Appendix V3-4F

Geochemical Source Term Predictions for the Proposed Madrid North, Madrid South and Boston Mines, Hope Bay Project

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Geochemical Source Term Predictions for the Proposed Madrid North, Madrid South and Boston Mines, Hope Bay Project

Prepared for

TMAC Resources

Prepared by

SRK Consulting (Canada) Inc.
1CT022.004
December 2016

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Technical Summary

This report documents the methods, assumptions and results for geochemical source terms (contact water chemistry) associated with the Phase 2 Project. Base and upper case source terms were estimated for the following Phase 2 mine facilities:

- Madrid and Boston waste rock and ore stockpiles;
- Madrid and Boston pads and infrastructure;
- Doris and Boston tailings areas;
- Quarry rock covers on the tailings areas at closure;
- Surface pads and infrastructure;
- Doris and Madrid underground mines (including reflooded closure scenario); and
- Doris and Boston processing plants.

Source terms for drilling brines, explosives residues surface and groundwater quality and water treatment plant effluent are presented in SRK (2016e).

Base and upper case source term estimates were based on a combination of scale-up calculations from the geochemical characterization programs, monitoring data from existing facilities at Hope Bay, and extrapolation of monitoring data from geologically similar mine sites.

The results are a key input to the water and load balance used to predict discharge and receiving water quality for Phase 2 of the Project, for use in the effects assessment (SRK 2016e). The source terms generally reflect dissolved concentrations resulting from geochemical reactions as water comes into contact with each of these geological materials. However, guidelines for receiving water quality are based on total metals concentrations. Therefore, an estimate of suspended metal concentrations was also required for discharges to Doris Creek and the Marine Mix Box. At Boston, contact water from the mining facilities will undergo water treatment, and the water treatment plant effluent is considered to be representative of total metals.

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1 Introduction

The Hope Bay Project (the Project) is a gold mining and milling undertaking of TMAC Resources Inc. The Project is located 705 km northeast of Yellowknife and 153 km southwest of Cambridge Bay in Nunavut Territory, and is situated east of Bathurst Inlet. The Project comprises three distinct areas of known mineralization plus extensive exploration potential and targets. The three areas that host mineral resources are Doris, Madrid, and Boston.

The Project consists of two phases: Phase 1 (Doris project), which is currently being carried out under an existing Water Licence, and Phase 2 which is in the environmental assessment stage. Phase 1 includes mining and infrastructure at Doris only, while Phase 2 includes mining and infrastructure at Madrid (Madrid North and Madrid South mines) and Boston (Boston Mine) located approximately 10 and 60 km south from Doris Mine, respectively (Figure 1-1).

This report documents the methods, assumptions and results for geochemical source term concentrations from geologically-sourced materials from Phase 2 of the Project. Specifically, source terms for the following mine facilities are presented: waste rock and ore stockpiles, Doris and Boston tailings areas, underground mines, Doris mill and Boston processing plant process water, pads and infrastructure, and the quarry rock covers on the tailings areas.

These source terms are inputs to the overall site wide water and load balance model used to assess the potential effects of Phase 2 of the Project on the receiving environment. The Phase 2 site wide water and load balance has been developed by SRK and is presented elsewhere in the DEIS (SRK 2016e).

Figure 1-1: Location of the Main Deposits, Hope Bay Project

2 Background

2.1 Mine Plan

The Phase 2 mine plan details are presented in the context of source term development. Details are based on the following information sources:

- TMAC (2016) mine plan.
- Engineering design and groundwater modelling (SRK 2015d, 2016f and 2016j).

Table 2-1 presents the operational timelines for the Madrid North, Madrid South and Boston mines, including total volumes of ore, waste rock, and tailings. Material volumes associated with the Doris Mine are consistent with the Type A application (TMAC 2015). Each mine will have separate waste rock and ore stockpiles.

Table 2-1: Material Volumes (tonnes) for Madrid North, Madrid South and Boston Mines

Material	Madrid North	Madrid South	Boston
Ore	12,501,000	991,000	5,104,000
Waste Rock - total	4,655,153	1,554,381	1,202,737
Waste Rock - Stockpile*	645,522	893,714	382,514
Flotation Tailings	11,750,940	931,540	4,797,760
Detoxified Tailings	750,060	59,460	306,240
Initial Year of Mine	2019	2029	2022
Final Year of Mine	2031	2032	2032

