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March 26, 2019

Mackenzie Valley Land and Water Board
P.O. Box 2130
7th Floor – 4922 48th Street
Yellowknife, NT X1A 2P6

Attention: Jacqueline Ho, Technical Regulatory Specialist

Re: 2018 Annual Water Licence Report – MV2017L2-0007

Please find enclosed one copy of the 2018 Annual Water Licence Report for Pine Point Mine as required under Water Licence MV2017L2-0007.

Please contact me if you have any questions or concerns regarding this report.

Yours truly,

MUnger

Digitally signed by Michelle Unger
DN: cn=Michelle Unger, o=Teck, ou, email=michelle.unger@teck.com, c=CA
Date: 2019.04.03 12:01:25 -06'00'

Michelle Unger,
Manager, Environmental Performance

Attachment (1)

cc: Wendy Bidwell, Water Resource Officer Department of Environment & Natural Resources
Chief Louis Balsillie, Deninu K'ue First Nation, Fort Resolution
President Garry Bailey, Fort Resolution Métis Council, Fort Resolution

2018 Annual Water Licence Report for Pine Point, NT - MV2017L2-0007

Company: Teck Metals Ltd.

Prepared By: Michelle Unger
Date: March 26, 2019

Teck

EXECUTIVE SUMMARY

The Pine Point mine was operated by Cominco (a predecessor of Teck Metals Ltd.) as a large open-pit lead (Pb) and zinc (Zn) mine from 1964 to 1988. When the Pine Point Mine closed in 1988, the original Closure and Reclamation Plan (titled "Restoration and Abandonment Plan", approved June 1987) was implemented. Updates to the plan were issued in 1990 and again in 1991 as reclamation work neared completion. In accordance with the plan, surfaces leases and mining claims were surrendered back to the Crown during the mid to late 1990s, with the exception of one surface land lease (#85B/16-9-9), which encompasses the Tailings Impoundment Area (TIA). Restoration work at the TIA has focused on surface stability, effluent quality, and long term stability of the dykes and decant structures. The TIA is considered to be in the Closure-Active Care phase of mine life and operates under a Type B Water License (license MV2017L2-0007).

In 2018, a Reclamation Research Plan was submitted which outlines research activities to be conducted in 2018, 2019 and 2020, which will inform the updated Closure and Reclamation Plan to be submitted to the MVLWB by December 31, 2020. The goal of research is to resolve uncertainties regarding zinc (and other metals as necessary) movement within environmental media in the Tailings Impoundment Area (TIA).

Community engagement was conducted in 2018 related to the Reclamation Research activities and plans continue to engage in 2019.

Water accumulates in the pond every spring from snowmelt and rainfall. The water is elevated in Zinc, Lead and Copper and cannot be released to the environment without treatment. In early May 2018, the water level was above the maximum operating water level and an emergency decant was conducted for 15 days. Routine water treatment was then conducted from 20 August 2018 to 29 September 2018. The effluent discharge water quality was analyzed as per the water licence and met all the effluent quality criteria.

Other activities in 2018 included the routine dam inspections, maintenance to repair wave erosion and surface erosion rills on the north dyke, as well as sludge removal from the polishing pond within the water treatment area.

Work in 2019 will include Phase two of the Reclamation Research plan activities, routine dam inspections and water treatment.

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1.0 Introduction

The Pine Point mine was operated by Cominco (a predecessor of Teck Metals Ltd.) as a large open-pit lead (Pb) and zinc (Zn) mine from 1964 to 1988. The mine is located approximately 75 km east of Hay River, 50 km SW of Fort Resolution, and 13 km south of the southern shoreline of Great Slave Lake. The site location is shown on Figure 1.

When the Pine Point Mine closed in 1988, the original Closure and Reclamation Plan (titled “Restoration and Abandonment Plan”, approved June 1987) was implemented. Updates to the plan were issued in 1990 and again in 1991 as reclamation work neared completion. In accordance with the plan, surfaces leases and mining claims were surrendered back to the Crown during the mid to late 1990s, with the exception of one surface land lease (#85B/16-9-9), which encompasses the Tailings Impoundment Area (TIA). Restoration work at the TIA has focused on surface stability, effluent quality, and long term stability of the dykes and decant structures. In 2006 the reclamation plan (titled “Update to Restoration and Abandonment Plan, Tailings Impoundment Area”) was updated to focus on the latter two elements. The TIA is considered to be in the Closure-Active Care phase of mine life and operates under a Type B Water License (license MV2017L2-0007).

The following constitutes the 2018 Annual Report required by Part B, Item 12 of Water Licence MV2017L2-0007 issued October 25, 2017.

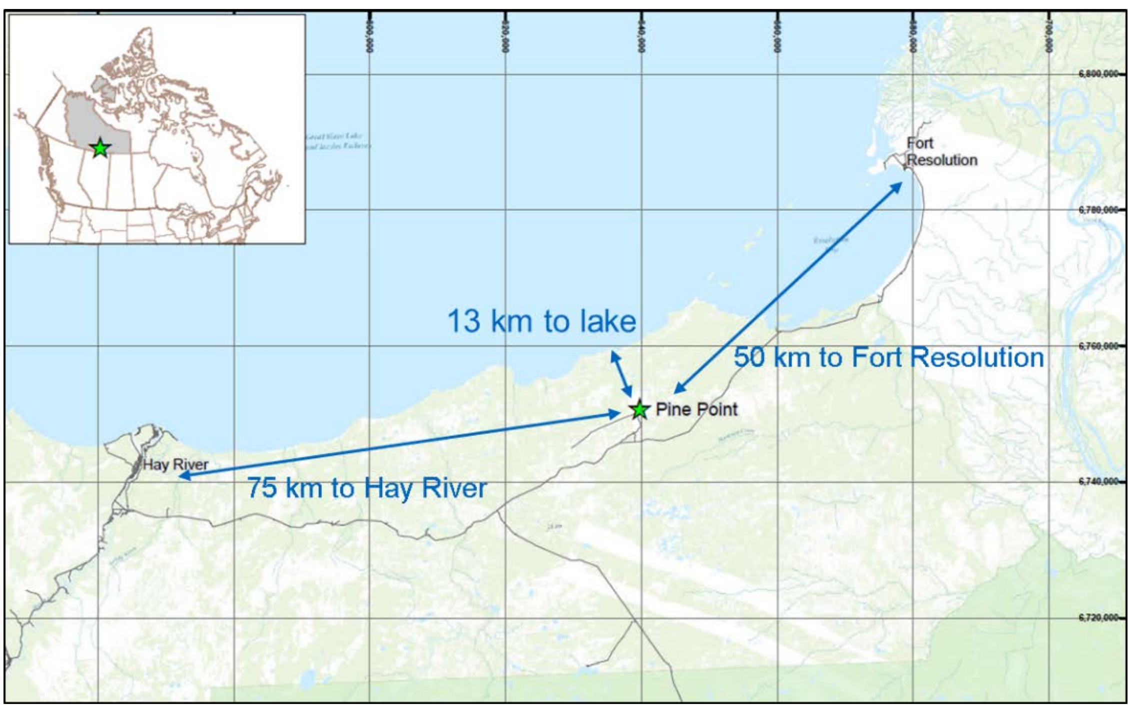

Figure 1: Site Location

2.0 Closure and Reclamation Research Plan Activity

In May 2018, Teck submitted a Reclamation Research Plan to the MVLWB outlining the phased research activities that would culminate in an updated Closure and Reclamation Plan. Phase one of the research was initiated in 2018. A summary of the 2018 activities and research activities planned for 2019 are provided below. The goal of research is to resolve uncertainties regarding zinc (and other metals as necessary) movement within environmental media in the Tailings Impoundment Area (TIA) at the former Pine Point Mine. Research activities in 2018, 2019 and 2020, will inform the updated Closure and Reclamation Plan to be submitted to the MVLWB by December 31, 2020.

Additional information is presented in the attached report *2018 Pine Point Mine Reclamation Research Report, Tailings Impoundment Area*, dated March 25, 2019 prepared by Barr Engineering.

2.1 2018 Research Results

The 2018 research activities focused on the following disciplines:

- Geotechnical evaluation of perimeter dykes and tailings
- Water balance evaluation
- Geochemical evaluation
- Cover assessment
- Human and ecological risk assessment
- Long term water treatment options

Geotechnical Evaluation

Geotechnical borings were used to log the stratigraphy at the site and to assess the tailings and soil properties. A total of 18 rotosonic borings were completed at the facility. Vibrating wire piezometers were installed in six of the borings to continuously monitor pore water pressure. Twelve cone penetrometer test holes were advanced through the tailings into native ground. Eight (8) pore water pressure dissipation tests were performed to assess the in-situ permeability of tailings and native soils.

The investigation confirmed that the tailings deposit is between about 3.3 m and 12.5 m thick and generally thins from south to north. The sand and gravel dust cover is intact and is approximately 0.15 m thick. There are exposed tailings (uncovered) on a relatively narrow swath along the far eastern edge of the tailings pile and in the direct vicinity of the TIA main pond. The tailings generally change from more poorly-graded sands at the southern lease limit to silts near the pond, which is consistent with dynamic segregation of the tailings during deposition. The tailings are underlain by a 0.10 to 0.15 m thick peat/organic layer, about 0.5 to 1.5 m of sand or gravel with large cobbles, and then dense silty or clayey native till. Saturated pore water in the tailings has radial flow from the tailings high point (south central portion of the TIA). The composition of the dykes and foundation soils, and the pore water levels in the dykes are being reviewed.

Tailings and soils samples were collected and submitted for geotechnical testing (in progress). Test analyses includes determination of water content, grain size distribution, Atterberg limits, unit weight, specific gravity, and organic content.

Water Balance Evaluation

A water balance evaluation, using the software GoldSim, is in progress using historical and site-specific data. The model includes several watersheds within the TIA and to the east, based on currently available topographic maps. The model of the TIA includes coarser to finer tailings zones that mimic the characteristics of the tailings deposition, and includes both unsaturated and saturated tailings layers. The model will be used to better understand the water movement through the tailings and TIA system. Once completed and calibrated, the model may be coupled with a geochemical model to better understand the fate and transport of metals at the facility. It will be updated and recalibrated as more information is collected.

A meteorological station was installed on the north-central portion of the TIA and is collecting precipitation, temperature, relative humidity, wind speed, wind direction, and short wave radiation measurements. A stilling well with a vibrating wire piezometer was installed in the TIA main pond to measure the water level. A grid of snowpack monitoring stations, including staff gauges and cameras, are collecting snow level measurements and snow coring is being conducted periodically to collect snow-water equivalent measurements. Initial snowpack monitoring data suggest water currently held within the snowpack is substantially more than previously thought, advancing understanding of the conceptual site model.

Geochemical Evaluation

A geochemical model is being developed to assess the fate and transport of zinc and other contaminants of concern within the TIA. The overall objectives of the geochemical model are to describe the current geochemical conditions at the TIA, estimate how those conditions may change over time, and evaluate the potential effects closure options will have on COC concentrations in the future. Geochemists Workbench® 12.0 (GWB), a thermodynamic equilibrium geochemical model, is being used to estimate equilibrium conditions, and evaluate changes to water quality and mineral precipitation.

The water quality data is currently being evaluated. Additional groundwater and surface water (namely the TIA main pond) monitoring, with consideration of infiltration rates generated from the water balance, will aid in further understanding the overall and seasonal changes in water quality.

Human and Ecological Risk Assessment

The human health and ecological risk assessment are underway based on analytical data from samples of soil, vegetation and water collected from the TIA and surrounding area in 2018. The risk assessment will continue to be refined with additional data collected in 2019. A preliminary human and ecological risk assessment was done to assess current conditions at the TIA. The objective of the risk assessment was to determine whether there are any potentially adverse effects to human and ecological receptors associated with the TIA and whether any specific mitigation is required to reduce risks in the closure plan. A preliminary aquatic risk assessment was also completed to understand the potential for effects on aquatic receptors on the immediate downstream environment based on current conditions and basic assumptions assuming that water was no longer retained and treated in the TIA.

The results of the preliminary risk assessment indicated that existing conditions on the covered tailings are unlikely to result in adverse health effects for people or ecological receptors. Preliminary risk estimates for the exposed tailings scenario were greater than the target risk estimates for toddlers and small-bodied wildlife with small home ranges (i.e., voles). Exposure estimate refinements will be considered and as necessary, mitigation options will be evaluated to reduce potential exposure for these receptors to the tailings under closure scenarios. Additional surface water monitoring is needed to understand seasonal differences in water quality conditions. In addition, the presence of aquatic receptors in the downstream environment needs to be identified. This data will be used in a more detailed aquatic risk assessment.

Long Term Water Management

One of the objectives of the closure plan is to limit, or eliminate to the extent practical, the need for long-term active care to protect human health and the environment. In 2018, an initial treatment technology screening was completed. The screening process identified the following semi-passive treatments as potentially viable for the site:

- Constructed wetland treatment systems,
- Permeable reactive barriers, and
- Hybrid systems based on a combination of these technologies.

Constructed wetland treatment systems (CWTS) have been demonstrated to be effective at various metals impacted sites and can be designed to promote either aerobic or anaerobic conditions to promote physical, chemical, or biological processes to remove zinc from water. For this site, a constructed wetland treatment system with anaerobic conditions to promote reducing conditions and sequestration of zinc primarily as zinc sulphide in sediment/soils appears to be the technology best-suited for treatment that can be relatively self-sustaining and require minimal maintenance, provided the CWTS is sized appropriately for the conditions..

2.2 2019 Research Activities

Research activities expected for 2019 are presented in the table below.

