality and management of substances, including substances that are released or discharged to the environment;
- *Water Act* (Government of BC, 1996d), including its *Ground Water Protection Regulation* (Government of BC, 2004a). This legislation regulates the diversion, extraction, use, and storage of surface water and installation, use, and decommissioning of groundwater wells; and
- *Fish Protection Act* (Government of BC, 2007). This legislation regulates surface water chemical or physical quality, flow conditions, or water depth, as well as habitat conditions within or near surface waterbodies near the Project that are impacted by Project-related effects to groundwater flow.

The *Mines Act* requires development of a conservation and reclamation plan to support closure of the Project. The Reclamation and Closure Plan (**Section 2.6**) meets the criteria of the *Mines Act* to support this assessment. Part 10 of the Health, Safety and Reclamation Code of Mines in British Columbia (BC Ministry of Energy, Mines and Petroleum Resources, 2008) also identifies reclamation and closure criteria applicable to BC mine closure.

5.3.6.1.2 Assessment Approach

Potential effects on the groundwater quality VC from interaction with Project components are described in this section. The potential effects of the proposed Project were based on the findings of the groundwater quality VC and Project component interaction analysis, which formed the basis for the effects assessment (as per **Table 4.3-1 in Section 4.3**). For the assessment a MODFLOW groundwater model was constructed, the assimilation and calibration of this model has been described in the groundwater baseline and groundwater quantity EA (**Section 5.3.5**). After the model was calibrated, the particle tracking simulations were modeled to simulate the path and time particles would take from key mine features to reach receiving streams. The potential effects Project activities might have on the groundwater quality VC were determined and described, and proven best practice mitigation measures were identified and applied to minimize or offset the potential effects. Effects remaining after the application of all mitigation measures were identified as residual effects.

5.3.6.2 Valued Component Baseline

5.3.6.2.1 Information Sources

This subsection provides detailed baseline information on the VC and the source of the information. Prior to commencement of environmental studies for the Project, no baseline groundwater data were available for the aquifers in the immediate area of the Project. Since 2012, groundwater baseline field programs were executed to fill this data gap. In these groundwater field programs the following activities were performed:

- Review of methods for geological interpretation, well design and well installation;
- Confirmation of sampling protocols for the list of elements to be analyzed as described in the 2013 Site Investigation Report; Knight Piésold 2012 Groundwater Quality Data Collection **Appendix 5.1.2.4A**;
- Review of potential data obtained from other sources;
- Collation of groundwater quality sampling results as described in the 2013 Site Investigation Report; Knight Piésold 2012 Groundwater Quality Data Collection **Appendix 5.1.2.4A**;
- Interpretation and analysis of groundwater quality results; and
- Production of Groundwater Quality Baseline Report (**Appendix 5.1.2.4B**).

The groundwater field program related approach and gathered information has been outlined in the following reports: Knight Piésold 2013 Site Investigation Report; Knight Piésold 2012 Groundwater Quality Data Collection Summary (Appendix 5.1.2.4A); and the Western Water Associates Ltd. – Stage 1 Environmental Impact Study: Rapid Filtration Basin Wastewater Disposal for the Blackwater Mine Construction Camp near Vanderhoof, BC (Appendix 5.3.6A), describing the feasibility of building and operating a waste water disposal system at the Project site. The groundwater quality effects assessment is based on these site-specific baseline investigative water quality results, on available regional hydrogeologic data, and on groundwater flow modelling conducted for the Project.

A three-dimensional quantitative MODFLOW computer model was constructed, calibrated and predictive particle tracking simulations were run to facilitate the assessment of the Groundwater Quality VC (as described in **Appendix 5.3.5A**). Additional information sources were used and quoted as per the list of references to write the effects assessment, and can be found in the reference section. The main reports consulted for geochemistry were AMEC, 2013 and Lorax, 2013a, and Lorax 2013b.

5.3.6.2.2 Project Overview

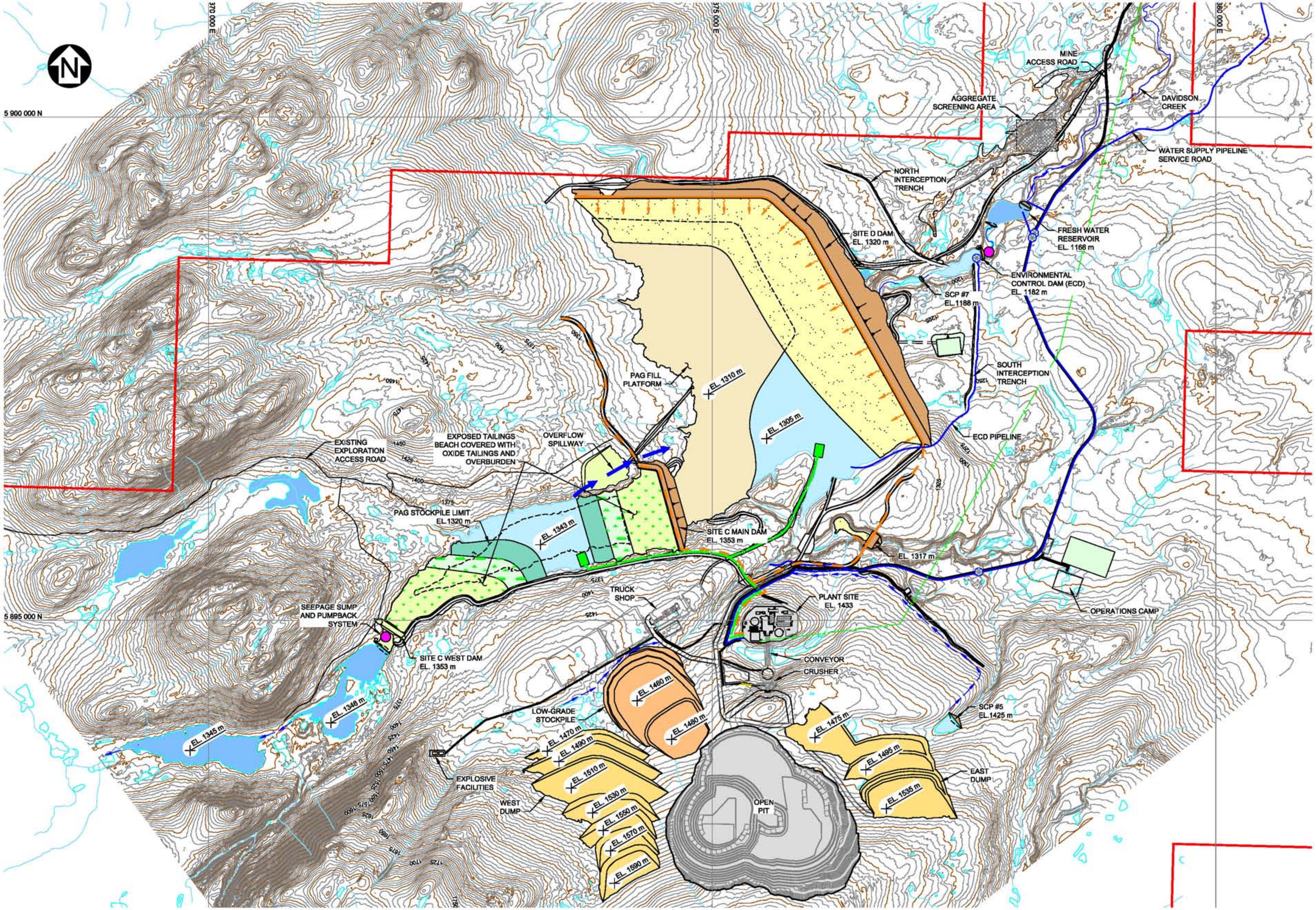
Section 2.2 provides a detailed overview of the Project, and mine water management is described in **Section 12.4.1.18.4.18**. A brief overview of the Project is provided here to provide context for the groundwater flow effects assessment that follows; **Figure 5.3.6-1** shows the facilities mentioned in this section.

The Project will be constructed over a two-year period, with some construction in the first operating year. Groundwater pumping wells will be installed around the pit perimeter at Year -2 in order to depressurize the pit area in preparation for mining.

Before construction, the Kluskus Forest Service Road (FSR) will be upgraded under a separate permit. The transmission line providing grid power to the Project will be built during the construction phase. The freshwater supply pipeline from Tatelkuz Lake will also be built, and an airstrip will be constructed three kilometres (km) north of the Project site. Best management practices (BMPs) will be employed for all these linear facilities to limit, to the extent practical, any interaction with groundwater.

An open pit will feed ore to a gold processing plant that will use whole ore carbon-in-leach cyanidation process to extract gold and silver as dore. Tailings will first be routed to an SO_2/air cyanide destruction circuit before disposal in the Tailings Storage Facility (TSF). This will significantly reduce concentrations of cyanide and residual metals; concentrations will further reduce in the TSF by natural degradation.

The TSF will be located in the Davidson Creek drainage and will permanently store tailings, potentially-acid generating (PAG) waste rock, and non-acid generating (NAG) waste rock with a high metal leaching potential produced during the operation of the mine. The TSF will have two cells (TSF Site C and TSF Site D). TSF Site C will be constructed first to provide storage capacity for start-up of the process plant and will contain the first two years of tailings and PAG and high metal leaching NAG waste rock. TSF Site D will be constructed to manage tailings and mine waste for the remainder of the operational life of the Project (Year 3 to Year 17). The TSF dams will consist of three zoned, water retaining, earth-rockfill structures, referred to as the Site C Main Dam, Site C West Dam, and Site D Main Dam. Each TSF Site will include a tailings beach and supernatant water pond. The TSF will not discharge surface water during the operations and early closure phases of the Project.



LEGEND:

▨	UPLAND BEACH
▨	BOG / WETLAND AREA
▨	EMERGENT VEGETATION WETLAND
▨	UPLAND SLOPE
▨	TAILINGS BEACH
▨	MINE WATER
▨	FRESH WATER
▨	EMBANKMENT FILL
▨	PAG WASTE ROCK
▨	NAG WASTE ROCK / OVERBURDEN
▨	LOW-GRADE ORE
▨	TOPSOIL
▨	BORROW AREA (ZONES S, C, AND ROCKFILL)
■	RECLAIM SYSTEM
⊛	PUMPSTATION
●	SEEPAGE SUMP AND PUMPBACK SYSTEM
—	MINE ACCESS ROAD
—	PIPELINE SERVICE ROAD
← - -	DIVERSION CHANNEL
—	WATER RECLAIM PIPELINE
—	NEW GOLD PROPERTY BOUNDARY
—	TRANSMISSION LINE
→	SPILLWAY
- · -	TAILINGS PIPELINE
↓	TAILINGS DEPOSITION

NOTES:

1. DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
2. SCP STANDS FOR SEDIMENT CONTROL POND.

SCALE A 400 200 0 400 800 1200 1600 2000 m

Figure from Knight Piésold Mine Waste and Water Management Design Report (VA101-457/6-11, Revision A) dated 22 November, 2013

CLIENT: newgold

AMEC Environment & Infrastructure
4445 Lougheed, Suite 600, Burnaby, B.C., V5C 0E4
Tel. 604-294-3811 Fax 604-294-4664

amec

DWN BY: KA
CHK'D BY: MY
DATUM: N/A
PROJECTION: N/A
SCALE: N/A

PROJECT: Blackwater Gold Project

TITLE:

Proposed Project
Site Arrangement - Year 8

DATE: January 2014
PROJECT NO: VE52277
REV. NO.: A
FIGURE No. 5.3.6-1

Y:\GIS\Projects\VE\VE52095_Richfield_Blackwater\Mapping\07_hydrogeology\EIA\07-200-044_GeneralArrangementYear8.ai

The TSF will be constructed over materials that will potentially provide a groundwater pathway to receiving waters. The source of seepage will include the supernatant pond, infiltration of transport water and precipitation into the tailings beach, and tailings consolidation water. Limited seepage is expected through the dam and through the dam foundation materials. Extensive surficial sand and gravel materials might potentially contribute seepage from the TSF if no engineering controls are in place. However, engineered mitigation methods designed and to be incorporated into the Project will reduce the seepage lost to receiving streams through the groundwater flow system. In particular, a low-permeability core zone within each TSF embankment will extend to low-permeability subgrade (LPS) materials at depth to cut off potential seepage. An Environmental Control Dam (ECD) and groundwater interception trenches will be located approximately 1 km downstream of the Site D Main Dam to recover potential seepage from the TSF. Seepage interception trenches will be constructed on each side of Davidson Creek, excavated through the surficial sand and gravel terraces downstream of the Site D Main Dam. Seepage to the collection trenches will report to the ECD pond. Recovered water in the ECD will be pumped to TSF Site D.

Seepage from the West TSF Dam will be prevented from flowing to the west by a hydraulic barrier created by constructing a pond with a water level above the TSF Site C pond level.

To address stream flow reduction as a result of the TSF placement in the upper Davidson Creek watershed, water from Tatelkuz Lake will be pumped to Davidson Creek below the ECD to augment flows and maintain instream flow needs for aquatic resources.

NAG waste rock with low metal leaching potential and overburden (OVB) will be placed in two dumps west and east (West Dump and East Dump) of the open pit. Engineered drainage ditches will be constructed down slope of the East Dump and West Dump to collect surface runoff and shallow groundwater seepage from the facilities and direct water to the TSF.

Low-grade ore (LGO) will be stored upslope of the TSF for processing during the last two years of mining. The LGO will be placed on an engineered compacted soil liner with a drainage collection system (**Section 2.2**) and all runoff and seepage will be treated with lime and directed to the TSF.

In general, all contact water from the mine site facilities will be directed to the TSF during operations and closure; non-contact water not required for processing will be diverted around the mine site by clean water ditches.

The existing exploration camp will initially be expanded for early construction activities and then a larger construction camp will be built to the east. A separate operations camp will be built adjacent to the larger construction camp and the latter removed when no longer required. Potable water will be provided by wells located near the camps. Sewage from the camps will be treated in a lagoon and discharged to a rapid infiltration basin (RIB) down-gradient of the camps. Sewage from mine processing and support facilities during operations will be treated in a Rotating Biological Contactor (RBC) and discharged to the TSF.

Once active tailings deposition has ceased, the TSF will be reclaimed by placing oxide tailings and OVB on the beaches and PAG waste rock, and constructing wetlands around the central pond margins, leaving a relatively small pond in the impoundments low points. During closure, the open pit will be flooded to form a pit lake. When full, after an estimated 18 years from the end of mill operations, pit lake overflow will be routed to TSF Site D, where it will discharge to Davidson Creek together with TSF supernatant through a constructed channel. The ECD will be removed, Tatelkuz Lake pumping will cease, and natural groundwater flows will resume. Surface water flows in Davidson Creek will be maintained following closure by a combination of impoundment surface water discharge and seepage. The East and West Dumps will be recontoured as required, covered with approximately 30 cm of OVB and re-vegetated.

5.3.6.2.3 Spatial and Temporal Scope

Section 4 describes the rationale for temporal and spatial boundaries of the Project that are also relevant to the groundwater quality effects assessment. **Section 5.3.6.2.6** describes the traditional, ecological, or community knowledge relevant to each VC.

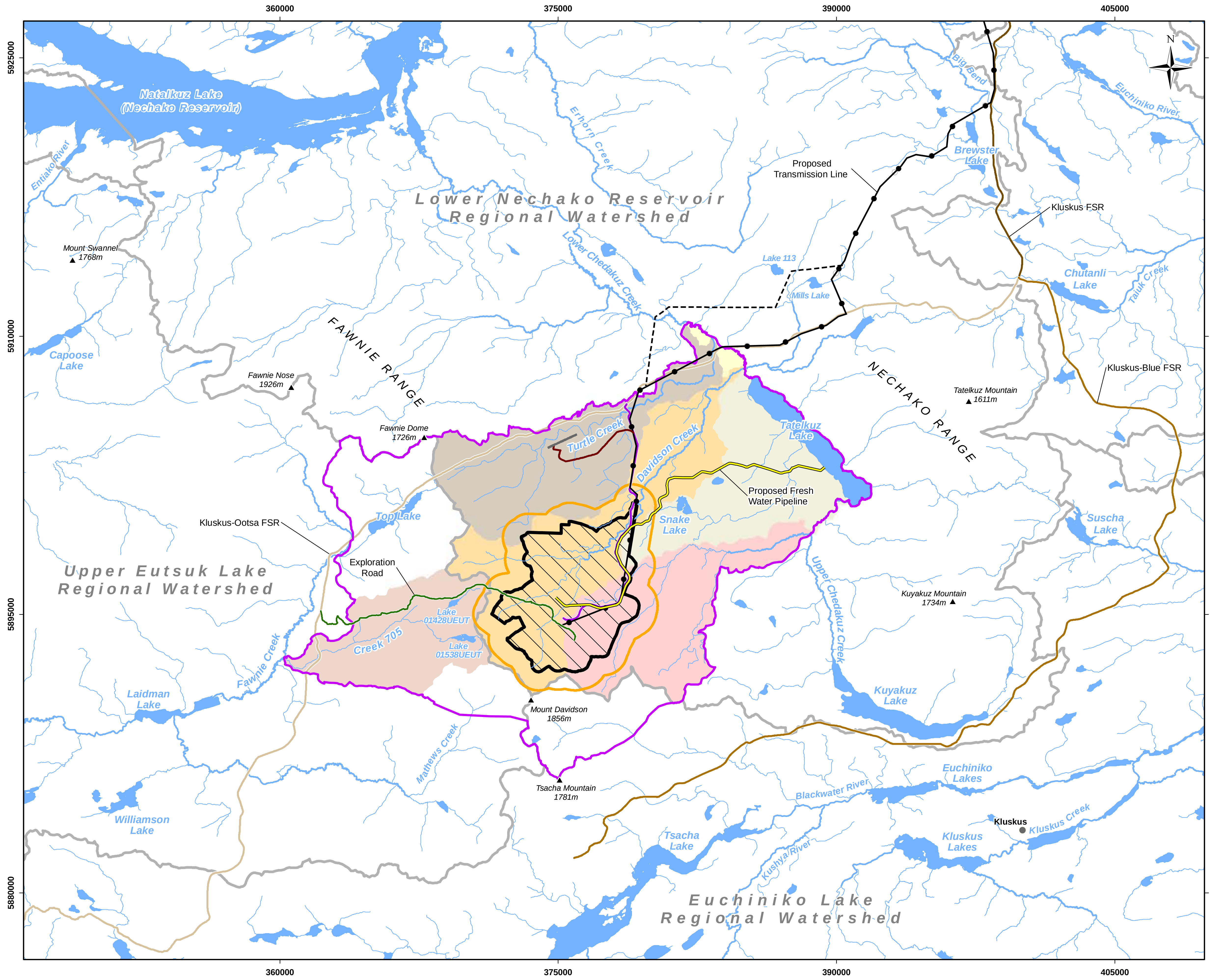
5.3.6.2.3.1 Spatial Scope

The Project and associated facilities will be located in the headwaters of Davidson Creek, with the exception of the East Dump, which will be located in the headwaters of Creek 661. The LSA includes (as per **Table 4.3-1** in **Section 4.3**) the entire mine site and a 1 kilometer buffer around it to capture potential groundwater drawdown effects due to open pit excavation and seepage effects from mine waste management facilities. The RSA includes all of the watersheds that might potentially be involved with the Project: the entire watersheds of Davidson Creek, Creek 661, Turtle Creek, and a portion of the watersheds of Chedakuz Creek, Laidman Lake, Creek 705, Blackwater River, and Fawnie Creek; and the tributaries flowing into the south side of Tatelkuz Lake. **Figure 5.3.6-2** shows the Project footprint, and the groundwater LSA and RSA. The linear components of the Project (i.e., transmission line, airstrip, Kluskus FSR, freshwater supply system, and mine access road) do not interact with the groundwater quality valued component, therefore they have not been considered in the definition of the spatial scope.

