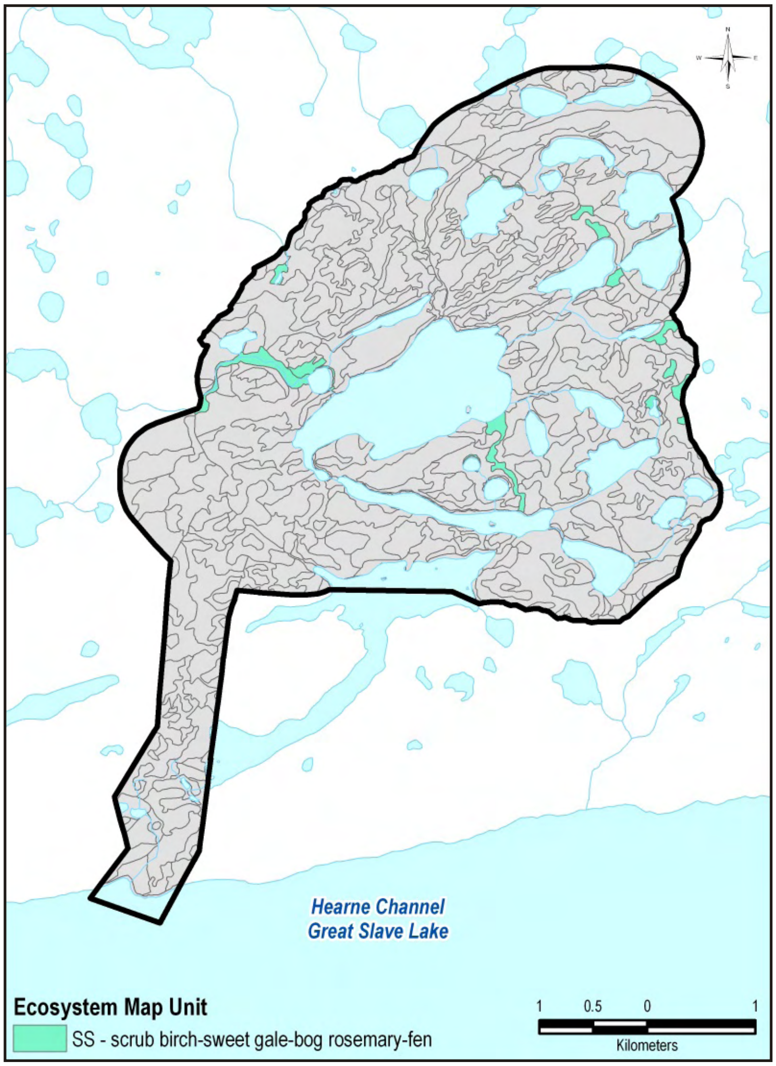
Shrub Fen

· Scrub Birch-Sweet Gale-Bog Rosemary-Fen (SS)

V15101007.007
November 2010
ISSUED FOR USE



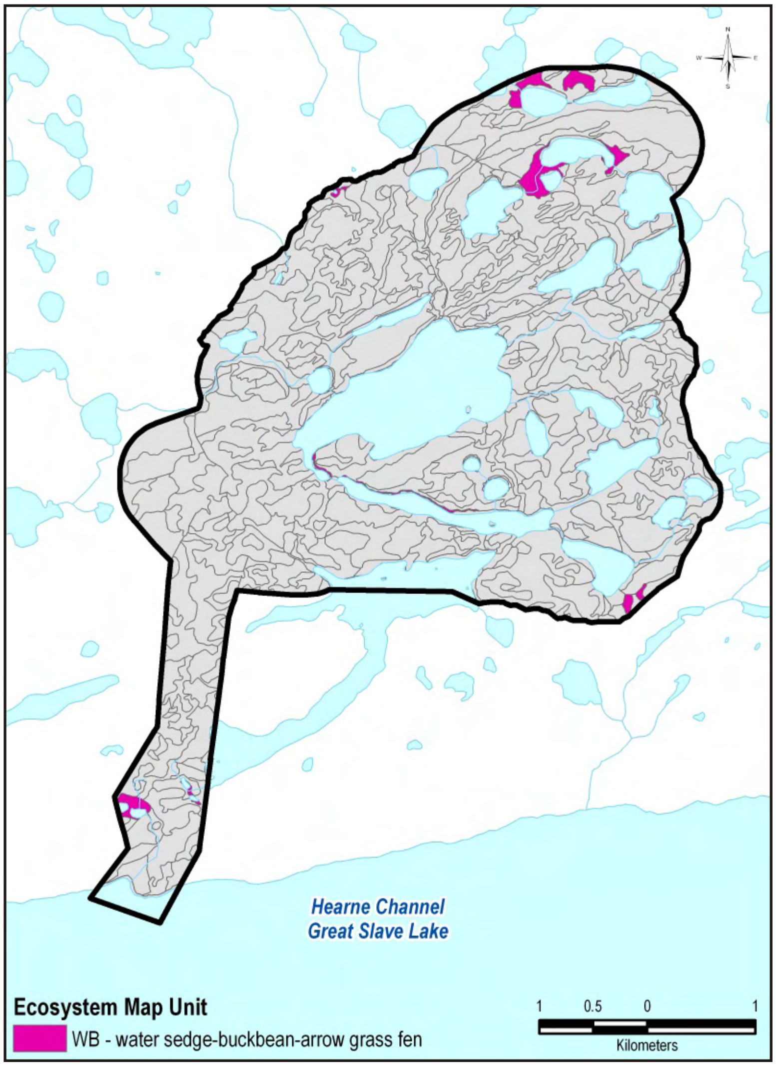
Representative Shrub Fen habitat (foreground) is a narrow transitional band between a Sedge Fen (mid ground) and a Treed Fen habitat (not shown).

Shrub fen habitats with an abundance of willow, sweet gale, and sedge provide moose spring and summer food resources.

Shrub Fen Wildlife Habitat Assessment

Habitat Description	This broad habitat type includes the Scrub Birch-Sweet Gale-Bog Rosemary-Fen (SS) ecosite. This ecosite habitat type is found on very poorly drained, medium to rich nutrient organic soils. The slope position is depressional or level, and typically transitions between ponds and lakes to treed fens or wet spruce forests. Sparse and stunted black spruce and tamarack occur; however, the shrub community is dominant. Shrubs are dominated by scrub birch, although some willow and sweet gale are present. Water sedge and tufted bulrush also common. (Stantec 2009).				
Species Sign*	None observed				
Species	**Season of Use**	**Life Requisite Ranking****			**Overall Habitat Ranking**
		Food Habitat	**Security Habitat**	**Over-Wintering Habitat**	
Moose	Spring	M	M	-	M
	Summer	M	M	-	M
	Fall	L	L	-	L
	Winter	L	L	L	L
Caribou	Winter	L	N	L	L
Olive-sided Flycatcher	Non-winter	M	L	-	M
Rusty Blackbird	Non-winter	M	H	-	H
Common Nighthawk	Non-winter	M	N	-	L

* Wildlife sign documented during the June and July 2010 survey events. Evidence of sign in habitat types were not considered during the ranking of broad habitat types.
** H = High; M = Moderate; L = Low; and N = Nil.
— = Not applicable



Representative Sedge Fen habitat.

Sedge Fen habitat types adjacent to lakes and ponds provide suitable food habitat for Common Nighthawk and Rusty Blackbird.

Sedge Fen Wildlife Habitat Assessment

Habitat Description	This broad habitat type includes the Water Sedge-Buckbean-Arrow Grass-Fen (WB) ecosite. It is commonly found on very poorly drained organic soils immediately adjacent to lakes and ponds or in isolated depressions. It has a rich to very rich nutrient regime. Trees are absent and the sparse shrub layer consists of scrub birch, sweet gale, and willow. This habitat type is dominated by the herb layer, consisting of buckbean, arrow-grass, and water sedge. (Stantec 2009).
Species Sign*	Moose

Species	Season of Use	Life Requisite Ranking**			Overall Habitat Ranking
		Food Habitat	Security Habitat	Over-Wintering Habitat	
Moose	Spring	H	N	-	M
	Summer	H	N	-	M
	Fall	L	N	-	L
	Winter	N	N	N	N
Caribou	Winter	L	H	L	M
Olive-sided Flycatcher	Non-winter	N	N	N	N
Rusty Blackbird	Non-winter	H	N	-	M
Common Nighthawk	Non-winter	H	N	-	M

* Wildlife sign documented during the June and July 2010 survey events. Evidence of sign in habitat types were not considered during the ranking of broad habitat types.
** H = High; M = Moderate; L = Low; and N = Nil.
— = Not applicable

Open Water

- Lake (LA)
- Shallow Water (OW)
- Pond (PD)

V15101007.007
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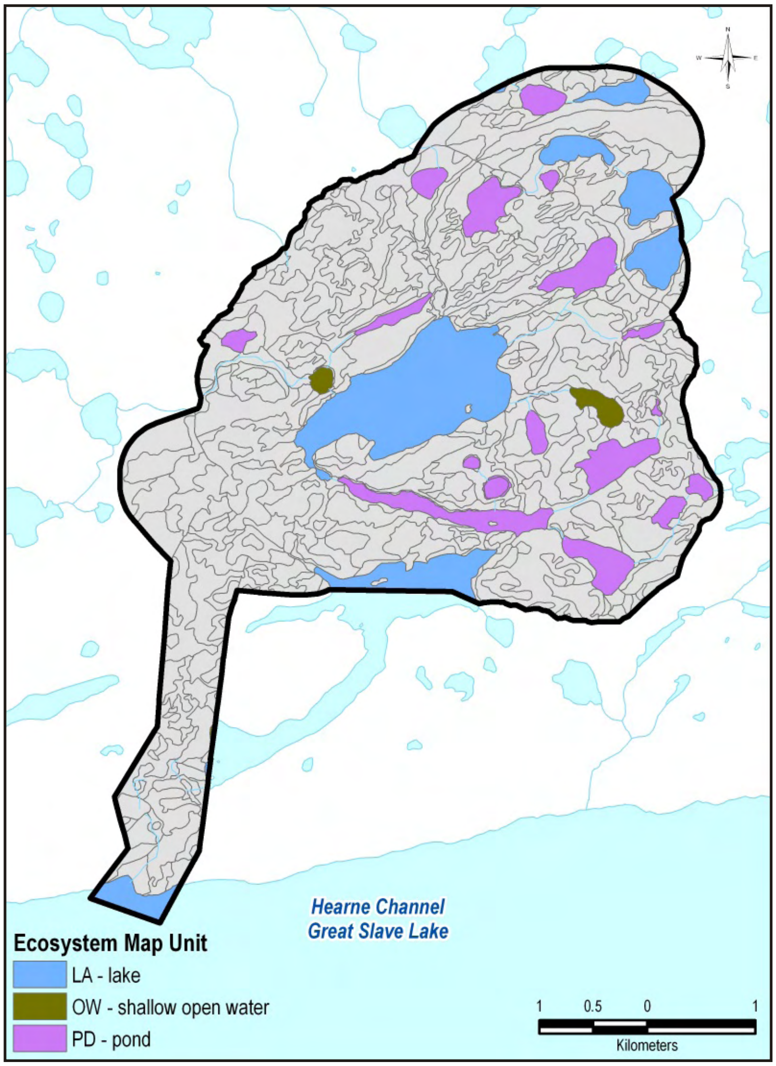

Representative Open Water habitat.

Open water provides moose relief from biting insects in the summer, and caribou security habitat in the winter.

Open Water Wildlife Habitat Assessment

Habitat Description	This broad habitat type includes lakes, ponds, and open water wetlands.				
Species Sign*	Waterfowl, common nighthawk, bald eagle, osprey, and beaver				
Species	**Season of Use**	**Life Requisite Ranking****			**Overall Habitat Ranking**
		Food Habitat	**Security Habitat**	**Over-Wintering Habitat**	
Moose	Spring	H	N	-	M
	Summer	H	H	-	H
	Fall	N	N	-	N
	Winter	N	N	N	N
Caribou	Winter	L	H	M	M
Olive-sided Flycatcher	Non-winter	N	N	-	N
Rusty Blackbird	Non-winter	N	N	-	N
Common Nighthawk	Non-winter	H	N	-	M

* Wildlife sign documented during the June and July 2010 survey events. Evidence of sign in habitat types were not considered during the ranking of broad habitat types.
** H = High; M = Moderate; L = Low; and N = Nil.
— = Not applicable

Appendix B.2

2010 Baseline Wildlife Habitat Assessment – Proposed Haul Road and Hydrometallurgical Plant Area, Pine Point, Northwest Territories.

November 05, 2010 EBA File: V15101007.008

Avalon Rare Metals Inc.
Unit 330 – 6165 Highway 17
Delta, BC, V4K 5B8

Attention: David Swisher, Vice President Operations

Subject: Baseline Wildlife Habitat Assessment – Proposed Haul Road and Hydrometallurgical Plant Area, Pine Point, Northwest Territories

1.0 INTRODUCTION

A baseline wildlife habitat assessment that involves the integration of site, vegetation, and wildlife information, was undertaken as part of the preliminary environmental investigations conducted by EBA Engineering Consultants Ltd. (EBA) for Avalon Rare Metals Inc. (Avalon).

The area studied for the wildlife habitat assessment included an area approximately 200 m on either side of the proposed haul road from Great Slave Lake to the proposed hydrometallurgical plant site, Pine Point, Northwest Territories (Figure 1). This area includes a number of previously disturbed areas related to the former operation of the historic Pine Point Mine including a former haul road/dirt road, a historic open pit and associated waste rock dump, and other cleared areas (former gravel borrow sites).

2.0 METHODS

The main objectives of the wildlife habitat assessment were to document wildlife and wildlife sign within each habitat type present within the study area and to identify the habitat types that specific wildlife species are expected to use within the study area.

On August 6, 2010, EBA conducted a one day field survey of the proposed haul road and hydromet facility sites. The field team included two EBA biologists Steve Moore and Karla Langlois, and a local Aboriginal assistant[1]. In the field, each habitat type present in the study area was identified and described based on the dominant plant species. These were then matched with previous Ecological Land Classification (ELC) work completed in the immediate area (EBA 2005a). Walking transects in each habitat type were conducted and an

[1] EBA sought assistance from the Fort Resolution band office to find an available field assistant for the one day program; however, no assistant was available at this time.

ATV was used to survey the habitat conditions adjacent to the existing road. All wildlife species observed and their sign were documented in relation to the corresponding habitat types.

It is difficult for an analysis to address all potential wildlife in the area (Beanlands and Duinker 1983); therefore, an essential step at the beginning of any project is the selection of indicator species that are regarded as being valuable to stakeholders (*i.e.* Aboriginal groups, researchers, governments, and the public).

As part of the wildlife habitat analysis, information from published species-habitat relationships and previous wildlife habitat assessments completed in the region were reviewed. Each habitat type present within the study area was assessed for its suitability to support indicator wildlife species based on the baseline ecological information and field results.

3.0 EXISTING HABITAT TYPES

A total of seven habitat types were documented to exist within the study area. Habitat types are described following previous ELC data collected in the general area (EBA 2005a). Wildlife habitat within the study area includes both upland and lowland habitats.

The existing road right-of-way and associated ditches were previously disturbed and were observed to be regenerating to previous habitat types. Along the road right-of-way, willow (*Salix* species) and deciduous shrubs dominate and the regenerating community is described as a young seral stage to the undisturbed neighbouring communities.

Habitat types within the study area that were large enough to delineate on a map are shown in Figure 2.

3.1 UPLAND HABITAT TYPES

3.1.1 Bearberry – Jack Pine Forest

This habitat type is located on dry upland sites, with rapidly drained soil and coarse textured glaciofluvial parent material. The soil has a poor to very poor nutrient regime that supports Jack pine (*Pinus banksiana)* as the dominant tree species. Bearberry (*Arctostaphylos uva-ursi)* is the dominant shrub, and cushion mosses (*Dicranum* species), haircap mosses (*Polytrichum* species), and reindeer lichens (*Cladina* species) are common in the understory (Photograph 1). A small area of Bearberry-Jack Pine forest was documented near the proposed facilities.

3.1.2 Canada Buffaloberry – Green Alder-Forest

Canada Buffaloberry-Green Alder habitats (Photograph 2) within the study area were found as small inclusions along the existing road (areas too small to map). This habitat type has a moderate nutrient regime with a submesic to subhygric moisture regime. White spruce

(*Picea glauca)* is the climax species, but younger communities contain varying amounts of jack pine, aspen (*Populus tremuloides)*, and paper birch (*Betula papyrifera).* Canada buffaloberry (*Sheperdia Canadensis)*, common juniper (*Juniperus communis)*, saskatoon (*Amelanchier alnifolia)*, and rose characterize the shrub layer, and bearberry, false toadflax (*Geocaulum lividum)*, and northern bedstraw (*Galium boreale*) are common in the herb layer. Moss and arboreal lichens are common.

3.1.3 Labrador Tea – Subhygric-Forest

Labrador Tea – Subhygric habitat types (Photograph 3) commonly occur as a transition between treed fens and upland Labrador Tea – mesic habitats. Soils are commonly moist with a poor to medium nutrient regime. Vegetation is similar as the Labrador tea – mesic community; however, this habitat type occurs on lower topographic positions and has wetter soils. Black spruce (*Picea mariana)* and jack pine are the common tree species. The shrub layer is dominated by Labrador tea (*Rhododendron groenlandicum*), black spruce, creeping juniper (*Juniperus horizontalis)*, and bog cranberry. A well developed moss layer exists, characterized by stair-step moss (*Hylocomium splendens*), red-stemmed feather moss (*Pleurozium schreberi)*, and reindeer lichens. Labrador Tea-Subhygric forests are common in the study area.