Table 1 - 2019 Research Activities

Category	Activity
Field Investigation	• Completion of topographic mapping – eastern portion of the TIA • Investigation of the dyke system and tailings deposit south of the lease limit • Pore water/groundwater and surface water quality data from various seasons • Water quality data for surface runoff • Water quality data for precipitation (rain and/or snow) • Groundwater/pore-water gradients from various seasons • Hydraulic conductivity of the TIA material • Porosity of the TIA material • Focused field study of infiltration and run-off rates for water balance evaluation • Aquatic habitat assessment of downstream drainage network • Downstream drainage network mapping and field reconnaissance • Passive treatment system siting investigation (wetland soils, vegetation, etc.)
Water Balance Evaluation	• Development of representative climate conditions and climate change forecast • Calibration of Goldsim model • Scenarios Modeling – Goldsim
Geochemical Evaluation	• Static and kinetic testing of tailings samples • Geochemical model development and simulations (historic, current, and future) • Coupled modeling with Goldsim (water balance) if needed
Cover Assessment	• Identify integration opportunities/ challenges with perimeter dyke • Map the exposed (uncovered) area of tailings along east edge of TIA
Geotechnical Evaluation	• Initial failure modes identification & stability modeling • Initial spillway concept design • Possible classification reduction or delisting
Risk Evaluation	• Berry monitoring program • Aquatic habitat evaluation • Mixing evaluation of downstream drainage network
Treatment Options Evaluation	• On site constructed wetland treatment system field trial • Off site mesocosm study of wetland treatment system • Bench scale study of adsorptive media for zinc and other metals retention • Development of passive treatment system design for the site
Future Use Considerations	• Continued community engagement • On site vegetation trial on TIA cover

3.0 Engagement Summary

As part of an annual review of the Engagement Plan, Teck identified that the existing engagement plan dated August 2017, which was developed for the Water Licence renewal application, required revision to account for activities associated with the Reclamation Research Plan and the Closure and Reclamation Plan. The engagement plan was revised to identify the opportunities for engagement with each of the affected parties for duration of the current Water Licence (beginning in 2018 to 2027).

Opportunities for engagement with the community were updated to account for the research activity at the TIA from 2018 to 2020, and anticipated activities associated with implementation of the closure plan. In May 2018, all affected stakeholders received the Reclamation and Research Plan, which was submitted to the MVLWB. In September 2018, Teck conducted a field program, which included a community member serving as a wildlife monitor. In November 2018, Teck met with community members in Fort Resolution and Hay River. Invitations to these meetings were sent to the Deninu K'ue First Nation, Fort Resolution Métis Council, Hamlet of Fort Resolution, K'atl'Odeeche First Nation, Hay River Métis Council, Town of Hay River, and West Point First Nation. The objective of the November meeting was to introduce the reclamation research planning work, the updates to the engagement plan and to seek feedback from the community in how they could be involved with the reclamation planning at Pine Point. In total, approximately 40 attended the four meetings held in Fort Resolution and Hay River.

In total, 74 email exchanges, 10 phone calls and 4 in-person meetings occurred in 2018 with affected parties, in addition to the dissemination of the Reclamation and Research plan that was distributed through the MVLWB process.

Teck will also be submitting a Land Use Permit application to the Mackenzie Valley Land and Water Board (MVLWB) for activities on the lease that require the use of heavy equipment (i.e., vehicle weight greater than 2.5 tonnes). As such the Engagement Plan will be revised as necessary.

4.0 Major Modification or Construction Activities

There were no modifications or construction activities in accordance with Part E of the Licence. Maintenance works were conducted and are further discussed in Section 2.5.

5.0 Water Management Plan Activities

Water accumulates in the pond every spring from snowmelt and rainfall. The water is elevated in Zinc, Lead and Copper and cannot be released to the environment without treatment. Therefore every summer the accumulated water is treated and the water level in the pond is dropped to a minimum level.

The water treatment plant is a simple lime treatment system that consists of: a lime silo, trailer mounted pump/blower unit, lime slurry tank, jet mixer, water pump and a trailer mounted laboratory. Most of the equipment is stored in Hay River through the winter and is assembled for the operating period.

Water treatment is typically carried out in summer each year to reduce pond levels and prepare the facility for the winter and spring freshet. On 3 May 2018, the pond water was recorded at

201.82 m elevation which was above the maximum operating water level of 201.8 m. Emergency dyke inspections were completed as per the *Operations, Maintenance and Surveillance Plan for Pine Point Tailings Impoundment Area* (Golder Associates, 2018) including daily water level checks and an inspection by the Engineer of Record. On 15 May 2018 emergency discharge was approved by the Water Resource Officer of the Department of Environment and Natural Resources. A total of 234,600 m^3 of water was released by siphoning over the polishing pond spillway from 17 to 31 May 2018 as shown in Table 2 below.

Prior to conducting the routine 2018 water treatment activities, maintenance of the polishing pond, including the removal of water treatment sludge from the polishing pond and maintenance of polishing pond baffles was completed between 24 July and 4 August 2018. Approval was obtained from the Water Resource Officer of the Department of Environment and Natural Resources in July 2018 prior to discharge of water within the polishing pond to the environment to allow maintenance. The culvert connecting the main and polishing pond was closed during maintenance.

Water treatment was initiated on 20 August 2018 and completed on 29 September 2018. A total of 388,797 m^3 of treated water was released during the 2018 water treatment period as shown in Table 2 below.

The total water discharged in 2018 during emergency discharge and water treatment operations was 623,397 m^3.

Table 2 – Discharge Volume at Station 35-1B

Sampling Date	Volume Discharged m^3	Cumulative Volume Discharged m^3	Comments
2018-05-17	13,600	13,600	High Pond Level Discharge May 17 – 30 Discharge volume estimated based on full siphon discharge
2018-05-18	17,000	30,600	
2018-05-19	17,000	47,600	
2018-05-20	17,000	64,600	
2018-05-21	17,000	81,600	
2018-05-22	17,000	98,600	
2018-05-23	17,000	115,600	
2018-05-24	17,000	132,600	
2018-05-25	17,000	149,600	
2018-05-26	17,000	166,600	
2018-05-27	17,000	183,600	
2018-05-28	17,000	200,600	
2018-05-29	17,000	217,600	
2018-05-30	17,000	234,600	
Total		**234,600**	

Sampling Date	Volume Discharged m^3	Cumulative Volume Discharged m^3	Comments
2018-08-20	3,241	3,241	Normal water treatment operations commenced
2018-08-21	6,948	10,189	
2018-08-22	10,203	20,392	
2018-08-23	15,715	36,107	
2018-08-24	17,010	53,117	
2018-08-25	16,799	69,916	
2018-08-26	17,007	86,924	
2018-08-27	17,054	103,978	
2018-08-28	16,877	120,855	
2018-08-29	16,347	137,202	
2018-08-30	16,264	153,466	
2018-08-31	6,082	159,548	
2018-09-01	8,014	167,562	
2018-09-02	4,803	172,365	
2018-09-03	6,274	178,639	
2018-09-04	708	179,347	
2018-09-05	0	179,347	
2018-09-06	0	179,347	
2018-09-07	0	179,347	
2018-09-08	0	179,347	
2018-09-09	0	179,347	
2018-09-10	10,605	189,952	
2018-09-11	8,904	198,856	
2018-09-12	8,600	207,456	
2018-09-13	14,074	221,530	
2018-09-14	15,821	237,352	
2018-09-15	14,789	252,140	
2018-09-16	15,493	267,634	
2018-09-17	15,234	282,867	
2018-09-18	14,988	297,855	
2018-09-19	14,099	311,954	
2018-09-20	5,500	317,454	
2018-09-21	3,800	321,254	
2018-09-22	13,977	335,231	
2018-09-23	6,312	341,543	

Sampling Date	Volume Discharged m^3	Cumulative Volume Discharged m^3	Comments
2018-09-24	10,973	352,516	
2018-09-25	8,211	360,727	
2018-09-26	9,234	369,961	
2018-09-27	3,588	373,549	
2018-09-28	6,124	379,673	
2018-09-29	9,125	388,797	
Total		**623,397**	Total 2018 discharge volume

6.0 Operations and Maintenance Plan Update and Activities

The Operations and Maintenance Plan was required to be updated and submitted by February 1, 2018. A plan was submitted on Feb. 1, 2018 but based on review by the Board an updated version was requested. The Operations and Maintenance Plan entitled *Operations, Maintenance and Surveillance Plan for Pine Point Tailings Impoundment Area – Version 3* which includes an updated *Contingency Plan (Appendix C) and Pine Point Water Treatment Manual (Appendix E)* was submitted on June 1, 2018 (Golder Associates, 2018) and was approved by MVLWB on July 19, 2018.

6.1 Surveillance Activities

Surveillance activities at the Pine Point TIA in 2018 included site inspections by both the Engineer of Record and by Maskwa Engineering Limited (Maskwa):

- Engineer of Record
  - 15 May 2018 – special inspection in response to high water levels
  - 23 July 2018 – DSI routine summer inspection (with Maskwa)
- Maskwa
  - 3 May 2018 – routine spring inspection
  - 9 May 2018 – supplementary inspection in response to high water levels
  - 11 May to 31 May 2018 – daily supplemental inspections in response to high water levels
  - 7 June to 10 August 2018 – weekly supplemental inspections in response to high water levels
  - 20 October 2018 – routine fall inspection

The results of the surveillance are documented in 2018 Dam Safety Inspection prepared by Golder (Golder Associates Ltd., 2019). The report was initially submitted under at the end of 2018 under separate cover. A revised version was submitted in February 2019.

6.2 Maintenance Activities

2018 maintenance activities were conducted to repair wave erosion and surface erosion rills on the north dyke, as well as sludge removal from the polishing pond within the water treatment area of the TIA. The following summarizes the activities:

Wave Erosion - A 700 m long section of the upstream face of the north dyke was observed to be eroded. An eroded bench was visible above the water line with as much as a 1 m step in the upstream face with exposed core in places. The erosion did not reach the dyke crest nor reduce the dyke crest width. The erosion repair was required as part of ongoing dyke maintenance. The work completed included placing non-woven geotextile against the exposed silty clay core, and placing rip rap in 2 layers. The work was completed from 10 to 15 October 2018.

Photograph 1: North Dyke – 1 m erosion scarp requiring repair

Photograph 2: North Dyke after repair work completed

Surface erosion rills (gullies) - Two rills, approximately 1 m deep, were observed on the downstream face of the north dyke and located approximately 70 m from the west dyke. These rills required repair as part of ongoing dyke maintenance. No rills extended into the dyke crest, and erosion is not considered to be an immediate concern to dam safety. The work completed included repairing the erosion rills by filling them with granular material. The work was completed in conjunction with the wave erosion repair from 10 to 15 October 2018.

 **Photograph 3 – North Dyke erosion rills**	 **Photograph 4 – Excavator filling erosion rills area**

Other maintenance work included draining and removing sludge from the polishing pond from 24 July to 4 August 2018. Some of the sludge was pumped back to the TIA pond as the sludge appeared to contain unreacted lime. The other portion of sludge removed from the polishing pond was placed at the northeast corner of the TIA.

Photograph 5 – Sludge pump pumping lime/zinc sludge from the polishing pond

7.0 Spill Contingency Plan

There were no unauthorized discharges or spills in 2018. The Spill Contingency Plan was updated in 2018 and included in the Operations, Maintenance and Surveillance Plan (Golder Associates, 2018).

8.0 Surveillance Network Program

SNP sampling was conducted as per Annex A Part B: Site Descriptions and Monitoring Requirements. A summary of the sample station descriptions, parameters and sampling frequency is presented in Table 3. The table also includes a column summarizing how the condition of the licence requirement was satisfied. Sample locations area shown on Figure 2.

Table 3 - Surveillance Network Program Stations, Sampling Parameters, and Compliance Summary

Surveillance Network Program Station	Descriptions	Location	Parameters	Frequency	2018 Compliance Summary
35-1a: Main Pond	Main pond prior to discharge to the serpentine channel (water treatment area/settling pond)	60º53'41.3"N 114º25'30.7"W	Total Copper Total Lead Total Zinc pH Total Suspended Solids Total Arsenic [(a)] Ammonia [(a)] Total Cyanide [(a)]	Weekly during discharge	Sampled Daily during emergency decant from 18 May to 30 May and weekly between 14 June to 14 August. Results included in Table 5 Note that water treatment occurred from 20 August to 29 September. Samples during this time were not submitted to an external lab, but daily field pH and zinc were analyzed. These results are included in Table 6
			Water level	3 times per year, once in Spring, Summer, and Fall; during periods of open water	Water levels were conducted 3 times as shown in Table 7
35-1b: Post-Treatment Effluent Discharge	Post-treatment effluent discharge at the decant structure	60º53'41.3"N 114º25'30.7"W	Volume, measured and recorded in cubic metres.	Weekly during discharge	Discharge volume was recorded and included in Table 2
			Total Copper Total Lead Total Zinc pH Total Suspended		Samples were collected daily during emergency decant operations and are included in Table 8 and during regular

Surveillance Network Program Station	Descriptions	Location	Parameters	Frequency	2018 Compliance Summary
			Solids Ammonia [(a)] Total Cyanide [(a)]		operations and are included in Table 9. Graphical summaries which include the previous two years results for Total Zinc, Lead, Copper, TSS, and pH, are included in Figure 3 to Figure 7
SNP Station 35-4	Pond surface water north of SNP station 35-1, 4.0 km from Great Slave Lake.	60º54’41.8"N 114º26’17.2"W	Total Copper; Total Lead; Total Zinc; and pH	Annually; in fall following discharge	Additional samples were collected from 35-4 during and after the emergency decant on May 18, 2018 and July 23, 2018 as required by the Inspector. These results are included in Table 10. The routine fall sampling was completed on October 3, 2018, results are included in Table 10
SNP Station 35-5	Pond surface water 1.6 km south of Great Slave Lake.	60º54’27.7"N 114º26’17.2"W			
SNP Station 35-6	Pond surface water 2.4 km due south of SNP station 35-5.	60º55’26.6"N 114º28’25.4"W			
SNP Station 35-9	Great Slave Lake, 2.4 km southwest of Presquile Point.	60º55’35.0"N 114º36’04.1"W			
SNP Station 35-10	Great Slave Lake, 4.8 km east of Presquile Point.	60º57’00.2"N 114º27’56.6"W			
SNP Station 35-12	Pond surface water 4.8 km north of Tailings area decant structures, 0.8 km south of Great Slave Lake shoreline.	60º57’02.1"N 114º25’06.6"W			
SNP Station 35-13	Pond surface water, 4.0 km east of SNP Station 35-9, and 0.8 km south of Great Slave Lake shoreline.	60º55’59.1"N 114º31’59.0"W			

(a) Test parameter is not stipulated in the Water Licence but is included in the analyses.

Figure 2: Pine Point SNP Stations

8.1 SNP Results

As outlined in the table above, tabular summaries of the data generated under the "Surveillance Network Program" are presented in Tables 5 to 10 in this section. Graphical summaries have been included for 35-1B which include the previous two years results and are included in Figures 3 – 7.

The following is a summary of the data results:

- 35-1A (sample within the pond before treatment), during the emergency decant and prior to water treatment the average lab pH was 7.87, average zinc concentrations were 1.14 mg/L with a max of 1.41 mg/L. During water treatment the average field pH 7.95 and the average field zinc concentration was 1.03 mg/L with a max of 1.25 mg/L. All the other parameters were less than the effluent quality criteria outlined in the water license. This demonstrates that zinc is the only parameter requiring treatment.