In general, the LSA includes all aquifers that have the potential to be measurably affected by the Project's development and operations. The RSA includes groundwater upstream and downstream of the Project that either potentially influences the LSA groundwater, or could be indirectly influenced by the Project.

5.3.6.2.3.2 Temporal Scope

The temporal scale for the groundwater quality effects assessment is from pre-construction (baseline) through post-closure (after the TSF discharges). Understanding of baseline groundwater quality is required to determine whether effects could occur during the phases of the Project. During construction, operations, and for a period of time after closure, there will be very limited groundwater seepage from the TSF into Davidson Creek. Approximately 18 years after the end of operations, the groundwater seepage from the TSF to Davidson Creek will increase somewhat as the ECD pumping system is removed. **Section 5.3.3** describes the potential effects of these seepage discharges on Davidson Creek water quality.



Y:\GIS\Projects\VE\VE52095_Richfield_Blackwater\Mapping\07_hydrogeology\Baseline\07-100-001_Groundwater_SA_v8.mxd

Legend

- ● Populated Place
- Kluskus FSR
- Kluskus-Blue FSR
- Kluskus-Ootsa FSR

Project Components

- Exploration Road
- Proposed Mine Access Road
- Proposed Fresh Water Pipeline
- Proposed Transmission Line
- Proposed Transmission Line (Mills Ranch Reroute)
- Proposed Airstrip Access Road
- Proposed Airstrip

Watersheds

- Chedakuz Creek Local
- Creek 661
- Creek 705
- Davidson Creek
- Tatelkuz Lake Tributaries
- Turtle Creek
- Regional Watersheds

Groundwater

- Regional Study Area
- Local Study Area

Scale:1:200,000

0 2.5 5 10

Kilometres

Reference

BC Government GeoBC Data Distribution

CLIENT:

newgold

PROJECT:

Blackwater Gold Project

Groundwater Quantity and Groundwater Quality Study Areas

DATE: February, 2014	ANALYST: WR	**Figure** 5.3.6-2
JOB No: VE52277	QA/QC: AP	PDF FILE: 07-100-001_Groundwater_SA_v8.pdf
GIS FILE: 07-100-001_Groundwater_SA_v8.mxd		
PROJECTION: UTM Zone 10	DATUM: NAD83	

amec

5.3.6.2.4 Administrative and Technical Boundaries

Administrative boundaries are not applicable to this VC. Technical boundaries for the assessment are established by the groundwater model predictions used in the effects assessment. There is an uncertainty/margin of error associated with the use of groundwater models; however, standards for modeling were followed. Therefore, the groundwater model includes an acceptable level of uncertainty for an assessment.

5.3.6.2.5 Past, Present or Future Projects and Activities

Section 4, Subsection 4.3.6.2, Table 4.3-11 shows the Summary Project Inclusion List developed for Cumulative Effects Assessment (CEA) (**Appendix 4C** contains the comprehensive Project Inclusion List). The groundwater quality VC does not interact with other projects or activities identified in the Project Inclusion List in the RSA as a result of spatial or temporal overlap. This is further described in **Section 5.3.6.5** Cumulative Effects**.**

The following past, present and future projects and activities may affect the Groundwater Quality VC:

- Exploration and other mining activities;
- Other groundwater users/water licenses; and
- Pacific Northern Gas Ltd. Looping Project.

No water licences related to groundwater use were found in the RSA aside from drinking water wells for the exploration camp. There is one domestic water well at the Mills Ranch on Tatelkuz Lake. The well is very shallow, and, at approximately 20 km removed from the Project.

Due to the remote location of the mine site, current groundwater extraction near the Project is negligible, and previous mine exploration is negligible as well. The closest off-site wells (Kluskus well and TTM Resources well) are registered on the provincial WELLS database (BC Ministry of Environment (BC MOE), 2013). One of these off-site wells reportedly supplies the Kluskus First Nation village at Kluskus Lake, and the other is reportedly owned by a forest company. Both off-site wells are located more than 20 km from the Project.

5.3.6.2.6 Traditional Knowledge

Part C discusses traditional knowledge (TK) with respect to groundwater flow and groundwater quality. Contamination of existing groundwater flow is an important concern for local residents and Aboriginal groups, and members of these groups have expressed interest in the Project's potential effects on groundwater flow. Comments provided during the engagement and consultation process offered insight into traditional, ecological, or community knowledge (Lhoosk'uz Dene Nation (LDN) and Saik'uz First Nation (SFN), 2013). This includes unique knowledge about the local environment, how it functions, and its characteristic ecological relationships.

Water is of great importance to First Nations that reside near the Project. In July 2013, interviews were conducted with residents of Indian Reserve (IR) #28 at the north end of Tatelkuz Lake. It was stated that “water is our life… it is the life for plants, trees, and animals” (interviews with Lhoosk’uz Dene Elders, pers. comm. 2013). Rainfall and spring water were also described as being important. One Elder noted that she prefers to fish for trout in surrounding lakes, as “trout caught in the rivers and creeks taste muddy.” According to one Elder, there is now *Escherichia coli* bacteria in lakes and streams near to Kuyakuz Lake and Kluskus Indian Reserve #1. The family residing at Indian Reserve #28 expressed concern that arsenic levels were high in nearby waterbodies. The family noted they used to get their drinking water from the well at the Mills Ranch but no longer do this because the water is now discoloured (interview with Lhoosk’uz Dene Nation and Saik'uz First Nation representatives, 2013). Based on tests conducted by AMEC in 2013, the water in the well was iron-stained but did not contain coliform bacteria. Bottled water for drinking purposes is now purchased in Vanderhoof or other communities.

Section 3 provides additional detail on comments and issues raised, as well as the public and Aboriginal issues tracking tables for the Project. **Section 14** through **Section 16** provides a summary of the Aboriginal background, rights, and interests for the Project.

5.3.6.3 Potential Effects of the Proposed Project and Proposed Mitigation

Potential effects on groundwater quality include the effect of seepage generated during the operations, closure and post-closure phases. The facilities within the mine site that generate seepage are TSF, Site C West Dam, waste rock dumps, and other mine related ancillary facilities.

Key and moderate interactions between project components and activities undertaken at the mine site and the groundwater quality VC during the construction, operations, closure, and post-closure phases are presented in **Table 4.3-2** in **Section 4**. During the construction phase there is no interaction with the groundwater quality VC because mine waste is not generated which constitutes the main source of seepage that affects groundwater quality. Effluent from the sewage treatment plant will be disposed of through an infiltration gallery; therefore, the effects on groundwater quality are expected to be negligible.

During operations, closure, and post-closure phases the ore processing plant, TSF, waste rock dumps and low grade stockpile will generate seepage that has potential effects on groundwater quality. The effects carried forward in the effects assessment are described in **Section 5.3.6.3.1** and the direction of these effects has been identified and rated.

Other known past, present, certain and reasonably foreseeable future projects or activities that were identified in **Section 5.3.6.2.5** may have effects on groundwater quality due to additional groundwater extractions or land disturbance activities that may change the quality of the groundwater. Those potential effects can be mitigated by adherence to Environmental Management Plans. Further details are discussed and provided in **Section 5.3.6.5** Cumulative Effects.

5.3.6.3.1 Potential Project Effects

5.3.6.3.1.1 Potential Direct Effects on Groundwater Quality

The assessment of groundwater effects assumes that the Project-designed mitigation measures will be in place and effective. The Project design was based on limited surface water discharge during construction and no surface water discharge during operations and closure (until the pit fills with water). The only releases during operations and closure are from groundwater seepage. Mitigation measures include construction and operation of measures to reduce the potential impact of the mine site on its surrounding environment. From a groundwater perspective, mitigation methods are designed to minimize the seepage and other contact water that may be lost to the areas surrounding the mine site through the groundwater system. The mine site arrangement is such that virtually all groundwater within the mine site area flows into the TSF. Consequently, mitigation methods aimed at reducing and/or collecting seepage and contact water from the perimeter of the tailings dam were integral to the TSF design. Seepage and contact water collection is especially important where seepage would be lost to catchments with relatively low stream flows. Because seepage rates generally change very little seasonally, there is less freshwater available for dilution of seepage water during low flows. In addition, a wastewater treatment system will be constructed near the mine camp. The design flow for the camp is approximately 375 m^3/day. Effluent will be treated to Class C effluent supplemented with ultra violet disinfection with a packaged RBC wastewater treatment plant, and disposed to ground via RIB. The current background groundwater quality is of good quality, particularly with respect to parameters associated with effluent disposal to ground. The effluent disposed at the RIB area is not likely to adversely affect the streams and supply wells downstream of the RIB (Western Water Associates Ltd., 2013).

Table 5.3.6-1 lists sources of direct effects on groundwater quality by mine phase.

Table 5.3.6-1: Potential Direct Effects on Groundwater Quality by Mine Phase

Mining Phase	Potential Direct Effects Source	Link (Y/N)	Parameters/ Comments
Construction			
Late Year -2 to end Year -1	Site clearing, grading, soil salvage, development of borrow pits, construction of main and ancillary facilities, water diversion/collection/treatment, storage and soil stockpiles, management of construction materials and waste, and workforce accommodation	Y	No operating TSF. Groundwater flow patterns and water table changes, and related changes in background water quality at site(1), (2)
Late Year -2 to end Year -1	Sewage treatment plant-treated effluent	Y	Groundwater flow patterns and water table changes and related changes in background water quality at site(1), (2)

Mining Phase	Potential Direct Effects Source	Link (Y/N)	Parameters/ Comments
Operations			
Years 1 to 17	TSF seepage to groundwater interception system	Y	TSF designed with interception system(1) potential changes background water quality at site(1), (2)
Years 1 to 14 (decreases after mining ceases)	Pit area groundwater	Y	Cone of depression draws groundwater levels down around the pit(1) Groundwater flow patterns and water table changes, potential for ARD effects
Years 1 to 17	Sewage treatment plant-treated effluent(2)	Y	Groundwater flow patterns and water table changes background water quality at site(1), (2)
Years 1 to 17	East and West dumps and low-grade ore stockpile		Groundwater flow patterns and water table changes background water quality at site(2)
Closure			
Until no longer required	TSF seepage to groundwater interception system	Y	TSF designed with downstream wetland system(1), (2)
Until no longer required	TSF seepage bypassing interception	Y	TSF designed with downstream wetland system(1), (2)
Until no longer required	Reclaimed East Dump runoff and seepage	Y	To Creek 661, changes background water quality at site(2)
Until no longer required	Site C West Dam and seepage mitigation pond		To TSF, changes background water quality at site(2)
During early decommissioning; Years 17 to 19	Sewage treatment plant-treated effluent(2)	Y	Groundwater flow patterns and water table changes background water quality at site(1), (2)
Post-Closure			
Indefinite	TSF seepage	Y	To Davidson Creek Groundwater flow patterns and water table changes
Indefinite	Residual East Dump, pit lake and TSF seepage	Y	To Creek 661 Groundwater flow patterns and water table changes, changes background water quality at site(1), (2), (3)
Indefinite	West Dump seepage	Y	Captured by collection channel routed to TSF, changes background water quality at site(1), (2)
Indefinite	Site C West Dam and seepage mitigation pond	Y	Routed to TSF, changes background water quality at site(1), (2)

Note: (1) Further discussion in the Mine Water Management Plan, **Section 12.2.1.18.4.18.**
(2) Further discussion in the Water Quality and Liquid Discharges Management Plan, **Section 12.2.1.18.4.10.**
(3) Should water quality meet BC guidelines and site-specific objectives, water will be allowed to discharge into Creek 661.

5.3.6.3.1.2 Potential Indirect Effects on Groundwater Quality

Based on the Project Description (**Section 2.2**), the change in baseline groundwater quality could have potential indirect effects on freshwater aquatic resources including fish and fish habitat, human health, groundwater quality, surface water quality, and environmental health.

5.3.6.3.1.3 Potential Combined Effects

Changes in baseline groundwater quality could potentially affect other VC's such as wetlands, wildlife and aquatic resources. During construction and operations, the potential combined Project effects include changes in groundwater quality due to water management within the Project facilities footprint, seepage from the TSF, runoff from NAG waste rock and OVB dumps, or changes in catchment areas of Project components.

During the closure and post-closure phases, there is a potential for a combined Project effect on groundwater quality due to changes of the Project's water management.

5.3.6.3.1.4 Potential Project Effects Carried Forward for Assessment

Changes in groundwater quality from Project activities could have an effect throughout the Project and could be negative in overall direction. Water quality in some surface waterbodies could be affected through changes in groundwater quality.

5.3.6.3.2 Specific Potential Project Effects

5.3.6.3.2.1 Information Sources and Methods

The approach for assessing residual effects includes the interpretation of results of the groundwater quantity residual effects assessment and the mine waste geochemistry characterization program to determine how the groundwater quality regime could be affected by the proposed Project components during the different mine phases. The focus is the potential quality of the seepage that could be generated by mine waste facilities, the expected quality of water in the pit lake during closure and how the seepages could affect downstream surface waters. To assess the potential effects of mine site construction, operations, and closure on groundwater quality, seepage from mine site elements and groundwater flows were assessed using a watershed model and numerical models (MODFLOW and SEEP/W models).

The watershed model was used to gain an understanding of the interaction between climate, surface water, and groundwater flows (**Appendix 5.1.2.1B**). A preliminary (coarse-scale) assessment of infiltration and runoff into waste rock dumps was assessed with the watershed model.

MODFLOW models were created to represent all phases of mining, from construction through post-closure (**Appendix 5.3.5A**). Results from the baseline watershed model were used in calibration of the baseline MODFLOW model. A seepage assessment was conducted using particle tracking (MODPATH) in MODFLOW to characterize potential seepage pathways from proposed mine facilities. The seepage assessment was conducted using a steady state MODFLOW model representing the post-closure phase of mine development. Characteristics of potential seepage originating from proposed mine facilities (pathways, travel time, and discharge locations) were assessed for the TSF, East and West Dumps, process plant site, and pit lake. Results of the seepage assessment only include advective groundwater flow and do not consider diffusion, dispersion or chemical degradation.

Two-dimensional SEEP/W models were developed to estimate seepage flows from the TSF facility at the end of ore processing when the TSF is at its maximum extent (**Appendix 2.2A-2**). TSF seepage estimated using the SEEP/W models was used in the effects assessment.

Potential changes in local groundwater quality conditions from baseline were assessed based on baseline groundwater sample analysis, estimates of seepage from the Seep/W and MODFLOW models, and separate geochemical benchmark studies and geochemical modelling. These geochemical studies were described in Geochemical Characterization Report (AMEC, 2013), in Metal Sorption Potential of Natural Substrates Underlying the Blackwater Tailings Storage Facility: Implications for Attenuation along Seepage Flow paths (Lorax, 2013a), and in Blackwater Gold Project: Conceptual Model for Contaminant Transport and Behaviour in Tailings Storage Facility (Lorax, 2013b).

Based on geochemistry field study and analysis, predictive water quality models were developed to provide estimates for the drainage quality from several prominent mine features:

- LGO stockpile;
- Temporary ore stockpile;
- PAG and NAG3 waste rock seepage from TSF;
- Combined East and West Dumps; and
- Open pit.

All geochemistry based water quality estimates were obtained from the results of mass balance models. Average annual results were used as inputs to the overall Project surface water quality model (**Section 5.3.3**) (AMEC, 2013).

5.3.6.3.2.2 Watershed Model Results

The watershed model results provided estimates of monthly mean groundwater flows at the outlet of each modelled sub-catchment; therefore, only large-scale (coarse resolution) changes in the groundwater flow system was estimated using the model. At this large scale, watershed model results indicated that groundwater flows were predicted to change from baseline conditions in headwater sub-catchments of Creek 705, Davidson Creek, and Creek 661 watersheds during mine development (**Appendix 5.1.2.1B**). No change in groundwater flows were predicted in Turtle Creek watershed associated with mine development.

Watershed model results indicated potential effects on groundwater flows due to mine development will include the following:

- Altered groundwater flows in the headwaters of Creek 705 due to the construction of the pond west of the Site C West Dam (referred to as the “coffer dam at 11-DC” in the watershed model report), which will act as a hydraulic barrier to control seepage from TSF Site C. Watershed model results indicate that average annual groundwater flows leaving the headwater sub-catchments of Creek 705 (nodes 6-705 and 4-705 of the watershed model) were predicted to negligibly increase (<0.01 L/s) while the maximum increase in monthly mean groundwater flows at these nodes was predicted to be less than 1 L/s from baseline conditions. Groundwater flows leaving the lower sub-catchments of the Creek 705 watershed (nodes H7 and 1-705 of the watershed model) were predicted to be similar to baseline conditions. Therefore, effects on groundwater flows associated with the TSF Site C West Dam seepage control pond are predicted to remain localized to the headwater catchments of Creek 705. These effects on groundwater flows were predicted during all phases of mine development from construction through post-closure.