3.2 LOWLAND HABITAT TYPES

3.2.1 Treed Fen

Treed fens (Photograph 4) have a rich to very rich nutrient regime and a subhydric to hydric moisture regime. An open tree canopy including both black spruce and tamarack is present. The shrub layer is characterized by scrub birch (*Betula* species), sweet gale (*Myrica gale)*, and shrubby cinquefoil (*Pentaphylloides floribunda).* Willow is present in low amounts. A diverse layer of sedges (*Carex* species), bog cranberry, common horsetail (*Equisetum arvense)*, and small bedstraw (*Galium tridifum)* occur in the herb layer. Treed fens are common within the study area.

3.2.2 Shrubby Fen

Shrubby fens commonly occur near open water, within larger fen complexes, or drainage areas where there is some water movement. They have a medium to rich nutrient regime and a subhydric to hydric moisture regime. Characteristic vegetation includes mixed woods dominated by a canopy of scrub birch or willow with limited black spruce or tamarack. Sweet gale and sedges are common in the understory.

3.2.3 Graminoid Fen

Graminoid fens (Photograph 5) are poorly drained sites with a hydric moisture regime that are often associated with shallow open water and shrub dominated fens. Trees and shrub cover absent in this habitat type. Sedges, reed grass (*Calamagrostis* species), and bulrushes (*Scirpus* species) are the dominant vegetation species. A single graminoid fen was documented within the study area.

3.2.4 Beaver Pond/Open Water

A single beaver pond (Photograph 6) was located near a historic Pine Point Mine waste rock dump within the study area. The beaver pond was dominated by cattails (*Typha latifolia)* and open water. Dead standing white spruce were inundated by water.

The shoreline of Great Slave Lake was shallow with cobble and boulder substrate with isolated pockets of sedges and rushes (*Juncus* species). A shallow gravel shoal approximately 30 m from the shoreline was present at the time of the site investigation. Willow and reed grass dominate the transition zone between the cobble shoreline and forest cover beyond.

4.0 WILDLIFE HABITAT ASSESSMENT RESULTS

A total of 148 species of birds, 39 mammals, and four amphibians occur or potentially occur within the study area (Appendix A).

Since it is difficult to assess the existing wildlife habitat for all species potentially occurring within the study area, a few indicator species were selected for assessment. These indicator species were selected for the wildlife habitat assessment as they possess inherently high conservation values for local stakeholders, have been previously identified as being important in other local environmental studies, are important harvestable species, are representative species to local habitats, and/or, are species with special conservation status. Indicator species selected for this study area include:

- Moose
- Boreal Woodland Caribou
- Olive-sided Flycatcher
- Common Nighthawk

4.1 MOOSE

Moose are an important subsistence species in the study area and are commonly included as an indicator species in many northern projects. Evidence of moose occupying many of the available habitat types within the study area were documented at the time of the August 2010 field event. Moose sign was also considered common along the existing road corridor.

Favourable moose feeding habitat includes semi-open early successional habitats with an abundance of browse (*e.g.* willow, aspen, balsam poplar, Saskatoon, Canada buffaloberry, rose, and red-osier dogwood). Floodplains, wetlands, regenerating burns, and previously disturbed areas commonly support an abundance of browse in the form of willows, young deciduous trees, and other early pioneer species. These habitats with a high cover of willow and other browse material support moose throughout the year, but particularly in the winter.

Within the study area, the shrubby fen, the existing road right-of-way, and the shoreline of Great Slave Lake have the highest cover of willow within the study area and would support moose feeding habitat year round. In the spring and summer when forbs, grasses, and aquatic plants are available the use of browse material declines. Wet and aquatic habitats for food commonly occur during all non-winter months, but tend to peak during late June to early August when plant nutrition and digestibility are highest (Peek 1998). The beaver pond and the shallow shoreline of Great Slave Lake may be used by moose during the summer season.

Moose also seek distinct habitats to minimize detection from predators and avoid insect harassment. Dense forests and tall shrub stands are used for security cover from wolves and black bears, and open wind exposed ridgelines and aquatic habitats are used to avoid insects. Moose likely use the treed habitats within the study area (except for the Bearberry-Jack Pine forests) for security cover.

4.2 BOREAL WOODLAND CARIBOU

Boreal woodland caribou are considered an important subsistence species and one that is culturally important to local peoples. In addition, woodland caribou (Boreal population) are listed by SARA as Threatened. By definition this is a species likely to become endangered if limiting factors are not reversed. In the NWT, woodland caribou are considered Sensitive.

A few Boreal woodland caribou likely occupy the study area year round. Woodland caribou sign was not observed at the time of the August 2010 field event; however, EBA has previously documented caribou in poor treed fens and Labrador Tea–Subhygric habitats on adjacent properties (EBA 2005b).

Boreal woodland caribou may occur in all forested habitats; however, prefer mature or old growth coniferous forests (greater than 100 years old) associated with bogs, lakes, and rivers that have abundant ground and tree lichens (ENR 2010). In winter, boreal woodland caribou tend to favour uplands, bogs and south facing slopes where the snow is not as deep. Their winter diet consists of up to 80 % ground and tree lichens. In summer, they prefer areas such as forest edges, marshes, and meadows that provide the fresh green growth of flowering plants and grasses. Calving areas are vital to the well being of all caribou populations. Caribou calve in small isolated meadows within the boreal forest. Within the study area, boreal woodland caribou can be expected to mainly utilize treed fens, graminoid fens, and the Labrador Tea – Subhygric habitat types.

4.3 OLIVE-SIDED FLYCATCHER

Olive-sided Flycatchers are ranked by ENR as At Risk under the general status program and listed by SARA as Threatened (Schedule 1). By definition this species is likely to become endangered if the factors leading to its population decline are not reversed.

Olive-sided Flycatchers arrive are expected to arrive in the study area by late May or early June and depart in late July to early August (ENR 2010). Olive-sided Flycatchers do not remain within the local study area during the winter.

Typical Olive-sided Flycatcher feeding habitat includes regenerating forests after a forest fire, edge habitats (including near man-made openings, bedrock outcrops, and lakeshores) with large trees and standing snags, and open to semi-open forest stands including treed fens (Altman and Sallabanks 2000). Feeding occurs throughout all semi-open to open spaces, including over forest canopies, wherever flying insects occur. They commonly forage from perches, snags or dead-topped trees (Altmann and Sallabanks 2000). Within the study area, disturbed sites, habitat edges, the beaver pond, Graminoid Fens, and Bearberry-Jack Pine forests provide suitable feeding habitat for Olive-sided Flycatchers.

Appropriate nesting habitat for the Olive-sided Flycatcher is similar to its required feeding habitat. Olive-sided Flycatchers commonly construct nests in coniferous trees; however, aspen and willow have also been used as nesting substrates (Altmann and Sallabanks 2000).

4.4 COMMON NIGHTHAWK

Common Nighthawks are listed by SARA as Threatened (Schedule 1) and ranked by ENR as At Risk. This conservation status is imparted upon species that are likely to become endangered if the factors leading to its population decline are not reversed.

Common Nighthawks are thought to arrive in the study area by mid May to early June and depart by mid August to mid September (ENR 2010b). Common Nighthawks do not over-winter within the study area.

Common Nighthawks feed on flying insects at dawn and dusk wherever an abundance of flying insects occurs. Their preferred feeding habitat includes open forests (*e.g.* Bearberry-Jack Pine forests), disturbance sites, recent burn and logged areas, Graminoid Fens, marshes, and lake shorelines.

Nests are prepared directly on the bare soil, sand, gravel, and rock in open feeding habitats. Nests are typically in the open or near logs, boulders, grass clumps, or shrubs (Poulin *et al.* 1996). Appropriate Common Nighthawk nesting habitat exists within the Bearberry-Jack Pine forest habitat, as well as in previously disturbed mine sites and gravel pits.

5.0 OTHER SPECIES WITH SPECIAL CONSERVATION STATUS

A total of eight other species with special conservation status may occur within the region, but were not selected as indicator species for the wildlife habitat assessment since the habitat within the study area is considered poorly suited, the species considered are migrants or transients, or the study area is beyond 50 km of the known species ranges. These species include: Whooping Crane, Peregrine Falcon, Short-eared Owl, Yellow Rail, Rusty Blackbird, Horned Grebe, Wood Bison, and Northern Leopard Frog.

5.1 WHOOPING CRANE

No Whooping Cranes, a species listed by SARA as Endangered, were observed during the one-day survey conducted in August 2010. However, a single juvenile Whooping Crane was observed at a recently flooded beaver pond in the Pine Point area during previous work in the region (EBA 2005). This is a species that is in imminent danger of extirpation or extinction. Since Whooping Cranes have a slow reproductive potential and restricted breeding and wintering habitat, populations could be impacted by a single natural and/or human-caused event (Fournier 1999; SARA 2010). Whooping Cranes are legally protected under the federal SARA, the Migratory Birds Convention Act, and the territorial Species at Risk Act.

A breeding population of Whooping Cranes is known to exist at the north east corner of Wood Buffalo National Park[2], where appropriate nesting habitat exists. This breeding population is the only natural wild breeding population in the world (ENR 2010).

The Wood Buffalo National Park population arrives on the breeding grounds in April and May, and migrates to wintering grounds in the Aransas National Wildlife Reserve in Texas beginning in mid-September (ENR 2010; Government of Canada 2010). Non-breeding individuals may not occupy traditional nesting grounds until breeding age. Transient non-breeding individuals are known to occupy appropriate feeding habitats between Wood Buffalo National park and the Mackenzie Bison Sanctuary; however, individuals non-breeders have also been documented further north up the Mackenzie Valley (ENR 2010). Whooping Cranes feed on insects, minnows, frogs, snakes, small mammals, seeds, and berries typically seen in or near marshes, bogs, and shallow lakes. Appropriate feeding habitat exists within the study area (*e.g.* Graminoid Fens, beaver ponds, existing road drainage ditch, and the shoreline of Great Slave Lake).

5.2 PEREGRINE FALCON

No Peregrine Falcons were observed during the one-day survey conducted in August 2010. However, one Peregrine Falcon was observed near the former Pine Point mine area during

[2] The study area is located approximately 50 km north of designated Whooping Crane Critical Habitat within Wood Buffalo National Park.

previous EBA work (September 2005) (EBA 2005b). The Peregrine Falcon observed near the study area was seen during its fall migration.

The Peregrine Falcon (*anatum/tundrius)* has been assessed by COSEWIC as Special Concern (April 2007), but has not been listed by SARA. Peregrine Falcons are ranked by ENR as Sensitive under the NWT general status program. In addition, Peregrine Falcons are legally protected under the NWT Wildlife Act.

A Peregrine Falcon has been reported nesting in one of the former Pine Point mine pits (Unka, pers. Comm.); however, the study area lies outside the known Peregrine Falcon range. Peregrines have three main habitat requirements. They need proper nesting sites, a nesting range (actively guarded range approximately 1 km from nest), and a home range that can extend up to 27 km from the nest for hunting (not defended) (ENR 2010). Between May and early June two to four eggs are laid in a scrap usually on cliff ledges near water. Peregrines mainly hunt other birds in the air; so open habitats and waterways are important.

Peregrine Falcons have the potential to occupy the study area during spring and fall migration. Habitats within the study area that may be utilized include open shorelines, disturbance areas, and the beaver pond.

5.3 SHORT-EARED OWL

The Short-eared Owl has been assessed by COSEWIC as Special Concern (April 2008) and was ranked by ENR as Sensitive. Short-eared Owls are expected to arrive in the NWT in April or May, and depart by late October (ENR 2010b).

While in the NWT, Short-eared Owls feed in open habitats, including marshes, open wetlands, and other non-forested areas. Typically prefers to nest in open areas with an abundance of grasses/sedges, where 90% of the vegetation is less than 0.5 m in height (Wiggins *et al.* 2006).

The small graminoid fen and beaver pond within the study area may provide appropriate Short-eared Owl feeding habitat.

5.4 YELLOW RAIL

The Yellow Rail is listed by SARA as Special Concern, and ranked by ENR as May Be At Risk. Yellow Rails arrive in the NWT in early May (ENR 2010b); however, their departure from the NWT to their wintering grounds is unknown. They feed on freshwater snails, aquatic and terrestrial insects, and seeds of sedges found in wet sedge meadows.

Yellow Rails prefer nesting habitats characterized by sedges and water depths ranging from moist substrate to 50 cm (Bazin and Baldwin 2007). The periphery of the small Graminoid Fen within the study area may provide marginal Yellow Rail habitat.

5.5 RUSTY BLACKBIRD

Rusty Blackbirds are listed by SARA as Special Concern (Schedule 1) and ranked by ENR as May Be At Risk. By definition this species possesses inherent characteristics (*e.g.* specific habitat requirements) that make them sensitive to human activities or natural events. Rusty Blackbird habitat occurs throughout the study area. Rusty Blackbirds may arrive in the study area as early as April to early May and depart by mid-October (Bird Studies Canada *et al.* 2010; Bromley and Trauger ND).

Typical feeding and nesting habitat consists of wet coniferous and mixed forests, such as fens, bogs, muskegs, beaver ponds, and swampy shores along lakes and streams (Avery 1995; ENR 2010b). Rusty Blackbirds forage primarily on the ground for aquatic and terrestrial insects and plant materials (*e.g.* seeds and fruits) (Avery 1995). The Labrador Tea-Subhygric forests immediately surrounding the beaver pond and Great Slave Lake within the study area may support Rusty Blackbirds.

5.6 HORNED GREBE

The Horned Grebe has been assessed by COSEWIC as Special Concern (as of April 2009), and is ranked by ENR as Secure under the NWT general status program. This conservation status is imparted upon species whose inherent characteristics (*e.g.* low reproductive rates) make them sensitive to human activities or natural events.

Horned Grebes occupy small ponds, wetlands, shallow lakeshores and protected bays, and other natural or man-made permanent or semi-permanent waterbodies (ENR 2010b; Government of Canada 2010). Horned Grebes prefer small waterbodies (less than 1 hectare (ha) in size), although breeding has also been recorded on larger lakes (Fournier and Hines 1999). Favourable breeding ponds include areas of open water with emergent vegetation, such as the beaver pond within the study area.

Horned Grebes are expected to arrive within the study area in May and depart by mid-August to early September (ENR 2010b).

5.7 WOOD BISON

Although no wood bison or sign were observed during the August 2010 survey, EBA had previously documented the presence of wood bison near the former Pine Point mine site (EBA 2005; 2006). Wood bison are listed by SARA as Threatened, and ranked by ENR as At Risk under the NWT general status program. By definition this is a species likely to become endangered if limiting factors are not reversed.

However, the study area is located within a Bison Control Area, where all bison are removed to ensure diseased animals from Wood Buffalo National Park do not migrate and infect other disease-free herds, such as at the Mackenzie Bison Sanctuary. Two wood bison herds (Wood Buffalo National Park and Slave River Lowlands) contain diseased individuals, while the other two herds (Liard River and Mackenzie Bison Sanctuary) are believed to be disease free.

Wood bison use different habitats depending on the season. Wood bison are grazers, and rely heavily on grasses and sedges that grow in meadow openings, particularly in the winter. In summer, bison can be found in small willow pastures and uplands where they feed on sedges, forbes, and willow leaves and twigs. In the fall, they can be found in forests where they feed on lichens, and in winter, bison move to graminoid fens and lakeshores where they feed on sedges.

Wood bison habitat exists throughout the study area, particularly along the existing road and the shrubby fen. Wood Bison have the potential to occupy the study area throughout the year.

5.8 NORTHERN LEOPARD FROG

Northern leopard frogs are listed by SARA as Special Concern, and ranked by ENR as Sensitive. Northern leopard frogs are known to occur east of the study area by Fort Resolution; however, they may be more widely distributed across the southern NWT than currently known (ENR 2010b).

Northern leopard frogs use various habitat types throughout their life history including lakes, ponds, roadside ditches, and flooded areas during breeding; meadows and grasslands close to water in summer, and unfrozen lake and river bottoms in winter. Northern leopard frog habitat is present within the study area in the form of the beaver pond, existing road drainage ditch, Graminoid Fen, Shrubby Fen, Treed Fens, and Great Slave Lake.

6.0 AUGUST 2010 INCIDENTIAL WILDLIFE SPECIES OBSERVATIONS

At the time of the site visit, other species of birds, mammals, and an amphibian were documented (Table 1). Black bear sign, including scat, feeding sign, and claw marks (Photograph 7) were most common, followed by red fox, and snowshoe hare sign. The observations recorded during this one-day survey confirms the common understanding amongst residents of the nearby communities (Fort Resolution and Hay River) that although the general area has been subject to extensive historic mining activities, the area is also in a state of healing from an environmental perspective.

TABLE 1. INCIDENTAL WILDLIFE OBSERVATIONS, AUGUST 2010

Species	Observation	Species	Observation
Mallard	6 visual	Woodpecker species	3 feeding sign
Blue-winged Teal	1 visual	Common Grackle	1 visual
Green-winged Teal	1 visual	Beaver	Lodge, trails, feeding sign

TABLE 1. INCIDENTAL WILDLIFE OBSERVATIONS, AUGUST 2010			
Species	**Observation**	**Species**	**Observation**
Bufflehead	3 visual	Black Bear	19 scat, feeding sign, claw marks
Spruce Grouse	1 visual	Marten	1 scat
Grouse species	2 pellet groups	Moose	8 tracks, trails, browsing
Northern Harrier	1 visual	Red Fox	10 scats
Bald Eagle	1 visual	Red Squirrel	3 dens and vocal call
American Kestrel	3 visual	Snowshoe Hare	9 pellet groups, skull, and browse
Merlin	2 visual	Wolf	3 scat
Unknown Shorebird species	50 visual	Wood Frog	1 visual
Herring Gull	1 visual		

CLOSURE

We trust this report meets your present requirements. Should you have any questions or comments, please contact the undersigned at your convenience.