- 35-1B (post treatment effluent discharge) – samples during emergency decant discharge had an average lab zinc concentration of 1.12 mg/L with a maximum lab concentration of 1.38 mg/L. Samples during water treatment were below the effluent quality criteria outlined in the water license with a lab total zinc average sample concentration of 0.29 mg/L which is below the 0.5 mg/L effluent quality criteria. The lab total zinc max grab sample concentration was 0.476 mg/L which is below the 1.0 mg/L effluent quality criteria. The TSS average concentration was 16.6 mg/L which is below the average effluent quality criteria of 25 mg/L. The TSS maximum concentration was 44.8 mg/L which was below the average effluent quality criteria of 50 mg/L.

  All other parameters were also below the effluent quality criteria.

- 35-4 (downstream sample location) – samples were collected during the emergency decant and was 0.015 mg/L which is below the CCME guideline of 0.03 mg/L. All other samples were below the laboratory detection limits.

8.2 Action Levels

The Action Levels included in the approved 2018 OMS (Golder Associates, 2018) for Station 35-1b are summarized in Table 9. Monitoring endpoints (Action Levels) are only meaningful for Station 35-1b, where treated water is discharge from the facility. The Action Levels for all parameters except for pH are the maximum average concentration specified in the Water License. The Action Level for pH is 9.3 standard units (s.u.). This is because pH is the only parameter that historically has deviated from the concentrations specified in the Water License and because pH is the most sensitive parameter to water treatment. Setting the Action Level lower than the Water License levels allows the operator time to respond.

The operator measures pH, turbidity[1] and concentrations of zinc at least 3 times a day, which provides an opportunity to determine if any of the measured parameters are trending upwards and approaching the Action Levels. If the ***average*** value of samples collected that day exceeds the Action Level, then the response action sequence should be initiated. A single grab sample above the Action Level would not constitute a trigger for response actions, however a single grab sample above the Grab Maximum Concentration would initiate cease of operation and notification to the appropriate authorities.

Table 4 - Action Levels for Station 35-1b

Parameter	Maximum Average Concentration (mg/L)	Maximum Grab Concentration (mg/L)	Action Level for Station 35-1b
pH (in s.u.)	6.5 to 9.5 s.u.	6.5 to 9.5 s.u.	9.3 s.u. maximum
Arsenic, total	0.50	1.00	0.50
Copper, total	0.15	0.30	0.15
Cyanide, total	0.10	0.20	0.10
Lead, total	0.20	0.40	0.20
Zinc, total	0.50	1.00	0.50
Ammonia as N	2.00	4.00	2.00
Total Suspended Solids	25.00	50.00	25.00

In 2018, total lab zinc concentrations never exceeded the action level, however there was a prolonged increasing trend (August 29 to September 4) and it was decided to shut the plant down (September 5 long) before we reached the Action Level for Station 35-1B (September 7) of 0.546 mg/L (field zinc measurement). Thus by the time the Total Zinc got the alert level in the pond we had already stopped discharging and were addressing the issues that caused the elevated zinc level.

On 2018 September 20, we received analytical results from the external lab that some of our daily grab samples at Station 35-1B exceeded the Action Level for Total Suspended Solids (TSS). Unfortunately the samples were for weekend days (September 13, 15, 16 and 17) and thus they were analysed as a batch on September 19. In spite of this we were able to keep the plant in control and did not exceed the weekly weighted average the TSS target as per the Water License. The TSS was exceeded on September 25 and 27th as well at the end of the treatment season. The increase in TSS was likely caused by wind within the serpentine

[1] The relationship between Turbidity and TSS is developed for the site by comparing TSS laboratory data with the turbidity meter.

channel and or upsets with the turbidity curtains, as such measures will be evaluated to better control TSS in 2019.

The TSS action level exceedances were communicated to Wendy Bidwell, NWT Water Resource Officer via email on September 27, 2018.

8.3 Calibration

The SNP locations 35-1a and 1b are tested regularly during water treatment operations and are tested in the field using a pH meter, turbidity, and a Hach meter to measure the amount of zinc in the water in the field. All instruments are calibrated as per the manual instructions with each sample collected. The Hach Company is the manufacturer of the Hach 3900 Spectrophotometer and the Zincon Method with a range of 0-1.5, 0-3.0 mg/l is used to measure zinc levels. This instrument is calibrated as per the manual instructions with each sample collected. The field results are compared to the lab results. In 2018, there appeared to be a positive correlation of 0.62. On average the difference between the field results and the lab results were 0.05 mg/L. Note that in 2018, daily water samples were submitted to the laboratory as opposed to the weekly submissions required in the Water Licence.

Table 5 - Water Sampling in the Tailings Containment Area (Station 35-1A) (Part B Item 2) – Lab results

Sampling Date	Lab pH	Total Zinc mg/L	Total Arsenic mg/L	Total Lead mg/L	Total Copper mg/L	TSS mg/L	Cyanide mg/L	Ammonia mg/L
2018-05-09	7.61	1.090	0.00012	0.0665	0.0066	5.7	<0.002	<0.05
2018-05-18	7.69	1.120	0.00050	0.0448	0.0064	4.90	0.0022	<0.05
2018-05-19	7.75	1.170	0.00017	0.0538	0.0088	7.10	0.0028	<0.05
2018-05-20	7.71	1.140	0.00015	0.0527	0.0076	6.00	0.0024	<0.05
2018-05-21	7.70	1.160	0.00019	0.0577	0.0089	8.10	<0.002	<0.05
2018-05-22	7.80	1.280	0.00017	0.0573	0.0088	7.30	0.0021	<0.05
2018-05-23	7.57	1.150	0.00014	0.0481	0.0072	6.60	<0.002	<0.05
2018-05-24	7.61	1.120	0.00012	0.0477	0.0067	7.10	<0.002	<0.05
2018-05-25	7.70	1.400	0.00020	0.0506	0.0080	5.60	<0.002	<0.05
2018-05-26	7.86	1.410	0.00018	0.0476	0.0086	4.50	<0.002	<0.05
2018-05-27	7.85	1.310	0.00016	0.0482	0.0089	4.30	<0.002	<0.05
2018-05-28	7.89	1.400	0.00017	0.0458	0.0090	4.20	<0.002	<0.05
2018-05-29	7.83	1.220	0.00014	0.0380	0.0080	3.00	<0.002	<0.05
2018-05-30	7.76	1.150	0.00055	0.0409	0.0072	4.60	<0.002	<0.05
2018-06-14	7.86	1.210	0.00015	0.0327	0.0087	4.30	<0.002	<0.05
2018-06-21	7.93	1.160	0.00018	0.0318	0.0089	3.40	<0.002	<0.05
2018-06-28	8.04	1.150	0.00015	0.0274	0.0088	4.30	<0.002	<0.05
2018-07-05	8.07	1.060	0.00017	0.0345	0.0105	3.00	<0.002	<0.05
2018-07-12	8.09	1.020	0.00019	0.0326	0.0098	3.00	<0.002	<0.05
2018-07-19	8.13	0.960	0.00017	0.0320	0.0109	3.00	<0.002	<0.05
2018-07-24	7.95	1.040	0.00025	0.0285	0.0098	3.00	<0.002	<0.05
2018-07-27	8.08	0.752	0.00018	0.0243	0.0110	3.10	<0.002	<0.05
2018-08-08	8.17	0.893	0.00025	0.0302	0.0099	3.70	na	na
2018-08-14	8.11	0.921	0.00041	0.0307	0.0124	3.80	na	na
Average	7.87	1.14	0.00021	0.0419	0.0088	4.73	0.0021	<0.05
Max.	8.17	1.41	0.00055	0.0665	0.0124	8.10	0.0028	<0.05
Min.	7.57	0.75	0.00012	0.0243	0.0064	3.00	<0.0020	<0.05

Table 6 - Water Sampling in the Tailings Containment Area (Station 35-1A) (Part B Item 2) – Field results

Sampling Date	Field pH	Field Zinc mg/L
2018-08-11	7.75	1.055
2018-08-12	7.83	1.055
2018-08-13	7.78	1.030
2018-08-14	7.88	1.025
2018-08-15	7.90	1.050
2018-08-16	8.19	1.020
2018-08-17	8.19	na
2018-08-18	8.10	1.025
2018-08-19	8.10	0.987
2018-08-20	8.14	na
2018-08-21	8.06	0.990
2018-08-22	8.06	0.915
2018-08-23	8.08	0.980
2018-08-24	8.11	0.990
2018-08-25	8.15	0.940
2018-08-26	8.07	0.935
2018-08-27	8.03	0.950
2018-08-28	8.10	0.945
2018-08-29	7.96	0.970
2018-08-30	8.02	1.005
2018-09-02	8.15	na
2018-09-03	7.92	0.960
2018-09-04	8.15	0.980
2018-09-05	8.09	0.995
2018-09-06	8.24	0.980
2018-09-07	8.27	0.975
2018-09-08	8.18	0.985
2018-09-09	8.03	0.970
2018-09-10	7.95	0.985
2018-09-11	7.84	na
2018-09-12	7.83	1.090
2018-09-13	7.82	1.050
2018-09-14	7.80	1.040
2018-09-15	7.84	0.990
2018-09-16	7.88	1.070
2018-09-17	7.85	1.060

Sampling Date	Field pH	Field Zinc mg/L
2018-09-18	7.80	1.130
2018-09-19	7.80	1.050
2018-09-20	7.72	na
2018-09-21	7.78	na
2018-09-22	7.79	1.200
2018-09-23	7.83	1.160
2018-09-24	7.78	1.150
2018-09-25	7.79	1.170
2018-09-26	7.77	na
2018-09-27	7.80	na
2018-09-28	7.77	1.250
2018-09-29	7.79	na
Average	7.95	1.028
Max.	8.27	1.250
Min.	7.72	0.915

Table 7 - Water Levels in the Tailings Pond at 35-1A

Date	Metres (AMSL)
Spring (May 3)	201.82
Summer (August 20)	201.44
Fall (September 29)	200.47

Table 8 - Tailings area discharge at decant structure at SNP 35-1B during Emergency Decant Water (Untreated)

Sampling Date	Lab pH	Total Zinc mg/L	Total Lead mg/L	Total Copper mg/L	Total Arsenic mg/L	TSS mg/L	Cyanide mg/L	Ammonia mg/L
2018-05-17	8.28	0.335	0.0154	0.0157	0.00050	7.4	na	na
2018-05-18	7.84	0.787	0.0351	0.0094	0.00050	5.8	<0.0500	< 0.0020
2018-05-19	7.87	1.060	0.0472	0.0086	0.00017	5.7	<0.0500	< 0.0020
2018-05-20	7.83	1.060	0.0480	0.0078	0.00018	7.3	<0.0500	0.0023
2018-05-21	7.84	1.050	0.0509	0.0079	0.00016	8.4	<0.0500	0.0026
2018-05-22	7.87	1.170	0.0507	0.0081	0.00020	6.0	<0.0500	< 0.0020
2018-05-23	7.83	1.140	0.0473	0.0079	0.00014	7.1	<0.0500	< 0.0020
2018-05-24	7.78	1.130	0.0480	0.0074	0.00013	6.6	<0.0500	< 0.0020
2018-05-25	7.82	1.320	0.0464	0.0087	0.00018	6.3	<0.0500	< 0.0020
2018-05-26	7.86	1.360	0.0468	0.0090	0.00017	5.6	<0.0500	< 0.0020
2018-05-27	7.86	1.340	0.0437	0.0092	0.00016	3.7	<0.0500	< 0.0020
2018-05-28	7.92	1.380	0.0441	0.0092	0.00021	5.1	<0.0500	< 0.0020
2018-05-29	7.91	1.290	0.0396	0.0091	0.00017	4.8	0.0530	< 0.0020
2018-05-30	7.88	1.200	0.0366	0.0078	0.00014	3.8	<0.0500	< 0.0020
Average Sample Concentration	7.89	1.12	0.043	0.009	0.0002	6.0	0.051	0.002
EQC Max. Average	na	0.50	0.20	0.15	0.50	25.0	0.10	2.00
Max Sample Concentration	8.28	1.38	0.051	0.016	0.0005	8.4	0.053	0.002
EQC Max Grab	6.50 - 9.50	1.00	0.40	0.30	1.00	50.0	0.20	4.00

Table 9 - Tailings area discharge at decant structure at SNP 35-1B Post Treatment Effluent Discharge

Sampling Date	Lab pH	Field pH	Field Zinc mg/L	Total Zinc mg/L	Total Arsenic mg/L	Total Lead mg/L	Total Copper mg/L	TSS mg/L	Cyanide mg/L	Ammonia mg/L
2018-08-20	8.72	8.80	0.180	0.226	0.00027	0.0083	0.0103	7.8		
2018-08-21	9.03	8.92	0.116	0.130	0.00023	0.0061	0.0090	19.9		
2018-08-22	9.05	8.98	0.093	0.139	0.00018	0.0062	0.0082	13.9	<0.002	<0.05
2018-08-23	8.40	8.98	0.113	0.165	0.00050	0.0074	0.0091	13.0		
2018-08-24	8.51	8.97	0.113	0.227	0.00017	0.0092	0.0091	11.9		
2018-08-25	8.85	8.92	0.096	0.237	0.00019	0.0100	0.0093	18.1		
2018-08-26	8.82	8.90	0.083	0.228	0.00018	0.0091	0.0087	20.2		
2018-08-27	8.71	8.94	0.098	0.239	0.00019	0.0097	0.0082	20.1		
2018-08-28	8.59	8.93	0.105	0.252	0.00018	0.0000	0.0084	13.8		
2018-08-29	8.73	8.96	0.115	0.229	0.00019	0.0087	0.0085	8.6	<0.002	<0.05
2018-08-30	8.76	9.06	0.139	0.236	0.00018	0.0094	0.0084	11.5		
2018-08-31	9.02	9.09	0.160	0.264	0.00018	0.0093	0.0082	7.8		
2018-09-01	9.06	8.96	0.195	0.212	0.00022	0.0096	0.0096	7.3		
2018-09-02	9.14	9.01	0.343	0.386	0.00023	0.0121	0.0106	7.4		
2018-09-03	9.05	8.94	0.277	0.356	0.00025	0.0123	0.0126	9.3		
2018-09-04	8.90	8.85	0.343	0.372	0.00027	0.0132	0.0117	7.1		
2018-09-05	ns	8.88	0.406	ns	ns	ns	Ns	ns		
2018-09-06	ns	8.80	0.484	ns	ns	ns	Ns	ns		
2018-09-07	ns	8.64	0.546	ns	ns	ns	Ns	ns		
2018-09-08	ns	8.73	0.453	ns	ns	ns	Ns	ns		
2018-09-09	ns	8.68	0.373	ns	ns	ns	Ns	ns		
2018-09-10	8.64	8.73	0.214	0.269	0.00019	0.0096	0.0112	10.1		
2018-09-11	8.75	8.96	0.202	0.254	0.00015	0.0070	0.0088	12.1		
2018-09-12	8.75	8.75	0.103	0.199	0.00016	0.0086	0.0095	16.2		
2018-09-13	8.59	8.84	0.123	0.234	0.00020	0.0088	0.0085	30.6	<0.002	<0.05
2018-09-14	8.31	8.94	0.161	0.368	0.00020	0.0118	0.0091	13.4		
2018-09-15	8.65	8.84	0.130	0.287	0.00020	0.0095	0.0089	32.9		