- Altered groundwater flows in Davidson Creek valley due to the construction and operation of the TSF and ECD interception trenches during operations and closure. The watershed model included a conservative assumption that no groundwater flow passes beneath the interception trenches during operations and closure. The watershed model results indicated that groundwater flows from sub-catchments downstream of the ECD on Davidson Creek (at watershed model node H4B and downstream nodes) were predicted to be at baseline conditions; therefore, effects on groundwater flows in the Davidson Creek watershed from the TSF and ECD are expected to remain localized to the area adjacent to the TSF. Pumping from Tatelkuz Creek to the freshwater reservoir during operations and closure will provide a source of water that will limit reductions in groundwater flow along Davidson Creek. No change in groundwater flow was predicted during the construction phase of mine development. Post-closure groundwater flows leaving sub-catchments downstream of H2 node in the watershed model (located immediately downstream of the ECD) were predicted to be similar to baseline conditions.
- Decreased groundwater flows in the headwater sub-catchments of Creek 661 due to inflows to the open pit. Predicted effects on the groundwater flow system associated with development of the open pit were assessed with the MODFLOW model. Due to the coarse resolution of the watershed model, MODFLOW model results are considered to provide a more representative estimate of groundwater flow conditions associated with development of the open pit. The MODFLOW model predictions are discussed in **Section 5.3.5.3**.
- Infiltration of surface water from the TSF spillway channel will potentially contribute to groundwater flows in adjacent catchments. The TSF spillway channel will be constructed and will route runoff within the local spillway catchment to Davidson Creek in closure. Surface water within this spillway channel may provide a source of infiltration to groundwater. Infiltration of surface water from the TSF spillway catchment was assumed in the watershed model to contribute groundwater flows to a sub-catchment beyond the extent of the watershed model (i.e., not Davidson Creek or Creek 661 watersheds). This assumption of infiltration from the spillway was included in the watershed model in order to provide a conservative estimate of stream flow impacts along Davidson Creek and Creek 661. However, since the TSF spillway channel traverses Creek 661 and Davidson

Creek watersheds, the potential infiltration from the TSF spillway channel may contribute to groundwater flow in these watersheds.

- Altered recharge to groundwater beneath the footprints of the East and West Dumps. The net effect on predicted recharge to groundwater beneath each dump footprint was a decrease in recharge during the spring and an increase in recharge during the low flow (winter) season.

5.3.6.3.2.3 MODFLOW and SEEP/W Model Results

Knight Piésold developed the MODFLOW models, dividing the Project into four timeframes:

- Baseline;
- Operations: Year 1 through Year 17;
- Closure: Year 18 to Year 35; and
- Post-closure: Year 35 and beyond.

The results of the MODFLOW and SEEP/W models are briefly discussed below and in the Numerical Groundwater Modelling Report (**Appendix 5.3.5A**) and the Mine Waste and Water Management Design Report (**Appendix 2.2A-2**).

5.3.6.3.2.4 Tailings Storage Facility

5.3.6.3.2.4.1 Seepage Flow and Travel Times

The TSF will be constructed over materials that could potentially provide a groundwater pathway to the surface water environment. The source of seepage would include seepage from the supernatant pond, infiltration of construction water, and precipitation into the tailings beach and tailings consolidation water. Some seepage is expected through the dam and through the dam foundation materials. Extensive surficial sand and gravel materials could contribute to seepage from the TSF without engineering controls in place. Engineered mitigation methods are designed to reduce the impact on stream flow rates and reduce the seepage and other contact water that may be lost to the area surrounding the mine site through the groundwater flow system.

As a conservative approach, no chemical degradation is considered in the groundwater assessment in this assessment. However, the effect of travel and residence times of seepage is expected to have an important effect on groundwater concentrations since contaminants in the mine site sources, such as the TSF are finite. Over long time periods, concentrations of contaminants in seepage are expected to decrease from peak levels. For example, sulphide oxidation rates will decrease over multiple decades to century time scales due to the removal of surficial sulphide minerals and longer path lengths for oxygen diffusion.

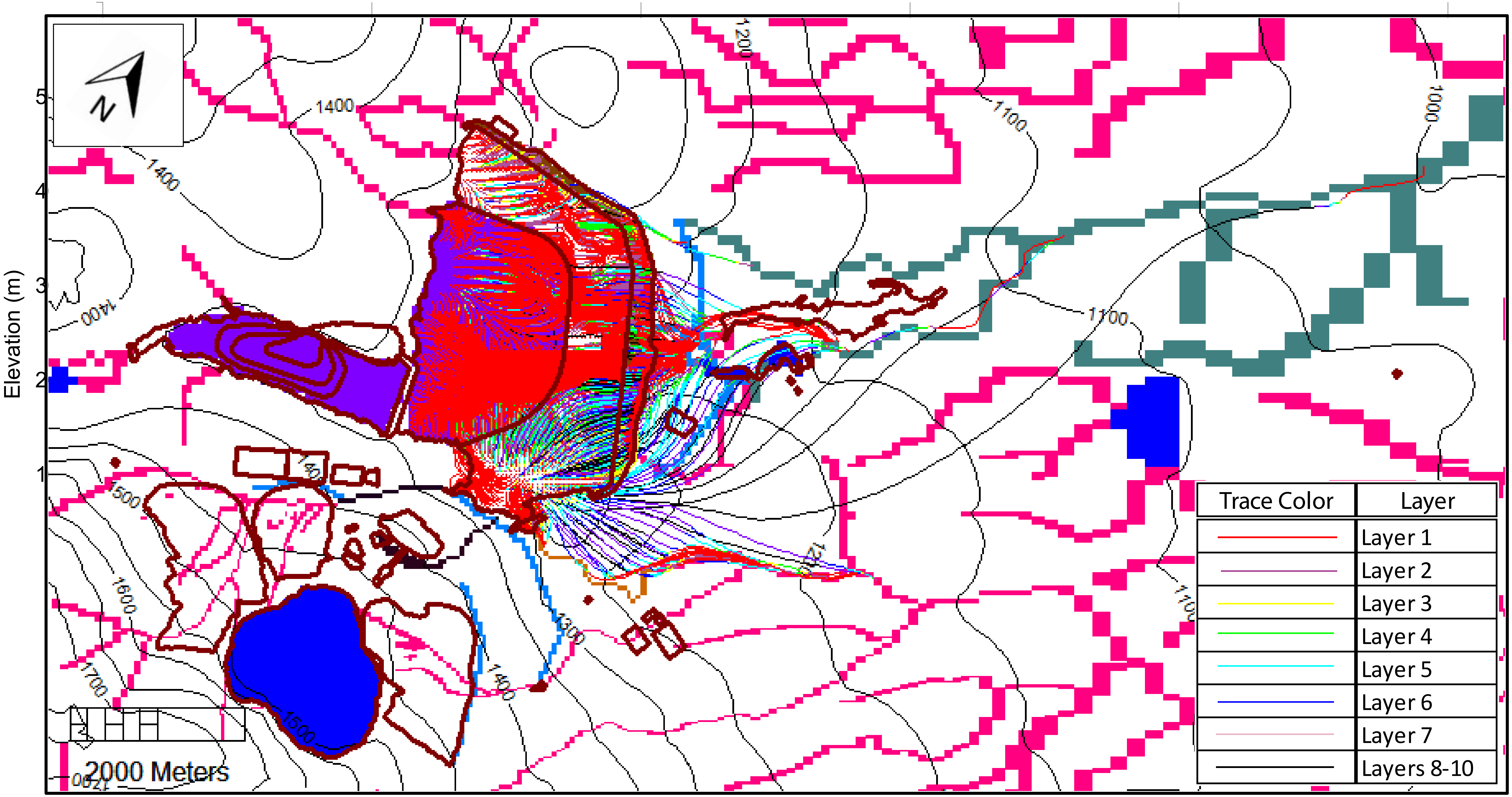
Results of SEEP/W two-dimensional modelling estimated that approximately 55 L/s seepage will originate from the TSF and 2 L/s of that seepage was predicted to be unrecoverable with the current engineering design measures. The estimated 2 L/s of unrecoverable seepage were used in the effects assessment.

Seepage pathways and travel times to downstream discharge locations was assessed using particle tracking (MODPATH) in the steady state MODFLOW model. The MODFLOW model only simulated foundation seepage and did not account for embankment seepage from the TSF. From MODFLOW model results (**Figure 5.3.6-3** and **Table 5.3.6-2**), it is predicted that all seepage originating from the TSF Site D foundation alone will be captured primarily by the TSF main embankment drains (15 L/s) and the ECD collection system (5 L/s). Travel time for seepage to arrive at TSF embankment drains is relatively fast, on the order of 40 years. All of the seepage destinations except the Davidson Creek, Creek 661, and TSF spillway values would be collected in the ECD and pumped back to the TSF during operation and closure, or discharged through the constructed wetland in the ECD during post-closure. Much less TSF foundation seepage is predicted to reach Creek 661 (0.2 L/s), Davidson Creek (0.4 L/s) and to the south abutment drains (0.4 L/s), and the TSF spillway (0.1 L/s).

Table 5.3.6-2: Results of MODFLOW MODPATH Particle Tracking and Advective Travel Times TSF D

Facility	MODPATH/Seepage Discharge Location	Simulated Seepage Flux Rates		Travel Time to Discharge Location (Years)			
		Discharge (L/s)	Discharge (% of Total)	Average	Median	Minimum	Maximum
Davidson Creek		0.4	2	1,807	585	127	6,979(1)
Creek 661		0.2	1	365	254	97	1,037
TSF Main Embankment Drains		15	72	90	40	0.3	2,824(1)
TSF South Abutment Drains		0.4	2	21	15	1	84
TSF Spillway		0.1	<1	82	70	22	217
ECD System		5.0	24	224	129	13	2,492(1)
Natural Channel Reporting to TSF		0.1	<1	15	10	0.5	93.0
Total Seepage From TSF D		**21.3**	**100**	**-**	**-**	**-**	**-**

Note: (1) Particles with long travel times originate near the boundary of the TSF Site D pond discharge zone. The proximity to this boundary may influence the modelled travel times.
TSF = Tailings Storage Facility; ECD = environmental control dam; L/s = litres per second; % = percent



Notes:
Particle Traces are coloured according to the model layer it is travelling in.
The contours showin above are of water table elevation (masl)

Figure from Knight Piésold Numerical Groundwater Modelling Report (VA101-457/6-13, Revision 0)
dated 16 January, 2013 (Appendix D).

CLIENT:	newgold
DWN BY:	AA
CHK'D BY:	MY
DATUM:	N/A
PROJECTION:	N/A
SCALE:	N/A
PROJECT	Blackwater Gold Project
TITLE	**TSF D Modflow MODPATH Particle Analysis**
DATE:	January 2014
PROJECT NO:	VE52277
REV. NO.:	A
FIGURE No.	5.3.6-3

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Seepage from the TSF is predicted to enter and flow through the surficial glaciofluvial deposits within a limited distance downstream of TSF D Dam. Within Davidson Creek valley, seepage through the glaciofluvial deposits is predicted primarily within 1,000 m downstream of Dam D, at or upstream of the ECD location. The limited seepage that travels along deeper groundwater flow paths is predicted to enter Davidson Creek and Creek 661 up to about 2,000 m downstream of TSF D. Seepage through glaciofluvial deposits downstream of the ECD location is predicted to discharge to Davidson Creek upstream of the proposed compliance point at the mine access road crossing and within the area proposed for a contingency treatment wetland for the seepage. Only trace seepage is predicted to enter Davidson Creek further downstream of the proposed compliance point. Therefore, seepage effects on near surface groundwater quality will be generally restricted to very near to the site. The effect of all predicted seepage releases on surface water quality is included in **Section 5.3.3** analysis.

To provide insight into the origin, behaviour, and near-term fate of mine-related contaminants associated with the TSF mass, a qualitative conceptual model was developed that links contaminant sources, seepage pathways, attenuation processes, water management, and contingency planning (Lorax, 2013b).

Potential contaminant sources associated with the TSF include those associated with the tailings supernatant as well as those associated with neutral-pH metal leaching that may occur post-deposition (pH- and/or redox-controlled dissolution of metal bearing tailings and waste rock components). In contrast, metal leaching associated with acid rock drainage (ML/ARD) is not relevant given that the TSF will be engineered to ensure that the reactive (transition/sulphide) tailings materials remain saturated below the final water table elevation where oxygen transfer will be severely limited.

During operations, the quality of pore waters within the TSF and corresponding seepage waters will be largely governed by the composition of tailings supernatant. However, the supernatant signature will be altered within the pond environment due to the breakdown of elements of concern such as cyanide compounds, metal removal following degradation of metal-cyanide complexes, and re-carbonation from the atmosphere. The degradation of cyanide and cyanate will also contribute to elevated ammonia levels within the pond environment during operations. From the pond system, waters will migrate downward through the saturated tailings and waste rock mass. Within suboxic zones of the saturated tailings and waste rock, the reductive dissolution of redox-sensitive phases (e.g., secondary iron oxides that form in the mill/treatment process) will result in an increase in dissolved iron in pore waters. This mechanism may also promote increases in the concentration of other elements (e.g., copper and cadmium) that show associations with iron oxides.

Mineralogical and sequential extraction data for the sulphide tailings suggest that zinc and cadmium occur predominately as primary and secondary sulphide minerals, with minor to negligible amounts associated with reducible phases (e.g., iron oxides). In contrast, the transition/oxide zone materials are characterized by a mixed mineral assemblage containing both oxidizable and reducible cadmium and zinc phases. In this regard, the oxide/transition materials have a greater potential for redox and pH derived dissolution of metal bearing components. Overall, however, the generally low abundance of redox-sensitive phases (e.g., iron oxides) identified in the tailings and waste rock samples suggest that reductive dissolution processes will not have a profound effect on the concentrations of trace elements in pore waters (e.g. cadmium and zinc). Given the low abundance of soluble cadmium-zinc phases associated with the tailings, the potential relevance of pH dependent dissolution processes is predicted to be low, and less significant in comparison to redox-related mechanisms.

At the base of the impoundment where tailings and waste rock are in contact with remnant vegetation and organic soils, there is an increased potential for sulphate reduction and the precipitation of secondary metal sulphides. The introduction of suboxic waters from the TSF into the underlying groundwater system may result in development of a suboxic plume in the natural aquifer. This seepage plume may be characterized by elevated concentrations of iron, manganese, and ammonia and possibly trace metals in comparison to background conditions. The results of adsorption test work indicate that substrates underlying the TSF afford a solid to significant potential for the attenuation of cadmium and zinc. This imparts an element of conservatism into water quality predictions that do not account for trace element removal along seepage ways (Lorax, 2013a).

The geochemical study performed by AMEC provides predictions of TSF seepage water quality over the mine operations period (AMEC, 2013). Predicted annual TSF seepage water quality results are presented in **Table 5.3.6-3** based on the leaching potential and mass of PAG and NAG3 waste rock placed in the TSF combined with TSF supernatant (**Section 5.3.3**).

Table 5.3.6-3: TSF Seepage Quality – Annual Average: Best Estimate

Parameter	Unit	Operations Last Year of Open Pit Mining Year 13	Closure Pit Filling / TSF Pumping Year 18
pH	pH unit	9.1	8.5
Conductivity	mS/cm	284	195
TDS	mg/L	171	120
TSS	mg/L	5.7	4.4
Turbidity	mg/L	3.3	2.4
Total hardness	mg $CaCO_3$/L	72	57
Total alkalinity	mg/L	79	62
Fluoride	mg/L	0.10	0.082
Sulphate	mg/L	67	38
Chloride	mg/L	0.80	0.59
Ammonia	mg/L	1.8	0.097
Nitrate	mg/L	14	0.18
Nitrite	mg/L	0.33	0.013
TOC	mg/L	13	10
T_Aluminum	mg/L	0.27	0.083
T_Antimony	mg/L	0.090	0.057
T_Arsenic	mg/L	0.012	0.0074
T_Barium	mg/L	0.075	0.050

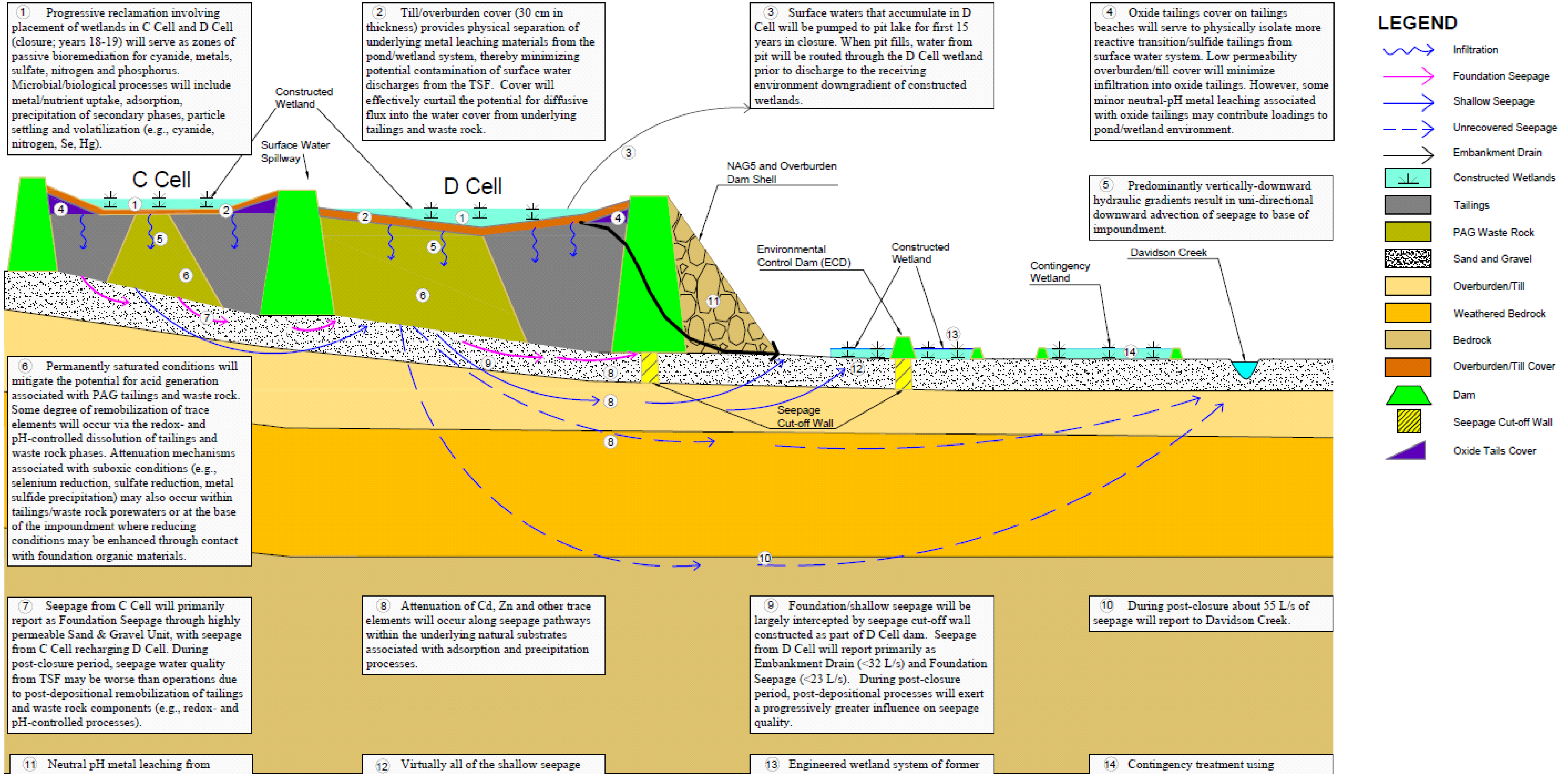
Parameter	Unit	Operations Last Year of Open Pit Mining Year 13	Closure Pit Filling / TSF Pumping Year 18
T_Beryllium	mg/L	0.00020	0.00016
T_Boron	mg/L	0.038	0.024
T_Cadmium	mg/L	0.0050	0.0031
T_Calcium	mg/L	36	19
T_Chromium	mg/L	0.0018	0.0012
T_Cobalt	mg/L	0.090	0.057
T_Copper	mg/L	0.025	0.014
T_Iron	mg/L	0.65	0.43
T_Lead	mg/L	0.0018	0.00049
T_Lithium	mg/L	0.020	0.012
T_Magnesium	mg/L	5.1	4.1
T_Manganese	mg/L	0.51	0.32
T_Mercury	mg/L	0.000017	0.000013
T_Molybdenum	mg/L	0.15	0.10
T_Nickel	mg/L	0.0053	0.0033
T_Phosphorus	mg/L	0.10	0.043
T_Potassium	mg/L	98	62
T_Selenium	mg/L	0.0014	0.0011
T_Silicon	mg/L	10	8.9
T_Silver	mg/L	0.000035	0.000033
T_Sodium	mg/L	19.7	11.7
T_Strontium	mg/L	0.77	0.51
T_Thallium	mg/L	0.00016	0.00011
T_Tin	mg/L	0.024	0.016
T_Titanium	mg/L	0.0040	0.0020
T_Uranium	mg/L	0.0031	0.0020
T_Vanadium	mg/L	0.00058	0.00033
T_Zinc	mg/L	0.12	0.069
D_Aluminum	mg/L	0.25	0.067
D_Iron	mg/L	0.63	0.41
Cyanide_T	mg/L	0.16	0.093
Cyanide_WAD	mg/L	0.0081	0.0052