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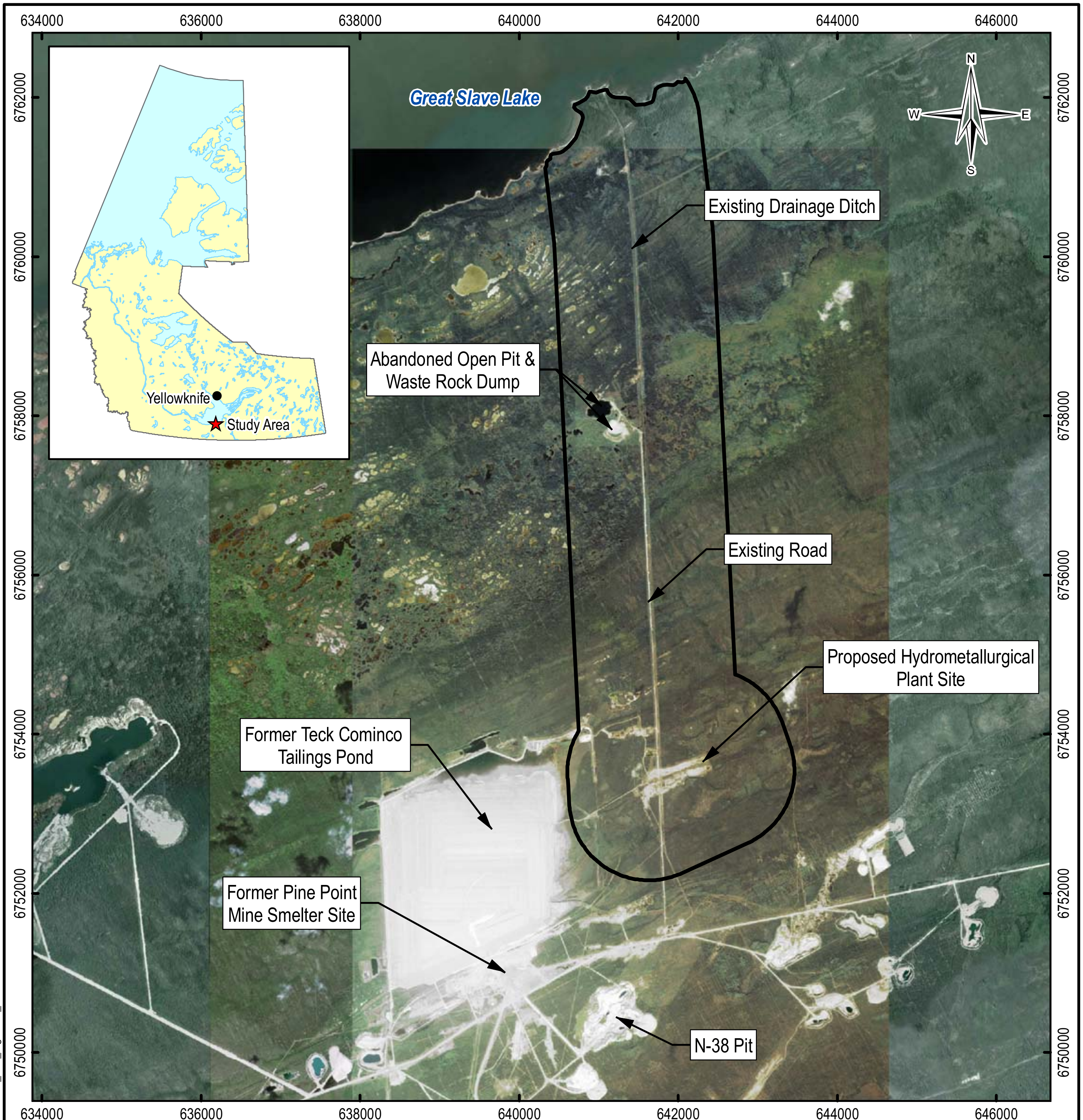
FIGURES



LEGEND

Study Area

NOTES

Base data source:
Imagery provided by Avalon (October, 2010)

ISSUED FOR USE

THOR LAKE PROJECT

Hydrometallurigal Plant Site
Local Study Area

PROJECTION	DATUM
UTM Zone 11	NAD83

Scale: 1:70,000

1 0.5 0 1

Kilometres

FILE NO.
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PROJECT NO.	DWN	CKD	REV
V15101007.008	MEZ	KL	0

OFFICE	DATE
EBA-VANC	November 3, 2010

AVALON RARE METALS INC

EBA Engineering Consultants Ltd.

Figure 1

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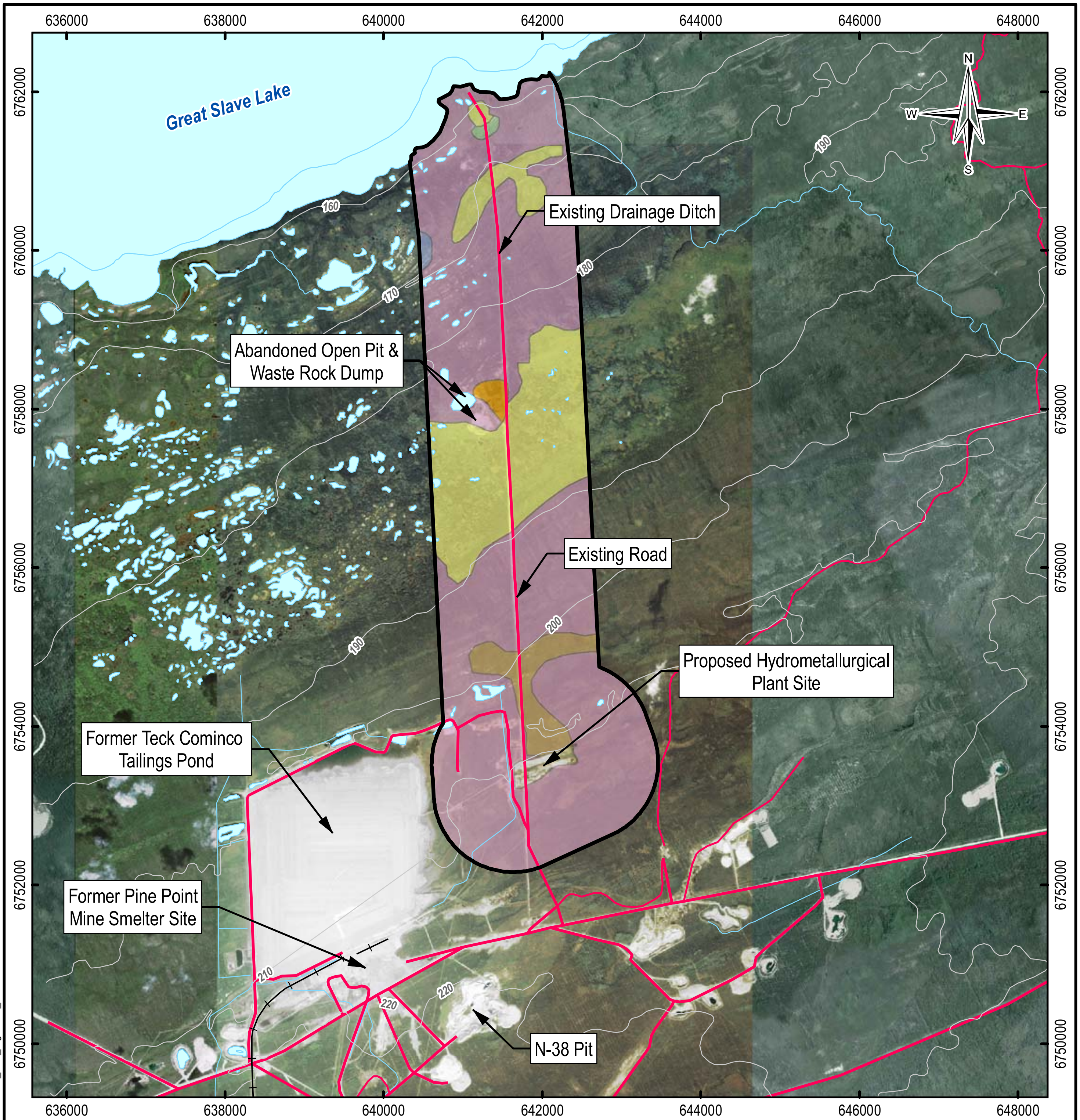


LEGEND

Study Area

Wildlife Habitat

- Bearberry - Jack Pine Forest
- Graminoid Fen
- Labrador Tea - Subhygic Forest
- Shrubby Fen
- Treed Fen
- Beaver Pond

- Contour (10m)
- Road
- Limited Use Road
- Railway
- Watercourse
- Waterbody

NOTES

Base data source:
Imagery provided by Avalon (October, 2010)

ISSUED FOR USE

THOR LAKE PROJECT

2010 Wildlife Habitat Map for Hydrometallurgical Plant Site Study Area

PROJECTION	DATUM
UTM Zone 11	NAD83

Scale: 1:70,000

1 0.5 0 1

Kilometres

FILE NO.
V15101007_008_Figure02_WLHab.mxd

PROJECT NO.	DWN	CKD	REV
V15101007.008	MEZ	KL	0

OFFICE	DATE
EBA-VANC	November 3, 2010

AVALON RARE METALS INC

EBA Engineering Consultants Ltd. eba

Figure 2

Q:\Vancouver\GIS\ENGINEERING\V151\V15101007_ThorLake\Maps\008\V15101007_008_Figure02_WLHab.mxd

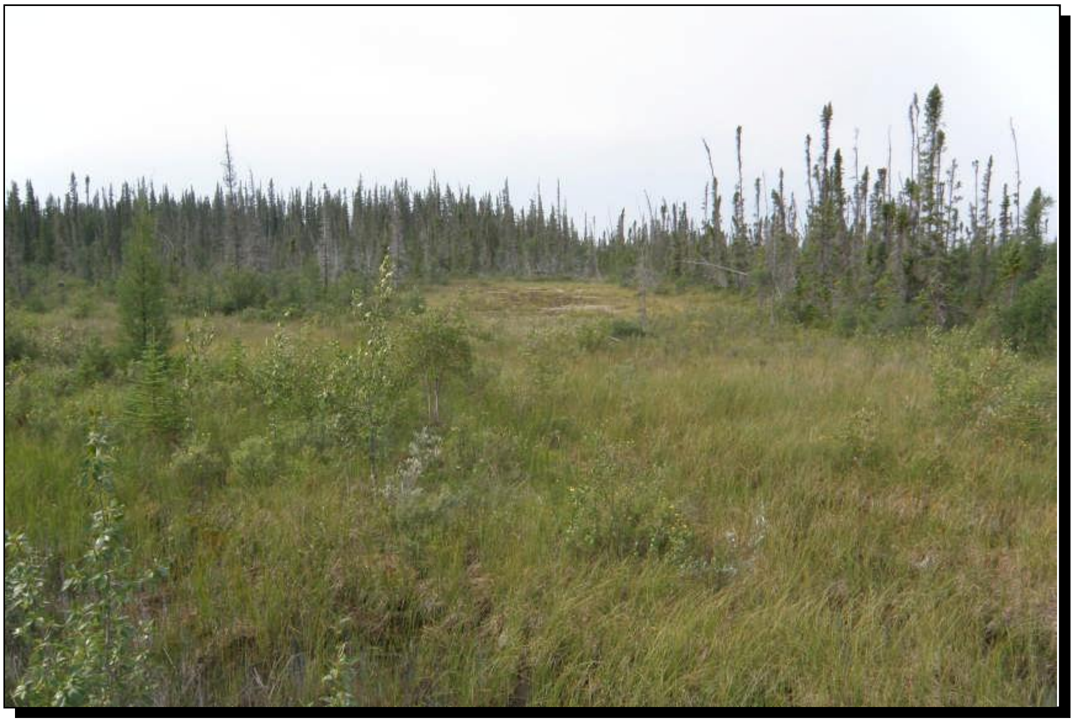
PHOTOGRAPHS

Photograph 1
Representative Bearberry-Jack Pine Forest

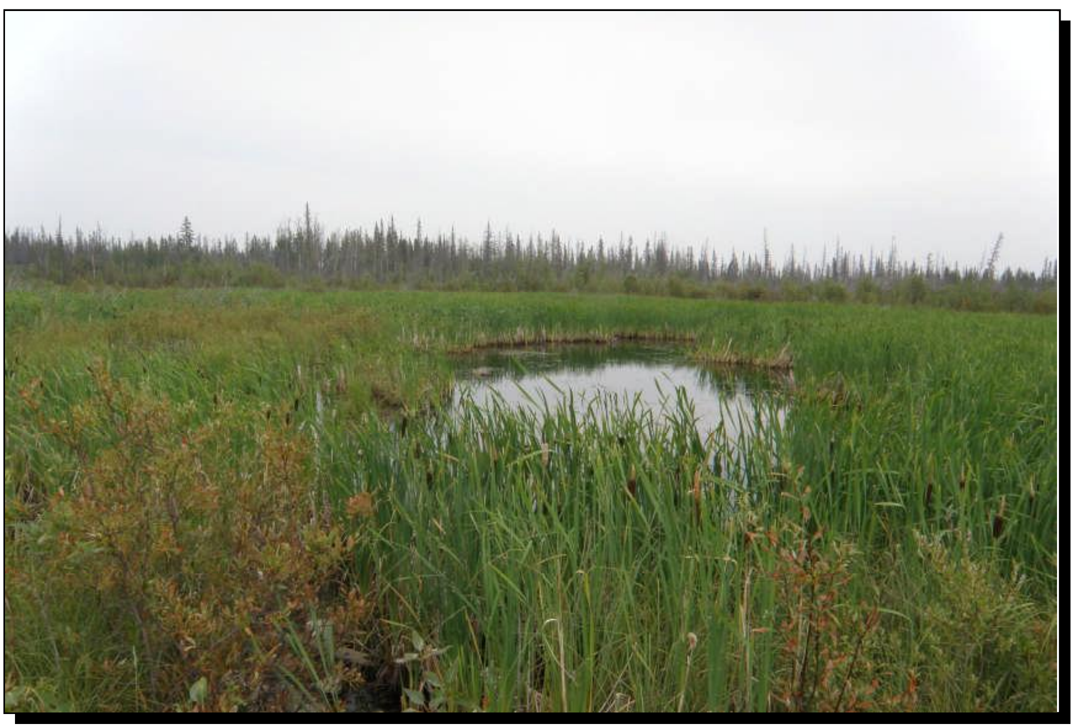
Photograph 2
Woodpecker species feeding sign within a Canada Buffaloberry- Green Alder forest.

Photograph 3
Representative Labrador Tea-Subhygric forest.

Photograph 4
Typical Treed Fen habitat.



Photograph 5
Representative Graminoid Fen habitat.



Photograph 6
Beaver pond with cattails and open water.

Photogrpah 7
Old black bear claw marks observed up and aspen tree along the existing road.

APPENDIX

APPENDIX A WILDLIFE SPECIES OCCURRING OR POTENTIALLY OCCURRING WITHIN THE STUDY AREA

APPENDIX A. WILDLIFE SPECIES OCCURRING OR POTENTIALLY OCCURRING WITHIN THE STUDY AREA				
Common Name	Scientific Name	Conservation Status		
		NWT	SARA	COSEWIC
Birds[1]				
Canada Goose	*Branta canadensis*	Secure	-	Not Assessed
Gadwall	*Anas strepera*	Undetermined	-	Not Assessed
American Wigeon	*Anas americana*	Secure	-	Not Assessed
Mallard	*Anas platyrhynchos*	Secure	-	Not Assessed
Blue-winged Teal	*Anas discors*	Secure	-	Not Assessed
Northern Shoveler	*Anas clypeata*	Secure	-	Not Assessed
Northern Pintail	*Anas acuta*	Sensitive	-	Not Assessed
Green-winged Teal	*Anas crecca*	Secure	-	Not Assessed
Canvasback	*Aythya valisineria*	Secure	-	Not Assessed
Redhead	*Aythya americana*	Secure	-	Not Assessed
Ring-necked Duck	*Aythya collaris*	Secure	-	Not Assessed
Greater Scaup	*Aythya marila*	Secure	-	Not Assessed
Lesser Scaup	*Aythya affinis*	Sensitive	-	Not Assessed
Surf Scoter	*Melanitta perspicillata*	Sensitive	-	Not Assessed
White-winged Scoter	*Melanitta fusca*	Sensitive	-	Not Assessed
Bufflehead	*Bucephala albeola*	Secure	-	Not Assessed
Common Goldeneye	*Bucephala clangula*	Secure	-	Not Assessed
Common Merganser	*Mergus merganser*	Secure	-	Not Assessed
Red-breasted Merganser	*Mergus serrator*	Secure	-	Not Assessed
Ruddy Duck	*Oxyura jamaicensis*	Secure	-	Not Assessed
Ruffed Grouse	*Bonasa umbellus*	Secure	-	Not Assessed
Spruce Grouse	*Falcipennis canadensis*	Secure	-	Not Assessed
Willow Ptarmigan	*Lagopus lagopus*	Secure	-	Not Assessed
Rock Ptarmigan	*Lagopus muta*	Secure	-	Not Assessed
Sharp-tailed Grouse	*Tympanuchus phasianellus*	Secure	-	Not Assessed
Pacific Loon	*Gavia pacifica*	Secure	-	Not Assessed
Common Loon	*Gavia immer*	Secure	-	Not At Risk
Horned Grebe	*Podiceps auritus*	Secure	No Status	Special Concern
Red-necked Grebe	*Podiceps grisegena*	Secure	-	Not At Risk
American Bittern	*Botaurus lentiginosus*	Sensitive	-	Not Assessed
Osprey	*Pandion haliaetus*	Secure	-	Not Assessed
Bald Eagle	*Haliaeetus leucocephalus*	Secure	-	Not At Risk
Northern Harrier	*Circus cyaneus*	Secure	-	Not At Risk