Sampling Date	Lab pH	Field pH	Field Zinc mg/L	Total Zinc mg/L	Total Arsenic mg/L	Total Lead mg/L	Total Copper mg/L	TSS mg/L	Cyanide mg/L	Ammonia mg/L
2018-09-16	8.66	9.02	0.178	0.392	0.00020	0.0115	0.0089	44.8		
2018-09-17	8.69	8.90	0.151	0.352	0.00019	0.0104	0.0088	32.3		
2018-09-18	8.56	8.90	0.136	0.323	0.00022	0.0100	0.0082	31.4		
2018-09-19	8.53	8.88	0.145	0.308	0.00021	0.0095	0.0084	14.9	<0.002	<0.05
2018-09-20	8.92	9.03	0.207	0.385	0.00023	0.0110	0.0090	3.0		
2018-09-21	8.67	8.79	0.088	0.221	0.00018	0.0068	0.0084	16.0		
2018-09-22	8.99	9.05	0.238	0.347	0.00020	0.0091	0.0090	5.4		
2018-09-23	9.03	9.09	0.381	0.476	0.00021	0.0099	0.0091	9.4		
2018-09-24	8.88	9.07	0.238	0.471	0.00018	0.0094	0.0091	11.5		
2018-09-25	8.64	8.88	0.159	0.391	0.00016	0.0091	0.0085	31.9		
2018-09-26	8.80	8.99	0.209	0.396	0.00016	0.0087	0.0081	10.1	<0.002	<0.05
2018-09-27	7.99	8.90	0.152	0.393	0.00020	0.0096	0.0086	32.7		
2018-09-28	8.29	8.59	0.140	0.216	0.00020	0.0062	0.0083	14.8		
2018-09-29	7.94	8.86	0.357	0.268	0.00017	0.0084	0.0050	24.8		
Action Level Concentration	9.30	9.30	0.50	0.50	0.50	0.20	0.15	25.0		
Average Sample Concentration	8.71	8.90	0.21	0.29	0.0002	0.009	0.009	16.6	<0.002	<0.05
EQC Max. Average	6.50 - 9.50	6.50 - 9.50	0.50	0.50	0.50	0.20	0.15	25	0.10	2.00
Max Sample Concentration	9.14	9.09	0.546	0.476	0.0005	0.013	0.013	44.8	<0.002	<0.05
EQC Max Grab	6.50 - 9.50	6.50 - 9.50	1.00	1.00	1.00	0.40	0.30	50.0	0.20	4.00

Table 10- Results of Fall SNP Locations

Sample Location	Sampling Date	Lab pH	Total Zinc mg/L	Total Arsenic mg/L	Total Lead mg/L	Total Copper mg/L
35-4	5/21/2017	8.10	0.0153	0.00026	0.00049	0.00086
	9/25/2017	8.34	<0.0030	0.00053	0.00007	<0.00050
	5/18/2018	7.64	0.0150	0.00050	<0.00025	<0.00250
	7/23/2018	8.31	<0.0030	0.00072	0.00010	0.00109
	10/3/2018	8.13	<0.0030	0.00055	0.00019	<0.00050
35-5	5/21/2017	8.12	<0.0030	0.00034	0.00012	<0.00050
	9/25/2017	8.34	0.0096	0.00029	0.00021	0.00075
	10/3/2018	8.08	0.0059	0.00050	0.00056	0.00132
35-6	5/21/2017	8.12	<0.0030	0.00039	0.00011	<0.00050
	9/25/2017	8.08	<0.0030	0.00101	0.00010	<0.00050
	10/3/2018	8.02	0.1170	0.00150	0.00120	0.00234
35-9	5/21/2017	8.09	<0.0030	0.00041	<0.00005	<0.00050
	9/25/2017	8.21	<0.0030	0.00055	<0.00005	<0.00050
	10/3/2018	8.25	0.0031	0.00107	0.00037	<0.00050
35-10	5/21/2017	8.02	<0.0030	0.00032	<0.00005	0.00120
	9/25/2017	8.08	<0.0030	0.00045	0.00008	0.00143
	10/3/2018	8.05	<0.0030	0.00054	0.00033	0.00170
35-12	5/21/2017	8.18	<0.0030	0.00047	<0.00005	<0.00050
	9/25/2017	8.13	<0.0030	0.00043	<0.00005	<0.00050
	10/3/2018	8.26	<0.0030	0.00051	<0.00005	<0.00050
35-13	5/21/2017	8.12	<0.0030	0.00039	<0.00005	<0.00050
	9/25/2017	7.89	<0.0030	0.00044	<0.00005	<0.00050
	10/3/2018	8.05	0.0116	0.00067	0.00243	0.00077