Note: TDS = total dissolved solids; TSS = total suspended solids; T = total; D = dissolved; WAD = weak acid dissociable; mg/L = milligram per litre; mS/cm = microSiemens per centimetre

At post-closure (**Figure 5.3.6-4**), fully reclaimed conditions apply to TSF Site D. Cover reclamation for TSF Site D will include a combination of OVB and oxide tailings (derived from the LGO stockpile). The OVB layer will extend over the full footprint of tailings and waste rock; this will provide an effective means to physically and chemically isolate the surface water system from underlying waste material. In this design, all transition/sulphide tailings will remain below the final water table elevation (Lorax, 2013b).

Vertical downward hydraulic gradients will drive the downward advection of seepage towards the base of the TSF impoundment and towards the embankment drain. Within the saturated mass of tailings and waste rock, pore water chemistry will become increasingly governed by post-depositional reactions with respect to pH- and redox-dependant solubility controls. Based on water balance considerations and taking into account the saturated water volume of the combined tailings and waste rock, a hydraulic residence time of approximately 50 years was estimated for one pore volume of the saturated pore spaces in the TSF. This implies that the supernatant-related signature may persist for at least several decades. In this context, the supernatant signature applies to major ions only (e.g., SO_4, Na, Ca, and K). For trace elements that exhibit strongly non-conservative behaviour (e.g., Cd, Cu, and Zn), post-depositional reactions will become relevant over much shorter time scales (months to years following burial).

As shown by the MODPATH modelling, seepage discharging to Davidson Creek and Creek 661 from the TSF is predicted to have very long travel times, up to about 7,000 and 1,000 years respectively, before the maximum steady state seepage comprised of TSF constituents is discharged to these locations. This is further illustrated on **Figure 5.3.6-5**, which shows the seepage discharge from each mine source to Creek 661 by year. Over these very long periods, the concentrations of contaminants leaving the TSF and other mine sources in seepage are expected to reduce steadily due to flushing of soluble contaminants within the tailings mass via multiple pore volume exchanges (infiltrating TSF supernatant) during post-closure.



① Progressive reclamation involving placement of wetlands in C Cell and D Cell (closure; years 18-19) will serve as zones of passive bioremediation for cyanide, metals, sulfate, nitrogen and phosphorus. Microbial/biological processes will include metal/nutrient uptake, adsorption, precipitation of secondary phases, particle settling and volatilization (e.g., cyanide, nitrogen, Se, Hg).

② Till/overburden cover (30 cm in thickness) provides physical separation of underlying metal leaching materials from the pond/wetland system, thereby minimizing potential contamination of surface water discharges from the TSF. Cover will effectively curtail the potential for diffusive flux into the water cover from underlying tailings and waste rock.

③ Surface waters that accumulate in D Cell will be pumped to pit lake for first 15 years in closure. When pit fills, water from pit will be routed through the D Cell wetland prior to discharge to the receiving environment downgradient of constructed wetlands.

④ Oxide tailings cover on tailings beaches will serve to physically isolate more reactive transition/sulfide tailings from surface water system. Low permeability overburden/till cover will minimize infiltration into oxide tailings. However, some minor neutral-pH metal leaching associated with oxide tailings may contribute loadings to pond/wetland environment.

⑤ Predominantly vertically-downward hydraulic gradients result in uni-directional downward advection of seepage to base of impoundment.

⑥ Permanently saturated conditions will mitigate the potential for acid generation associated with PAG tailings and waste rock. Some degree of remobilization of trace elements will occur via the redox- and pH-controlled dissolution of tailings and waste rock phases. Attenuation mechanisms associated with suboxic conditions (e.g., selenium reduction, sulfate reduction, metal sulfide precipitation) may also occur within tailings/waste rock porewaters or at the base of the impoundment where reducing conditions may be enhanced through contact with foundation organic materials.

⑦ Seepage from C Cell will primarily report as Foundation Seepage through highly permeable Sand & Gravel Unit, with seepage from C Cell recharging D Cell. During post-closure period, seepage water quality from TSF may be worse than operations due to post-depositional remobilization of tailings and waste rock components (e.g., redox- and pH-controlled processes).

⑧ Attenuation of Cd, Zn and other trace elements will occur along seepage pathways within the underlying natural substrates associated with adsorption and precipitation processes.

⑨ Foundation/shallow seepage will be largely intercepted by seepage cut-off wall constructed as part of D Cell dam. Seepage from D Cell will report primarily as Embankment Drain (<32 L/s) and Foundation Seepage (<23 L/s). During post-closure period, post-depositional processes will exert a progressively greater influence on seepage quality.

⑩ During post-closure about 55 L/s of seepage will report to Davidson Creek.

⑪ Neutral pH metal leaching from NAG5/overburden (minor NAG4) used for construction of D Cell dam will contribute only minor loadings to runoff and shallow seepage system that ultimately reports to a wetland constructed in the ECD.

⑫ Virtually all of the shallow seepage that bypasses the seepage cut off wall at the D Cell dam will recharge the surface drainage up-gradient of the former Environmental Control Dam (ECD), with upward flows controlled by depressurization of surficial sand and gravels. Wetlands will afford passive treatment for the combined seepage flow (~55 L/s) prior to discharge to Davidson Creek. Attenuation of metals can also be expected for seepage waters recharging the wetland system through organic-rich sediments.

⑬ Engineered wetland system of former ECD and water reservoirs will provide secondary polishing for mine-related discharges from TSF prior to entry to Davidson Creek.

⑭ Contingency treatment using Permeable Reactive Barriers and/or wetlands represent enhanced mitigation measures that may be implemented if further passive treatment is required to ensure compliance with water quality objectives in Davidson Creek.

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amec

DWN BY:	MY
CHK'D BY:	MY
DATUM:	N/A
PROJECTION:	N/A
SCALE:	N/A

PROJECT
Blackwater Gold Project

TITLE
Conceptual model for contaminant transport and behaviour in TSF (Closure and Post Closure)

DATE:	January 2014
PROJECT NO:	VE52277
REV. NO.:	A
FIGURE No.	5.3.6-4

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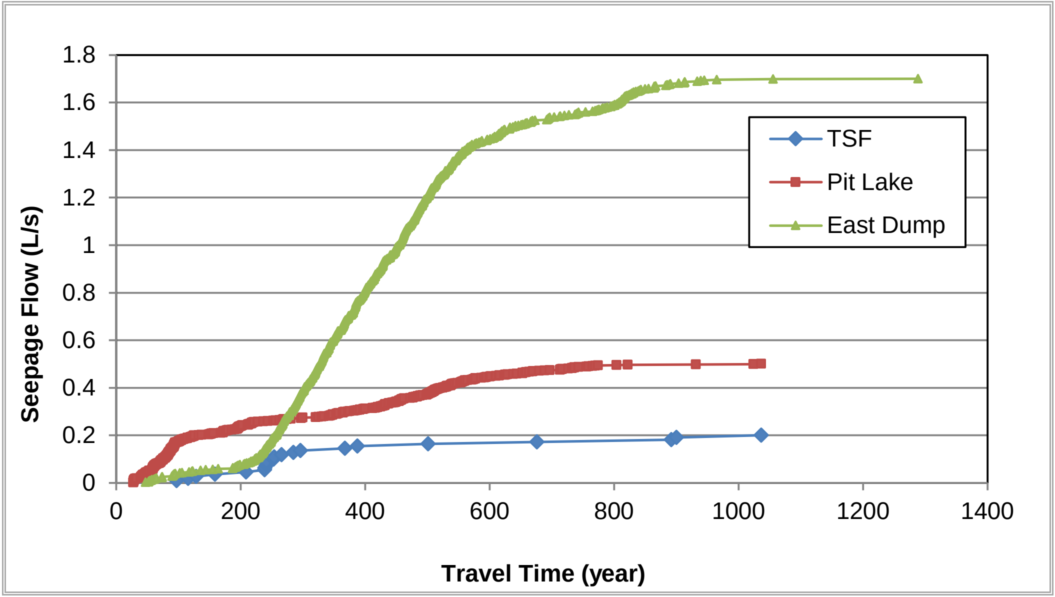


Figure 5.3.6-5: Predicted Seepage Flow by Source to Creek 661

The concentration of contaminants in the seepage reaching the creeks at any time would be related to the evolution of contaminants in the mine source and travel of seepage particles. However, the surface water quality modelling presented in **Section 5.3.3** assumed that the seepage would:

- Be at the full steady state flow rate;
- Not decrease in concentration due to the different origin times of the seepage particles;
- Fully discharge to the receiving waters high up in the watersheds;
- Enter the receiving water at a single point rather than via a dispersed seepage front;
- Not be attenuated in subsurface materials or removed in organic material in the bottom of streams or in multiple constructed and natural wetlands; and
- Not decrease in flow during extreme dry conditions due to water table depression.

Therefore, the effect of seepage discharge on surface water quality presented in **Section 5.3.3** is conservative.

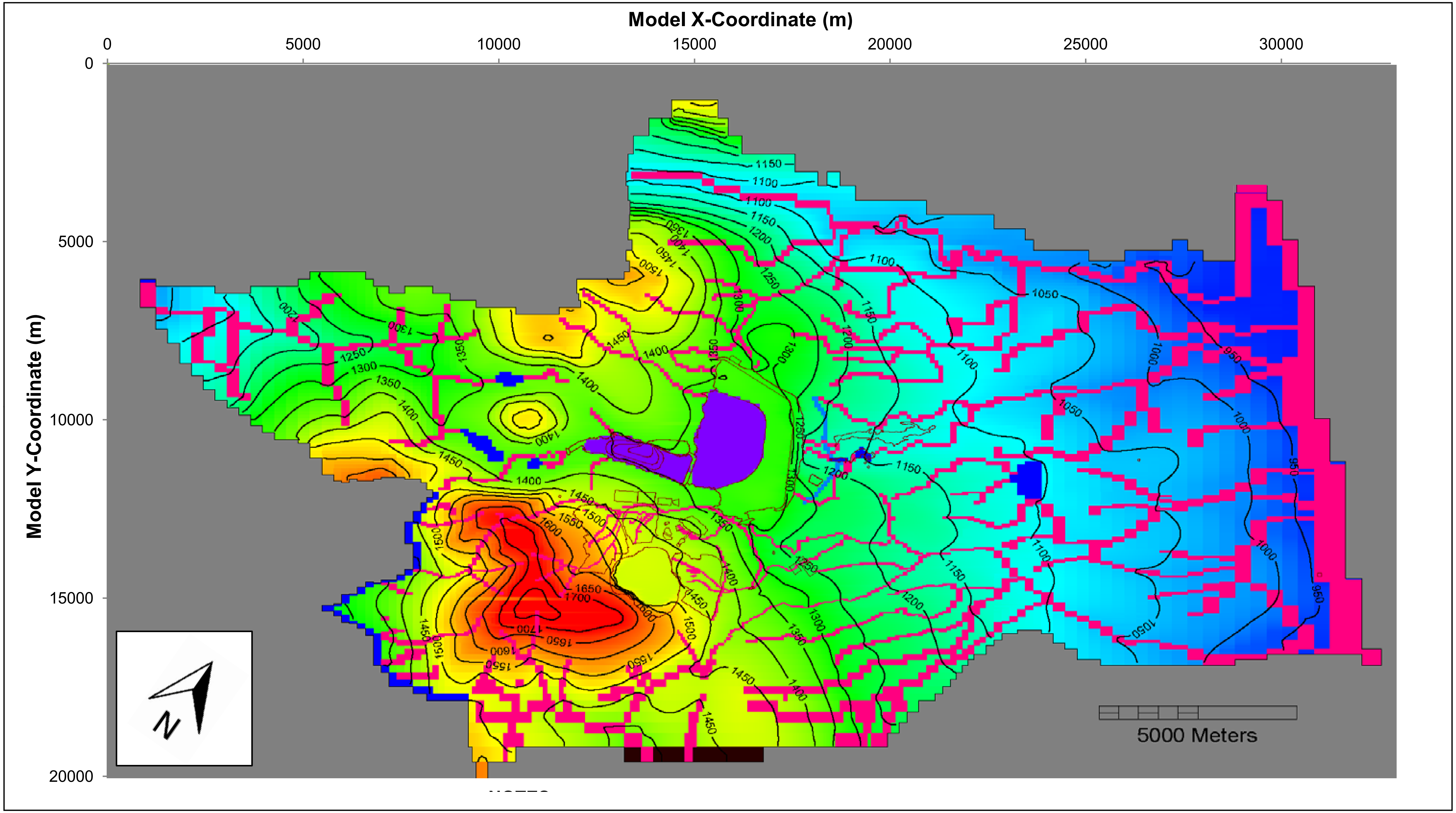
5.3.6.3.2.5 Open Pit

Dewatering will be required to excavate the open pit. The dewatering will result in lowering the water table near the open pit. The MODFLOW model results for pit dewatering during operations indicated that simulated groundwater inflow rates to the open pit were expected to increase from the start of operations through Year 13, as the open pit increased in size. Annual average groundwater inflows to the open pit were estimated to be 50 L/s with a maximum annual inflow rate of approximately 60 L/s.

Upon closure, the open pit will be flooded, creating a pit lake. Model runs estimated the length of time for the pit lake to fill to its spillway elevation at 20 years after the end of operational dewatering. This prediction assumes that water is pumped to the pit lake from TSF Site D at a rate of 362 L/s to assist groundwater inflows, runoff and direct precipitation in rapid pit filling. During closure and after pit filling, groundwater elevations directly surrounding the pit lake are expected to recover to the elevation of the pit lake water surface as shown on **Figure 5.3.6-6**.

The steady state MODFLOW post-closure simulations predict groundwater inflows to the pit lake will be 4.5 L/s when the pit lake will be at its maximum elevation of 1,475 m. Similarly, seepage from the pit lake in post-closure is predicted to be 1.3 L/s. MODFLOW model results indicate that seepage from the pit lake is expected to contribute to the Davidson Creek and Creek 661 watersheds but not to the Blackwater River catchment (**Figure 5.3.6-7**).

A large portion of the relatively limited seepage originating from the pit lake is predicted to discharge to drainages that ultimately report to the TSF, including natural channels upstream of the East Dump drainage ditches (0.4 L/s) and drainages reporting to the TSF Site D (0.3 L/s). Model results indicate seepage to the East Dump drainage ditches is expected to follow shallow flow paths primarily through the OVB. Seepage to Creek 661 (0.5 L/s) is expected to travel though the upper layers of bedrock and reach Creek 661 after a MODFLOW model predicted average travel time of almost 300 years (**Table 5.3.6-4**). A lesser amount of seepage (0.01 L/s) is predicted to discharge to Davidson Creek with a median travel time of 800 years. As with seepage from the TSF, travel times for seepage from the pit lake to receiving streams are very long. Results of the seepage analysis indicate that seepage flow paths originating from the pit lake and the TSF Site D will converge toward each other beneath the TSF spillway and Creek 661 via local groundwater flow paths. Modelling indicates that seepage along these local flow paths will be forced upward and will discharge to the TSF spillway and Creek 661 where the flow paths converge. Seepage flow paths originating from the pit lake are predicted to travel to Davidson Creek via deeper (regional) groundwater flow paths within the competent bedrock.



Water Table Elevation (masl)

1800
1700
1600
1500
1400
1300
1200
1100
1000
900

Boundary Conditions

- 🟦 Constant Head
- 🟪 River
- 🟥 Drain
- ⬛ GHB
- ▏ Flow Barrier
- ⬜ No Flow

NOTES:

1. THE CONTOUR LINES SHOWN ABOVE ARE OF MODEL SIMULATED WATER TABLE ELEVATION (masl).

2.THE ECD SYSTEM (DRAIN BOUNDARY CONDITIONS) ARE HIGHLIGHTED IN LIGHT BLUE DOWNSTREAM FROM THE MAIN TSF EMBANKMENT.