APPENDIX A. WILDLIFE SPECIES OCCURRING OR POTENTIALLY OCCURRING WITHIN THE STUDY AREA

Common Name	Scientific Name	Conservation Status		
		NWT	SARA	COSEWIC
Sharp-shinned Hawk	*Accipiter striatus*	Secure	-	Not At Risk
Northern Goshawk	*Accipiter gentilis*	Secure	-	Not At Risk
Red-tailed Hawk	*Buteo jamaicensis*	Secure	-	Not At Risk
Golden Eagle	*Aquila chrysaetos*	Secure	-	Not At Risk
American Kestrel	*Falco sparverius*	Secure	-	Not Assessed
Merlin	*Falco columbarius*	Secure	-	Not At Risk
Peregrine Falcon	*Falco peregrinus anatum/tundrius*	Sensitive	No Status	Special Concern
Yellow Rail	*Coturnicops noveboracensis*	May Be At Risk	Special Concern (Schedule 1)	Special Concern
Sora	*Porzana carolina*	Secure	-	Not Assessed
American Coot	*Fulica americana*	Secure	-	Not At Risk
Sandhill Crane	*Grus canadensis*	Secure	-	Not Assessed
Whopping Crane	*Grus americana*	At Risk	Endangered (Schedule 1)	Endangered
Semipalmated Plover	*Charadrius semipalmatus*	Secure	-	Not Assessed
Killdeer	*Charadrius vociferus*	Secure	-	Not Assessed
Greater Yellowlegs	*Tringa melanoleuca*	Undetermined	-	Not Assessed
Lesser Yellowlegs	*Tringa flavipes*	Sensitive	-	Not Assessed
Solitary Sandpiper	*Tringa solitaria*	Undetermined	-	Not Assessed
Spotted Sandpiper	*Actitis macularius*	Secure	-	Not Assessed
Least Sandpiper	*Calidris minutilla*	Sensitive	-	Not Assessed
Short-billed Dowitcher	*Limnodromus griseus*	Undetermined	-	Not Assessed
Wilson's Snipe	*Gallinago delicata*	Undetermined	-	Not Assessed
Wilson's Phalarope	*Phalaropus tricolor*	Undetermined	-	Not Assessed
Red-necked Phalarope	*Phalaropus lobatus*	Sensitive	-	Not Assessed
Bonaparte's Gull	*Larus philadelphia*	Secure	-	Not Assessed
Mew Gull	*Larus canus*	Secure	-	Not Assessed
Ring-billed Gull	*Larus delawarensis*	Secure	-	Not Assessed
California Gull	*Larus californicus*	Secure	-	Not Assessed
Herring Gull	*Larus argentatus*	Secure	-	Not Assessed
Common Tern	*Sterna hirundo*	Secure	-	Not At Risk
Arctic Tern	*Sterna paradisaea*	Secure	-	Not Assessed
Black Tern	*Chlidonias niger*	Sensitive	-	Not At Risk
Great Horned Owl	*Bubo virginianus*	Secure	-	Not Assessed
Northern Hawk Owl	*Surnia ulula*	Secure	-	Not At Risk
Great Grey Owl	*Strix nebulosa*	Secure	-	Not At Risk
Long-eared Owl	*Asio otus*	Undetermined	-	Not Assessed

APPENDIX A. WILDLIFE SPECIES OCCURRING OR POTENTIALLY OCCURRING WITHIN THE STUDY AREA				
Common Name	Scientific Name	Conservation Status		
		NWT	SARA	COSEWIC
Short-eared Owl	*Asio flammeus*	Sensitive	Special Concern (Schedule 3)	Special Concern
Boreal Owl	*Aegolius funereus*	Secure	-	Not At Risk
Common Nighthawk	*Chordeiles minor*	At Risk	Threatened (Schedule 1)	Threatened
Belted Kingfisher	*Ceryle alcyon*	Secure	-	Not Assessed
Yellow-bellied Sapsucker	*Sphyrapicus varius*	Secure	-	Not Assessed
Downy Woodpecker	*Picoides pubescens*	Secure	-	Not Assessed
Hairy Woodpecker	*Picoides villosus*	Secure	-	Not Assessed
American Three-toed Woodpecker	*Picoides dorsalis*	Secure	-	Not Assessed
Black-backed Woodpecker	*Picoides arcticus*	Secure	-	Not Assessed
Northern Flicker	*Colaptes auratus*	Secure	-	Not Assessed
Olive-sided Flycatcher	*Contopus cooperi*	At Risk	Threatened (Schedule 1)	Threatened
Western Wood-Pewee	*Contopus sordidulus*	Secure	-	Not Assessed
Yellow-bellied Flycatcher	*Empidonax flaviventris*	Secure	-	Not Assessed
Alder Flycatcher	*Empidonax alnorum*	Secure	-	Not Assessed
Least Flycatcher	*Empidonax minimus*	Secure	-	Not Assessed
Eastern Phoebe	*Sayornis phoebe*	Secure	-	Not Assessed
Northern Shrike	*Lanius excubitor*	Secure	-	Not Assessed
Blue-headed Vireo	*Vireo solitarius*	Secure	-	Not Assessed
Warbling Vireo	*Vireo gilvus*	Secure	-	Not Assessed
Red-eyed Vireo	*Vireo olivaceus*	Secure	-	Not Assessed
Gray Jay	*Perisoreus canadensis*	Secure	-	Not Assessed
Black-billed Magpie	*Pica hudsonia*	Secure	-	Not Assessed
American Crow	*Corvus brachyrhynchos*	Secure	-	Not Assessed
Common Raven	*Corvus corax*	Secure	-	Not Assessed
Horned Lark	*Eremophila alpestris*	Secure	-	Not Assessed
Tree Swallow	*Tachycineta bicolor*	Secure	-	Not Assessed
Bank Swallow	*Riparia riparia*	Secure	-	Not Assessed
Cliff Swallow	*Petrochelidon (Hirundo) phyrrhonota*	Secure	-	Not Assessed
Barn Swallow	*Hirundo rustica*	Sensitive	-	Not Assessed
Black-capped Chickadee	*Poecile atricapillus*	Secure	-	Not Assessed
Boreal Chickadee	*Poecile hudsonica*	Sensitive	-	Not Assessed

APPENDIX A. WILDLIFE SPECIES OCCURRING OR POTENTIALLY OCCURRING WITHIN THE STUDY AREA				
Common Name	Scientific Name	Conservation Status		
		NWT	SARA	COSEWIC
Red-breasted Nuthatch	*Sitta canadensis*	Secure	-	Not Assessed
Ruby-crowned Kinglet	*Regulus calendula*	Secure	-	Not Assessed
Gray-cheeked Thrush	*Catharus minimus*	Secure	-	Not Assessed
Swainson's Thrush	*Catharus ustulatus*	Secure	-	Not Assessed
Hermit Thrush	*Catharus guttatus*	Secure	-	Not Assessed
American Robin	*Turdus migratorius*	Secure	-	Not Assessed
Bohemian Waxwing	*Bombycilla garrulus*	Secure	-	Not Assessed
Tennessee Warbler	*Vermivora peregrina*	Secure	-	Not Assessed
Orange-crowned Warbler	*Vermivora celata*	Secure	-	Not Assessed
Yellow Warbler	*Dendroica petechia*	Secure	-	Not Assessed
Magnolia Warbler	*Dendroica magnolia*	Secure	-	Not Assessed
Cape May Warbler	*Dendroica tigrina*	Secure	-	Not Assessed
Yellow-rumped Warbler	*Dendroica coronata*	Secure	-	Not Assessed
Palm Warbler	*Dendroica palmarum*	Secure	-	Not Assessed
Bay-breasted Warbler	*Dendroica castanea*	Secure	-	Not Assessed
Blackpoll Warbler	*Dendroica striata*	Sensitive	-	Not Assessed
Black-and-white Warbler	*Mniotilta varia*	Secure	-	Not Assessed
American Redstart	*Setophaga ruticilla*	Secure	-	Not Assessed
Ovenbird	*Seiurus aurocapillus*	Secure	-	Not Assessed
Northern Waterthrush	*Seiurus noveboracensis*	Secure	-	Not Assessed
Common Yellowthroat	*Geothlypis trichas*	Secure	-	Not Assessed
Wilson's Warbler	*Wilsonia pusilla*	Secure	-	Not Assessed
Western Tanager	*Piranga ludovicana*	Secure	-	Not Assessed
American Tree Sparrow	*Spizella arborea*	Sensitive	-	Not Assessed
Chipping Sparrow	*Spizella passerina*	Secure	-	Not Assessed
Clay-colored Sparrow	*Spizella pallida*	Undetermined	-	Not Assessed
Savannah Sparrow	*Passerculus sandwichensis*	Secure	-	Not Assessed
Le Conte's Sparrow	*Ammodramus leconteii*	Secure	-	Not Assessed
Nelson's Sharp-tailed Sparrow	*Ammodramus nelsoni*	Undetermined	-	Not Assessed
Fox Sparrow	*Passerella ilia*	Secure	-	Not Assessed
Song Sparrow	*Melospiza melodia*	Undetermined	-	Not Assessed
Lincoln's Sparrow	*Melospiza lincolnii*	Secure	-	Not Assessed
Swamp Sparrow	*Melospiza georgiana*	Secure	-	Not Assessed
White-throated Sparrow	*Zonotrichia albicollis*	Sensitive	-	Not Assessed
White-crowned Sparrow	*Zonotrichia leucophrys*	Secure	-	Not Assessed

APPENDIX A. WILDLIFE SPECIES OCCURRING OR POTENTIALLY OCCURRING WITHIN THE STUDY AREA				
Common Name	Scientific Name	Conservation Status		
		NWT	SARA	COSEWIC
Dark-eyed Junco	*Junco hyemalis*	Secure	-	Not Assessed
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	Secure	-	Not Assessed
Red-winged Blackbird	*Agelaius phoeniceus*	Secure	-	Not Assessed
Rusty Blackbird	*Euphagus carolinus*	May Be At Risk	Special Concern (Schedule 1)	Special Concern
Common Grackle	*Quiscalus quiscula*	Secure	-	Not Assessed
Brown-headed Cowbird	*Molothrus ater*	Secure	-	Not Assessed
Pine Grosbeak	*Pinicola enucleator*	Secure	-	Not Assessed
Purple Finch	*Carpodacus purpureus*	Secure	-	Not Assessed
Red Crossbill	*Loxia curvirostra*	Secure	-	Not Assessed
White-winged Crossbill	*Loxia leucoptera*	Secure	-	Not Assessed
Common Redpoll	*Carduelis flammea*	Secure	-	Not Assessed
Hoary Redpoll	*Carduelis hornemanni*	Undetermined	-	Not Assessed
Pine Siskin	*Carduelis pinus*	Secure	-	Not Assessed
Amphibians				
Boreal Chorus Frog	*Pseudacris maculata*	Secure	-	Not Assessed
Canadian Toad	*Anaxyrus hemiophrys*	May Be At Risk	-	Not Assessed
Northern Leopard Frog	*Lithobates pipiens*	Sensitive	Special Concern (Schedule 1)	Special Concern
Wood Frog	*Lithobates sylvatica*	Secure	-	Not Assessed
Mammals[2]				
Moose	*Alces americanus*	Secure	-	Not Assessed
Barren-ground Caribou	*Rangifer tarandus groenlandicus*	Sensitive	-	Not Assessed
Wood Bison	*Bison bison athabascae*	At Risk	Threatened (Schedule 1)	Threatened
Gray Wolf	*Canis lupus*	Secure	-	Not At Risk
Red Fox	*Vulpes vulpes*	Secure	-	Not Assessed
Arctic Fox	*Vulpes lagopus*	Secure	-	Not Assessed
Coyote	*Canis latrans*	Secure	-	Not Assessed
Canada Lynx	*Lynx canadensis*	Secure	-	Not At Risk
Wolverine	*Gulo gulo*	Sensitive	Special Concern	No Status
North American River Otter	*Lontra canadensis*	Secure	-	Not Assessed
American Marten	*Martes americana*	Secure	-	Not Assessed
Fisher	*Martes pennanti*	Sensitive	-	Not Assessed

APPENDIX A. WILDLIFE SPECIES OCCURRING OR POTENTIALLY OCCURRING WITHIN THE STUDY AREA

Common Name	Scientific Name	Conservation Status		
		NWT	SARA	COSEWIC
Ermine	*Mustela erminea*	Secure	-	Not Assessed
Least Weasel	*Mustela nivalis*	Secure	-	Not Assessed
American Mink	*Neovison vison*	Secure	-	Not Assessed
Striped Skunk	*Mephitis mephitis*	Undetermined	-	Not Assessed
American Black Bear	*Ursus americanus*	Secure	-	Not At Risk
Snowshoe Hare	*Lepus americanus*	Secure	-	Not Assessed
Beaver	*Castor canadensis*	Secure	-	Not Assessed
Cinereus Shrew	*Sorex cinereus*	Secure	-	Not Assessed
Dusky Shrew	*Sorex monticolus*	Secure	-	Not Assessed
American Water Shrew	*Sorex palustris*	Secure	-	Not Assessed
Arctic Shrew	*Sorex arcticus*	Secure	-	Not Assessed
American Pigmy Shrew	*Sorex hoyi*	Secure	-	Not Assessed
Red Squirrel	*Tamiasciurus hudsonicus*	Secure	-	Not Assessed
Northern Flying Squirrel	*Glaucomys sabrinus*	Secure	-	Not Assessed
Least Chipmunk	*Tamias minimus*	Secure	-	Not Assessed
Woodchuck	*Marmota monax*	Secure	-	Not Assessed
North American Deer Mouse	*Peromyscus maniculatus*	Secure	-	Not Assessed
Meadow Jumping Mouse	*Zapus hudsonius*	Undetermined	-	Not Assessed
Southern Red-backed Vole	*Myodes gapperi*	Secure	-	Not Assessed
Northern Bog Lemming	*Synaptomys borealis*	Secure	-	Not Assessed
Eastern Heather Vole	*Phenacomys ungava*	Secure	-	Not Assessed
Common Muskrat	*Ondatra zibethicus*	Secure	-	Not Assessed
Meadow Vole	*Microtus pennsylvanicus*	Secure	-	Not Assessed
Taiga Vole	*Microtus xanthognathus*	Secure	-	Not Assessed
North American Porcupine	*Erethizon dorsata*	Secure	-	Not Assessed
Little Brown Myotis	*Myotis lucifugus*	Sensitive	-	Not Assessed
Hoary Bat	*Lasiurus cinereus*	Undetermined	-	Not Assessed

(Cornell Lab of Ornithology and the American Ornithologists' Union 2010; COSEWIC 2010; ENR 2010; Government of Canada 2010; Sibley 2003; Banfield 1977)

1. Bird species list does not include those that may flyover or briefly stop within the study area during spring and fall migrations.

Appendix B.3

Water Quality Modeling for the Thor Lake Project – Technical Memorandum. March 2011

EBA, A Tetra Tech Company
Oceanic Plaza, 9th Floor, 1066 West Hastings Street
Vancouver, BC V6E 3X2 CANADA
p. 604.685.0275 f. 604.684.6241

TECHNICAL MEMO

ISSUED FOR USE

TO:	Rick Hoos	**DATE:**	May 9, 2011
C:		**MEMO NO.:**	001
FROM:	Albert Leung and Jim Stronach	**EBA FILE:**	V15101007.006
SUBJECT:	Water Quality Modelling for the Thor Lake Project		

1.0 INTRODUCTION

The Thor Lake Property is located at Thor Lake in the Mackenzie Mining District of the Northwest Territories, about 5 km north of the Hearne Channel of Great Slave Lake and approximately 100 km southeast of the City of Yellowknife. Avalon Rare Metals Inc. proposes to mine, mill and produce combined rare earth oxides, zirconium, niobium and tantalum oxides from the Nechalacho deposit, located on its Thor Lake Property. The proposed project is referred to as the Thor Lake Project (TLP).

A water quality modelling study was conducted to investigate the impact of the tailings effluent discharge on the water quality in Thor Lake. The model encompasses the interconnected system, hereinafter called the Thor Lake system, of water bodies: The tailings pond, the polishing pond, Drizzle Lake, Murky Lake and Thor Lake. The schematic of the Thor Lake system is shown in Figure 1.1. Also shown in Figure 1.1 is the bathymetry for Thor, Murky and Drizzle lakes. The bathymetry and shape of the tailings and polishing ponds shown are approximation only. Mine tailings are discharged into the tailings pond from the plant. As tailings solids settle out to the bottom of the tailings pond, significant amounts of contaminant associated with the solids will be removed, leaving only the dissolved contaminants in the water column available to travel downstream.

Hydrologic and meteorologic data were incorporated into the model. The water balance and hydrology of the lake system was determined by Knight Piésold Consulting (2011). Wind, air temperature, humidity and cloud cover data have been collected at Yellowknife Airport since 1953 and the data collected between 1987 and 2007 were utilized in the model.

2.0 WATER QUALITY MODELLING

2.1 Hydrology

The Thor Lake system consists of a complex hydrological network that interconnects the water bodies and controls the water balance in the system. The proposed mine water management will modify hydrology and, hence, the water balance in the area, particularly with the plan to recycle water from Thor Lake to the concentrator plant. Knight Piésold Consulting (2011) conducted a long term study to investigate the water balance in the area for the pre-operation and the 20-year period during mine operations. This information was utilized in the hydrodynamic model.

The proposed tailings and polishing ponds will replace Ring Lake and Buck Lake and become the main upstream water bodies of Drizzle Lake. Drizzle Lake then drains into Murky Lake which is located slightly to the west. Thereafter, Murky Lake drains into Thor Lake, which also receives significant amounts of runoff from Long Lake and other small tributaries. The Thor Lake outflow drains into Fred Lake immediately to the north. Water will be withdrawn from Thor Lake and recycled to the concentrator plant, which will in turn discharge the tailings water to the tailings pond.

Groundwater inflow and outflow were assumed absent in the Thor Lake system, and therefore were not considered in this model study.