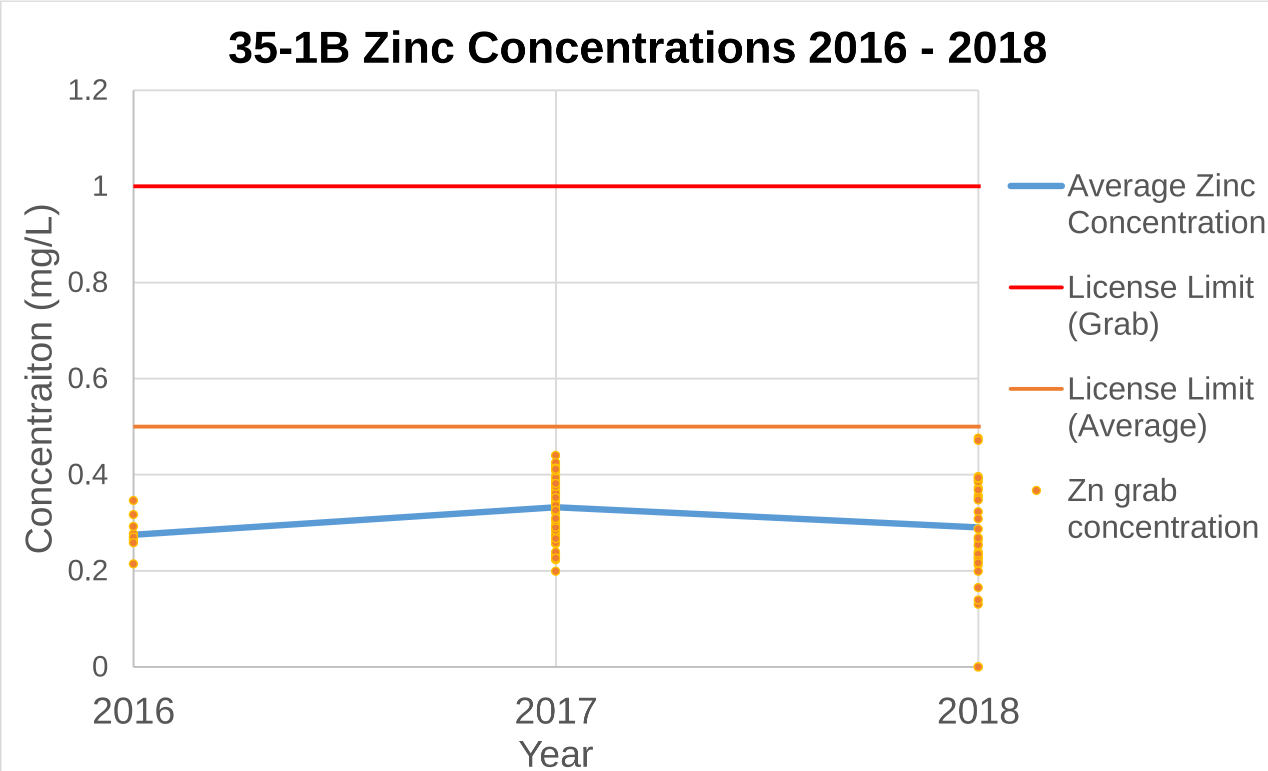

Figure 3: 35-1B Zinc Concentrations 2016 - 2018

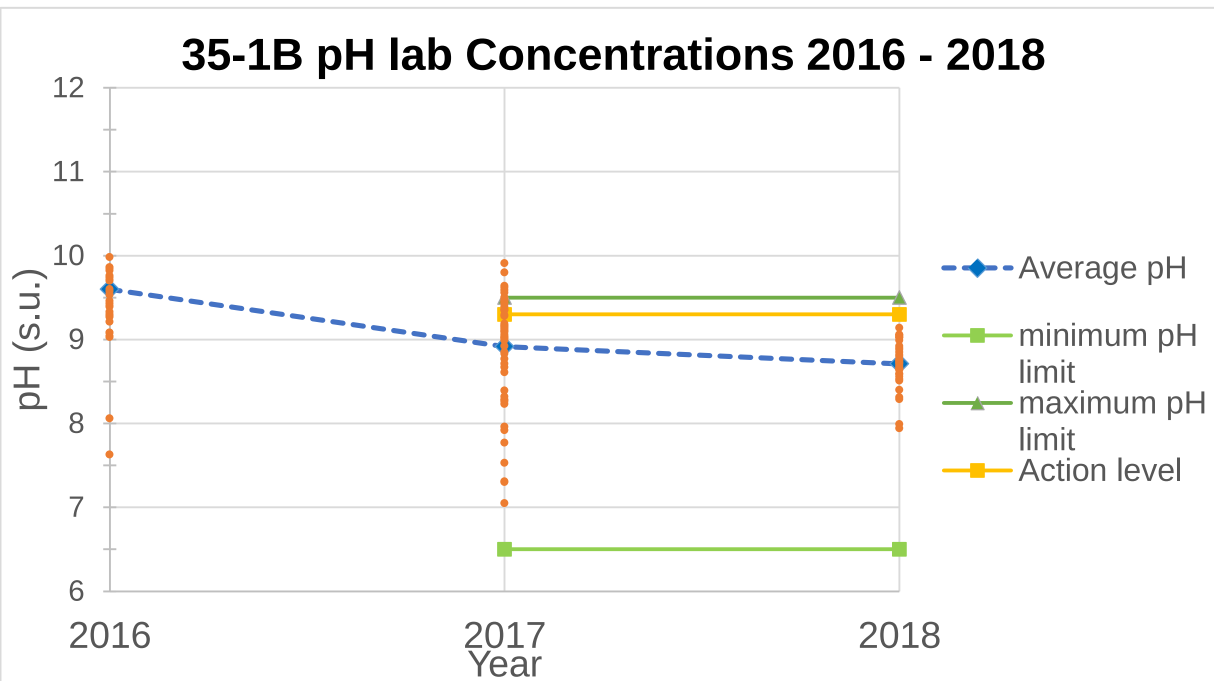

Figure 4: 35-1B pH Concentrations 2016 - 2018

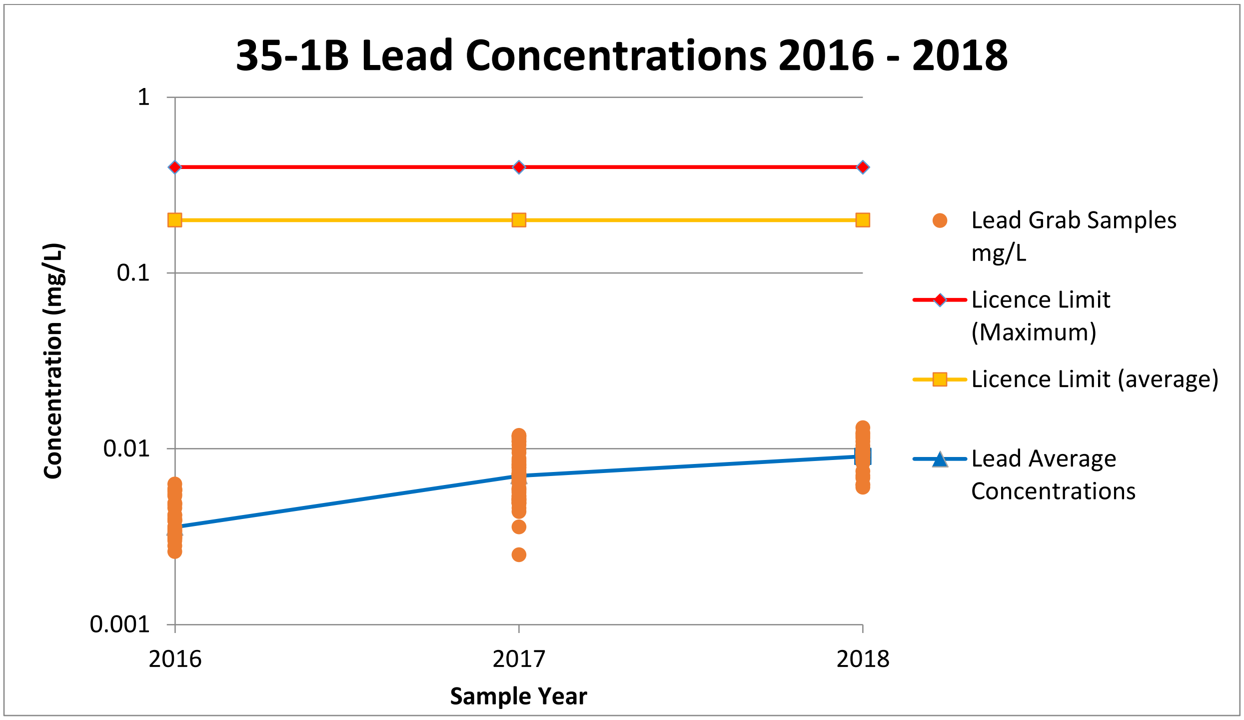

Figure 5: 35-1B Lead Concentrations 2016 - 2018

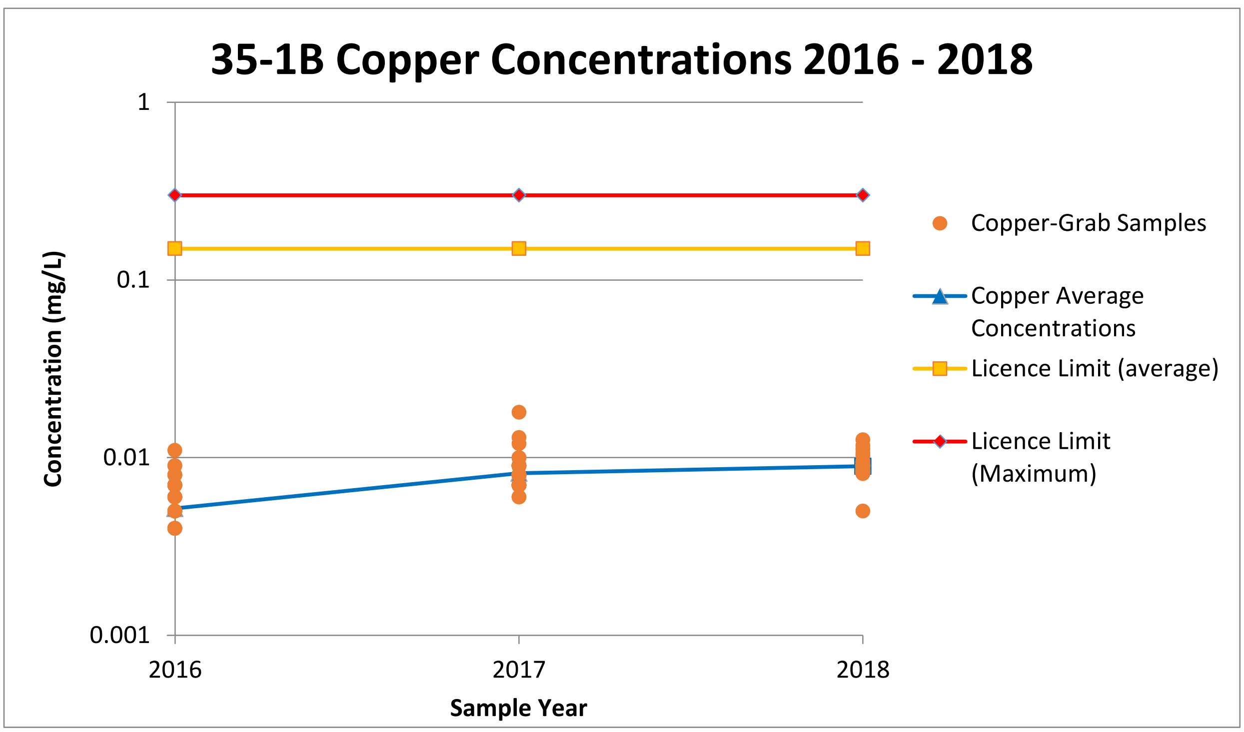

Figure 6: 35-1B Copper Concentrations 2016 - 2018

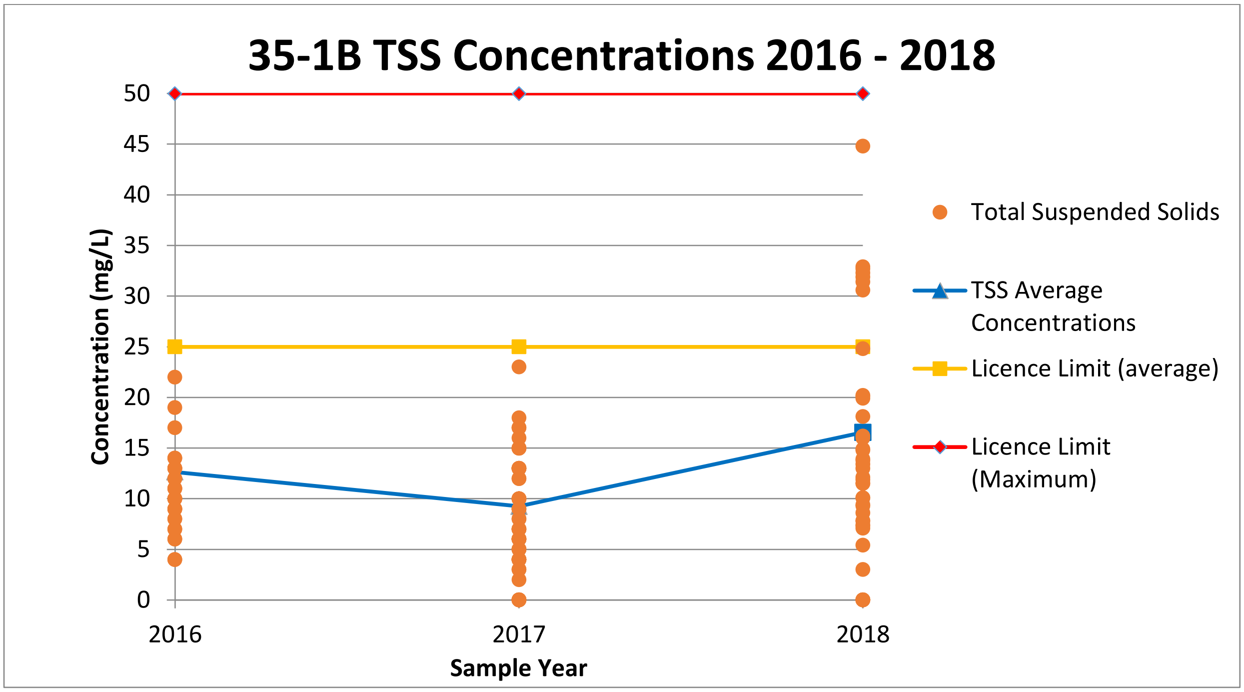

Figure 7: 35-1B TSS Concentrations 2016 - 2018

9.0 Regulator Inspections

A site inspection was conducted by Mr. Mike Vassal, Manager, Resource Management, and and Water Resource Officer Wendy Bidwell from Department of Lands, South Slave Region on July 24, 2018. The inspection was conducted during the sludge removal from the serpentine channel. No orders or non-compliances were noted.

A site inspection was conducted by Mr. Mike Vassal, Manager, Resource Management, Department of Lands, South Slave Region on October 11, 2018. The inspection was conducted during the erosion repair work along the north dyke. It was noted in the inspection that the lease and the water license for the site does not cover the use of heavy equipment or drilling. These activities require a Land Use permit. Teck is currently proceeding with the application process for a Land Use permit.

10.0 References

Golder Associates. (2018). *Operations, Maintenance and Surveillance Plan for Pine Point Tailings Impoundment Area.*

Golder Associates Ltd. (2019). *2018 Dam Safety Inspection, Pine Point Tailings Impoundment, Pine Point, NT, dated 22 February 2019.*

APPENDIX I
APPENDED REPORTS

1. *2018 Pine Point Mine Reclamation Research Report, Tailings Impoundment Area*, dated March 25, 2019 prepared by Barr Engineering.

BARR

2018 Pine Point Mine Reclamation Research Report

Tailings Impoundment Area

Prepared for
Teck Metals Ltd.

March 25, 2019

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2018 Pine Point Mine Reclamation Research Report

March 25, 2019

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Acronyms

Acronym	Description
ABA	acid base accounting
AP	acid potential
ARD	acid rock drainage
BOD	biochemical oxygen demand
CCME	Canadian Council of Ministers of the Environment
COC	contaminants of concern
CPT	cone penetrometer test
CSM	conceptual site model
CWTS	constructed wetland treatment system
GWB	Geochemists Workbench® 12.0
HRT	hydraulic retention time
ML	metals leaching
MVLWB	Mackenzie Valley Land and Water Board
NP	neutralization potential
NPR	net potential ratio
ORP	oxidation-reduction potential
PRB	permeable reactive barrier
RRP	Reclamation Research Plan
TIA	Tailings Impoundment Area
TOC	total organic carbon
TSS	total suspended solids
VWP	vibrating wire piezometer

1.0 Introduction

This report provides a summary of reclamation research activities conducted in 2018 and those planned for 2019. The goal of research activities is to resolve uncertainties allowing for development of a long-term closure and reclamation plan for the TIA at the former Pine Point Mine. Reclamation research is being conducted as a condition of the Water Licence issued by the MVLWB (Water Licence MV2017L2-007). The Licence requires proposal of a final long-term closure option for the TIA in an updated Closure and Reclamation Plan submitted by December 31, 2020.

The MVLWB identifies four core closure principles for mine sites (MVLWB, 2013). Therefore, the reclamation research focused on, and activities are organized around, the closure principles that are presented below:

1. **Physically Stable** facility that does not pose a hazard. This includes the tailings deposit, dust cover in place over the tailings, and perimeter dyke that contains the tailings, and the decant structures.
2. **Chemically Stable** facility that does not harm fish, wildlife, or people in the long term. This includes the tailings deposit itself and receiving environment. It requires that surface water and groundwater be of acceptable quality, and that metals concentrations do not build up to undesirable concentrations in plants. It also requires a better understanding of residual tailings quality and its potential to affect these media over time.
3. **Long-Term** condition that does not require Active Care, which is the current approach to address TIA water quality in exceedance of Water Licence limits. This requires a better understanding of the facility water balance and the fate and transport of metals reporting to the TIA pond and determination of the capability of a passive treatment approach to achieve chemical stability goals over time.
4. **Future Use** condition that is compatible with surrounding land and water bodies. It considers the values of the community and aesthetics of the TIA, which should include blending into the surrounding environment to the extent practicable.

In 2018, Teck submitted the Pine Point Mine Reclamation Research Plan (RRP) for the TIA (Barr, 2018) to the MVLWB. The RRP provided the objectives for reclamation research, the site background and current understanding of the site (included as a CSM), a listing of closure goals and principles, reviewed options for remaining acid rock drainage (ARD)/metals leaching (ML) impacts, and identified reclamation research components that will aid in developing the final long-term closure option. The reclamation research conducted in 2018 (year 1), which is summarized in Section 2, was conducted in accordance with this plan and included the following:

- Field investigation
- Water balance evaluation
- Geochemical evaluation

- Cover assessment
- Geotechnical evaluation of perimeter dykes and tailings
- Risk evaluation
- Treatment options evaluation

2.0 2018 Research

An overview of the 2018 Research Activities is presented on Figure 2-1. Field and/or desktop activities were done to obtain information related to each of the four closure principles. This section describes the research work completed in 2018, which is year 1 of the 3-year research program. Details regarding the completed research activities are shown in Table 2-1, with reference to those that were planned in the RRP (see Figures 8 and 9 of the RRP).

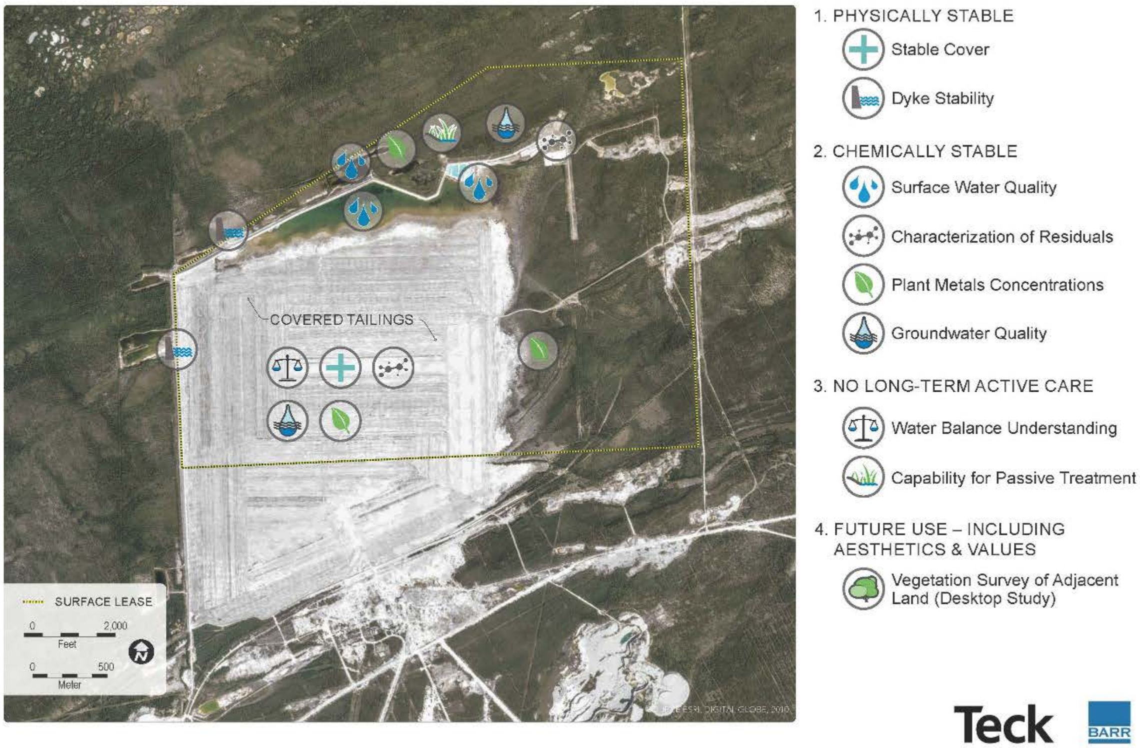

Figure 2-1 2018 Research Activities

Table 2-1 2018 Research Activities

Category	Completed Activities per Plan	Deferred Activities to 2019
Field Investigation	• Reconnaissance and mapping (topographic survey, local hydrology and drainage, local landforms) • Borings/sampling and lab work, and piezometers in dyke to improve understanding of constructed condition and foundation • Tailings distribution and character: borings and CPTs, lab work (physical and geochemical) • Tailings cover borings and lab work to confirm thickness and character, including geotechnical aspects • Characterization of residuals/ precipitates • Borings/sampling and lab work for organic/peat layer underlying TIA and downgradient muskeg • Monitoring wells/piezometers inside and below deposit, upgradient (background), within and downgradient of the dyke • Monitoring well sampling and lab work • Pond water level and quality monitoring • Existing vegetation survey and lab work • Identify local sources for borrow material	• Investigation of the dyke system and tailings deposit south of the lease limit
Water Balance Evaluation	• Climatic data collection from existing sources (Hay River) • Climatic data (site specific) collection with meteorological station • Develop GoldSim model	• Development of representative climate conditions and climate change forecast • Focused field study/control plots • Scenarios Modelling – GoldSim
Geochemical Evaluation	• Develop model – geochemists workbench	• Coupled modelling with GoldSim (water balance) if needed
Cover Assessment	• Develop concepts and perform initial quantity take-offs • Identify potential vegetation plans for future use; considering species, metals uptake, aesthetics, etc.	• Identify integration opportunities/challenges with perimeter dyke
Geotechnical Evaluation	• Investigation including borings and cone penetration testing	• Initial failure modes identification and stability modelling • Initial spillway concept design • Possible classification reduction or delisting
Risk Evaluation	• Identification of potential exposure pathways • Human and ecological – screening with existing data and literature • Determine background concentrations	None deferred
Treatment Options Evaluation	• Best Available Technology review • Conceptualization of treatments – both active and semi-passive • Sizing based on available data • Estimation of treatment potential • Screening of technologies based on effectiveness, implementability, and cost	None deferred

2.1 Physical Stability

The research goal for this category is to better understand the current structure characteristics and stability. Physical stability, by MVLWB definition, requires any project component that remains after closure to be constructed or modified to be physically stable. That means that it does not erode, subside (cave-in), or move from its intended location under extreme natural events. The intent is that the final closure landscape be stable for the long term (hundreds of years).