3. THE ULTIMATE PIT LAKE ELEVATION ASSIGNED TO THE MODEL WAS 1475 masl.

3. EMABKMENT DRAINS ARE NOT ASSIGNED WITHIN THE FOOTPRINTS OF THE TSF EMBANKMENTS.

Reference
Figure from Knight Piésold Numerical Groundwater Modelling Report (VA101-457/6-13, Revision 0) dated 16 January, 2013.

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DATUM:	N/A
PROJECTION:	N/A
SCALE:	N/A

PROJECT

Blackwater Gold Project

TITLE

Post-Closure Model
Groundwater Elevation Map

DATE:	January 2014
PROJECT NO:	VE52277
REV. NO.:	A
FIGURE No.	5.3.6-6

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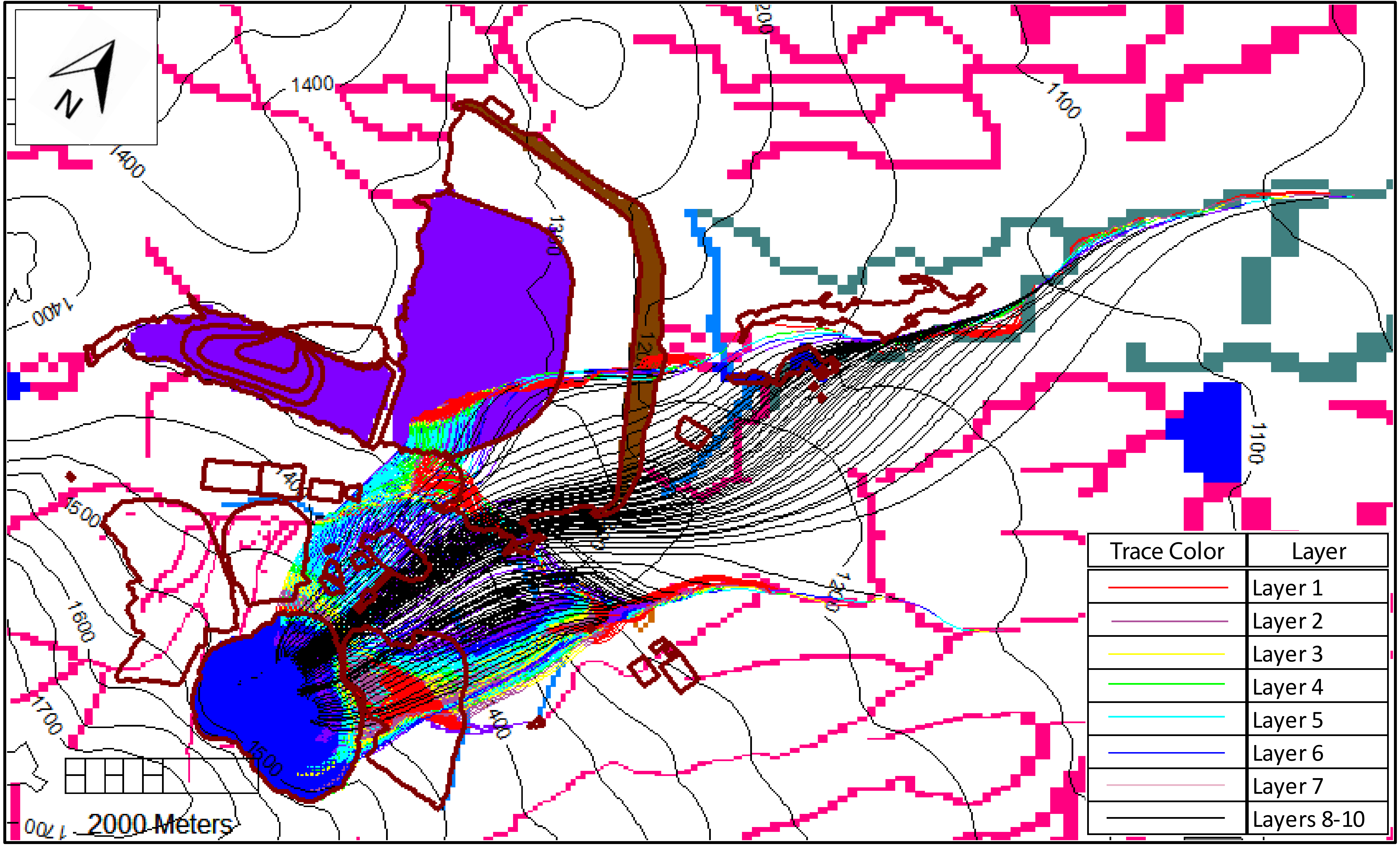

Notes:
Particle Traces are coloured according to the model layer it is travelling in.
Particles were inserted into layers 1 through 8.
The contours shown above are of water table elevation (masl).

Figure from Knight Piésold Numerical Groundwater Modelling Report (VA101-457/6-13, Revision 0)
dated 16 January, 2013 (Appendix D).

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DATUM: N/A
PROJECTION: N/A
SCALE: N/A

PROJECT
Blackwater Gold Project

TITLE
Post Closure Pit Lake Model
Particle Track Analysis

DATE: January 2014
PROJECT NO: VE52277
REV. NO.: A
FIGURE No. 5.3.6-7

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Table 5.3.6-4: Results of MODFLOW MODPATH Particle Tracking and Advective Travel Times Pit Lake

Facility	MODPATH/Seepage Discharge Location	Simulated Seepage Flux Rates Discharge (L/s)	Discharge (% of Total)	Travel Time to Discharge Location (Years) Average	Median	Minimum	Maximum
Davidson Creek		0.01	1	809	781	424	1,334
Creek 661		0.5	42	290	218	28	1,037
TSF Main Embankment Drains		0.01	1	226	120	78	711
TSF Spillway		0.01	1	24	25	21	26
ECD System		0.03	2	364	279	122	1,313
Natural Channel Reporting to TSF		0.3	22	202	150	51	2,113
Channel to East Dump Drainage Ditches		0.4	31	103	102	12	227
Total Seepage From Pit Lake		**1.3**	**100**	**-**	**-**	**-**	**-**

Note: L/s = litres per second; % = percent; TSF = tailings storage facility; ECD = environmental control dam

The Creek 661 secondary seepage front originating from deeper particles enters the creek up to approximately 2,000 m downstream of the East Dump collection ditch. Virtually all the pit lake seepage front into Davidson Creek is upstream of the proposed compliance point at the mine access road crossing of Davidson Creek and within the area of the planned and contingency wetland treatment systems. A minor volume of seepage particles is predicted to enter Davidson Creek further down the watershed. Potential effects from pit lake seepage on near surface groundwater quality will be restricted to the mine site. The other seepage particles travel through deeper isolated subsurface layers before upwelling into the surficial glaciofluvial layer at the seepage fronts. The effect of this upwelling seepage is included in surface water quality assessment described in **Section 5.3.3**. Seepage from the pit lake is predicted to enter glaciofluvial deposits in Davidson Creek valley and Creek 661. Seepage is predicted to enter the glaciofluvial deposits after flowing through bedrock. Seepage into glaciofluvial deposits along Davidson Creek is predicted to travel a limited distance within the shallow permeable deposit before discharging to the creek.

In the seepage analysis, a minor amount of seepage from the pit lake is predicted to enter Davidson Creek downstream of the compliance point at the mine access road crossing of Davidson Creek and the contingency wetland treatment systems. Seepage into glaciofluvial deposits along Creek 661 is predicted to travel up to a distance of 1,000 m within the glaciofluvial deposits before discharging to the creek. This seepage is predicted to flow from the pit lake through deeper flow paths and discharge to Creek 661 up to a distance of approximately 2,000 m downstream of the East Dump collection ditch.

For the pit geochemical water quality study (AMEC, 2013), a block model indicates the overall zonation from PAG material towards the centre of the ore body with an increase in NAG material towards the periphery (**Figure 5.3.6-8** and **Figure 5.3.6-9**).

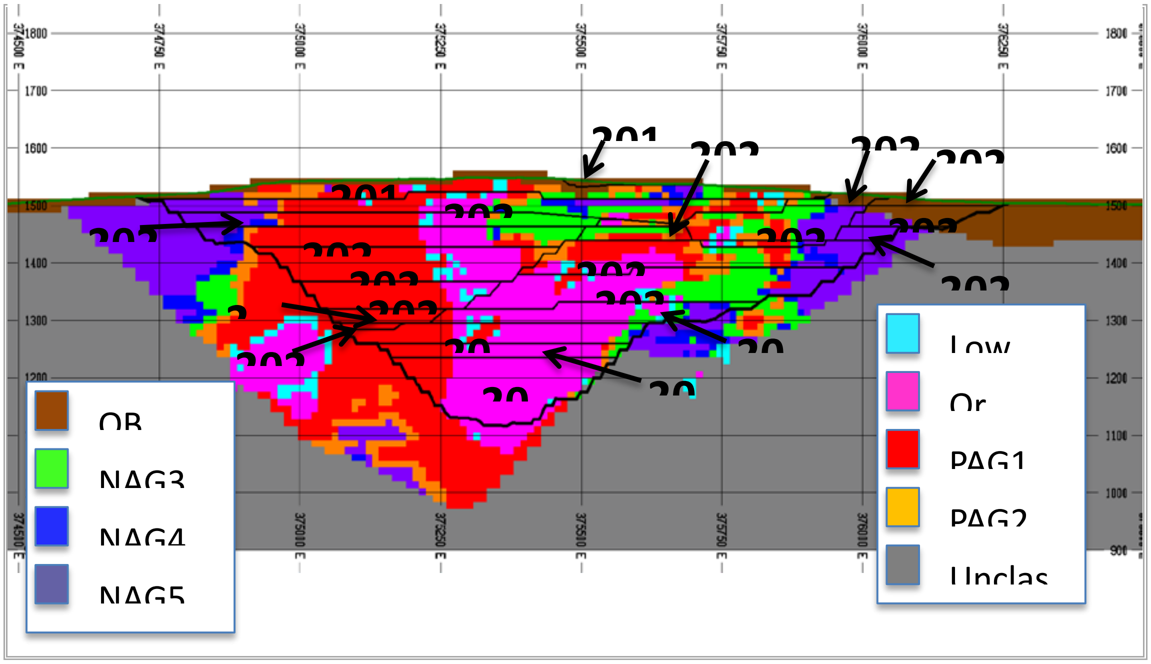


Figure 5.3.6-8: ***Block Model Cross Section showing ARD Classification***

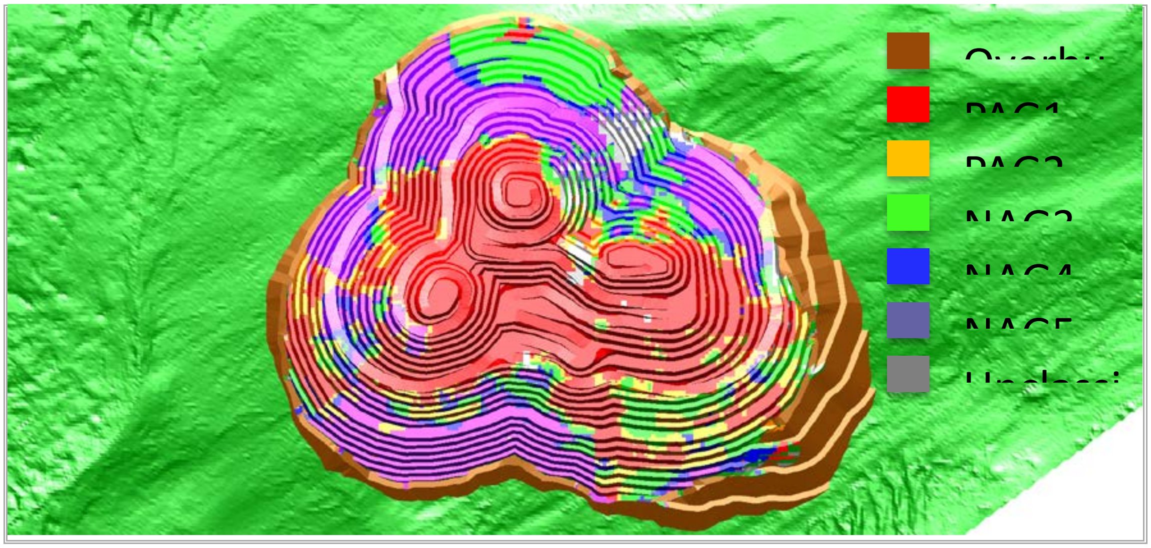


Figure 5.3.6-9: ***Block Model – ARD Classification of Ultimate Pit Walls***

The block model was also used to examine the waste rock types exposed in the open pit after the pit lake is flooded (**Figure 5.3.6-10**). The flooding of the open pit will reduce the exposed area of PAG waste rock from 32% of the ultimate pit walls to 16%.

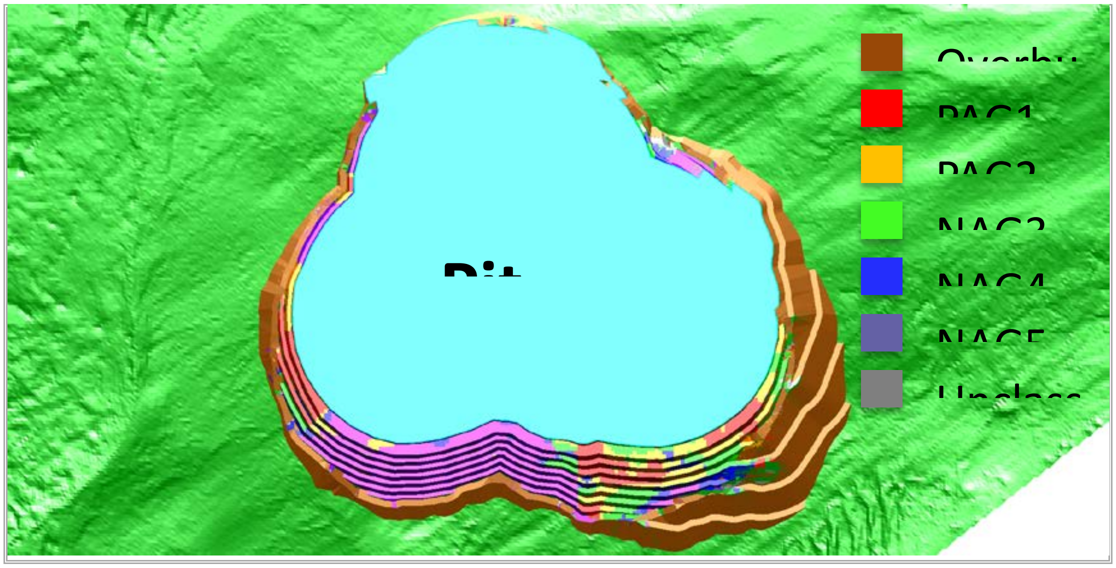


Figure 5.3.6-10:   Block Model – ARD Classification of High Wall after Flooding of Open Pit

Precipitation on the upper pit walls and runoff from the surrounding slopes across the pit walls will be in contact with mineralized rock. After closure, the pit lake will flood much of the pit walls and floors, thereby reducing the rock surface area exposed to weathering and consequent metal leaching.

Water quality and the proportional volume from each water inflow to the pit was input to a spreadsheet based mixing model to estimate the resulting pH of pit lake water. Based on this modelling, the average pH is estimated to be approximately 6.8 during operations. A pH of 8.2 was estimated for pit lake water during pit closure. A higher pH was predicted during closure due to the relatively high pH assumed for the TSF pond water; the long-term post-closure pH will be controlled by runoff from exposed pit walls and is estimated to be alkaline.

The contribution from each source to the drainage chemistry of the pit lake is shown on **Figure 5.3.6-11** and **Figure 5.3.6-12** for zinc and cadmium (AMEC, 2013). These figures show the mine operating phase from Years 1 through 17, the pit filling period to Year 35, and after filling. The impact of the TSF inflows on the pit lake water quality during closure can be seen. Once the pit lake fills, the concentrations will be controlled by runoff in contact with exposed wall rock and OVB. Concentrations were predicted to decline or stabilize due to the high proportion of OVB and NAG rock in the remaining exposed high wall (AMEC, 2013).