2.2 Meteorology

There is no meteorological station with long term data in the immediately vicinity of the project site. Therefore, the meteorological station at Yellowknife Airport, maintained by the Meteorological Service of Canada, was used in this study. The station have been collecting hourly climate data, such as wind, air temperature, humidity and cloud cover since 1953.

The data collected was used as the meteorological inputs to the model. While the wind direction at the Yellowknife Airport and the project site should be similar as there are no mountains or valleys to alter the local air flow, reduction of the wind speed as measured at Yellowknife Airport was required to take account of the shielding effects of the trees that surround the water bodies of such small size. A reduction of wind speed by 50% was deemed appropriate after model calibration by comparing the simulated temperature profiles with measured profiles (Stantec Inc. 2010).

The wind data were used in the model to mainly drive the circulation in water body. Coupled with the air temperature, relative humidity, cloud cover, the winds also governs the heat exchange of the water body with the atmosphere. These complex processes ultimately control the physical structure of the water column, which in turn governs the lake circulation pattern.

2.3 Physical Limnology

The Thor Lake system, located in the Northwest Territories, demonstrates significant seasonality in its physical structure typical of inland, mid to high-latitude lakes. The circulation dynamics and patterns, therefore, change with the physical structure.

In summer, deeper lakes normally form a two-layer system: a relatively shallow surface warm layer (epilimnion) and a cool deep layer (hypolimnion), separated by a thermocline at depth. The depth and appearance of the thermocline changes throughout the course of summer season, and the two layers can have considerably different motions. The two-layer structure was seen only in parts of Thor Lake, the Polishing Pond and Tailings Pond where the water depth is greater than 4 metres and the thermocline is located at about 2-4 metres depth depending on the time in the season. This was reproduced from the model and the section view of water temperature is shown in Figure 2.1. Large parts of the water bodies in the Thor Lake system are relatively shallow with depths less than 3 m. The shallow water depths, coupled with the wind, leads to local vertical mixing and uniformly mixed region in the shallow areas.

In fall, the surface water temperature decreases and eventually becomes the same as the temperature in the bottom layer, leading to overturn. A roughly uniform temperature distribution throughout the water column is formed as a result.

In winter, surface water continues to cool. Reverse thermal stratification forms as the water temperature drops below 4^0C, the temperature of highest density for freshwater. As water continues to cool, ice starts to form on the surface, forming an insulating layer and cutting off the energy from the wind to the water bodies.

Ice melts in spring as air temperature rises and the water bodies once again become exposed to the atmospheric and wind forcing. The lakes, as mentioned before, are exposed to wind-driven forcing during the ice-free period that, in conjunction with other meteorological parameters such as air temperature, humidity and cloud cover, causes water circulation patterns such as seiching and stratification.

The main driving force for currents and circulations within each water body, and hence movement of contaminants, is wind. Wind forcing will drive surface currents in the up-wind and down-wind directions, and will also generate a return flow at depth. All lakes and ponds considered in this modelling study are freshwater water bodies; therefore the major factor controlling lake stratification is the water temperature. When the lake is stratified, it experiences internal seiching, an internal wave motion of the stratified layers, in response to wind forcing, which leads to a complex current and mixing pattern. When the lake is unstratified, the barrier preventing contaminants from being transported down to deeper water disappears; as a result, vertical mixing becomes significant.

2.4 Hydrodynamic Model

2.4.1 General Description of H3D

Releases and fate of dissolved metal contaminants from the tailings discharge were simulated using the proprietary three-dimensional hydrodynamic model H3D. The model is derived from GF8 (Stronach, Backhaus and Murty, 1993), originally developed for Fisheries and Oceans Canada. It is a three-dimensional time-stepping model that computes the three components of velocity (u,v,w) on a rectangular grid in three dimensions (x,y,z), as well as scalar fields such as temperature and contaminant concentrations. The metal contaminants are modelled as tracer, added at the tailings release point and closely tracked in the model until it leaves the model domain.

The spatial grid may be visualized as a number of interconnecting computational cells, collectively representing the water body. Velocities are determined on the faces of each cell, and non-vector variables, such as temperature or dissolved contaminant concentrations, are computed at the centre of each cell. All cells have identical width and length dimensions in the horizontal plane, with the selection of grid size established by considerations of the scale of the phenomena of interest. In the vertical, the cells are configured such that they are relatively thin near the surface and increase in thickness with depth. The increased vertical resolution near the surface is required because much of the variability (stratification, wind mixing, inputs from streams and land drainage) is concentrated near the surface.

The following discussion provides characteristics common to the implementations of H3D:

- Wind forcing produces currents within enclosed water bodies as well as water level differences. It also significantly affects vertical mixing, and hence scalar distribution.
- Turbulence modelling is important in determining the distribution of velocity and scalars such as water temperature and dissolved contaminants. The diffusion coefficients for momentum and scalars at each computational cell depend on the level of turbulence at that point. For momentum, H3D uses a shear-dependent turbulence formulation in the horizontal, and a shear-stratification dependent formulation in the vertical. These parameters have been shown to correctly simulate the annual temperature cycle within several lakes in British Columbia, and are consistent with current practice. For scalars, the eddy diffusivity values are set equal to the corresponding eddy viscosity values.
- The model operates in a time-stepping mode over the period of simulation. During each time step, values of velocity, temperature and concentration of other scalars are updated in each cell.

2.4.2 Model Implementation

A 40 m resolution model of the entire Thor Lake system was constructed, encompassing the tailings pond, polishing pond, Drizzle Lake, Murky Lake and Thor Lake. Also included in the model are the tailings discharge, the freshwater drainage and withdrawal, as well as channels that interconnect the water bodies.

The vertical resolution was chosen so that the layers are sufficiently close together near the surface where processes such as the thermocline occur. The layers become progressively further apart as they go deeper into the water column. The model used the bathymetry data made available from Stantec Inc. (E-mail communication 2011). Freshwater inflows from runoffs and upstream discharges are included in the model. In addition, tailings discharge enters the Thor Lake system in the tailings pond. Figure 1.1 illustrates the model showing the lake bathymetry and the approximately locations of major inflows and outflows. Note that the shape and area of the tailings and polishing ponds are approximation, and their locations are for illustrative purpose only.

The model was run for a 20-year period starting at the commencement of mine operations. The transport and fate of the dissolved contaminants modelled in the study were represented as a conservative tracer. The tracer with unity concentration was released into the tailings pond. The concentration of any dissolved metal contaminants of concern can be easily calculated anywhere in the model domain by multiplying the tracer concentration by the actual concentration of the metal contaminants at the release point. At model initiation, a tracer concentration of zero in all water bodies in the model was assumed.

In the model, water is withdrawn from Thor Lake to the concentrator plant. The tracer concentration in the recycled water going to the plant is the same as that at the withdrawal point in Thor Lake. The tracer concentrations in the tailings discharge were assumed to remain the same as specified.

The main concern of this study is the possible degradation of water quality in the Thor Lake system due to excessive concentration of dissolved metals during mine operations. The modelled data have been compared to the Metal Mining Effluent Regulation (MMER) criteria and Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of aquatic life. The metals of concern are Mercury (Hg), silver (Ag), Aluminum (Al), Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Molybdenum (Mo), Nickel (Ni), Lead (Pb), Selenium (Se), and Zinc (Zn) and their concentrations were simulated in the model. Three radioactive metals, Uranium (U), Thorium (Th), and Radium-226 (Ra-226) are also included in the simulation. U, Th and Ra-226 have very long half-life, therefore, they were treated as conservative elements. Ra-226 is expressed in unit of becquerel per litre, a standard SI unit for radioactivity. In this study, the radioactivity of Ra-226 is assumed linearly proportional to the concentration of Ra-226 in water. Table 2.1 below shows the Day 5 decant concentration of the concerned metals analysed in November, 2010 (Avalon Rare Metals Inc. 2011). For the metals with decant concentration below detection limits, the detection limits were used as the concentration input to the tailings effluent in the model. The metal concentrations of concern at any time and location can be calculated by multiplying the modelled tracer concentration by the decant concentration.

Table 2.1: Day 5 Decant Metal Concentration in Tailings Discharge

Metal	Day 5 Decant Metal Concentration
Hg	Below detection limit of 0.0001 mg/L
Ag	0.00003 mg/L
Al	0.62 mg/L
As	0.0022 mg/L
Cd	0.000067 mg/L
Cr	0.0011 mg/L
Cu	0.0023 mg/L
Fe	0.570 mg/L
Mo	0.0471 mg/L
Ni	0.0070 mg/L
Pb	0.00060 mg/L
Se	Below detection limit of 0.001 mg/L
Zn	0.007 mg/L
U	0.00880 mg/L
Th	0.000694 mg/L
Ra-226	Below detection limit of 0.01 Bq/L

3.0 MODEL RESULTS

The simulation covers the 20-year period after the commencement of mine operations. Table 3.1 details the evolution of the inert tracer concentration at the surface in the Thor Lake system over the course of the simulation period. Surface concentrations are presented here because higher concentrations were always found near the top of the water column. While the tracer concentrations presented in the table do not represent the concentration of metals of concern, they indicate the trend of contaminant dilution by the natural surface runoff flow in the Thor Lake system.

Table 3.1: Average Concentration of Inert Tracer in The Thor Lake System

Year of Simulation	Plant Discharge	Tailings Pond	Polishing Pond	Drizzle Lake	Murky Lake	Thor Lake
1	1.0	0.00091	0.00026	0.00004	0.00003	<0.00001
2	1.0	0.00160	0.00073	0.00021	0.00017	0.00001
3	1.0	0.00215	0.00119	0.00043	0.00037	0.00004
4	1.0	0.00260	0.00164	0.00064	0.00058	0.00009
5	1.0	0.00299	0.00208	0.00092	0.00085	0.00016
6	1.0	0.00331	0.00241	0.00111	0.00104	0.00024
7	1.0	0.00360	0.00269	0.00126	0.00119	0.00031
8	1.0	0.00386	0.00292	0.00138	0.00132	0.00038
9	1.0	0.00408	0.00313	0.00152	0.00144	0.00044
10	1.0	0.00423	0.00330	0.00159	0.00152	0.00050
11	1.0	0.00437	0.00342	0.00178	0.00159	0.00057
12	1.0	0.00455	0.00355	0.00179	0.00166	0.00058
13	1.0	0.00466	0.00369	0.00180	0.00171	0.00061
14	1.0	0.00477	0.00379	0.00185	0.00177	0.00063
15	1.0	0.00485	0.00387	0.00190	0.00183	0.00066
16	1.0	0.00492	0.00394	0.00199	0.00186	0.00070
17	1.0	0.00500	0.00392	0.00194	0.00186	0.00068
18	1.0	0.00500	0.00389	0.00191	0.00176	0.00067
19	1.0	0.00504	0.00400	0.00199	0.00186	0.00070
20	1.0	0.00508	0.00408	0.00207	0.00191	0.00071

In general, the tracer concentrations in all water bodies increase and the rate of increase slows with time. Meanwhile, the tracer concentration decreases progressively from one water body to another as the water travels downstream. This is mainly due to mixing of the tracer with the large volumes of water in the downstream water bodies. As well, the fresh natural runoff entering into different parts of the Thor Lake system leads to further dilution of the tracer.

While thermal stratification occurs in Thor Lake, vertical variation of temperature in the other water bodies remains small because they are very shallow. Tracer concentration in each of the individual water bodies remains relatively constant, indicating the tracer is well mixed horizontally and vertically within each water body. This is because the stratification has been maintained only by temperature, which results in relatively weak density stratification. Combined with the shallow depths of the Thor Lake system, wind energy at the site is sufficient to cause mixing and transport of the tracer throughout all depths of the water bodies. As well, the meromictic overturn in fall and spring as surface and bottom water temperatures converge leads to additional vertical transport and mixing.

Figures 3.1-3.2 illustrate in plan view the concentration of Al and Fe, the two metal species with decant concentration over the limit of the CCME water quality guideline, in the Thor Lake system at the end of the model simulation in Year 20. Figures 3.3 and 3.4 show the cross-section view the concentrations of Al and Fe in Year 20. Figure 3.5 shows the time series concentration of Al, Fe, U and Th at the outflow to Fred Lake. Table 3.2 summarizes the maximum concentration of all metal species in Drizzle, Murky and Thor lakes. Also included in the table are the MMER regulation and CCME water quality guideline requirements.

Table 3.2: Maximum Metal Concentration in The Thor Lake System and Water Quality Guidelines for The Metals of Concern

Metal Species	Thor Lake	Murky Lake	Drizzle Lake	CCME Water Quality Guideline	MMER Effluent Criteria
Al (mg/L)	0.0005	0.0013	0.0017	0.1	-
Fe (mg/L)	0.0004	0.0012	0.0015	0.3	-
Cd (mg/L)	5.1E-8	1.4E-7	1.8E-7	0.00002-0.00013	-
Hg (mg/L)	7.6E-8	2.1E-7	2.7E-7	0.000026	-
Ag (mg/L)	2.3E-8	6.4E-8	8.1E-8	0.0001	-
As (mg/L)	1.7E-6	4.7E-6	5.9E-6	0.005	0.5
Cr (mg/L)	8.3E-7	2.3E-6	3.0E-6	0.0089	-
Cu (mg/L)	1.7E-6	4.9E-6	6.2E-6	0.002-0.004	0.30
Mo (mg/L)	3.6E-5	1.0E-4	1.3E-4	0.073	-
Ni (mg/L)	5.3E-6	1.5E-5	1.9E-5	0.025-0.150	0.50
Pb (mg/L)	4.5E-7	1.3E-6	1.6E-6	0.001-0.007	0.20
Zn (mg/L)	5.3E-6	1.5E-5	1.9E-5	0.03	0.50
U (mg/L)	7.3E-6	1.7E-5	2.3e-5	0.015	-
Th (mg/L)	5.8E-7	1.3E-6	1.8E-6	-	-
Ra-226(Bq/L)	8.3E-6	1.9E-5	2.6E-5	-	0.37

The important factor controlling the metal concentrations in the Thor Lake system is the balance of the tailings inflow, the freshwater inflows, the outflow at Thor Lake and the water withdrawal from Thor Lake to the concentrator plant. The metal concentrations continue to increase from year to year while showing an annual fluctuation cycle which coincides with the freshwater water input, indicating that the fluctuation of the freshwater inflow control.

While the concentrations of the metals of concern continue to increase with time, the water quality guideline is met for all metal species in Drizzle, Murky and Thor lakes, including AL and Fe, over the entire simulation period.

4.0 CONCLUSION AND RECOMMENDATIONS

While it has been shown that the concentration of the dissolved metal continue to increase over the course of the entire 20-year period of mine operations, the model shows that the water quality in Drizzle, Murky and Thor lakes will meet the water guideline requirements for all metals of concern outlined in CCME during and at the end of the 20-year mine operation period.

All metals considered in this report, including the radioactive Uranium, Thorium and Radium-226, which all have very long half-life, were assumed chemically inert. The results shown in this study with regard to the radioactive metal species would be conservative as a result.

5.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Avalon Rare Metals Inc. EBA, A Tetra Tech Company, does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Avalon Rare Metals Inc., or for any project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in EBA's Services Agreement. EBA's General Conditions are provided in Appendix A of this report.

6.0 CLOSURE

We trust this report meets your present requirements. Should you have any questions or comments, please contact the undersigned at your convenience.

Sincerely,
EBA, A Tetra Tech Company

Prepared by:

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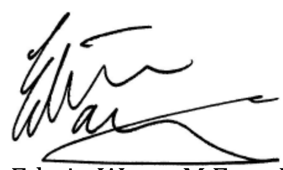

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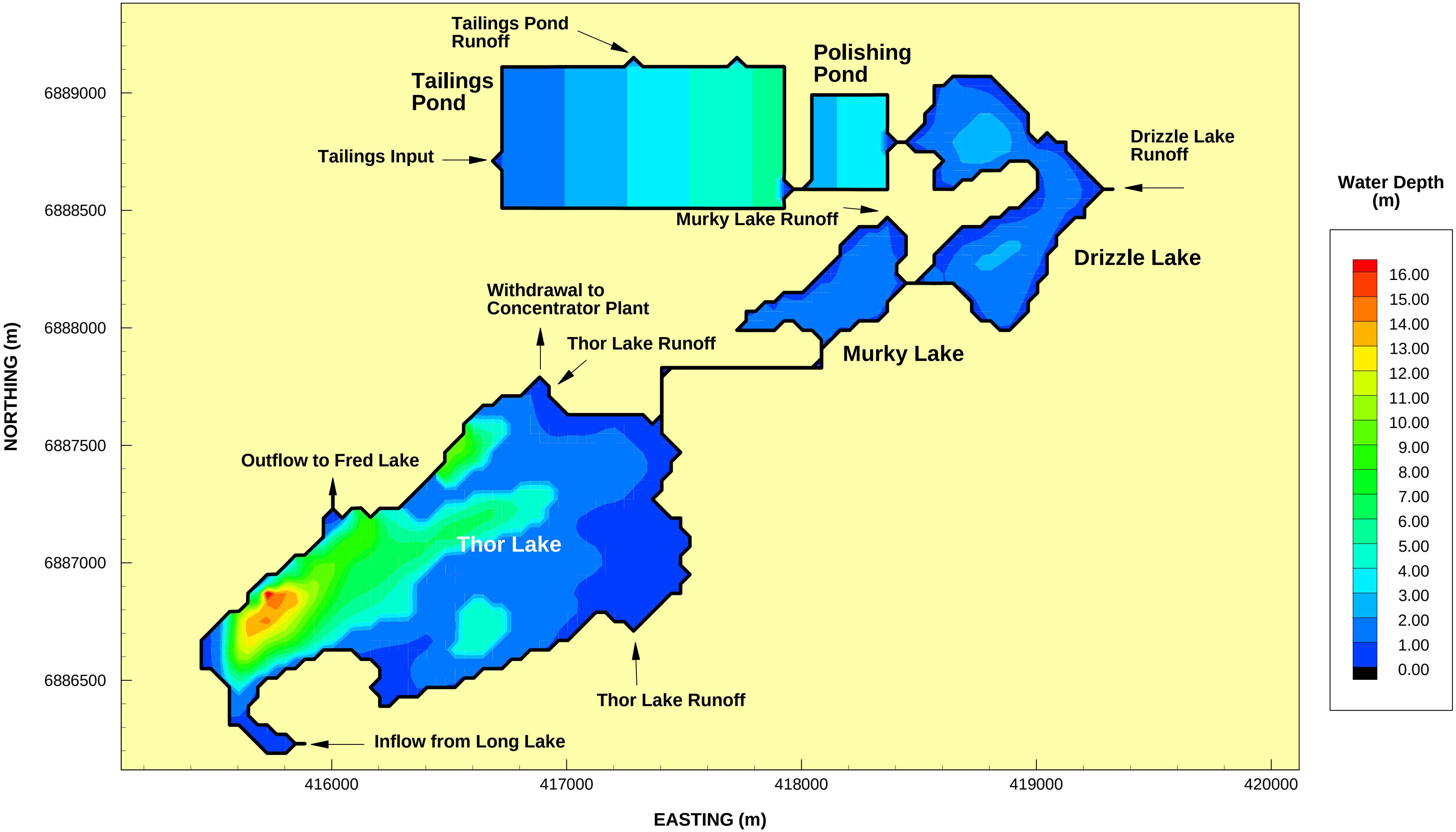
Knight Piésold Consulting. "Memorandum: Time Series Data from Thor Lake Watershed Water/Solid Balance." 2011.