Geotechnical borings were used to log the stratigraphy at the site and to assess the tailings and soil properties. A total of 18 rotosonic borings were completed at the facility including at the TIA (8), along the dykes (6), immediately downgradient of the northern dyke (4), and upgradient/cross gradient of the TIA in the southeast corner of the lease area (1). Vibrating wire piezometers (VWPs) were installed in six of the borings to continuously monitor pore water pressure including at the TIA (4) and immediately downgradient of the pond (2). The other 12 were converted to monitoring wells including outside of the TIA (3) and three well nests (comprised of three monitoring wells per nest (9 total)) were installed within the TIA.

Twelve (12) cone penetrometer test (CPT) holes were advanced through the tailings into native ground. Eight (8) pore water pressure dissipation tests were performed to assess the in-situ permeability of tailings and native soils. The field investigation also included the completion of 21 test pits using a backhoe to observe tailings and soil conditions both in the TIA (3) and in the vicinity of the TIA (18).

The investigation confirmed that the tailings deposit is between about 3.3 m and 12.5 m thick and generally thins from south to north. The sand and gravel dust cover is intact and is approximately 0.15 m thick. There are exposed (uncovered) tailings on a relatively narrow swath along the far eastern edge of the tailings pile and in the direct vicinity of the TIA main pond. The tailings generally change from more poorly-graded sands at the southern lease limit to silt near the pond, which is consistent with dynamic segregation of the tailings during deposition. The tailings are underlain by a 0.10 to 0.15 m thick peat/organic layer, about 0.5 to 1.5 m of sand or gravel with large cobbles, and then dense silty or clayey native till. Saturated pore water in the tailings has radial flow from the tailings high point (south central portion of the TIA). The composition of the dykes and foundation soils, and the pore water levels in the dykes are being reviewed.

Tailings and soils samples were collected and submitted for geotechnical testing (in progress). Test analyses includes determination of water content, grain size distribution, Atterberg limits, unit weight, specific gravity, and organic content.

2.2 Chemical Stability

The research goal for this category is to better understand the current chemical properties of the tailings, water movement through tailings and environment, and fate and transport of metals at the facility. The closure principle, by MVLWB definition, is for any project component that remains after closure to be chemically stable. Chemical constituents released from the project components should not endanger human, wildlife, or environmental health and safety in the long term.

A CSM (Figure 2-2) was developed to illustrate potential zinc movement, which guided field investigations to determine zinc and other metals concentrations in tailings, tailings cover, pore water, groundwater, surface water and vegetation. These investigations and the resulting water balance, geochemical, and risk evaluations are described below.

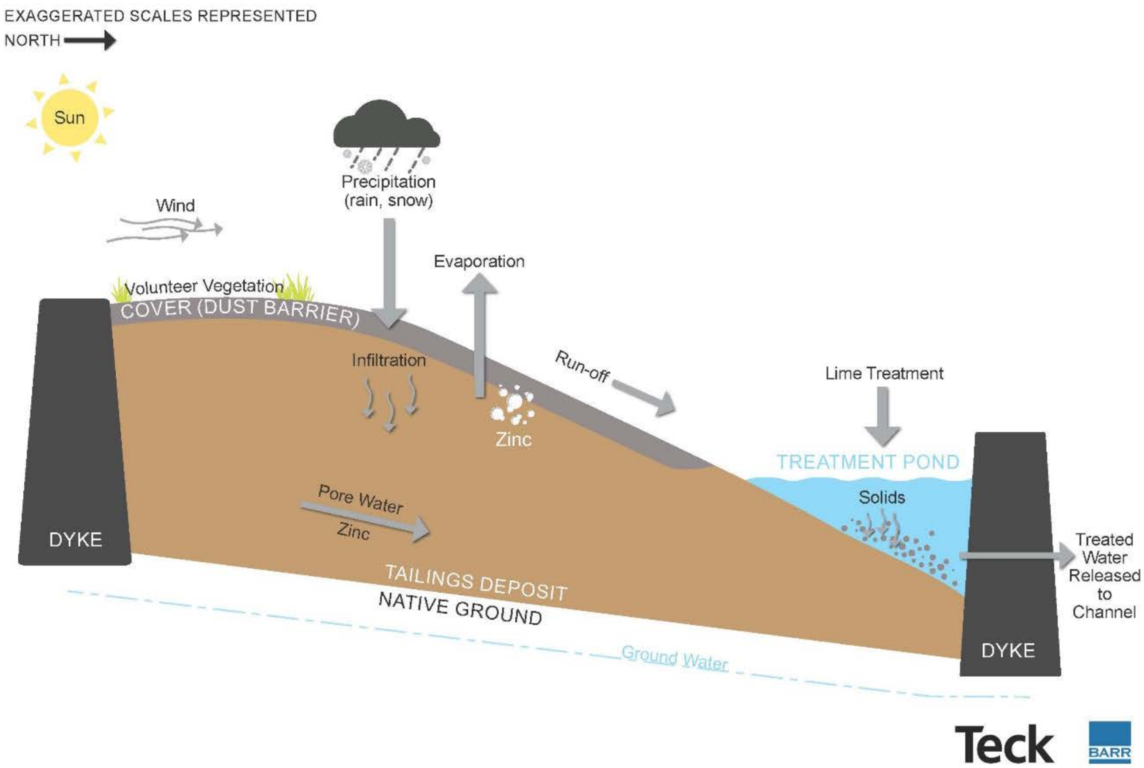

Figure 2-2 Conceptual Site Model Showing Potential Zinc Movement in the TIA

2.2.1 Field Investigation

The research work included collection of samples as described below:

- Cover soil (three samples), tailings (nine samples), and native soil and organics (nine samples) were collected from boreholes and test pits during the field investigation and analyzed for water content, pH, total organic carbon (TOC), metals, and routine anions and cations.
- Groundwater samples (a total of 11) were collected from the monitoring wells in Fall 2018. Field parameters measured were temperature, pH, specific conductivity, dissolved oxygen, and oxidation-reduction potential (ORP). The samples were analyzed for biochemical oxygen demand (BOD), total suspended solids (TSS), metals (total and dissolved), routine anions and cations, nutrients, and cyanide.
- Surface water samples were collected in the TIA main pond, and the downstream drainage channel (north of the dyke) and ponds. In-situ measurements of temperature, pH, specific

conductivity, dissolved oxygen, and ORP were collected at 0.5-m depth intervals until the bottom was reached. Samples from each location were collected at the surface and analyzed for BOD, TSS, metals (total and dissolved), routine anions and cations, nutrients, and cyanide. Secchi depth, as a measure of water clarity, and total depth measurements were also taken.

- Vegetation samples and associated shallow surface soil (top 0.15 m) samples were collected from the TIA area and an off-site reference location. Samples from random locations included vascular plants (primarily small shrubs) growing on the TIA cover (20), lichen (10) growing east of the TIA, and tubers from cattails in the wetland downstream of the treated water discharge (3) and adjacent to the dyke (3). Two reference locations were identified for cattail, lichen, and vascular plant samples. One was approximately 9 km southeast of the TIA where vascular plants, lichen, and associated soil samples were collected. The cattail and sediment samples were collected at Paulette Creek, approximately 25 km northeast of the TIA. Samples were analyzed for water content and metals in all samples, and TOC, organic matter, and pH in soil samples.

2.2.2 Water Balance Evaluation

A water balance evaluation, using the software GoldSim, is in progress using historical and site-specific data as discussed below. The GoldSim model has been created as described in the Water Model Development Document (Barr, 2019) and calibration is underway. The model includes several watersheds within the TIA and to the east, based on currently available topographic maps. The model of the TIA includes coarser to finer tailings zones that mimic the characteristics of the tailings deposition, and include both unsaturated and saturated tailings layers. The model will be used to better understand the water movement through the tailings and TIA system. Once completed and calibrated, the model may be coupled with a geochemical model to better understand the fate and transport of metals at the facility. It will be updated and recalibrated as more information is collected.

A meteorological station was installed on the north-central portion of the TIA and is collecting precipitation, temperature, relative humidity, wind speed, wind direction, and short wave radiation measurements. A stilling well with a VWP was installed in the TIA main pond to measure the water level. A grid of snowpack monitoring stations, including staff gauges and cameras, are collecting snow level measurements and snow coring is being conducted periodically to collect snow-water equivalent measurements. Initial snowpack monitoring data suggest water currently held within the snowpack is substantially more than previously thought, advancing our understanding of the CSM.

2.2.3 Geochemical Evaluation

This evaluation will rely on historical data and updated with results from the field investigation described in Section 2.2.1. A geochemical model is being developed to assess the fate and transport of zinc and other contaminants of concern (COCs) within the TIA. The overall objectives of the geochemical model are to describe the current geochemical conditions at the TIA, estimate how those conditions may change over time, and evaluate the potential effects closure options will have on COC concentrations in the future. Geochemists Workbench® 12.0 (GWB), a thermodynamic equilibrium geochemical model, is being used to estimate equilibrium conditions and evaluate changes to water quality and mineral precipitation.

A 1996 investigation at the site identified the majority of the tailings pore water (in the saturated zone of the tailings) as magnesium-sulphate (Mg-SO_4) bearing, the surface water as calcium-sulphate (Ca-SO_4) bearing, and snow as calcium-bicarbonate (Ca-HCO_3) bearing water. In that 1996 investigation, the surface water and pore water were differentiated from one another based on the relative concentrations of cations in solution. Activity coefficients were calculated for bicarbonate, sulphate, calcium, and zinc to develop a series of Eh-pH diagrams for zinc. These diagrams are used to understand the field of stability of zinc in terms of the activity of the hydrogen ions (pH) and the activity of electrons (Eh). The Eh-pH diagrams indicate that zinc is the main aqueous species and the potential solid species are hydrated zinc carbonate (like smithsonite), zincite (ZnO), and sphalerite (Zn,FeS). Recent data collected in Fall 2018 showed pore water was Ca-SO_4-type water and may be the result of the mixing effect of atmospheric precipitation infiltration on pore water quality or it may represent a shift in mineral species available in the TIA to react with pore water. The Eh-pH diagrams and zinc mineral speciation were consistent with the previous assessment and is shown below. Additional groundwater and surface water (namely the TIA main pond) monitoring, with consideration of infiltration rates generated from the water balance, will aid in further understanding the overall and seasonal changes in water quality.

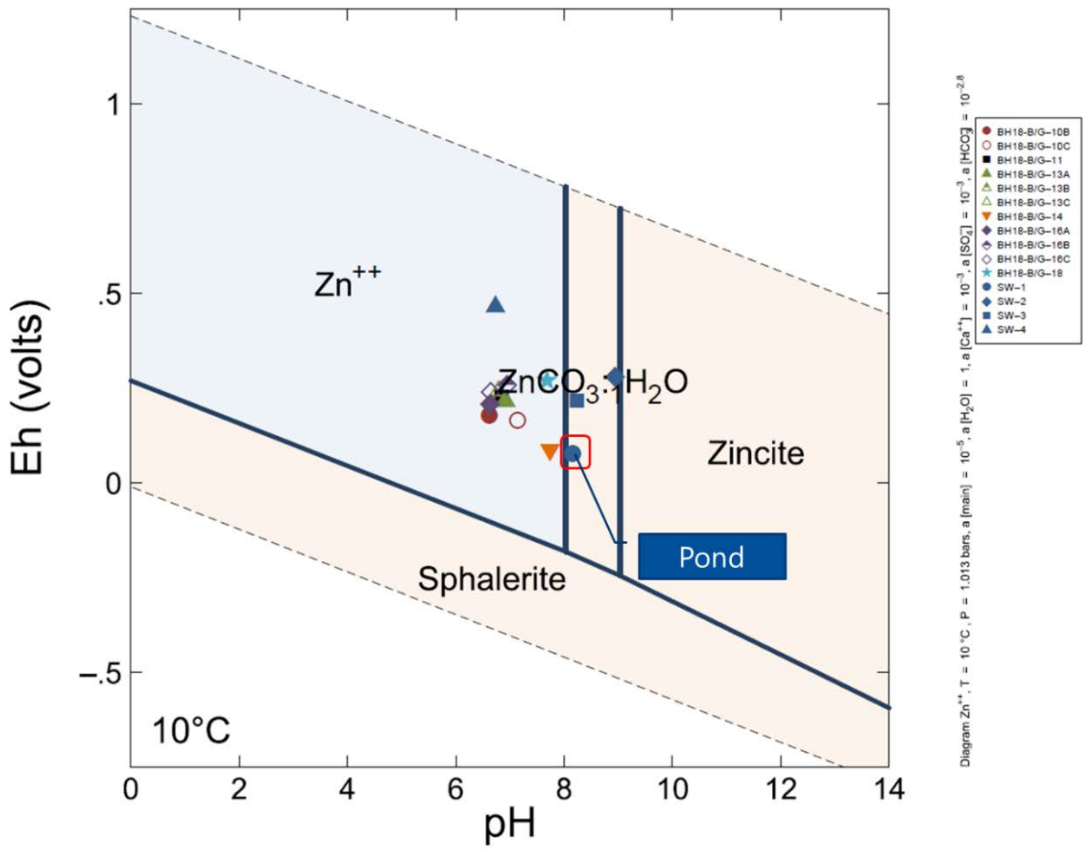

Figure 2-3 Eh-pH Diagram for Zinc in Pore Water (BH) and Surface Water (SW) from 2018 Investigation

2.2.4 Risk Evaluation

The preliminary human health and ecological risk assessments evaluated the potential for long-term (or chronic) effects of chemical exposure on people and wildlife. A preliminary baseline aquatic risk assessment was also completed to understand the potential for effects on aquatic receptors on the immediate downstream environment based on current conditions and basic assumptions assuming that water was no longer retained and treated in the TIA. The human and ecological risk assessments relied upon analytical data from samples of soil, vegetation, and water collected from the TIA and surrounding area (Section 2.2.1). These results were used to evaluate the following:

- The potential for effects to human health from exposure to metals from the TIA in water, soil, and plants and the consumption of traditional foods (e.g., game);
- The potential for effects to wildlife health from exposure to metals from the TIA in water, soil, and food (i.e., plants and terrestrial prey); and
- The potential for effects to fish from exposure to discharge water from the TIA.