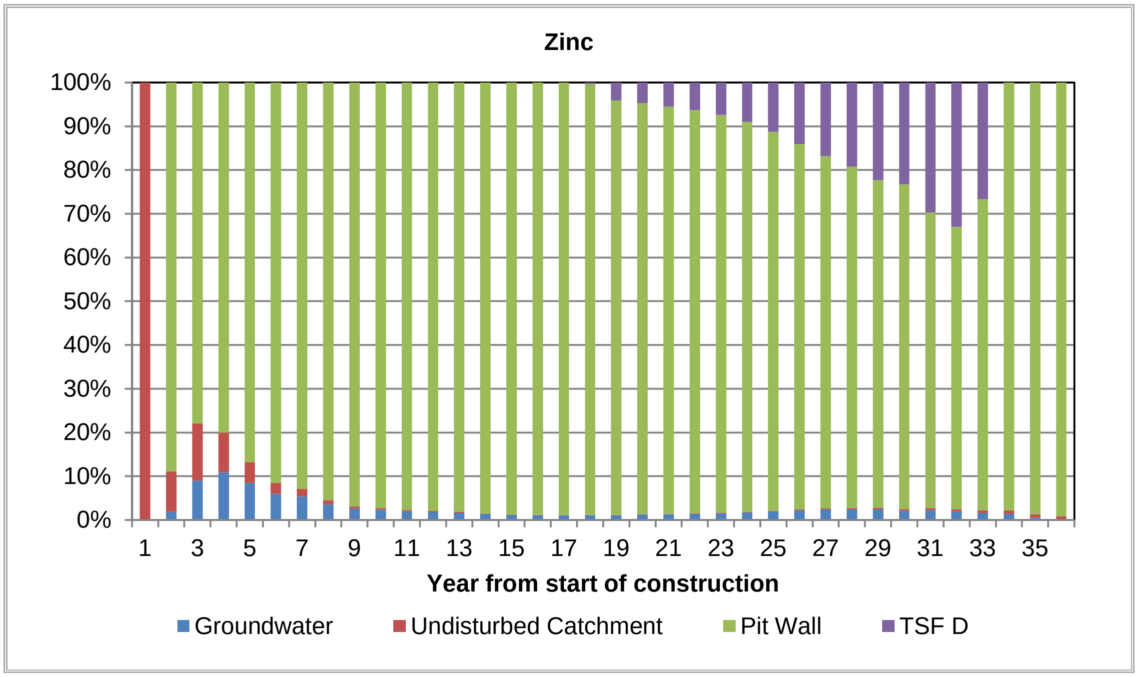


Figure 5.3.6-11: Relative Zinc Load Contributions to Pit Lake Water Quality by Source

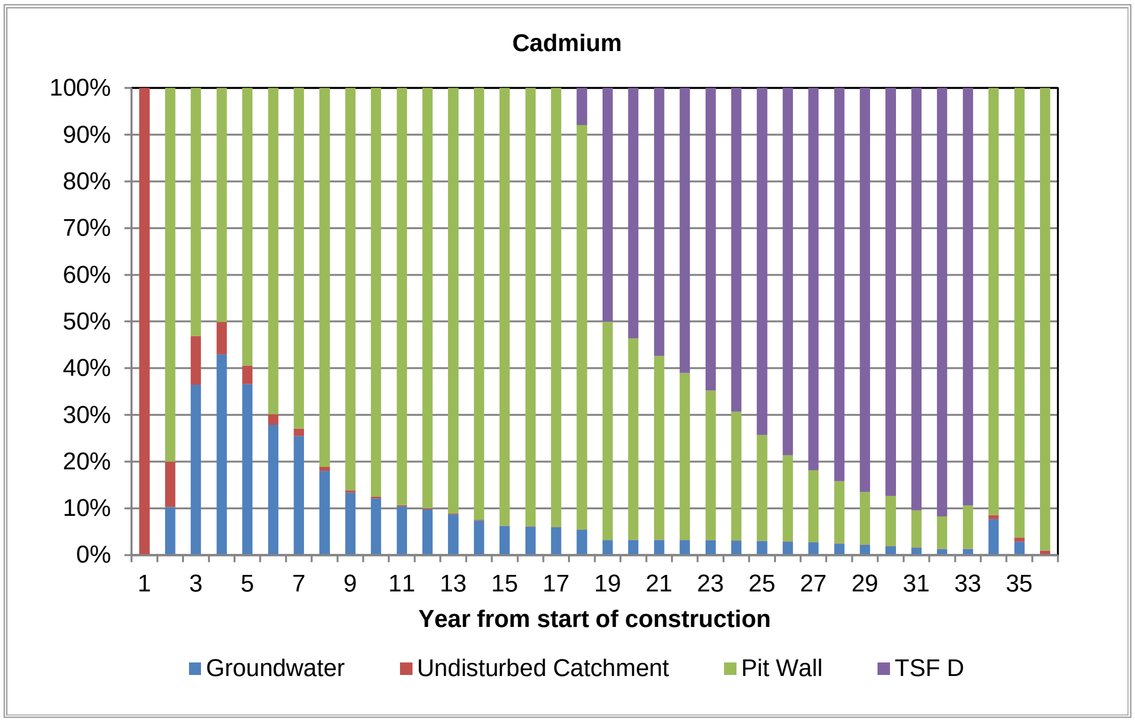


Figure 5.3.6-12: Relative Cadmium Load Contributions to Pit Lake Water Quality by Source

Over long periods of time (i.e., decades), concentrations of elements in seepage are expected to decrease from peak levels. For example, sulphide oxidation rates will decrease over multiple decades to century time scales due to the removal of surficial sulphide minerals and longer path lengths for oxygen diffusion. This is particularly applicable to exposed pit walls, as PAG exposures are limited (both aerially and near surface). Therefore, pit lake quality and resulting seepage from the lake is expected to improve over the long term.

5.3.6.3.2.6 West Dump

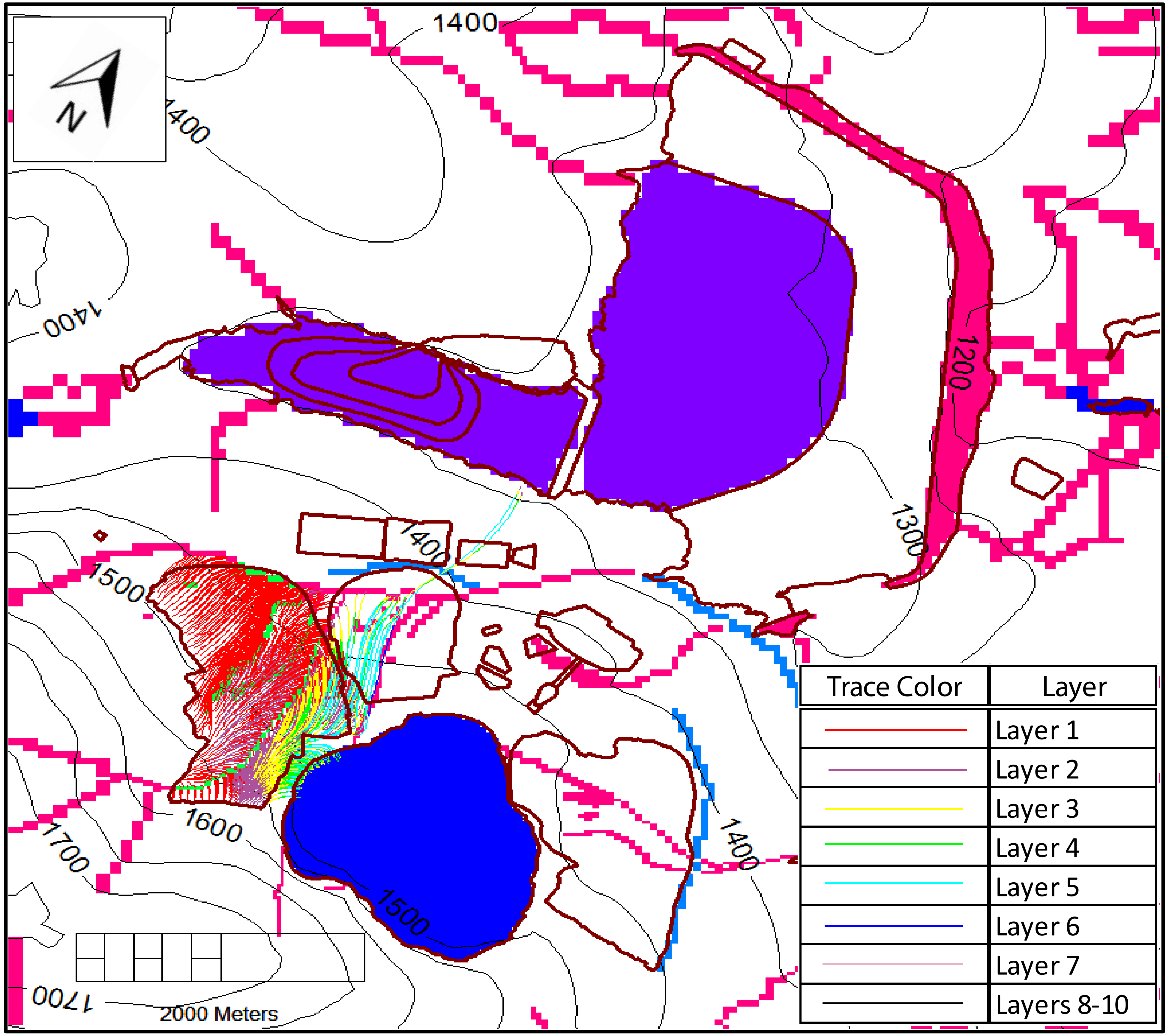
NAG waste rock and OVB will be combined and placed in the West Dump. Engineered drainage ditches will be constructed down slope of the West Dump to collect surface runoff and shallow groundwater seepage from the facility. Drainage ditches will direct water to the TSF. Results of the MODFLOW seepage analysis indicate that all seepage originating from the West Dump is predicted to discharge to downstream mine facilities or drainages leading to mine facilities. The total seepage rate of 3.3 L/s is predicted to discharge primarily to springs within the footprint of the waste rock dump and to the drainage ditch north of the West Dump. This seepage will be collected in drainages that flow to the TSF Site D with a MODFLOW model predicted median travel time of 160 years (**Table 5.3.6-5**). A small portion of seepage is predicted to be captured by the pit lake (0.1 L/s), and a trace amount of seepage is predicted to discharge to TSF Site C. **Figure 5.3.6-13** shows the MODFLOW predicted travel pathways for particles representing seepage originating from the West Dump.

The effect of the West Dump seepage on TSF supernatant quality was included in the surface water quality assessment described in **Section 5.3.3**.

Table 5.3.6-5: Results of MODFLOW MODPATH Particle Tracking and Advective Travel Time West Waste Rock Dump

Facility	MODPATH/Seepage Discharge Location	Simulated Seepage Flux Rates		Travel Time to Discharge Location (years)			
		Discharge (L/s)	**Discharge (% of Total)**	**Average**	**Median**	**Minimum**	**Maximum**
Springs within West Dump Footprint		0.7	22	55	17	0.1	336
Natural Channel Reporting to TSF		2.4	74	198	160	0.5	558
TSF Site C Pond		<0.1	<1	-	-	159	-
Pit Lake		0.1	4	18	13	0.2	59
Total Seepage From West Waste Rock Dump		**3.3**	**100**	**-**	**-**	**-**	**-**

Note: L/s = litres per second; % = percent; TSF = tailings storage facility



Notes:
Particle traces are coloured according tot he model layer it is travelling in.
The contours shown above are of water table elevation (masl).
Figure based on Knight Pieshold drawing January 2014

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DATUM: N/A
PROJECTION: N/A
SCALE: N/A

PROJECT
Blackwater Gold Project

TITLE
West Dump Modflow MODPATH Particle Analysis

DATE: January 2014
PROJECT NO: VE52277
REV. NO.: A
FIGURE No. 5.3.6-13

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5.3.6.3.2.7 East Dump

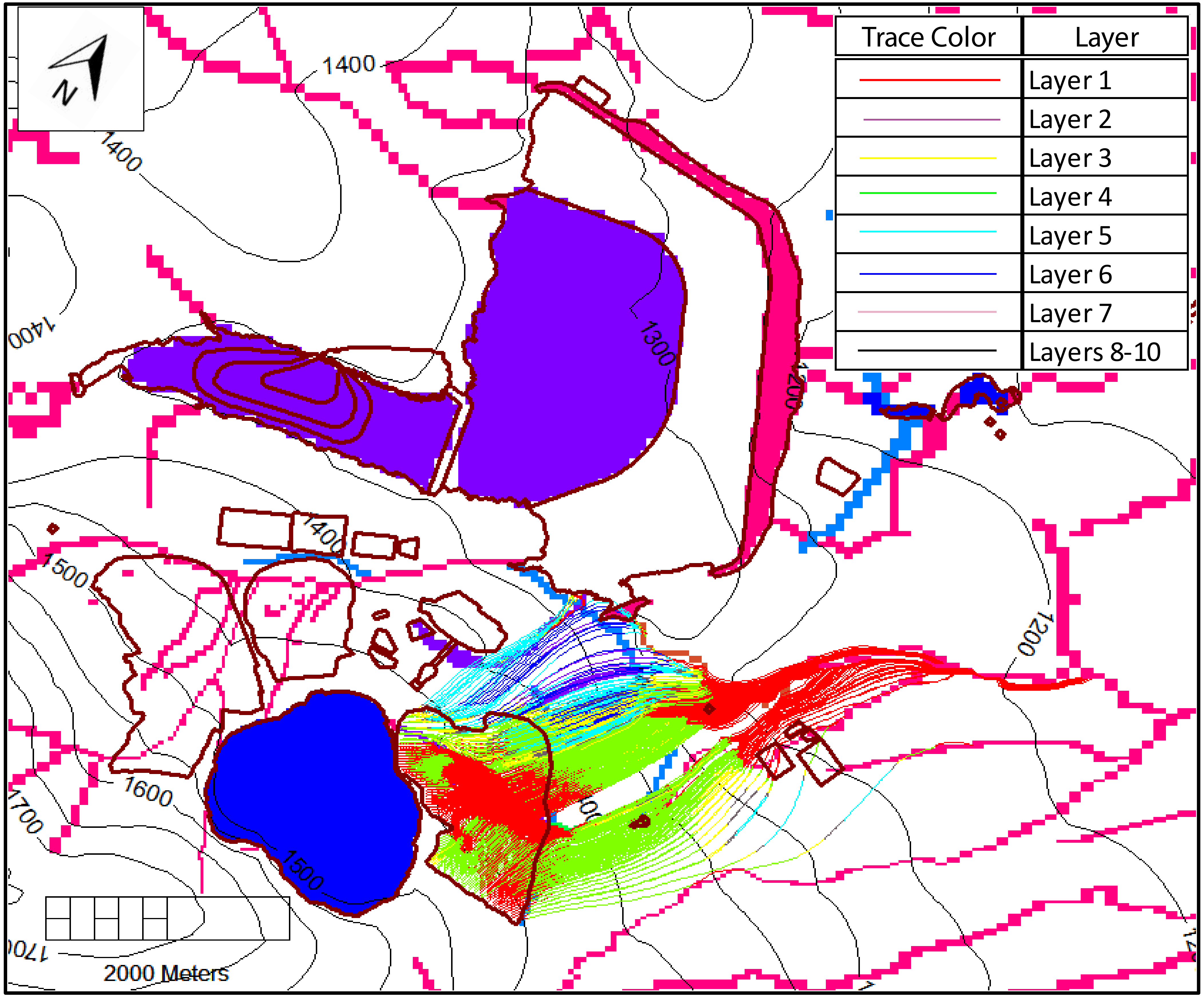
NAG5 waste rock and OVB will be combined and placed in the East Dump. Engineered drainage ditches will be constructed down slope of the East Dump to collect surface runoff and shallow groundwater seepage from facility. Drainage ditches will direct water to the TSF. Seepage originating from the East Dump is predicted to be approximately 3 L/s, based on the MODFLOW model results. Approximately 1.7 L/s of seepage from the East Dump is predicted to discharge primarily to Creek 661 along flow paths with travels times ranging from 47 to more than 1,000 years (with a median travel time of more than 400 years) (**Table 5.3.6-6** and **Figure 5.3.6-14**). Particle traces indicate that seepage is predicted to travel to Creek 661 along local groundwater flow paths in the OVB and shallow bedrock. Approximately 1.3 L/s of the seepage is predicted to discharge to springs within the East Dump footprint, engineered drainage ditches, and natural channels that will be routed to TSF Site D. A trace proportion of seepage (<1%) is predicted to discharge to the TSF spillway. Seepage discharging to Creek 661 will flow through natural wetlands located downstream from these seepage entry points into Creek 661.

Seepage travelling along deeper groundwater flow paths is predicted to discharge to Creek 661 approximately 2,000 m downstream of the East Dump collection ditch. The effect of this upwelling seepage on Creek 661 water quality is included in the surface water quality assessment described in **Section 5.3.3**. The effect of East Dump seepage on TSF supernatant quality was included in the **Section 5.3.3** assessment.

Table 5.3.6-6: Results of MODFLOW MODPATH Particle Tracking and Advective Travel Time East Waste Rock Dump

		Simulated Seepage Flux Rates		Travel Time to Discharge Location (years)			
Facility	**MODPATH/Seepage Discharge Location**	**Discharge (L/s)**	**Discharge (% of Total)**	**Average**	**Median**	**Minimum**	**Maximum**
Creek 661		1.7	56	424	405	47	1,288
Springs within East Dump Footprint		0.4	13	32	23	0.5	123
Channel to East Dump Drainage Ditches		0.7	22	109	88	2	297
Natural Channel Reporting to TSF		0.05	2	27	27	21	33
Lower East Dump Drainage Ditch		0.2	6	448	482	328	544
TSF Spillway		0.04	1	38	36	23	63
Total Seepage From East Waste Rock Dump		**3.0**	**100**	**-**	**-**	**-**	**-**

Note: L/s = litres per second; % = percent; TSF = tailings storage facility



Notes:
Particle traces are coloured according to the model layer it is travelling in.
Contours indicate water table elevation (masl).

Figure from Knight Piésold Numerical Groundwater Modelling Report (VA101-457/6-13, Revision 0)
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SCALE: N/A

PROJECT
Blackwater Gold Project

TITLE
East Dump Modflow MODPATH
Particle Analysis

DATE: January 2014
PROJECT NO: VE52277
REV. NO.: A
FIGURE No. 5.3.6-14

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For an indication of potential seepage quality under the East Dump and West Dump, geochemistry model results for dump drainage show annual drainage quality for acidity, alkalinity, sulphate, zinc, cadmium, and iron (**Table 5.3.6-7**). This annual geochemistry model does not reflect the actual groundwater quality; rather, it shows the potential seepage water quality from the dumps. The drainage results show that the seepage is predicted to have greater concentrations of alkalinity compared to acidity and therefore the pH will be neutral to slightly alkaline in agreement with laboratory tested NAG waste rock. The zinc, cadmium, and iron concentrations are generally predicted to increase slightly during operations and decrease towards the end of operations; during closure, the concentrations were conservatively set to constant values.

The post-closure concentrations do not include the effects of later stage oxidation of sulphide minerals, which is expected to reduce concentrations. Over long periods of time (i.e., decades), concentrations of constituents in seepage are expected to decrease from peak levels. Sulphide oxidation rates will decrease over multiple decades to century time scales due to the removal of surficial sulphide minerals and longer path lengths for oxygen diffusion. This is applicable to NAG waste rock dumps; therefore, over the long term, seepage from the East and West Dumps is expected to improve from the values shown in **Table 5.3.6-7**. Nevertheless these values were used to predict TSF supernatant quality in **Section 5.3.3**.