Stantec Inc. "Thor Lake Earth Metals Baseline Project. Environmental Baseline Report: Volume 3 – Aquatics and Fisheries." 2010.

FIGURES



NOTES

- The shape, area and bathymetry of the tailings and polishing ponds as shown are only an approximation

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WATER QUALITY MODELLING THOR LAKE PROJECT

Bathymetry Thor Lake System

PROJECT NO.	DWN	CKD	REV
V15101007.006	AL	JAS	1

OFFICE	DATE
EBA-VANC	March 1, 2011

Figure 1.1

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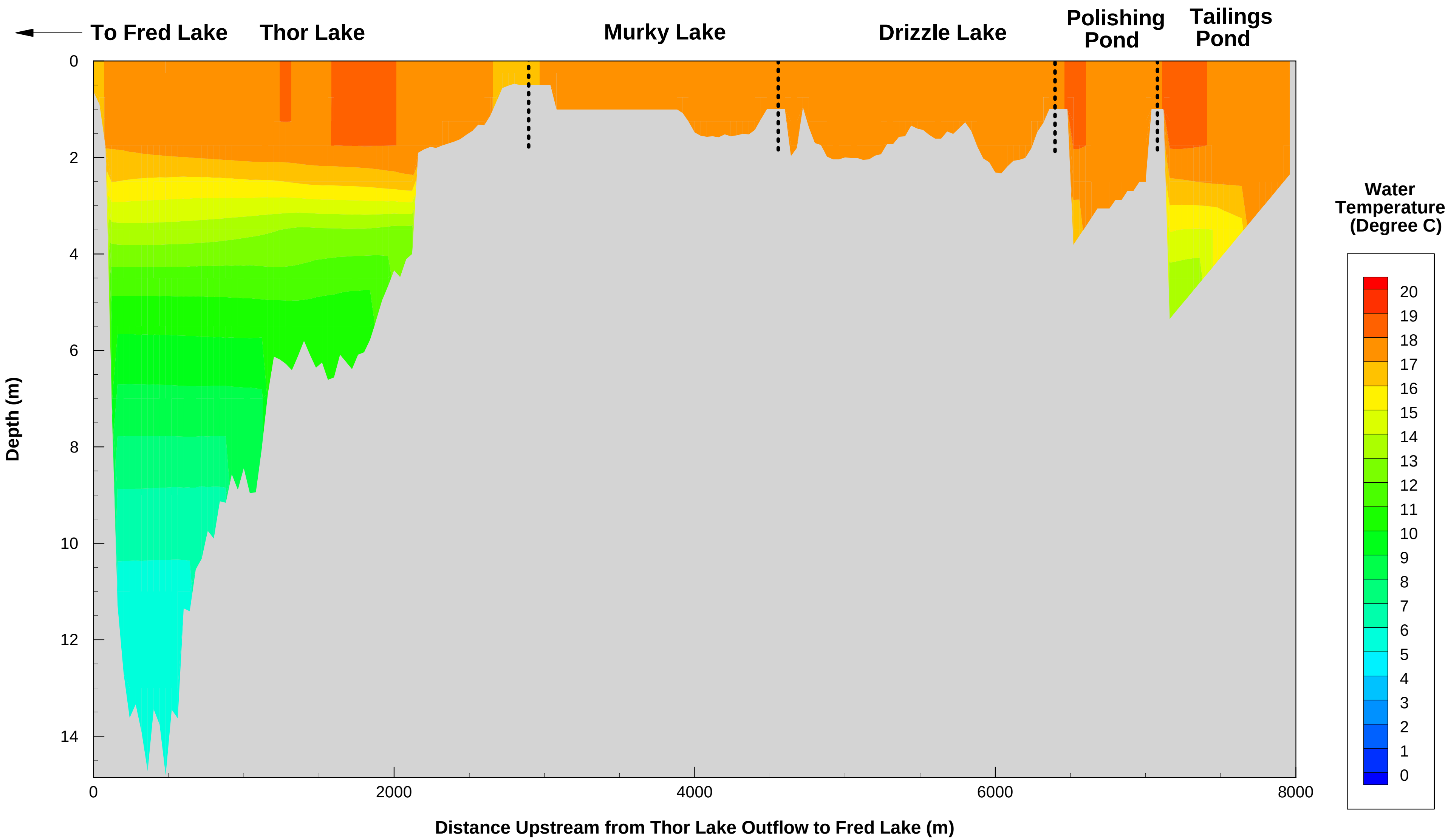

LEGEND

NOTES

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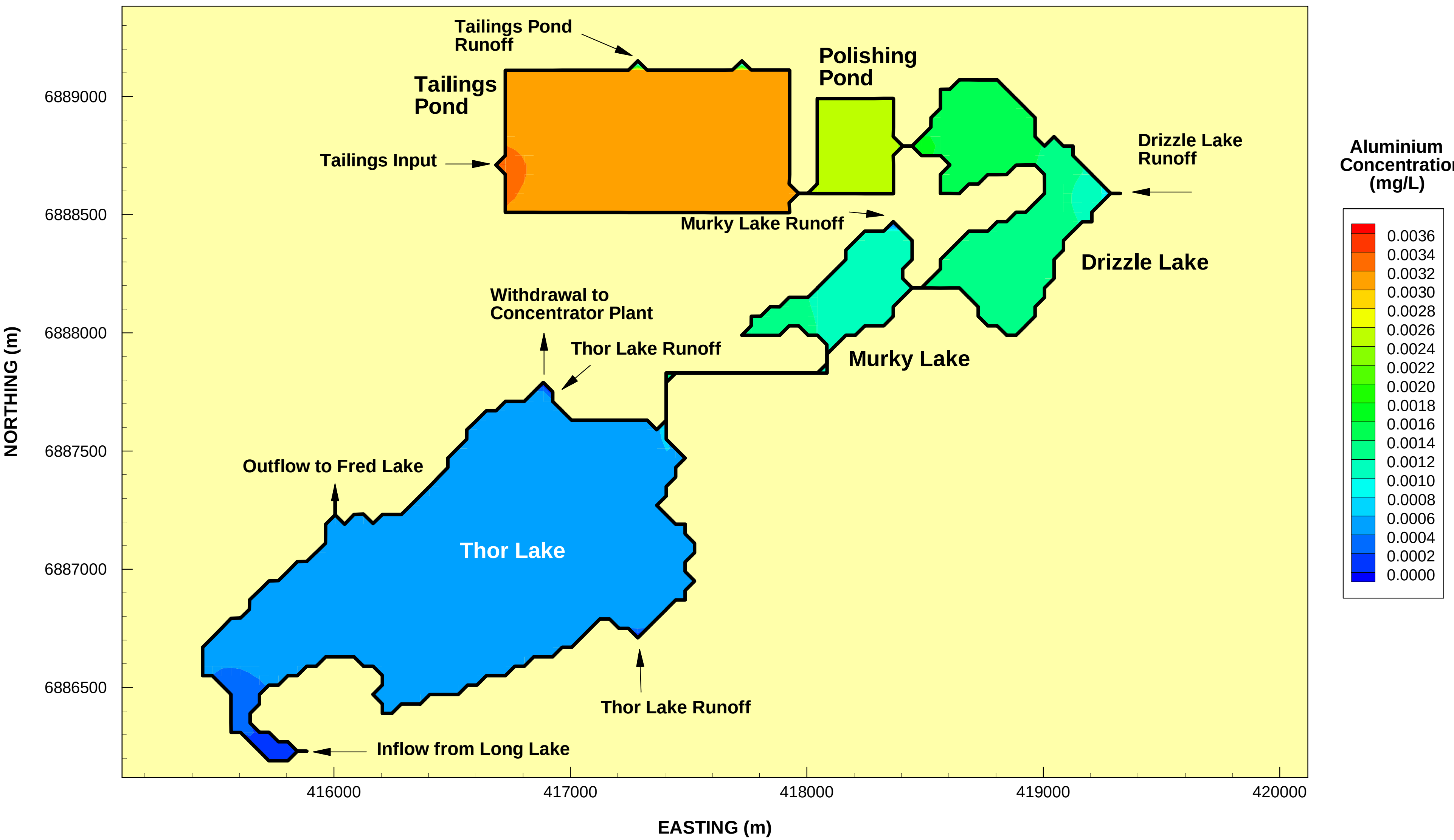
WATER QUALITY MODELLING THOR LAKE PROJECT

Cross Section Water Temperature Summer Season After Commencement of Mine Operation

PROJECT NO.	DWN	CKD	REV
V15101007.006	AL	JAS	1

OFFICE	DATE
EBA-VANC	March 1, 2011

Figure 2.1



NOTES

- The shape and area of the tailings and polishing ponds as shown are only an approximation

CLIENT

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WATER QUALITY MODELLING THOR LAKE PROJECT

Concentration of Aluminium Year 20 After Commencement of Mine Operation

PROJECT NO.	DWN	CKD	REV
V15101007.006	AL	JAS	1

OFFICE	DATE
EBA-VANC	March 10, 2011

Figure 3.1

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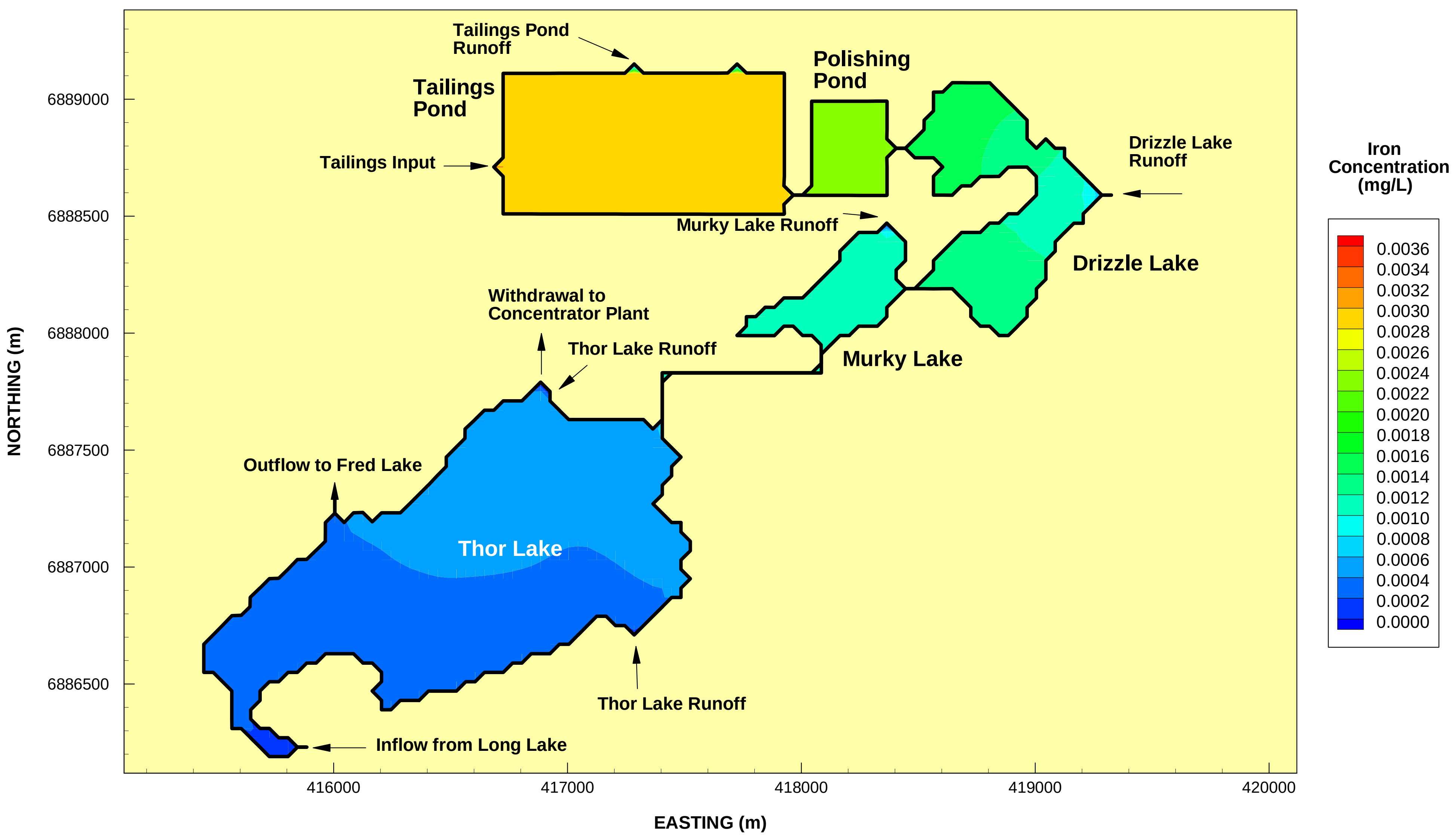

NOTES

- The shape and area of the tailings and polishing ponds as shown are only an approximation

CLIENT

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EBA Engineering Consultants Ltd.

WATER QUALITY MODELLING
THOR LAKE PROJECT

Concentration of Iron
Year 20
After Commencement of Mine Operation

PROJECT NO.	DWN	CKD	REV
V15101007.006	AL	JAS	1

OFFICE	DATE
EBA-VANC	March 10, 2011

Figure 3.2

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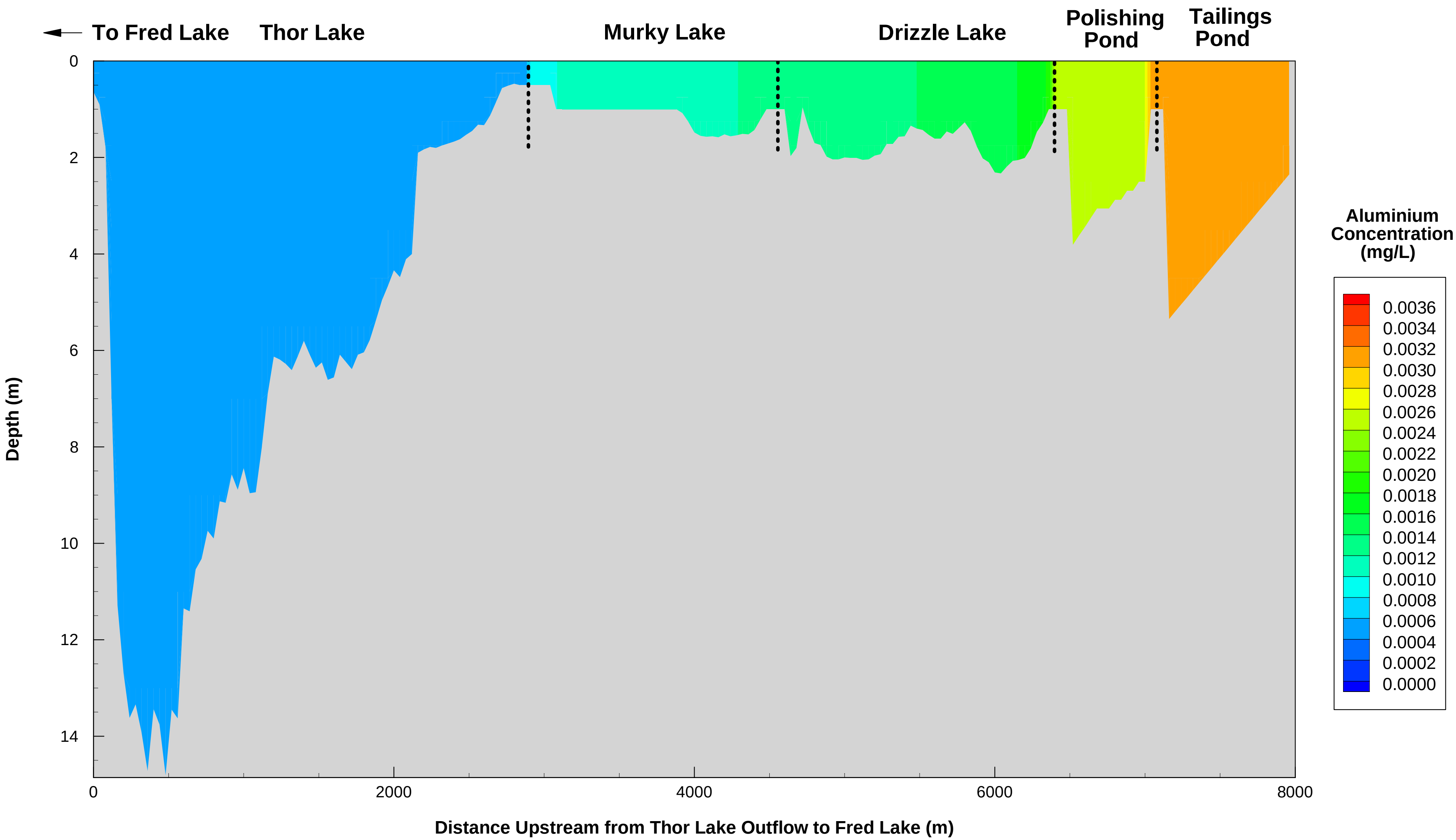