The results of the preliminary risk assessment indicated that covered tailings conditions at the TIA are unlikely to result in adverse health effects for people or ecological receptors. The uncovered tailings located in the relatively narrow swath on the far eastern edge of the tailings pile have increased risk estimates for wildlife with small home ranges and toddlers, and covering options will be considered in the closure plan. Zinc exposures for the vole were greater than the target values for exposure to plants at the TIA. It is unlikely that a vole would choose the TIA as a primary habitat source, as was assumed in the risk assessment. Even if there was greater vegetation establishment on the cover, it is unlikely that voles would select the TIA as habitat since they and other small mammals in the boreal forest that surrounds the TIA prefer moist soils with a dense organic layer that allows for burrowing. The TIA will not provide this type of habitat and so it is unlikely that the TIA would support a population of small mammals. However, at exposure ratio values greater than the target, individual voles may have exposure to elevated zinc concentrations that may interfere with the uptake of other essential nutrients such as calcium.

The downstream environment was included in the wildlife risk assessment and specifically included wildlife receptors that are reliant on wetland vegetation (i.e., beaver and goose), water and sediment from immediately downstream of the treated water discharge. Risk estimates for beaver and goose were below the target risk estimate, which indicates that exposures to zinc are low and would not pose a health risk for wildlife spending all of their time in the downstream environment. Thus, zinc attenuation in the downstream environment is not resulting in accumulation of zinc that would pose a health risk to wildlife that inhabit the downstream environment.

A comparison of the water quality in the main pond and the downstream drainage network with water quality guidelines for the protection of aquatic life was also done as a preliminary aquatic risk assessment. One surface water sample was collected in the TIA main pond and three locations in the drainage network downstream of the treated discharge in Fall 2018. There are three ponds downstream of the discharge that are assumed to be former borrow areas and are not connected to any other streams or natural waterbodies. Treated water is released via a channel to the surrounding muskeg. Concentrations of metals and general parameters were compared with Canadian Council of Ministers of the Environment short-term and long-term protection of aquatic life guidelines, which are risk based guidelines derived to be protective of all fish, amphibian, and aquatic invertebrate receptors. Total fluoride concentrations were higher than long-term guidelines in all four samples. Total copper concentrations were higher in the TIA main pond and the first pond downstream of the discharge point. Total lead and cadmium concentrations exceeded long-term guidelines in the TIA main pond only. Additional surface water monitoring is needed to understand seasonal differences in water quality conditions. In addition, the presence of aquatic receptors in the downstream environment needs to be identified. This data will be used in a more detailed aquatic risk assessment.

2.3 Long-Term Water Management

The research goal for this category is to better understand how existing muskeg and natural processes might be able to help in continuing to treat water in the future and to enable prediction of water quality over time. For any project component that remains after closure, the principle of no long-term active care refers to components (i.e., passive and semi-passive treatment approaches) that are relatively to fully self-sustaining and require minimal to no maintenance. The current lime treatment of the TIA main pond water requires active care and maintenance, and thus is not desirable as a long-term solution.

The TIA main pond water quality has improved significantly over the past 20 years, but zinc concentrations continue to be greater than the Water Licence limits of 0.5 mg/L for the maximum average limit and 1 mg/L for the maximum grab limit. Grab samples that have had concentrations of zinc in the TIA main pond had been in the range of 2.5 mg/L, and as high as 3.5 mg/L. The current concentrations of zinc are approximately 1 to 1.5 mg/L. Concentrations in this range are potentially more amenable to a passive or semi-passive treatment approach. During the September 2018 field investigation, the TIA main pond had a zinc concentration of 1 mg/L, the treated discharge from the serpentine channel was in the range of 0.3 to 0.4 mg/L, and the end of the drainage network had a zinc concentrations 0.03 mg/L zinc, which is similar to concentrations measured in monitoring locations on the south side of Great Slave Lake from the community-based monitoring program (ENR, 2019). Thus, the downstream drainage network, which includes flow through an existing wetland, provides additional zinc attenuation capacity in the range of two orders of magnitude.

In 2018, an initial treatment technology screening was completed. The screening process identified the following semi-passive treatments as potentially viable for the site:

- Constructed wetland treatment systems (CWTS);
- Permeable reactive barriers (PRBs); and
- Hybrid systems based on a combination of these technologies.

CWTS have been demonstrated to be effective at various metals-impacted sites and can be designed to promote either aerobic or anaerobic conditions to promote physical, chemical, or biological processes to remove zinc from water. For this site, a CWTS with anaerobic conditions to promote reducing conditions and sequestration of zinc primarily as zinc sulphide in the CWTS sediment/soils appears to be the technology best suited for treatment that can be relatively self-sustaining and require minimal maintenance, provided the CWTS is sized appropriately for the conditions. Likewise, PRBs have been demonstrated to be effective at metals-impacted sites and can be designed to remove metals by physical, chemical, and/or biological processes depending on the selected media and operating conditions. However, PRBs often require more maintenance, as they tend to clog over time and lose efficacy, thus rendering them as more viable in a secondary polishing process or contingency application than a primary process for a relatively self-sustaining and minimal care semi-passive treatment implementation.

A conceptual design for a CTWS at the site has been completed. The sizing for a full-scale system is anticipated to be on the order of 30 hectares (ha), which is primarily driven by the area needed to maintain inputs to the system through primary production over time, not by zinc loading which could likely be managed by a much smaller system, but would require more frequent maintenance. Conceptual CWTS sizing based on key design parameters and assuming 0.5-m thickness is shown in Table 2-2 below. Further evaluation of the site topography, current wetland soils and vegetation present in the area, and scaled trials are needed to further develop the CWTS concept.

Table 2-2 Conceptual Constructed Wetland Treatment System Sizing

Parameter	CWTS size (ha)	Comment
Sulphate loading	0.3	Sulphate concentration is sufficient to support zinc sulphide precipitation
Zinc loading	2	Reducing conditions for zinc sulphide can be established in 3-day HRT
Hydraulic retention time (HRT)	1 – 65	For variable flow conditions, based on 3-day HRT
Carbon generation rate	8 - 30	Based on area needed for primary production to maintain organic substrate in CWTS

Conceptual PRB design for zinc removal considered multiple types of media, but specifically organic matter (natural materials such as peat, products such as Biochar™, etc.) and iron oxide to adsorb zinc onto the media. Previous Zn removal column tests (Teck, early 1990s), with peat/muskeg from the site, produced water with less than 0.20 mg/L zinc at residence times as low as four hours at a zinc-loading rate of approximately 54 g/m^3-d. Zinc was measured at concentrations above 0.5 mg/L when the muskeg was drained during leaching tests, but in a test that simulated freshet infiltration through the muskeg, concentrations remained below Water Licence limits, suggesting low probability for the zinc to elute from the adsorbent material. The adsorbent capacity of the organic matter options will need to be better defined and the loading rates and rate of exhaustion will need to be better understood to carry this option forward. Ferric iron adsorption and co-precipitation to remove some heavy metals is a widely used technology in the mining industry and can be effective even at low hydraulic residence times. However, most of the experience with iron oxide is at the bench and pilot-scale level and scale-up limitations will need to be considered.

2.4 Future Use Considerations

The research goals for this category are to determine if the dykes and cover can be modified to better blend in with surrounding area, to better understand how the current ponds and drainage system function now and how they would ideally function when the ponding in the TIA is reduced to improve stability, and engage surrounding community members to learn how the area would be used in the future.

The future use scenarios rely heavily on the results from the evaluations discussed in Section 2.2 and Section 2.3, namely with regard to efforts needed to stabilize the dykes and tailings, and to passively treat water to a quality that does not pose an unacceptable risk to human health or the environment.

In November 2018, Teck met with community members in Fort Resolution and Hay River. Invitations to these meetings were sent to the Deninu K'ue First Nation, Fort Resolution Métis Council, Hamlet of Fort Resolution, K'atl'Odeeche First Nation, Hay River Métis Council, Town of Hay River, and West Point First Nation. The objectives of the November meeting were to introduce the reclamation research planning work, the updates to the engagement plan and to seek feedback from the community in how they could be involved with the reclamation planning at Pine Point. In total, approximately 40 attended the four meetings held in Fort Resolution and Hay River. The main concerns that were heard related to operating practices in the 1960s and 1970s that impacted the environment, water quality, communication of results and progress towards reliable closure.

3.0 2019 Research Plans

An overview of the 2019 Research Activities is presented on Figure 3-1. Field and/or desktop activities will continue to focus on data gathering related to each of the four closure principles. This section describes the research work proposed for 2019, which is year 2 of the 3-year research program. Details are included in Table 3-1.

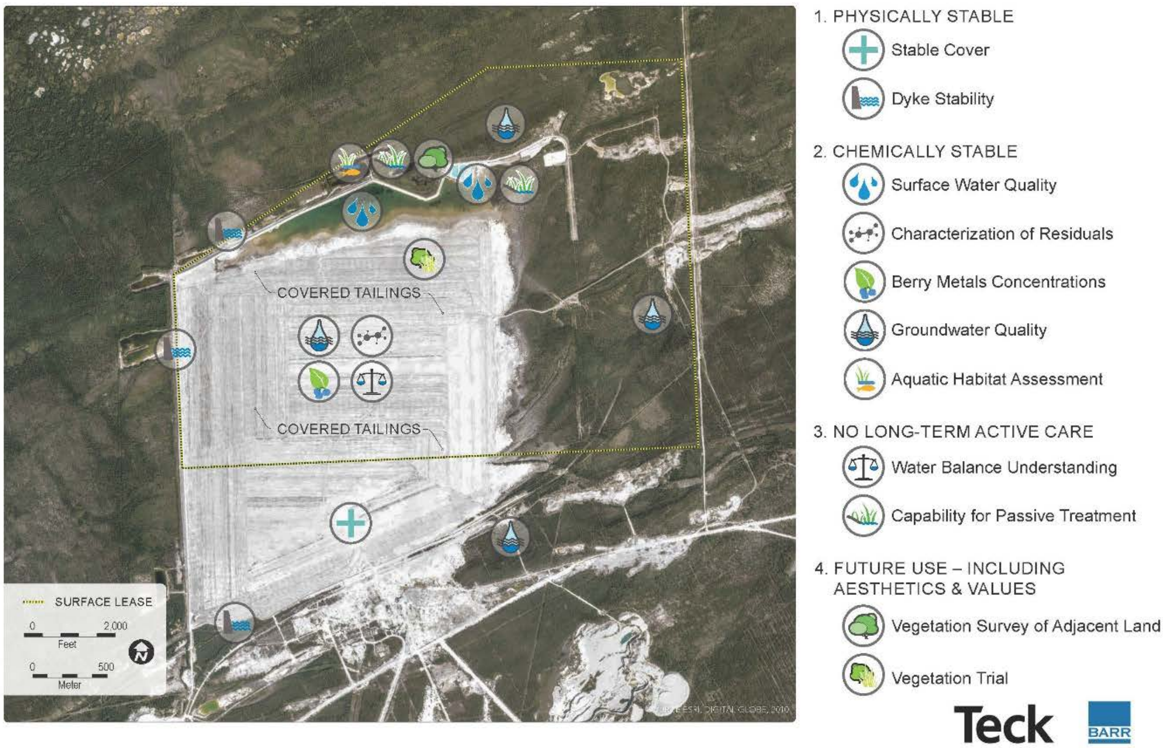

Figure 3-1 2019 Research Activities

Table 3-1 Summary of 2019 Research Activities

Category	Activity
Field Investigation	• Completion of topographic mapping – eastern portion of the TIA • Investigation of the dyke system and tailings deposit south of the lease limit • Pore water/groundwater and surface water quality data from various seasons • Water quality data for surface runoff • Water quality data for precipitation (rain and/or snow) • Groundwater/pore water gradients from various seasons • Hydraulic conductivity of the TIA material • Porosity of the TIA material • Focused field study of infiltration and runoff rates for water balance evaluation • Aquatic habitat assessment of downstream drainage network • Downstream drainage network mapping and field reconnaissance • Passive treatment system siting investigation (wetland soils, vegetation, etc.)
Water Balance Evaluation	• Development of representative climate conditions and climate change forecast • Calibration of GoldSim model • Scenarios modelling with GoldSim
Geochemical Evaluation	• Static and kinetic testing of tailings samples • Geochemical model development and simulations (historic, current, and future) • Coupled modelling with GoldSim (water balance) if needed
Cover Assessment	• Identify integration opportunities/challenges with perimeter dyke • Map the exposed (uncovered) area of tailings along east edge of TIA
Geotechnical Evaluation	• Initial failure modes identification and stability modelling • Initial spillway concept design • Possible classification reduction or delisting
Risk Evaluation	• Berry monitoring program • Aquatic habitat evaluation • Mixing evaluation of downstream drainage network
Treatment Options Evaluation	• On-site constructed wetland treatment system field trial • Off-site mesocosm study of wetland treatment system • Bench-scale study of adsorptive media for zinc and other metals retention • Development of passive treatment system design for the site
Future Use Considerations	• Continued community engagement • On-site vegetation trial on TIA cover

3.1 Physical Stability

The dyke composition and foundation conditions will be assessed and stability modelling will be performed. Potential failure modes and factors of safety will be determined considering the setting and range of pore pressures that would be anticipated, based on current monitoring and forecasting of ponding conditions. The opportunity to flatten the dykes, reduce ponding (hydraulic head against the dyke), and any other modifications that would improve long-term stability will also be evaluated and integrated with the closure options aimed at improving water quality.