Table 5.3.6-7: Predicted Annual Drainage Chemistry from Combined East and West Dumps

Year	Zn (mg/L)	Cd (mg/L)	Fe (mg/L)	Acidity (mg/L)	Alkalinity (mg/L)	Sulphate (mg/L)
Year 1	0.005	0.0002	0.08	3.4	54	29
Year 2	0.01	0.0005	0.12	7.3	99	69
Year 3	0.014	0.0008	0.15	11	138	105
Year 4	0.011	0.0006	0.13	8.2	110	78
Year 5	0.01	0.0006	0.12	7.7	103	73
Year 6	0.012	0.0007	0.13	9.2	120	89
Year 7	0.011	0.0006	0.13	8.3	110	79
Year 8	0.01	0.0005	0.12	7.4	101	70
Year 9	0.012	0.0007	0.13	8.8	115	85
Year 10	0.015	0.0008	0.15	11.2	142	109
Year 11	0.014	0.0008	0.15	10.3	134	100
Year 12	0.013	0.0007	0.14	9.5	125	92
Year 13	0.012	0.0007	0.13	8.9	118	85
Year 14	0.011	0.0006	0.13	8.3	111	79
Year 15	0.01	0.0006	0.12	7.7	104	73
Year 16	0.01	0.0005	0.12	7.3	98	69
Year 17	0.009	0.0005	0.11	6.9	93	65
Closure Year 1	0.009	0.0005	0.11	6.6	91	62
Closure Year 10	0.009	0.0005	0.11	6.6	91	62
Closure Year 25	0.009	0.0005	0.11	6.6	91	62
Closure Year 50	0.009	0.0005	0.11	6.6	91	62

Note: Zn = zinc; Cd = cadmium; Fe = iron; mg/L = milligrams per litre

Subsequently, a separate model was constructed to predict seepage quality for the East Dump only (**Table 5.3.6-8**). These values were used in **Section 5.3.3** to predict the effect of seepage discharge from the East Dump on Creek 661 surface water quality.

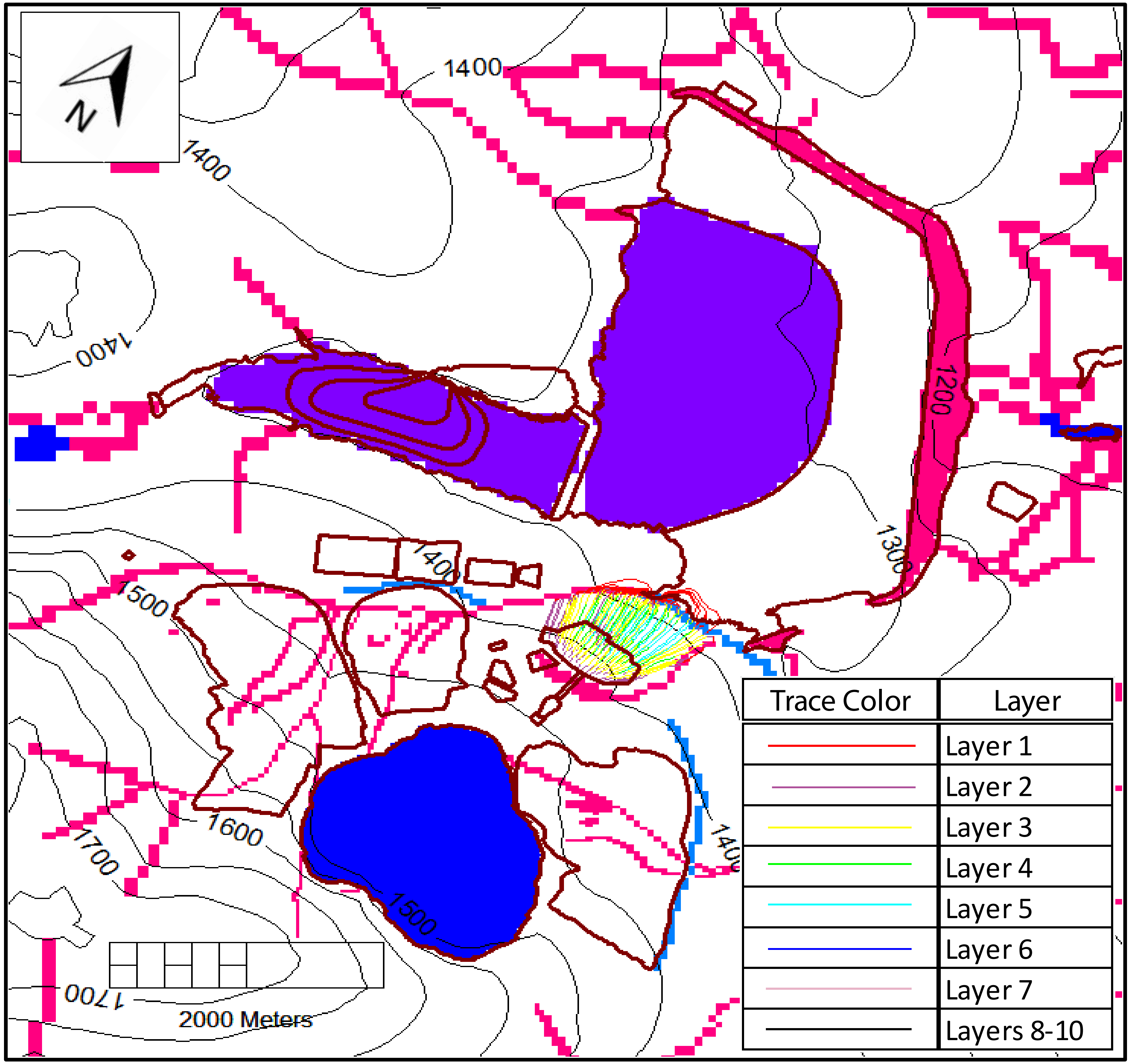
Table 5.3.6-8: Predicted East Dump Only Seepage Quality

Parameter	Unit	East Dump Seepage	Parameter	Unit	East Dump Seepage
Acidity	mg/L $CaCO_3$	0.1	Phosphorus	mg/L	0.039
Sulphate	mg/L	9.6	Potassium	mg/L	12.1
Aluminum	mg/L	0.017	Selenium	mg/L	0.0006
Antimony	mg/L	0.0106	Silicon	mg/L	6.32
Arsenic	mg/L	0.0035	Silver	mg/L	0.00005
Barium	mg/L	0.015	Sodium	mg/L	5.2
Beryllium	mg/L	0.00011	Strontium	mg/L	0.156
Boron	mg/L	0.0064	Thallium	mg/L	0.00006
Cadmium	mg/L	0.00074	Tin	mg/L	0.0030
Calcium	mg/L	13.0	Titanium	mg/L	0.0019
Chromium	mg/L	0.0006	Uranium	mg/L	0.0006
Cobalt	mg/L	0.0108	Vanadium	mg/L	0.0003
Copper	mg/L	0.0030	Zinc	mg/L	0.042
Iron	mg/L	0.13	Ammonia	mg/L	0.041
Lead	mg/L	0.0016	Nitrate	mg/L	0.108
Lithium	mg/L	0.0030	Nitrite	mg/L	0.007
Magnesium	mg/L	2.7	Total Cyanide	mg/L	0.0227
Manganese	mg/L	0.101	WAD Cyanide	mg/L	0.0013
Mercury	mg/L	0.000009	Cyanate	mg/L	0.001
Molybdenum	mg/L	0.019	Thiocyanate	mg/L	0.001
Nickel	mg/L	0.0013			

Note: Values for cyanide species are an artefact of the modelling and are conservative since there is no cyanide source for the East Dump seepage;
WAD = weak acid dissociable; mg/L = milligrams per litre

5.3.6.3.2.8 Process Plant Site

Storage and process tanks within the process plant will have secondary containment. However, seepage from the plant site might contain some process chemicals or petroleum products originating from spills. All seepage from the footprint of the plant site is predicted to discharge to engineered drainage ditches and natural channels that flow to TSF Site D (**Figure 5.3.6-15**). Seepage originating from the footprint of the plant site is predicted to be approximately 2.4 L/s based on the MODFLOW model with an average travel time of 40 years (**Table 5.3.6-9**). The potential effects of storage of chemical tanks on plant site seepage on near surface groundwater quality are restricted to the mine site.



Notes:
Particle traces are coloured according to the model layer it is travelling in.

Figure from Knight Piésold Numerical Groundwater Modelling Report (VA101-457/6-13, Revision 0) dated 16 January, 2013 (Appendix D).

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CHK'D BY:	MY
DATUM:	N/A
PROJECTION:	N/A
SCALE:	N/A
PROJECT	Blackwater Gold Project
TITLE	Plant Site MODFLOW MODPATH Particle Analysis
DATE:	January 2014
PROJECT NO:	VE52277
REV. NO.:	A
FIGURE No.	5.3.6-15

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Table 5.3.6-9: Results of MODFLOW MODPATH Particle Tracking and Advective Travel Time Plant Site

Facility	MODPATH/Seepage Discharge Location	Simulated Seepage Flux Rates		Travel Time to Discharge Location (years)			
		Discharge (L/s)	**Discharge (% of Total)**	**Average**	**Median**	**Minimum**	**Maximum**
Natural Channel Reporting to TSF		0.5	22	72	77	26	102
Lower East Dump Drainage Ditch		1.9	78	38	36	11	92
Total Seepage From Plant Site		**2.4**	**100**	-	-	-	-

Note: L/s = litres per second; % = percent; TSF = Tailings Storage Facility

5.3.6.3.2.9 Low Grade Ore Stockpile

A LGO stockpile will be established between the East and West Dumps. The LGO will be placed on an engineered liner and seepage collection system as the drainage is expected to be acidic with elevated metals. Engineered drainage ditches will be constructed down slope of the LGO stockpile to collect surface runoff and shallow groundwater seepage from facilities. Drainage ditches will direct water to the TSF. This stockpile is only present during mining operations and will be reclaimed and processed in the mill by Year 17.

Geochemical modelling was conducted to estimate the potential quality of seepage originating from the LGO stockpile. Although pH was not modelled, there is an excess of acidity compared to alkalinity and pH is expected to be acidic based on laboratory testing. The predicted unequilibrated concentration of zinc ranged from 364 mg/L to 876 mg/L, whereas cadmium ranged from 2.8 mg/L to 6.8 mg/L, as shown in **Table 5.3.6-10** below. Overall, drainage from the LGO stockpile is expected to be acidic with elevated metals. During operations, all drainage will be collected and neutralized with lime prior to discharge to the TSF in order to ensure low metal concentrations in the TSF supernatant and seepage. There will be no LGO stockpile at the end of operations, and the LGO site will be monitored and remediated, if required. Any very limited seepage from the LGO stockpile that might bypass the liner and collection systems would flow by gravity to the TSF where it would be neutralized and mix with the much larger volume of alkaline TSF supernatant.

Table 5.3.6-10: Annual Predicted Low Grade Ore Stockpile Drainage Quality during Operations

Year	Zn (mg/L)	Cd (mg/L)	Fe (mg/L)	Acidity (mg/L)	Alkalinity (mg/L)	Sulphate (mg/L)
Pre-prod	0	0	0	0	0	0
Year 1	668	5.2	157	2,547	20	2,527
Year 2	540	4.2	127	2,059	16	2,043
Year 3	876	6.8	206	3,340	26	3,314
Year 4	690	5.3	162	2,632	21	2,612
Year 5	534	4.1	126	2,038	16	2,022
Year 6	436	3.4	102	1,663	13	1,650
Year 7	364	2.8	85	1,387	11	1,376
Year 8	433	3.3	102	1,653	13	1,640
Year 9	423	3.3	99	1,613	13	1,600
Year 10	523	4	123	1,994	16	1,979
Year 11	549	4.2	129	2,095	17	2,078
Year 12	584	4.5	137	2,227	18	2,210
Year 13	639	4.9	150	2,438	19	2,419
Year 14	818	6.3	192	3,120	25	3,095
Year 15	763	5.9	179	2,911	23	2,888
Year 16	640	4.9	151	2,442	19	2,422

Note: Zn = zinc; Cd = cadmium; Fe = iron; mg/L = milligrams per litre

5.3.6.3.2.10 Temporary Ore Stockpile

Geochemical modelling was conducted to estimate the potential quality of seepage originating from the temporary ore stockpile. Although pH was not modelled, an excess of acidity compared to alkalinity is predicted, suggesting the stockpile drainage will be acidic. The predicted zinc concentrations ranged from 34 mg/L to 1,093 mg/L. Cadmium concentrations ranged from 0.15 mg/L to 5.0 mg/L. Iron concentrations in the seepage ranged from 13 mg/L to 422 mg/L. Overall, drainage from the temporary ore stockpile is expected to be acidic with elevated metals. The temporary ore stockpile will be placed on an engineered liner with drainage collection system. During operations, all drainage will be collected and neutralized with lime prior to discharge to the TSF in order to ensure low metal concentrations in the TSF supernatant and seepage. Any very limited seepage from the temporary ore stockpile that will bypass the liner and collection systems will flow to the TSF where it will be neutralized by the much larger volume of alkaline TSF supernatant.

The temporary ore stockpile will be limited in size. The stockpile will be rotated during mine operations so that ore will have a relatively short residence time and limited potential to generate ML/ARD. There will be no temporary ore stockpile at the end of operations, and the site will be monitored and remediated, if required.

5.3.6.3.2.11 Attenuation Potential along Seepage Flow Paths

The sorption characteristics of subsurface units that will be encountered along TSF, pit lake, and East and West Dumps are dependent on the relative distribution of geologic units, the overall site hydrostratigraphy, and subsurface pH controls such as naturally occurring carbonates.

The stratigraphy underlying the central part of the TSF through Davidson Creek valley follows a succession where the sand and gravel overlies glacial till overlies the weathered bedrock. The relative thickness of these units, their hydraulic conductivity, and the residence time of seepage within them will influence the extent of sorption that can occur and thus the potential for attenuation of zinc and cadmium and other elements. The results of sorption experiments suggested that all three subsurface units share a relatively similar degree of metal attenuation capacity.

The sand and gravel unit has the highest hydraulic conductivity. However, the presence of a cut-off wall under the TSF Site D Dam will cause seepage to flow through glacial till. Carbonate minerals present in the till and sand and gravel units are expected to impart some buffering and constituent reduction. An increase in pH is expected to enhance metal sorption potential through increasing metal affinity for particle surfaces as well as through pH-dependent precipitation reactions (Lorax, 2013). **Table 5.3.6-11** provides an estimate of the mass of zinc and cadmium that can be sorbed to weathered bedrock, basal till, sand and gravel, and the corresponding residual equilibrium metal concentration. The table shows sorption to the 0.15 mm fraction and an upscaled sample (using a field representation of particle size fraction ratios), representing a more realistic field condition. Equilibrium between the sorbed and aqueous concentration exists. An aqueous cadmium concentration of 0.022 micrograms per litre (µg/L) corresponds to a sorbed concentration of 0.059 µg/g in the weathered bedrock. If the influent concentration of the seepage increases, it would result in an increase in sorbed concentration. The relationship cannot be extrapolated indefinitely, since the sorption capacity of the substrate is limited by available sorption sites. Overall, results of geochemical studies indicate that the sand and gravel unit has a somewhat lower attenuation potential for cadmium and zinc in comparison to the till and weathered bedrock units. However, all units exhibited a substantial attenuation potential for cadmium and zinc; the principle metals of interest for the Project.

Table 5.3.6-11: Example of Sorbed Concentrations Measured in a Rock Solution Experiment, Upscaled as a Function of Particle Size Distribution

	% of Unit Sub-0.15 mm Fraction	Sorption Potential of Sub 0.15 mm Fraction (µg/g)		Upscaled Sorbed Concentration (µg/g)		Equilibrium Aqueous Concentration (µg/L)	
		Cd	**Zn**	**Cd**	**Zn**	**Cd**	**Zn**
Weathered Bedrock	45.1	0.13	3.73	0.059	1.67	0.022	2.4
Basal Till	41.6	0.13	3.73	0.054	1.54	0.03	2.3
Sand and Gravel	26.2	0.13	3.74	0.034	0.97	0.036	1.7

Note: Cd = cadmium; mm = millimetre; % = percent; µg/g = micrograms per gram; Zn = zinc

5.3.6.3.3 Mitigation of Potential Effects

Conceptual management of mine water is discussed in **Section 2.2** and in the Mine Water Management Plan (MWAMP) (**Section 12.2.1.18.4.18**). Mitigation methods to reduce the potential impact of seepage and groundwater extraction from the Project on the surrounding environment were included in the previous discussion. This section consolidates the measures.

Mitigation measures include but are not limited to:

- Naturally drain and route seepage from mine sources to the TSF by gravity or collection systems;
- Minimize seepage releases from mine sources to the environment to the extent possible;
- Reduce and maintain low concentrations of contaminants in mine source interstitial water and seepage through effective effluent treatment and waste management; and
- Close and reclaim facilities to reduce seepage flow and improve seepage quality.

Specific mitigation methods include construction and operation of measures to reduce the potential impact of the mine site on the surrounding environment. Such integrated mitigation measures include but are not limited to:

- PAG/ML tailings and waste rock segregation and submerged co-disposal in TSF;
- NAG waste rock segregation and disposal into East and West Dumps;
- Treatment of process plant tailings, LGO, and temporary ore drainage prior to discharge to the TSF;
- Clustering of facilities around TSF (surface water and groundwater capture);
- Collection and diversion ditches (surface water and groundwater capture);
- TSF dam cut-off trench and downstream seepage collection ditches;
- ECD;
- Seepage collection and pump-back systems;
- Hydraulic barrier (West Dam – Creek 705);
- Constructed wetlands in TSF, ECD, and water reservoir in post-closure; and
- Natural attenuation and source long-term contaminant reduction (not included in effects modelling).

From a groundwater quality perspective, mitigation methods are designed to reduce the potential impact of the seepage and other contact water that may be unrecoverable to receiving streams surrounding the mine through the groundwater flow system. Mitigation methods focused on reducing and collecting seepage throughout the mine site are especially important where seepage might be lost to catchments with relatively low stream flows.

Mitigation includes any action taken to avoid, minimize, restore on-site, compensate, or offset the adverse effects of a project or activity. The following sections describe mitigative measures for the TSF, open pit, waste dumps, process plant site, and stockpiles.

5.3.6.3.3.1 Tailings Storage Facility Mitigation

The key mitigation strategy for preventing impacts to Davidson Creek water quality during operations and early closure will be a no surface water discharge design for the TSF. TSF D Dam is anticipated to produce up to 55 L/s seepage comprising foundation and embankment seepage. However, an additional dam (ECD) will be constructed downstream of the main TSF dam and will capture most of this seepage. Only an estimated 2 L/s seepage is predicted to be unrecoverable, with the balance being pumped back to the TSF during operations and closure. This represents 96% efficiency in recovering seepage.

On the west side of the TSF, a dam and seepage recovery sump will be constructed within the Davidson Creek watershed that will be designed to prevent seepage from flowing into the headwaters of Creek 705. In addition, a hydraulic barrier will be established to the west of the saddle dam to force any seepage east into the TSF.

After about Year 3 of operations, TSF Site C will be partially reclaimed. Seepage from TSF Site C will be naturally captured in TSF Site D.