*At closure, all stockpiled material will be placed underground as backfill

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The Project includes a mill at Doris and processing plants at Madrid and Boston. The Doris mill is designed to have a maximum milling rate of 2,400 tonnes per day (tpd) and would have both flotation and cyanide leach circuits. The Madrid and Boston processing plants would have a maximum milling rate of 1,200 tpd with only flotation circuits operating. Concentrate produced at the Madrid and Boston processing plants would be transported to the Doris for cyanidation. There are two options being considered for the ore processing which are described as follows:

- Option 1: All Doris ore and a portion of ore from the Madrid Mine is processed at Doris mill. The remaining portion of the Madrid ore is processed at the Madrid processing plant. All Boston ore is processed at Boston. The concentrates from the Madrid and Boston processing plants are transported to the Doris mill for cyanidation.
- Option 2: All Doris ore and a portion of ore from the Madrid and Boston mines is processed at the Doris mill. The remaining portion of Madrid and Boston ores are processed at the Madrid and Boston processing plants, respectively, with the resulting concentrates transported to the Doris mill for cyanidation.

The Doris milling process would produce flotation and detoxified tailings, the latter which are from the leach circuit. The flotation tailings from the Doris mill would be placed as a subaerial slurry in the Doris tailings impoundment area (TIA), which has an 18 Mt (14 Mm^3) capacity. Detoxified tailings would be co-disposed with waste rock as backfill in the stopes of the Doris and Madrid North underground. Process water from the Doris mill (of which 6% and 94% are from the flotation and detoxified tailings circuits, respectively) would be pumped to the Doris TIA. Flotation tailings from the Boston processing plant will be managed in a dry stack tailings management area (TMA) with a 5.0 Mt (2.8 Mm^3) capacity. The process water bleed from the Boston processing plant would be pumped to the water treatment plant.

During operations, waste rock will preferentially be used as backfill underground. This rock will never come to surface. In contrast, a proportion of waste rock will be stockpiled on surface during operations on a designated waste rock pad for each mine. Contact water from the waste rock will be managed in a contact water pond, which will be managed along with all site contact water. All waste rock stockpiled on surface will be placed underground as backfill over the course of operations. At closure, there will be no waste rock stockpiles remaining on surface.

Contact water at Doris will be pumped to the Doris TIA and intercepted underground water from Doris and Madrid will be pumped to the Marine Mixing Box (MMB). The end-of-pipe discharge points would be within Doris Creek (water from Doris TIA) or submarine disposal in Roberts Bay (water from the MMB). At Boston, runoff from infrastructure, stockpiles, and the TMA and mill process water will undergo water treatment. The discharge from the water treatment plant is the end-of-pipe discharge point. Effluent from the water treatment plant will be released into Aimaokatalok Lake.

Table 2-2 the underground backfill materials balance at closure. The Boston Mine is completely within permafrost whereas the other mines partially intersect talik (SRK 2016f). A summary of Table 2-2 is as follows:

- Madrid South Mine has a surplus of waste rock, which will be placed underground at Madrid North.
- Madrid North and Boston mines have a deficit of backfill and require imported sources.
- Detoxified tailings from the Doris mill will be placed underground at Doris and Madrid North.
- The total backfill volume for the Doris Mine is consistent with the Type A application (TMAC 2015); however, the proportions of waste rock and detoxified tailings placed underground at Doris have changed in accordance with the Phase 2 mining schedule.

Table 2-2: Backfill Volumes (tonnes) for Doris, Madrid North, Madrid South and Boston Mines

Material	Source Area	Backfill Destination			
		Doris	Madrid North	Madrid South	Boston
Waste Rock	Doris	1,464,611	112,189	--	--
	Madrid North	--	4,655,153	--	--
	Madrid South	--	893,714	660,667	--
	Boston	--	--	--	1,812,127
Detoxified Tailings	Doris Mill	240,570	1,029,930	--	--
Quarry Rock	Quarry	--	1,582,430	--	1,590,541

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Key aspects of the closure plan are described as follows:

- All waste rock stockpile material will be placed underground.
- When mining activities cease within a given mine, the underground will be allowed to reflood. Once flooding is complete, all backfill will be submerged. Section 3.3.4 discusses reflood times for each mine.
- A quarry rock cover will be placed on the Doris TIA.
- A cover system (geosynthetic membrane and protective quarry rock layer) will be placed on the Boston TMA.
- The Boston water treatment plant will operate until two years after mining stops and until ponds are gone.
- The closure date of the Doris Mine is consistent with the Type A application (TMAC 2015).