Topographic survey of the TIA, dykes, and interior and exterior toes is currently underway, as well as bathymetric survey to determine the elevation of the bottom of the TIA main pond. This work will enable geometrically representative cross sections of the dyke to be created and modelled. Survey of the exposed tailings along the far eastern edge of the tailings pile and in the direct vicinity of the TIA main pond will be performed to aid in closure planning. Ongoing pore water pressure measurements will be used in the modelling. Additional geotechnical drilling and/or test pitting is anticipated to fill any data gaps identified during preliminary physical stability modelling and evaluation. Advanced geotechnical testing in the laboratory will also be performed to the extent needed to refine modelling parameter value assignments and/or sensitivities.

3.2 Chemical Stability

Additional research is aimed at defining water movement through tailings and environment, and fate and transport of metals at the facility.

3.2.1 Field Investigation

Additional field investigation and monitoring is planned to provide the following:

- Pore water/groundwater and surface water quality data from various seasons
- Water quality data for surface runoff
- Water quality data for precipitation (rain and/or snow)
- Groundwater/pore water gradients from various seasons
- Hydraulic conductivity of the TIA material
- Porosity of the TIA material

Collection of temporal pore water/groundwater and surface water data will aid in assessing how parameter concentrations and flow into the TIA pond fluctuate with location and time. The data will also be used in forecast modelling of seasonal behavior. The existing monitoring well and piezometer network will be used, and three additional monitoring wells are planned to supplement the monitoring network. The supplemental wells will aid in refining flow conditions and water quality in the TIA and vicinity.

Spring, summer, and fall sampling is proposed for the pore water/groundwater monitoring wells in 2019 and 2020. A total of seven sampling events (Fall 2018, Spring 2019, Summer 2019, Fall 2019, Spring 2020, Summer 2020, and Fall 2020) will be completed by the end of the reclamation research period. Monthly surface water sampling of the main pond from ice out (approximately May) until the onset of freezing (approximately November) is proposed in 2019 and 2020. About 13 sampling events (one in Fall 2018, six in 2019, and six in 2020) will be completed by the end of the reclamation period. This will allow for seasonal evaluation of major ion and COC chemistry in the water, as well as COC trend analysis to be performed. This information will aid in evaluating how the flux of external sources of water to the system (infiltration, runoff, etc.) affects the overall chemistry of the TIA, which ultimately helps answer a major objective of the geochemical modelling effort (how COCs and flow into the TIA pond fluctuate with location and time).

Collection of surface runoff will be performed during spring freshet and opportunistically after significant storm events. A snow and rain sample will also be collected in 2019. Collected data will be compared with historical data that is available for surface runoff and snow from 1996. This will allow for evaluation of how the flux of external sources of water to the system effects the overall chemistry of the TIA.

Ongoing collection of groundwater elevation data throughout the TIA, as well as evaluation of the hydraulic conditions of the TIA material, will be used to assess groundwater flow dynamics, including rate of transport, and upwelling or downwelling of pore water into or from the groundwater. Understanding the flow dynamics of the TIA system will be crucial in determining how long it will take zinc in the TIA to fall below the Water License Limit (0.5 mg/L) under current conditions and to evaluate the potential effects of closure options, particularly if they deal with changes to flow dynamics. Slug testing of existing monitoring wells is planned to provide in-situ hydraulic conductivity measurements.

Porosity of the tailings will be determined through sampling in 2019. California samplers or other similar coring approaches will be used to collect undisturbed samples for unit weight determination, which will enable porosity determination. Soil water retention capacity of the finer-grained unsaturated tailings will also be determined from samples collected from the TIA in 2019 if the model shows sensitivity to this parameter.

Through the development of the water balance model (discussed in the following section), it may be necessary to install a lysimeter in the a small field plot within the TIA to better understand infiltration rates, runoff rates, soil moisture content, and unsaturated flow through the upper layer of the tailings. Unsaturated flow is an important variable in the water balance model.

Topographic mapping of the TIA will be used to refine the watersheds (as necessary), and additional topographic mapping of the watershed area east of the TIA is planned to aid in runoff determination and assignment of flow contribution to the TIA main pond from this area. Topographic mapping and bathymetric survey data will be used to refine the stage area storage curve for the TIA main pond.

3.2.2 Water Balance Evaluation

The water balance model (GoldSim) will be further developed in 2019. Initial efforts will focus on the calibration and validation of the model. At this point in time, available data sets of observed data are off site, and coarse spatially. We have used historical data at Hay River, Fort Resolution, and Fort Smith to generate a long record (65 years) of on-site climate data. Additionally, on-site data from 2018 and planned data collection in 2019 will be incorporated as it becomes available. These data sets will be used for calibration, with the recognition that the actual recent on-site data covers only one year and will be limited in its ability to address the effects of natural variability. Therefore, the calibration process will likely include the combination of both the generated historical on-site data and the detailed data collected during the research period. The subsequent years of collected research data will be used for model validation.

The first simulation that will be developed will be the historic/current conditions that will be conducted as part of model calibration. This model simulation will be used to help inform future data collection that may be needed. Additional simulations and scenarios to be modelled will be developed as the goals and objectives outlined in the Water Model Development Document are followed. One objective is to provide the water balance output metrics required to forecast water quality improvement over time (e.g., in 10, 50, 100, 500, 1,000 years) under the current closure strategy, which includes dyke flattening and spillway improvements to distribute the flow. Additionally, hydrologic implications from potential closure options, such as the implementation of passive treatment or regrading and shaping of the TIA surface, will be evaluated. Modelling will eventually include an assessment of possible climate change, system uncertainties, and sensitivities to the water balance, recognizing that drivers such as warming and higher-intensity precipitation events may impact the long-term performance of the closure option.

3.2.3 Geochemical Evaluation

The purpose of the geochemical characterization of the TIA is to provide a framework to evaluate potential long-term impacts to surface-water quality at the site. Additional laboratory testing on samples collected during the 2018 sampling effort includes static and kinetic testing. Static testing includes acid base accounting (ABA) analysis (such as sulphur and carbon speciation (as weight percent or wt. %), and determination of acid potential (AP), neutralization potential (NP), and the net potential ratio (NPR)). The results of static testing will be compared against historical results and inform kinetic testing needs. Kinetic testing, such as humidity cells and/or shake flasks, will also be conducted to evaluate release rates and assess short- and long-term leaching behavior of the COCs, primarily zinc.

It is anticipated that the results of the further material characterization will become part of the conceptual, and ultimately quantitative, models for understanding future water quality conditions associated with the project. These data likely will also be used with project water balances to develop and refine hydrogeochemical and mass-loading models to assess closure scenarios. All these types of models are subject to refinement due to changes in available data and closure plans.

Based on the results of the analytical testing, the geochemical model development will be advanced in 2019 with the goal to aid in determining:

1. When zinc in the TIA main pond will fall below the Water Licence Limit (0.5 mg/L) under current conditions;
2. How COCs and flow into the TIA pond fluctuate with location and time; and
3. How COCs may vary in response to the closure options being considered.

Further comparison of historical and current data collected from the TIA will include evaluating temporal changes to COC concentration profiles in the tailings pore water (as an analogue for leaching), temporal and spatial changes to the estimated total zinc mass in the tailings, and temporal changes to COC concentrations in the tailings pond.

3.2.4 Risk Evaluation

Vegetation samples from plants growing on the TIA were collected and analyzed in Fall 2018 for the human and wildlife risk assessments. In the human health risk assessment, vegetation (i.e., leaves) were used to represent berry consumption. The reason for this was that the 2018 sample collection program was done after berries were at their prime growing condition and, therefore, would have required more sample volume than feasible for chemical analyses. Therefore, in 2019, berries will be collected from the shrubs growing on the TIA to fill the gap of berry consumption in the risk assessment. It is expected that composite samples of several berry types will be required to obtain adequate sample volumes. The program will target Saskatoon, buffalo berry, bear berry, and juniper berries. Berry samples will be analysed for metals and moisture composition. The risk assessment will be updated to include the new data.

The aquatic health risk assessment included an assumption that the former borrow areas downstream of the treated water discharge provided adequate fish habitat. To refine this assumption, a field program is planned for 2019 to assess the availability of fish habitat in these waterbodies. Based on aerial imagery, there is no connectivity between these ponds, and streams or lakes that would be fish bearing. Therefore, fish presence would have been opportunistic (i.e., eggs or fish deposited as a result of transfer by birds). A qualified aquatic biologist will assess whether water depth, quality, and substrate composition are adequate for fish habitat and will observe for the presence of fish. Sediment and water column samples may be collected to determine the presence of benthic invertebrates and zooplankton.

In addition to understanding aquatic habitat, additional assessment of the waterbodies (former borrow areas) downstream of the treated water discharge is warranted to better understand the mixing of treated water in the receiving environment. Field investigation parameters will include getting more detailed bathymetry data to estimate the volume of receiving water available for mixing. Other characteristics that affect mixing, such as the presence of beaver dams, channel characteristics, and flow, will be measured. Data will be used in a water-quality model to estimate the downstream concentrations of COCs from a CWTS.

3.3 Long-Term Water Management

The semi-passive treatment technologies including CWTS and PRBs will be advanced in 2019, including performance of an on-site Semi-Passive Water Treatment Trial and off-site Mesocosm Study for the CWTS and bench-scale testing of adsorptive media. Additional field investigation will also be performed to aid in siting a full-scale, semi-passive treatment system, should scaled testing provide favourable results.

3.3.1 CWTS Field Trial

An on-site field trial will be implemented to evaluate a CWTS. The areal extent of the semi-passive water field trial will be approximately 1 ha, or less. The field trial area will be located near the existing serpentine channel, which will serve as the source of water for the semi-passive water treatment testing. This area within the TIA has some vegetation that will require clearing, but is not within native forest. The shrub vegetation will be shredded and larger logs will be used for the vegetation trial described below. The approximately 1-ha area will be cleared of vegetation and organic soil that will be stripped to a depth of approximately 0.30 m. The area will be graded (deep to shallow) to direct water from the main pond to and through the constructed wetland, and back toward the serpentine channel. This will require the use of excavators, dozers, and/or graders. A conveyance pipe and drain tile distribution piping may be added to assist with water supply and to provide hydraulic control in the constructed wetland.

The organic soil that was stripped will be mixed with the shredded vegetation from the site. Additional organic material including mulch, topsoil, manure, and/or biosolids may be also be mixed in to create suitable wetland substrate. This additional organic material will be sourced from local vendors. The substrate mix will be placed in a single lift across the constructed wetland trial area. The area will be vegetated using willow stakes and/or nursery-supplied seed or plugs of native wetland vegetation.

3.3.2 Wetland Assimilation Mesocosm Study

Another method that will be used to determine the water treatment capacity of local wetland vegetation is to conduct an off-site mesocosm study. Working from the edge of the TIA dyke (to minimize impacts to the existing wetland area by equipment), three 1-m square patches will be carefully removed from the existing wetland. The patches, up to 0.3 m thick, will be placed into a tote and wrapped for off-site shipment. The patch area will be carefully regraded to promote re-establishment of vegetation. The patch will be shipped to a research facility/laboratory and used in a controlled wetland mesocosm study. The wetland mesocosm study will be a controlled experiment to determine the capacity of the patch to treat tailings-impacted water.

3.3.3 Bench-Scale Study of Adsorptive Media

Portions of the wetland coupons removed for the mesocosm studies described above may be augmented in the laboratory for bench-scale testing of the addition of biochar, iron oxides, or other amendments to the CWTS soils. The objective of adding these amendments would be to improve the sorptive capacity of the solids within the mesocosm. By improving the sorptive capacity, chemical processes within the system may better retain dissolved zinc early in the year until conditions for sulphate reduction improve and zinc that is initially retained by sorption can be converted to zinc sulphide, thereby restoring the sorptive capacity of the solids.

3.3.4 Field investigation for Semi-Passive System Siting

Field sampling will be conducted during the construction of the CWTS. The samples collected will consist of:

- Wetland soils (unamended, prior to stripping)
- Blended CWTS soils – after incorporation of woodchips, biosolids, and other ingredients
- Mineral soils used for the base of the CWTS, berms, and other structures

A detailed sampling and analysis plan will be prepared prior to initiation of the CWTS construction work. It is anticipated that, at a minimum, wetland soils will be analyzed for organic content and hydraulic conductivity. Subsurface soils will be analyzed for iron oxide content and hydraulic conductivity.

3.3.5 Wetland Vegetation Survey

A wetland vegetation survey will be done to support the design of the semi-passive system. Wetland vegetation will be identified to understand the types of vegetation that are native to the area that might inform the design of the CWTS. The methods used in the vegetation survey will be a modified version of those presented in the protocol entitled "*Monitoring Vegetation in the Northwest Territories: A Community-Based Protocol for the Northwest Territories Cumulative Impact Monitoring Program*" (Lantz et al. 2013).

3.4 Future Use Considerations

3.4.1 Community Engagement

In November 2018, Teck presented the first phase of the RRP for the Pine Point TIA in Fort Resolution. During its presentation, Teck asked participants how they would like to be part of the planning, research, and closure development process for the site. It was recommended that an advisory committee be established for this purpose. Teck is currently in communication with the Deninu K'ue First Nation and the Fort Resolution Métis Council to develop a Terms of Reference for the advisory committee. Draft objectives for the advisory committee are as follows:

- Share information that is valuable for closure research and planning,
- Facilitate in the development of a closure plan that addresses community values and meets the closure objectives required by the MVLWB.
- Provide opportunities for community participation in the closure process and activities.

Teck also intends to meet with leadership of the K'atl'Odeeche First Nation and the Hay River Métis Council, as their interests direct, to provide summaries of activities underway and planned.

3.4.2 Vegetation Trial

A vegetation trial is planned to start in 2019 with the objective of improving the aesthetics of the tailings cover. During the 2018 field investigations, logs randomly placed on the TIA were observed to have a greater diversity of plant material on the leeward side of the log. The logs appear to provide microsites that encourage plant growth. The vegetation trial will include the establishment of three to five plots of approximately 10 m x 10 m in size. Within these plots, weathered logs and fresh logs (from clearing done for the CWTS field trial described in Section 3.3.1) will be scattered. A native grass seed mix will be used to establish growth expeditiously and to mitigate the establishment of non-invasive plants. The plots will be monitored for seed germination with respect to log placement. No equipment will be used, other than that identified for the CWTS field trial, since the goal is to do these two trials concurrently. Flagged poles will be used to demarcate the plot areas, which will remain on the TIA until the trials are complete (one or two years).

4.0 References

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Flysheet Line 1

Flysheet Line 2

Flysheet Line 3