Although model predictions of downstream effects from the seepage were evaluated on a conservative basis, there remains a residual uncertainty. This residual uncertainty is conventionally managed with an observational method. Typically, the observational method includes monitoring of groundwater levels and chemistry conditions downstream of the source as well as chemistry and flow rates of surface water that may be affected by discharging groundwater. Groundwater monitoring wells will be installed in the downstream areas below the TSF Site D. Results will be reviewed and appropriate measures taken as required. For example, recovery wells could be installed, if required, to recover foundation seepage during operations and at closure.

Post-closure, two wetlands (in the former ECD and water reservoir) will be constructed as required downstream of the TSF Site D, thus capturing groundwater seepage originating from reclaimed TSF Site D. A minimal seepage flow of 2 L/s will bypass these two wetlands. If future monitoring indicates potential downstream unacceptable effects might occur, additional wetlands could be constructed below the two wetlands and upstream of the proposed compliance point at the road crossing of Davidson Creek (where virtually all of the 2 L/s seepage is expected to well up into Davidson Creek channel). However, contingency mitigation is not indicated based on the results of the surface water quality effects assessment (**Section 5.3.3**, Surface Water Quality).

5.3.6.3.3.2 Open Pit Mitigation

During operations, the open pit dewatering system will consist of a combination of three subsystems: in-pit groundwater depressurization system; perimeter depressurization system; and surface water dewatering system, to minimize runoff from entering the pit (**Appendix 2.2A-2**). Surface water diversion systems were designed to manage surface water inflows from the rainstorm events and the associated snowmelt. A combination of in-pit and perimeter pumping wells will be implemented to achieve acceptable dewatering requirements. The flow from both the surface and groundwater systems will be combined and discharged via a pipeline to the sediment control pond and ultimately to the TSF Site D.

At closure, the pit filling will begin to create a post-closure pit lake. To increase the speed of the pit filling and augment the groundwater inflow, the surplus inflow to TSF Site D will be pumped to the open pit. The pit filling will take approximately 20 years, after which the pit lake level will discharge over a spillway and channel into TSF Site D.

5.3.6.3.3.3 West Dump Mitigation

The West Dump layout has been designed to minimize water control requirements. Foundation drains will be installed in areas of existing drainage courses or where excessive seeps or springs are encountered. Shallow discharge from the dump will be collected in ditches near the toe of the dump and routed to a sedimentary basin, prior to being directed to the TSF. During operations, pit-dewatering efforts are expected to influence and capture much of the seepage from the West Dump.

At closure the West Dump will be recontoured as required and covered with up to 30 cm of OVB and revegetated; this reclamation will reduce infiltration and seepage.

Down slope monitoring wells will be installed to monitor seepage from waste management structures so that corrective action, such as recovery wells or ditches and pump back systems, will be implemented in the unlikely event that they are required.

5.3.6.3.3.4 East Dump Mitigation

The East Dump layout has been designed to minimize water control requirements. Foundation drains will be installed in areas of existing drainage courses, or where excessive seeps or springs are encountered. Water that infiltrates through the dump (comprising NAG5 waste rock and OVB) will be collected in two collection ditches, one at the toe of the dump and one further downstream of the East Dump. The ditches will be constructed to capture runoff and shallow seepage from the dump and route it to the TSF, thus preventing any surface contact water reaching the headwaters of Creek 661. During operations, pit-dewatering efforts are expected to influence and capture some of the seepage from the East Dump.

At closure, the East Dump will be recontoured as required, covered with up to 30 cm of OVB, and revegetated; this reclamation will reduce infiltration and seepage.

Down slope monitoring wells will be installed to monitor seepage from waste management structures so that corrective action, such as recovery wells or ditches and pump back systems, can be implemented in the unlikely event that they are required.

5.3.6.3.3.5 Process Plant Site Mitigation

During operations, a perimeter ditch along the process plant site will intercept seepage from the plant site. After operations, the plant site will be reclaimed and revegetated. Down slope monitoring wells will be installed to monitor post-decommissioning seepage.

5.3.6.3.3.6 Low-Grade Ore Stockpile Mitigation

During operations, perimeter drains will divert natural drainage around the LGO stockpile. Foundation drains overlain by a 0.5 m thick compacted soil liner will collect seepage from the stockpile. The seepage will report to a sump for monitoring flow and quality of the foundation drainage and collected seepage. The foundation drainage and seepage will report to a ditch around the stockpile that will discharge to the TSF. Potential seepage bypassing the ditch will follow natural flow gradients towards the TSF. The LGO stockpile will be fully removed by the end of ore processing in Year 17 and the former stockpile liner and collection system removed and the site reclaimed.

5.3.6.3.3.7 Effectiveness of Mitigation

Table 5.3.6-12 provides ratings for effectiveness of mitigation measures to avoid or reduce potential effects on groundwater quality during mine site development. Mitigation measures will be based on site-specific information and construction engineering and are therefore preliminary at this stage.

Table 5.3.6-12: Mitigation Measures and Effectiveness of Mitigation to Avoid or Reduce Potential Effects on Groundwater Quality during Mine Site Development

Likely Environmental Effect	Project Phase	Mitigation/Enhancement Measure	Effectiveness of Mitigation Rating
Seepage and groundwater extraction on the surrounding environment	Construction, Operations, Closure, Post-closure	Naturally drain and route seepage from mine sources to the TSF by gravity or collection systems	High
		Reduce and maintain low concentrations of contaminants in mine source interstitial water and seepage through effective effluent treatment (e.g. cyanide destruction and lime treatment) and waste management	High
	Operation	PAG/ML tailings and waste rock segregation and submerged co-disposal in TSF	High
		NAG waste rock segregation and disposal into East and West Dumps	High
		Treatment of process plant tailings, LGO, and temporary ore drainage prior to discharge to the TSF	High
		Clustering of facilities around TSF (surface water and groundwater capture)	High
		Collection and diversion ditches (surface water and groundwater capture)	High
		TSF dam cut-off trench and downstream seepage collection ditches	High
		ECD to capture most TSF Dam seepage	High
		Seepage collection and pump-back systems	High
		Low-permeability core zone in dams to control seepage from the TSF	High

Likely Environmental Effect	Project Phase	Mitigation/Enhancement Measure	Effectiveness of Mitigation Rating
		Constructed wetlands in TSF, ECD, and water reservoir in post-closure to polish discharge and seepage groundwater	High
		Natural attenuation and source long-term contaminant reduction (not included in effects modelling)	High
	Closure, Post-closure	Close and reclaim facilities to reduce seepage flow and improve seepage quality	High

Note: ECD = Environmental Control Dam; LGO = low-grade ore; ML = metal leaching; NAG = non-acid generating; PAG = potentially acid-generating; TSF = Tailings Storage Facility

In summary, low success rating means mitigation has not been proven successful, moderate success rating means mitigation has been proven successful elsewhere, and high success rating means mitigation has been proven effective. The effectiveness of mitigation measures was rated high because the proposed mitigation measures are technologies that are widely used in mining and other industries and have a long-term proven record to be effective in mitigating groundwater quality effects.

5.3.6.3.4 Additional Mitigation –Triggers for Adaptive Management

Any additional mitigation will be completed in response to monitoring, and be integrated into adaptive management practices at the site.

The developed model predictions will be compared against actual site groundwater quality. Seepage from the TSF Site D embankment drains and inflows to the ECD will be monitored and compared to predicted values. Seepage from the TSF will report rapidly to the embankment drains and its quality can be assessed to predict the quality of unrecoverable foundation seepage that will have a much longer travel time.

Monitoring wells down gradient of TSF Site D will be used to monitor possible unrecoverable seepage rates. Triggers related to groundwater quality will be developed. Triggers could include increasing trends in groundwater quality concentrations that begin to approach predicted concentrations or applicable guidelines / site-specific water quality objectives. Sulphate (from SO_2/air treatment and sulphide mineral oxidation) and sodium (from use of NaCN for ore processing) will be useful tracers for seepage.

The measured concentrations in the pit sump during operations and the pit lake during filling and closure will be compared to the predicted values, and the models will be updated if required to reflect any differences.

In addition, monitoring will be conducted in streams to assess potential effects of seepage on surface water quality. Monitoring wells will also be installed down gradient of the proposed camp waste water disposal system to facilitate ongoing monitoring of groundwater quality. Results of monitoring will be reported regularly to BC MOE, relevant Aboriginal Groups and other interested stakeholders (**Appendix 5.3.5A**).

MODFLOW model predictions show that seepage leaving the East Dump may migrate downstream and discharge to Davidson Creek and/or Creek 661. Monitoring wells will be located as close as possible down gradient of the East Dump to provide early warning of possible seepage quantity or quality concerns. However, the East Dump will comprise low sulphur and metals NAG5 waste rock and OVB. Should observed conditions indicate higher seepage flows or poorer quality than those modelled and predicted, contingency activities will be implemented as required, as discussed below, to address potential downstream effects before they occur. Such activities will include updating and improving the understanding of groundwater conditions along the seepage pathway to best define needed contingency measures.

5.3.6.3.5 Additional Contingencies

Several contingency measures can be considered if adaptive management strategies are required for the Project:

- Groundwater source reduction contingencies:
    - Post-closure, lower the pit lake level so that some or all of the pit lake seepage and some of the East Dump seepage is routed towards the pit, rather than to downstream sites;
    - Install thicker engineered covers on the East or West waste rock dump to reduce infiltration and seepage;
- Groundwater interception contingencies:
    - Recovery wells are a common method for reducing migration of seepage away from the mine operations. Recovery wells can include conventional pumping wells, well points, and relief wells;
    - Deep trenches are a method for intercepting groundwater. Two ditches are provided in the current mine plan. Observations during operations and closure may identify additional or alternative locations for ditches to reduce the quantity of seepage migrating downstream;
- Groundwater treatment contingencies:
    - Wetlands constructed at or near groundwater discharge areas in Davidson Creek and Creek 661 to improve the quality of water as it emerges from the groundwater regime into the surface water regime. Natural wetlands are present in Davidson Creek and Creek 661 downstream, and these may also provide contaminant reduction in seepage.

5.3.6.4 Residual Effects and their Significance

5.3.6.4.1.1 Definition of Effects Criterion and Certainty of Predictions

Residual effects refer to changes in groundwater quality after mitigation that can reasonably be ascribed to the Project and not a result of natural groundwater quality variations. Certainty is high that predictions for the receiving environment are conservative. Some uncertainty exists with projections of site groundwater quality based on modelling results. However, conservative assumptions were included in the assessment and, taken together, represent an unlikely scenario. The Project design involves routing groundwater and surface contact water to the TSF during operations with no surface water discharge during operations and early closure.

Seepage estimates are based on extensive geotechnical investigations and assessment and it is assumed that all seepage from TSF that might reach fractured bedrock ultimately discharges to Davidson Creek upstream of the access road crossing. While seepage and groundwater can be monitored close to mine sources to confirm flow and quality predictions, most of the groundwater discharges to Davidson Creek will not occur until well after mine closure providing ample time to confirm predictions and implement contingency measures, as required.

5.3.6.4.1.2 Construction

No residual effects are expected during the construction phase, given the mitigation and management measures to be implemented (**Section 2.2** and **Section 5.3.3**).

5.3.6.4.1.3 Operations and Closure

Residual effects on groundwater quality related to mining activities are predicted to be localized (within 1 km of TSF Dam D) and essentially restricted to the mine footprint. The TSF will alter the local groundwater quality somewhat; however, this is predicted to be minimal since sorption studies have indicated there is a significant potential for natural attenuation in the sand and gravel, till and fractured bedrock deposit(s). Most of the seepage travelling through permeable near surface deposits within Davidson Creek valley will be captured by the interception trench collection system associated with the ECD. Residual unrecovered seepage from mine facilities to Davidson Creek and Creek 661 are predicted to be low; the potential effect on surface water quality is assessed in **Section 5.3.3**.

5.3.6.4.1.4 Post-Closure

Seepage travelling through surficial glaciofluvial deposits is primarily predicted under or very close to the mine facilities. Seepage travelling along deeper groundwater flow paths is predicted to enter Davidson Creek up to about 1,000 m downstream of the TSF dam and to enter Creek 661 up to about 2,000 m downstream of the East Dump drainage ditch. A negligible volume of seepage particles is predicted to enter Davidson Creek further down the watershed. Therefore, potential seepage effects on near surface groundwater quality during post-closure are restricted to the mine site or very near the site. The remaining seepage particles are predicted to travel through deeper subsurface layers before upwelling very near to the site into the surficial glaciofluvial deposits and subsequently into Davidson Creek and Creek 661. The effect of this upwelling seepage on surface water quality is included in the **Section 5.3.3** analysis.

Overall, the potential effect of seepage from mine sources on near-surface groundwater quality is very localized and limited, and will not affect existing or planned local or regional groundwater uses (i.e., construction and operations camps groundwater wells). The analysis of predicted seepage quality is conservative and does not consider reduction of source concentrations with time, natural attenuation, or dispersion of contaminants.

Monitoring conducted during the operations and extended closure periods will be used to verify these predictions, and adaptive management plans will be put into action if required.

5.3.6.4.1.5 Significance of Residual Project Effects

Where residual adverse effects have been identified in this Application/EIS, an assessment of the significance of those residual effects considering context, magnitude, geographic extent, duration, reversibility, frequency is provided by addressing;

- The likelihood of the effect;
- The significance of the residual effects; and
- The level of confidence and risk in the determination of significance and likelihood of the residual effect.

There are limited residual effects predicted for groundwater quality given mitigation is built into the design of the Project. Predicted natural attenuation is also expected to be effective. Residual effects relate to very localized and minor changes in groundwater quality and are therefore minor residual effects.

The context for groundwater quality is low since the VC has strong resilience to stress, the magnitude of predicted effects is low (5% to 10% change in quality from baseline conditions with no change constituting a new Contaminated Sites Regulation (CSR) standard exceedance), and the geographic extent is local (confined within the LSA). The duration is long term for post closure, and the reversibility is possible. The likelihood is high, and the significance is minor. Confidence in the significance is high since an extensive effort was made to gather site baseline data and to model both the groundwater quantity particle tracking and geochemistry interactions for Project related activities, as well as incorporation of mitigation measures which are considered effective. The assessment considers baseline conditions and operations, closure, and post-closure mine phases.

Table 5.3.6-13 presents the significance of residual Project effects on groundwater quality, which are very localized and minor changes in groundwater quality.

Categories are defined in **Section 4, Subsection 4.3.5**.

Table 5.3.6-13: Significance of Residual Effects on Groundwater Quality

Categories for Significance Determination	Project Phase		
	Construction	**Operations/Closure**	**Post-Closure**
Context	n/a	Low	Low
Magnitude	n/a	Low	Low
Geographic Extent	n/a	Local	Local
Duration	n/a	Long Term	Long Term
Reversibility	n/a	Reversible	Reversible
Frequency	n/a	Continuous	Continuous
Likelihood Determination	n/a	High	High
Statement of the level of Confidence for Likelihood	n/a	High	High
Significance Determination	n/a	Not Significant – minor	Not Significant - minor
Statement of the level of Confidence for Significance	n/a	High	High

Note: n/a = not applicable, because there is no interaction between the Project and the VC during that project phase.

5.3.6.5 Cumulative Effects

This subsection determines the need for assessing cumulative effects. As described in **Section 4.3.5.5** Assessment Methodology, the need for a cumulative effects assessment on a VC will be determined according to the following:

- The occurrence of a residual adverse Project effect has been determined, but this residual effect is not expected to be negligible; and
- The residual Project effects must be demonstrated to interact with the effect of other past, present or future projects, or activities.

There are no immediate principal developments active or planned in the near future within the RSA.

Exploration activities for the Project resulted in land disturbance, which potentially affected groundwater quality on a very limited and local scale from exploratory drilling, pumping test, or exploration water supply needs. The Proponent developed and implemented approved environmental management plans for its exploration licence. Access trails and drill pads require reclamation under the licence, and reclamation is carried out usually within a year or less of completion of site disturbance. Reclamation activities are inspected periodically by BC MEM and have been found to be satisfactory. There is unlikely to be any groundwater quality-related cumulative effects from exploration activities that pre-date Project construction.

In the RSA, no water licenses were found aside from the Project itself. There is one domestic water well user at the Mills Ranch on Tatelkuz Lake. The well is very shallow and located approximately 20 km from the Project; therefore, no cumulative effects are expected.

Pacific Northern Gas Ltd. is proposing a natural gas transmission pipeline between Summit Lake, BC, and Kitimat, BC. Based on the information provided in the pre-Application, the gas line will be located well away from the groundwater RSA, and therefore no cumulative effect is expected from the proposed gas pipeline.

No cumulative effects are expected on groundwater quality, since no other possible sources within the LSA or RSA contribute to cumulative effects to groundwater quality

5.3.6.6 Limitations

This subsection presents assumptions and limitations relative to the assessment of Project effects and the assessment of cumulative effects. The assessment of groundwater quality potential effects was based on geochemical test data and quantitative and qualitative modelling results. All sources derived from geochemical data and model results were subject to some uncertainly. Several models were used to provide insights in site conditions and provide predictions for the future site assessment. These models included:

- SEEP/W for tailings seepage;
- MODFLOW for general groundwater flows at the mine site and RSA;
- Site-wide watershed model for watershed water balance; and
- Geochemical mixing models.

Models were based on extensive baseline information and employed conservative assumptions and best practices. Ongoing monitoring of seepage and groundwater quality will be conducted to verify the accuracy of predictions.

5.3.6.7 Conclusion

This subsection will provide a conclusion regarding the significance of residual effects and cumulative effects if applicable. Several seepage and groundwater models were constructed, calibrated using site groundwater and surface water data, and run for the baseline and operations, closure, and post-closure mine phases. The models found that seepage from Project facilities would be limited and might have only a localized effect on groundwater quality. While there are changes of groundwater quality predicted, they will be minor and therefore not significant residual effects. There are no other possible sources of residual effects in the Project LSA or RSA that could contribute to cumulative residual effects. Thus, there will be no cumulative effects from the Project and other sources on groundwater quality.

Several levels of groundwater quality and seepage flow and quality control mitigation measures will be implemented for the Project. A program of monitoring site drainages, receiving waters, and groundwater chemistry and flow will be conducted, commencing at mine construction, to verify predictions. Should monitoring results indicate unexpected seepage or groundwater changes in concentrations of parameters of concern or increasing trends, proactive adaptive management will be put in place to correct effects or reverse these trends. Additional contingency measures are discussed in the MWAMP (**Section 12.2.1.18.4.18**). Taken together, the proposed mitigation, monitoring, and contingency measures provide a high level of environmental protection for groundwater quality.