LEGEND

NOTES

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WATER QUALITY MODELLING
THOR LAKE PROJECT

Sectional Concentration of Aluminium
Year 20
After Commencement of Mine Operation

PROJECT NO.	DWN	CKD	REV
V15101007.006	AL	JAS	1

OFFICE	DATE
EBA-VANC	March 1, 2011

Figure 3.3

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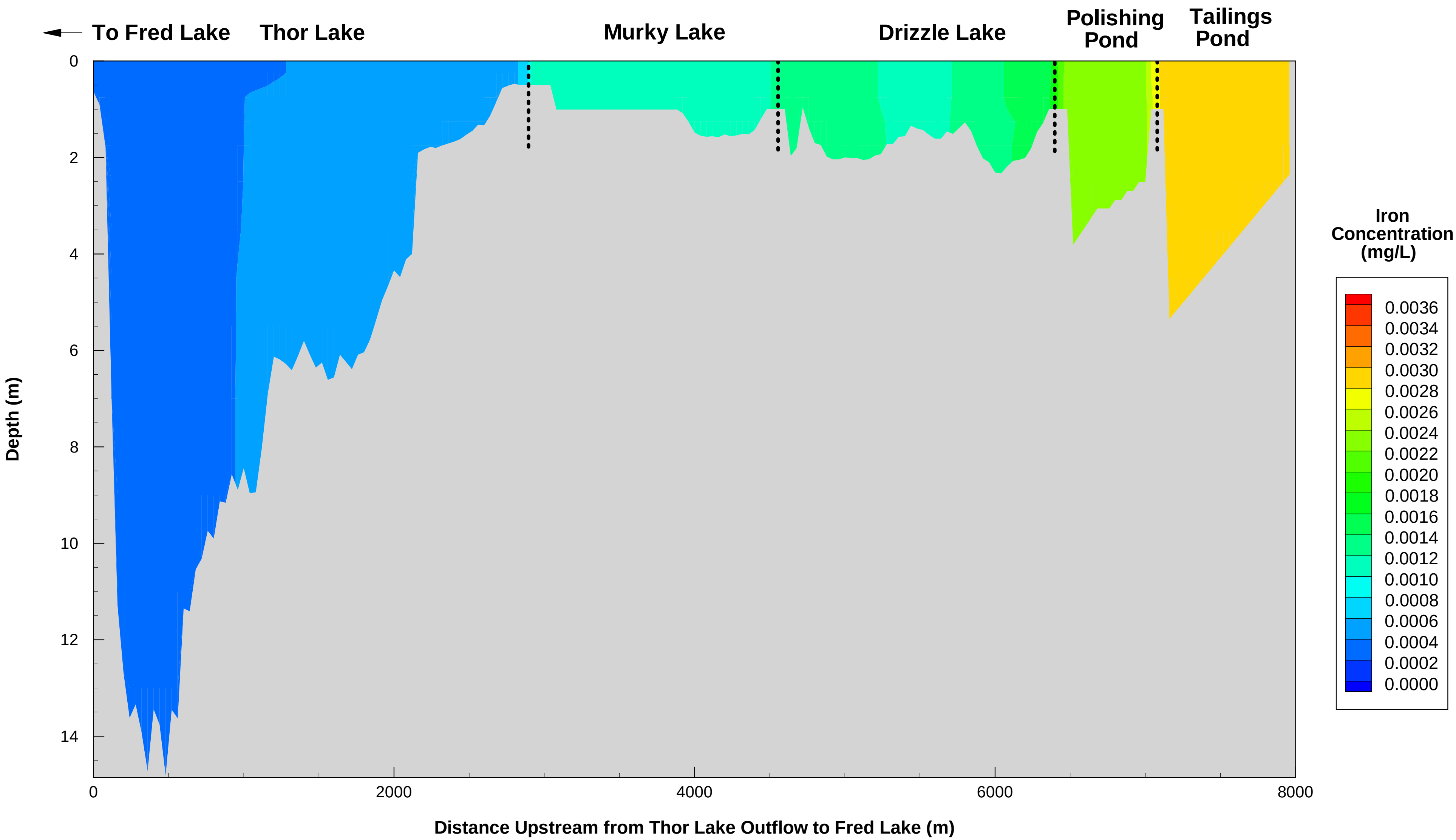

LEGEND

NOTES

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WATER QUALITY MODELLING
THOR LAKE PROJECT

Sectional Concentration of Iron
Year 20
After Commencement of Mine Operation

PROJECT NO.	DWN	CKD	REV
V15101007.006	AL	JAS	1
OFFICE	DATE		
EBA-VANC	March 10, 2011		

Figure 3.4

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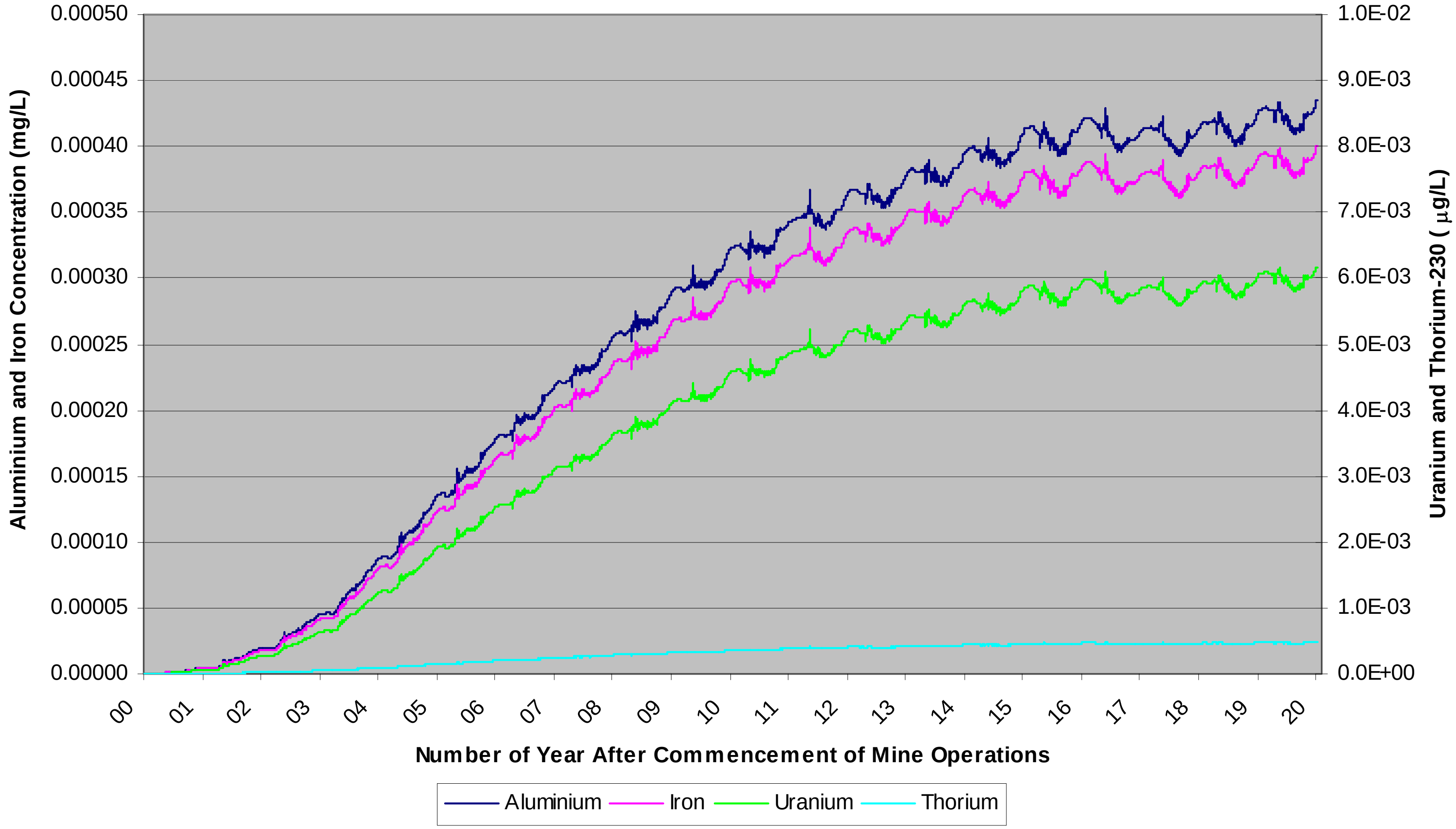

NOTES

- Modelling period starts in May 1987 and ends in December 2008
- CCME Water Quality Guideline: Aluminium = 0.1 mg/L; Iron = 0.3 mg/L; Uranium = 0.015 mg/L
- Uranium and Thorium have long half-life and therefore are considered conservative in the study.

CLIENT

AVALON RARE METALS INC.

EBA Engineering Consultants Ltd.

WATER QUALITY MODELLING
THOR LAKE PROJECT

Time Series Concentration
Aluminium, Iron, Uranium and Thorium
Outlet of Thor Lake to Fred Lake

PROJECT NO.	DWN	CKD	REV
V15101007.006	AL	JAS	1
OFFICE	DATE		
EBA-VANC	March 14, 2010		

Figure 3.5

APPENDIX A

APPENDIX A EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

DESIGN REPORT

This Design Report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT AND OWNERSHIP

This Design Report pertains to a specific site, a specific development, and a specific scope of work. The Design Report may include plans, drawings, profiles and other support documents that collectively constitute the Design Report. The Report and all supporting documents are intended for the sole use of EBA's Client. EBA does not accept any responsibility for the accuracy of any of the data, analyses or other contents of the Design Report when it is used or relied upon by any party other than EBA's Client, unless authorized in writing by EBA. Any unauthorized use of the Design Report is at the sole risk of the user.

All reports, plans, and data generated by EBA during the performance of the work and other documents prepared by EBA are considered its professional work product and shall remain the copyright property of EBA.

2.0 ALTERNATIVE REPORT FORMAT

Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA's instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. EBA's instruments of professional service will be used only and exactly as submitted by EBA.

Electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless so stipulated in the Design Report, EBA was not retained to investigate, address or consider, and has not investigated, addressed or considered any environmental or regulatory issues associated with the project specific design.

4.0 CALCULATIONS AND DESIGNS

EBA has undertaken design calculations and has prepared project specific designs in accordance with terms of reference that were previously set out in consultation with, and agreement of, EBA's client. These designs have been prepared to a standard that is consistent with industry practice. Notwithstanding, if any error or omission is detected by EBA's Client or any party that is authorized to use the Design Report, the error or omission should be immediately drawn to the attention of EBA.

5.0 GEOTECHNICAL CONDITIONS

A Geotechnical Report is commonly the basis upon which the specific project design has been completed. It is incumbent upon EBA's Client, and any other authorized party, to be knowledgeable of the level of risk that has been incorporated into the project design, in consideration of the level of the geotechnical information that was reasonably acquired to facilitate completion of the design.

If a Geotechnical Report was prepared for the project by EBA, it will be included in the Design Report. The Geotechnical Report contains General Conditions that should be read in conjunction with these General Conditions for the Design Report.

6.0 INFORMATION PROVIDED TO EBA BY OTHERS

During the performance of the work and the preparation of the report, EBA may rely on information provided by persons other than the Client. While EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

Appendix B.4

Nutrient Modeling for the Thor Lake Project – Technical Memorandum. May 2011

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TECHNICAL MEMO

ISSUED FOR USE

TO:	Rick Hoos	**DATE:**	May 9, 2011
C:		**MEMO NO.:**	001
FROM:	Albert Leung and Jim Stronach	**EBA FILE:**	V15101007.006

SUBJECT: **Nutrient Modelling for the Thor Lake Project**

1.0 INTRODUCTION

The Flotation Plant at the proposed Nechalacho Mine, to be located in the Northwest Territories, will discharge process tailings into the Tailings Management Facility (TMF). Decant water from the TMF will be directed into Drizzle Lake which drains into Murky Lake, Thor Lake, and eventually other downstream water bodies of the Thor Lake system. The water fraction of the tailings is expected to contain elevated levels of nitrogen, due mainly to the explosive chemicals (ANFO) used for underground mine blasting during the mining operation. Such discharges will lead to increased concentrations of nitrogen in these water bodies. This additional nitrogen, upon reaching the downstream lake system, will become available for phytoplankton growth and may result in increased productivity of phytoplankton in the downstream lakes.

Potential issues associated with excess phytoplankton productivity may relate to depletion of dissolved oxygen through bacterial processes fed by the enhanced production and degradation of the aquatic environment. Because the response of phytoplankton to increased nitrogen is a complex process, related also to levels of phosphorous, water temperature and sunlight primarily, a numerical model of the phytoplankton population, considering these additional processes, was used to determine the possible effects of nitrogen enrichment on phytoplankton productivity during mine operations.

2.0 NUMERICAL MODELLING

The dynamics of the phytoplankton population and possible changes have been simulated through the use of a three-dimensional hydrodynamic model, H3D, coupled with the phytoplankton equations as employed in CE-QUAL-W2, (Cole and Wells 2008), supported by the Army Corps of Engineers, a widely used two-dimensional, laterally averaged hydrodynamic and water quality model. The water quality module is readily transported to three dimensional systems such as H3D. The phytoplankton model also simulates the population of herbivorous zooplankton, which forms an essential part of the population dynamics of phytoplankton, the nitrogen and phosphorous uptakes by phytoplankton, and the regeneration of nitrogen and phosphorus from phytoplankton and herbivore respiration, metabolic products and death/decay.

2.1 Model Description

While H3D simulates the hydrodynamics and thereby the transport and movement of biological populations and nutrients in the Thor Lake system (Tetra Tech, 2011), the CE-QUAL portion embedded in H3D simulates the biological dynamics between the nutrients and zooplankton and phytoplankton populations. The input parameters to the biological component of the model are listed below with values in parentheses.

- Sinking rate for replete phytoplankton (0.1 m/day)
- Sinking rate for deplete phytoplankton (0.1 m/day)
- Carbon to nitrogen mass ratio (10)
- Carbon to phosphorous mass ratio (140)
- Gross production rate of phytoplankton (5.0 mg C / mg C /day)
- Light saturation for plant growth (30 Watt/m^2)
- Half saturation concentration for nitrogen limitation (0.025 mg/L)
- Half saturation concentration for phosphorus limitation (0.01 mg/L)
- Self-shading (0)
- Herbivore grazing efficiency (0.5)
- Maximum herbivore grazing rate (1.5 day^{-1})
- Phytoplankton concentration for grazing threshold (10 μg/L)
- Phytoplankton saturation concentration (300 μg/L)
- Herbivore excretion - ratio of herbivore respiration to grazing (0.1)
- Dark respiration rate (0.1 day^{-1})
- Photorespiration rate (0.03 day^{-1})
- Maximum mortality rate for phytoplankton (0.1 day^{-1})
- Respiration rate for herbivores (0.1 day^{-1})
- Mortality for herbivores (0.01 day^{-1})
- Minimum mass concentrations of nitrogen, phosphorus, phytoplankton and herbivore zooplankton (0.001 mg/L, 0.001 mg/L, 1 μg/L, 10 μg/L, respectively).

The above values were based on values published in the CE-QUAL-W2 manual for species of phytoplankton and herbivores that were found in the Thor Lake system, but in all cases, a range of values for each parameter presented itself. Ultimately, the selection of numerical values was also informed by the calibration process described below. The units of phytoplankton and herbivore concentrations in the model are grams of biomass per cubic metre.

In additional to the above parameters, initial concentrations of nitrogen (0.04 mg/L), phosphorus (0.001 mg/L), phytoplankton (100 μg/L), and herbivore zooplankton (10 μg/L) are given to the model. The nitrogen, phosphorous, phytoplankton and herbivore levels are based on data reported for the Thor Lake system (Stantec 2010). Specifically, the Stantec report provided nitrogen and phosphorous concentrations directly in Table F3-13. It provided chlorophyll concentrations in the range of 3 to 10 μg/L in Volume 3, Section 6. Assuming a carbon to chlorophyll ratio of 10, and a biomass to carbon ration of 2, the phytoplankton biomass values found in the Thor lake system range from about 60 μg/L to 200 μg/L. EBA took a representative value of 100 μg/L as the initial condition. The herbivore initial concentration was taken to be one tenth the phytoplankton biomass concentration.

The model outputs include water temperature, and concentrations of nitrogen, phosphorus, phytoplankton, and herbivore zooplankton.

2.2 Model Calibration

Calibration of the model was conducted based on measurements of existing (baseline) water quality in the Thor Lake System (Stantec 2010). The water quality parameter available for model calibration is the phytoplankton concentration. Generally, nutrient levels are prescribed to the model, based on observed data and then the model parameters provided are adjusted until reasonably repeatable observed phytoplankton and herbivore zooplankton concentrations are achieved.

The peak phytoplankton biomass concentration in Thor Lake during annual spring blooms (Figure 2.1) is predicted to reach approximately 100 μg/L, while the herbivore biomass concentration remains relatively stable at 10 μg/L. Nitrogen level displays annual fluctuation cycles, with most of the nitrogen depleted during the spring blooms and replenished during late fall and winter seasons. In the meantime, phosphorous levels remain low. The achievement of similar levels of phytoplankton biomass during the modelled spring bloom to the largest spring/summer values reported by Stantec is taken to be an indication that the model is a reasonable representation of the major characteristics of phytoplankton dynamics in the Thor Lake system. As well, the annual dissolved nitrogen cycle is similar in the model and in the observations, except that winter regeneration is underestimated in the model.

2.3 TMF Decant Water Nitrogen Concentration

A parallel simulation to that described in Section 2.2 was conducted, but with a nitrogen concentration of 8.9 mg/L in the TMF decant water discharge. The nitrogen concentration level in the TMF decant water was determined based on the discharge flow rate and the daily amount of nitrogen as ammonia and nitrate discharged in the tailings, as provided by Avalon.

The model simulation output predicts that the added nitrogen may lead to enhanced phytoplankton growth, and the peak phytoplankton biomass concentration during annual spring blooms may reach a level of 300 μg/L in Thor Lake and 400 μg/L in the TMF (Figures 2.2 and 2.3). The model also shows that the elevated phytoplankton population in turn will likely lead to an increase in the herbivore population, especially during the spring bloom periods, with biomass concentrations potentially reaching 150 μg/L in Thor Lake and 200 μg/L in the TMF.

The model predicts that nitrogen levels will continue to build up with time in the downstream water bodies; however the peak biomass concentration for phytoplankton remains relatively constant from year to year. This suggests that nitrogen, once reaching a certain level, will become a non-limiting nutrient for phytoplankton growth. It is interesting to note that predicted nitrogen levels in the TMF are about 10 times the levels predicted in Thor Lake, but the phytoplankton and herbivore concentrations are nearly identical in the two water bodies. It should also be noted that the predicted levels of nitrogen in Thor Lake range up to 0.35 mg/L after 10 years of operation. This value is similar to the current peak levels in Thor Lake, indicating that the system is already subject to significant nitrogen concentration at the start of the growing season.

Based on the results of the model, the additional nitrogen introduced by the TMF decant water appears to trigger an additional early and short-lived spring bloom, followed by a more typical extended summer bloom. Although phytoplankton concentrations in the early spring bloom are predicted by the model to be about 2-3 times higher than the summer bloom, the summer bloom remains about the same as the existing baseline case. The phytoplankton produced in the early spring bloom are predicted to be quickly consumed by the herbivore population, which is also higher in the case with the added nitrogen. It appears that the added nitrogen from the mining operations serves to kick-start the system once sufficiently warm conditions occur, compared to the present baseline case, where nitrogen may not be quite as available in the early spring.

Consequently, the growth-limiting nutrient is primarily phosphorus, which remains low in concentration throughout the simulation period.

3.0 DISCUSSION

The model predicts that the input of additional nitrogen from the TMF decant water to the Thor Lake system may lead to seasonally increased phytoplankton growth and concentration. Although the nitrogen level is predicted to continue to increase over the ten-year model simulation period, phytoplankton productivity appears to remain very similar from year to year.

It also appears that the phytoplankton biomass is likely limited by the amount of bio-available phosphorus in the water body as the annual peak phytoplankton biomass remains stable even as the annual peak nitrogen values rise in the system. It is important to note that with the input from the TMF decant water and the dilutions available in the Thor Lake system, nitrogen levels in Thor Lake and in the outflow from Thor Lake are predicted to be no more than approximately double their current observed peak values. That is, the current system appears to produce significant natural nitrogen concentrations in the water over the winter months as organic material collected on the bottom decays.

The natural production of nitrogen can be inferred from the dissolved oxygen profiles taken in the Thor Lake system, shown in Section 6 of Volume 3 of the Stantec (2010) report, which show a decline of dissolved oxygen, particularly at the bottom, during the winter months.

The model predicts that the input of additional nitrogen into the downstream lake environment may trigger a change in timing of the spring bloom, and an overall increase in planktonic biomass.

Preliminary estimates, comparing the increase in standing stock to the potential rate of supply of oxygen due to wind and waves, are that the system can readily supply many times more oxygen than what would be consumed by the decay of the additional planktonic biomass.

It has been assumed in the model that the additional input of phosphorus from the TMF decant will be negligible, equivalent to existing baseline levels. Since the phosphorous level in all tributaries and the TMF decant water discharge is assumed to remain low (~0.001 mg/L), the phytoplankton concentration and its evolution during mine operations are predicted to be generally similar to those predicted for the existing baseline condition, except for the development of an additional short-lived early-spring bloom. Water quality is not negatively affected by this additional spring bloom because oxygen input from the atmosphere can readily handle the additional oxygen demand associated with this bloom.

4.0 CLOSURE

We trust this report meets your present requirements. Should you have any questions or comments, please contact the undersigned at your convenience.

Sincerely,
EBA, A Tetra Tech Company

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Cole, T.M., and S.A. Wells. "CE-QUAL-W2: A Two Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.6." Department of Civil and Environmental Engineering, Portland State University, Portland, OR. 2008.

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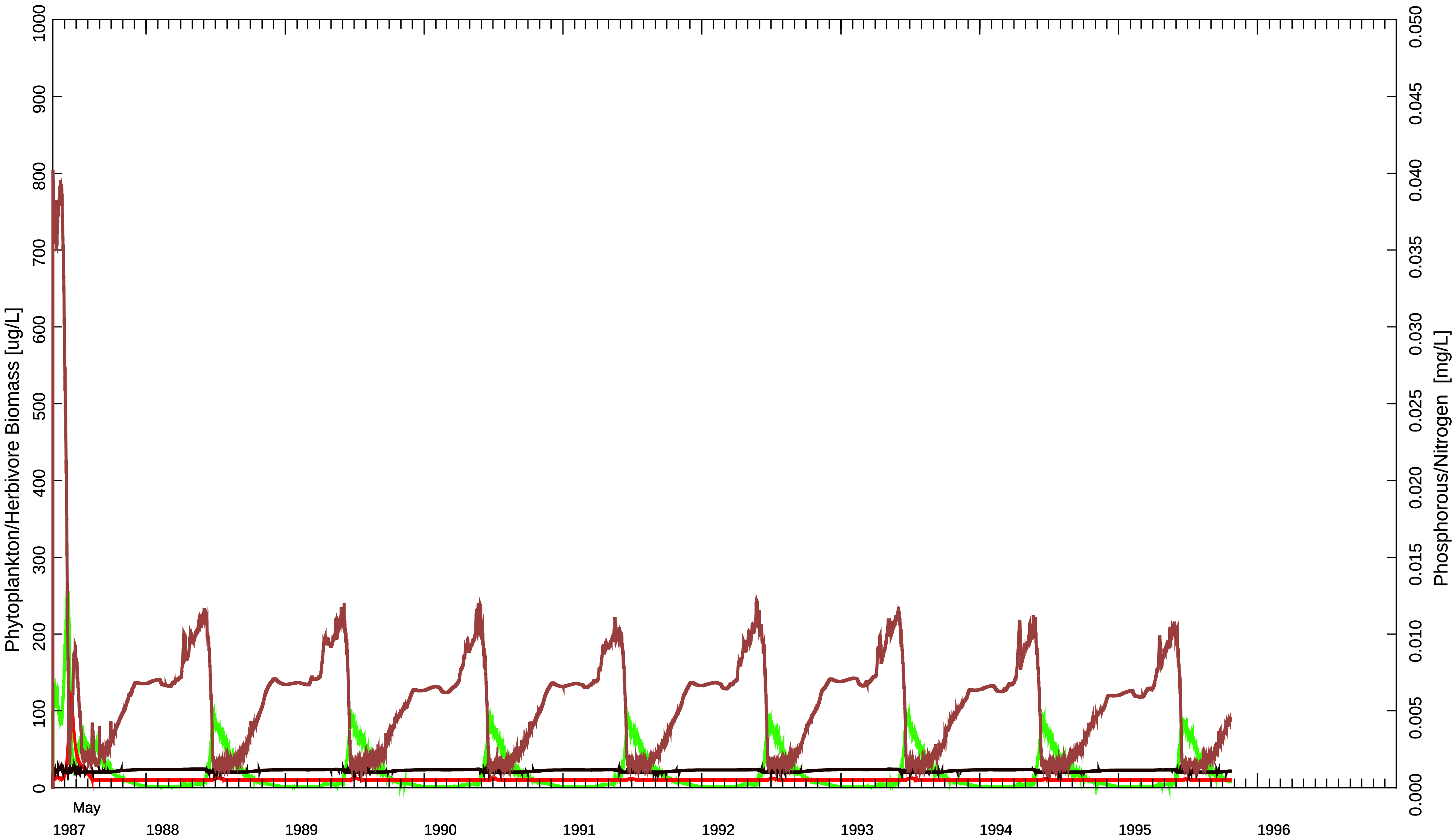
FIGURES



NOTES

Phytoplankton
Herbivore
Phosphorous
Nitrogen

STATUS

CLIENT

Avalon Rare Earth

eba
A TETRA TECH COMPANY

NUTRIENT MODELLING THOR LAKE

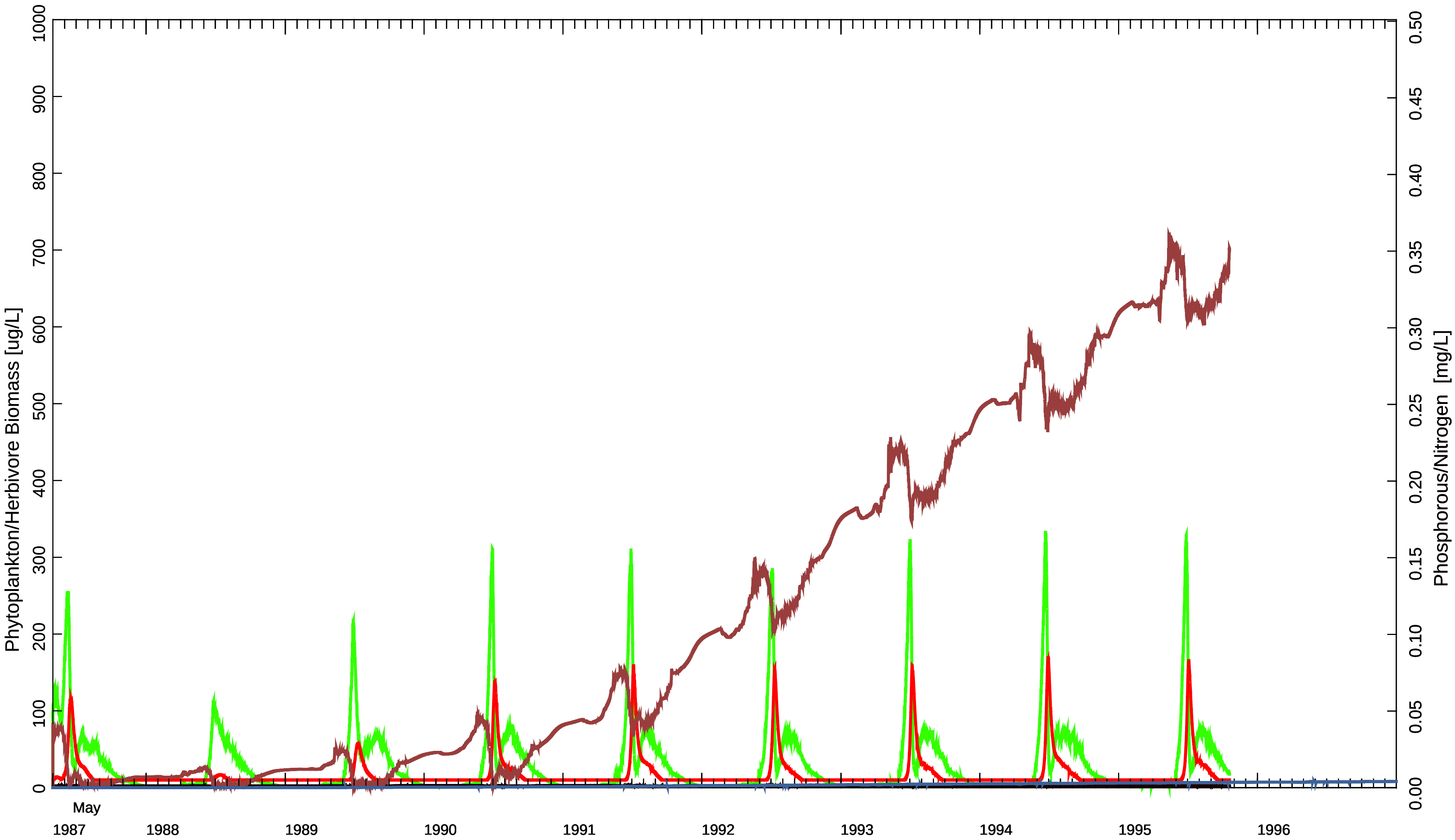
Pre-Mining Conditions Normal P, Normal N

PROJECT NO.	DWN	CHK	APVD	REV
V15101007	AL	JAS	JAS	0

OFFICE	DATE
EBA-VANC	MAY 2011

Figure 2.1

Mon May 09 14:23:44 2011:V:\V15101007-Avalon\Working\JAS\run10



NOTES

- Phytoplankton
- Herbivore
- Phosphorous
- Nitrogen
- Conservative Nitrogen

STATUS

CLIENT

Avalon Rare Earth

eba
A TETRA TECH COMPANY

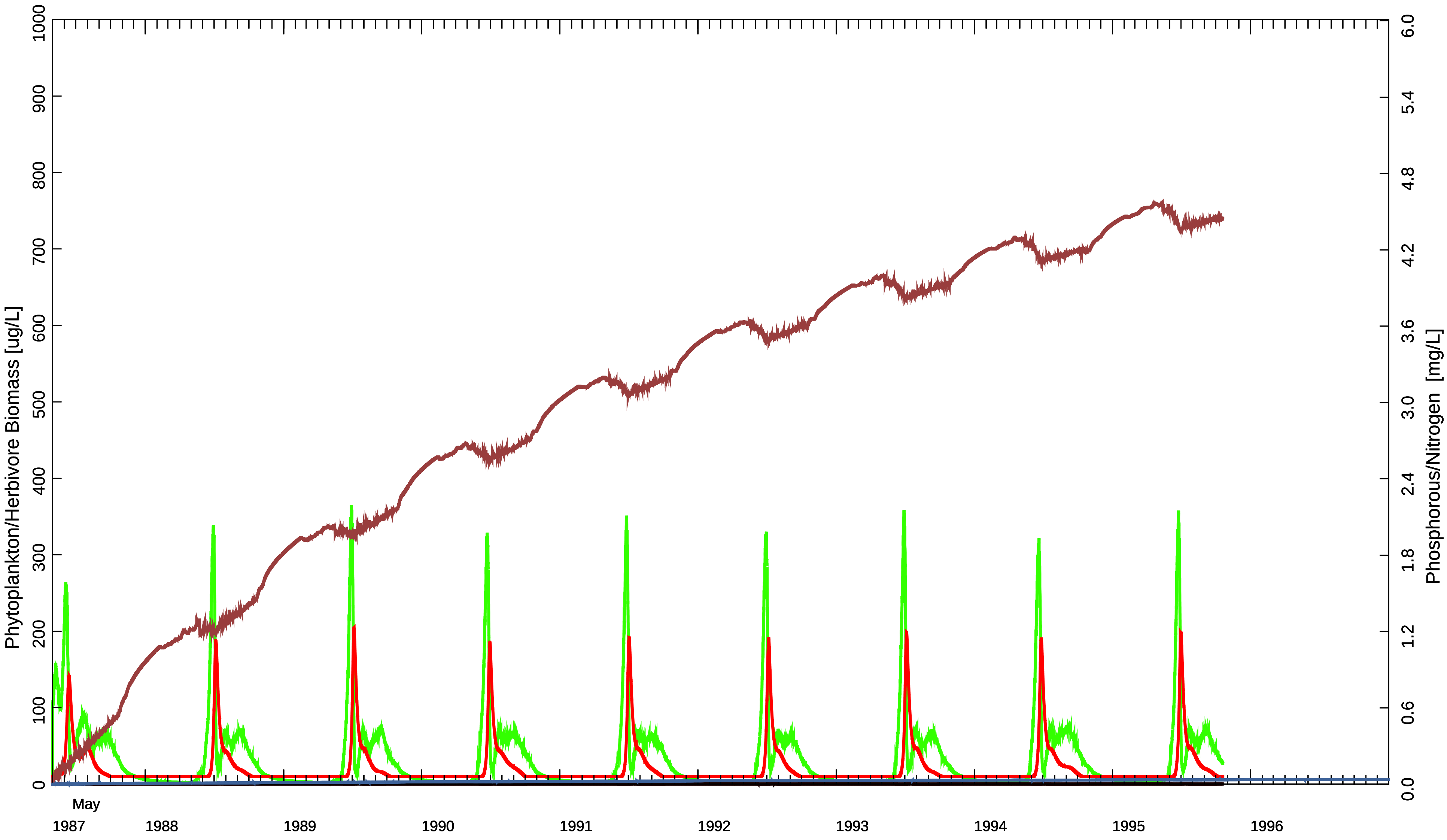
NUTRIENT MODELLING THOR LAKE

Operating Mine Conditions
Normal P, Elevated N, Surface

PROJECT NO.	DWN	CHK	APVD	REV
V15101007	AL	JAS	JAS	0

OFFICE	DATE
EBA-VANC	MAY 2011

Figure 2.2



NOTES

- Phytoplankton
- Herbivore
- Phosphorous
- Nitrogen
- Conservative Nitrogen

STATUS

CLIENT

Avalon Rare Earth

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NUTRIENT MODELLING TAILINGS POND

Operating Mine Conditions
Normal P, Elevated N, Surface

PROJECT NO.	DWN	CHK	APVD	REV
V15101007	AL	JAS	JAS	0

OFFICE	DATE
EBA-VANC	MAY 2011

Figure 2.3