2.2 Geochemical Characterization Studies

A number of geochemical characterization program have been conducted for quarry rock, waste rock and tailings for Doris, Madrid North, Madrid South and Boston. In summary, all waste rock, quarry rock and tailings are non-PAG, with the exception of detoxified tailings, which have a predicted onset to acidic conditions of 20 years. In terms of neutral pH metal leaching, arsenic is a constituent of concern from Madrid and Boston waste rock and tailings. The methods, sample sets and assessment of metal leaching and acid rock drainage that provide background to the source term water chemistry estimates are documented in the reports list below.

Waste Rock

- Kinetic Testing of Waste Rock and Ore from the Doris Deposits, Hope Bay. Report prepared for TMAC Resources by SRK Consulting (Canada) Inc., Project 1CT022.002. June 2015.
- Geochemical Characterization of Waste Rock and Ore, Madrid North Deposit, Hope Bay Project. Report prepared for TMAC Resources by SRK Consulting (Canada) Inc., Project 1CT022.004. 2016.

- Geochemical Characterization of Waste Rock and Ore, Madrid South Deposit, Hope Bay Project. Report prepared for TMAC Resources by SRK Consulting (Canada) Inc., Project 1CT022.004. 2016.
- Geochemical Characterization of Waste Rock and Ore from the Boston Deposit, Hope Bay Project. Report prepared for TMAC Resources by SRK Consulting (Canada) Inc., Project 1CT022.004. 2016.
- Doris North Project – Water and Load Balance. Report prepared for TMAC Resources by SRK Consulting (Canada) Inc., Project 1CT022.002. June 2015.

Tailings

- Geochemical Characterization of Tailings from the Doris Deposits, Hope Bay. Report prepared for TMAC Resources by SRK Consulting (Canada) Inc., Project 1CT022.002. June 2015.
- Geochemical Characterization of Tailings from the Madrid North, Madrid South and Boston Deposits, Hope Bay Project. Report prepared for TMAC Resources by SRK Consulting (Canada) Inc., Project 1CT022.004. 2016.

Quarry Rock

- Geochemical Characterization of Quarry Materials for the Doris-Windy All-Weather Road, Hope Bay Project – FINAL. Report prepared for Hope Bay Mining Limited by SRK Consulting, August 2008.
- Hope Bay Project Geochemical Characterization Program for Quarry G, H and I. Report prepared for TMAC Resources Inc. by SRK Consulting (Canada) Inc. Project 1CT022.002. August 2015.
- Geochemical Characterization of Phase 2 Quarries, Hope Bay Project. Report prepared for TMAC Resources by SRK Consulting (Canada) Inc., Project 1CT022.004. 2016.
- 2013 Hope Bay Seepage Monitoring Program. Report prepared for TMAC Resources by SRK Consulting (Canada) Inc., Project 1CT022.000. March 2014.
- 2014 Hope Bay Seepage Monitoring Program. Report prepared for TMAC Resources by SRK Consulting (Canada) Inc., Project 1CT022.001. March 2015.

3 Calculation Methods and Assumptions

3.1 Overview

“Source terms” refers to predicted water chemistry estimates for waters in contact with various types of geologically-sourced wastes and surfaces under the expected disposal conditions at the site. A source term is the water quality estimate associated with a mine component and can be composed of multiple material types (e.g. underground backfill at Madrid North is a combination of quarry rock, detoxified tailings and waste rock from Madrid and Doris). These estimates are inputs to the overall site wide water and load balance model used to assess the potential effects of the project on the receiving environment. The site wide water and load balance has been developed by SRK and is presented elsewhere in the DEIS (SRK 2016e).

The source terms were calculated based on information acquired from various sources, including results of site specific laboratory testing, information from the mine planners, and data from other sites. As with all predictions of this type, there are uncertainties in the input assumptions and the results that need to be considered in the subsequent effects assessment for the project. The approach used for the Project was to incorporate conservative assumptions wherever possible to ensure that the resulting predictions provide a conservative indication of the potential effects of the project. In other words, they provide a “reasonable upper bound” on contaminant concentrations. Sensitivity analyses were then incorporated to assess the potential magnitude of the conservatism.

For most source terms, two scenarios (base case and upper case) were developed to facilitate base and upper case assessments of the overall site wide water and load balance modelling. For the source terms, the base case is a geochemically conservative scenario that captures the statistical range exhibited in the geochemical database(s) for that source term. The statistics selected consider both the data and number of samples/tests. Accordingly, the statistical value selected for the base case varies for each source term. The geochemical source term upper case was similarly selected, and is more conservative than the base case. The upper case for source terms does not necessarily represent the maximum of the geochemistry.

In general, the source terms were calculated as annual average dissolved concentrations and do not consider seasonal transient effects such as dilution in contact waters that commonly occurs during snow melt events. Estimated concentrations were calculated on a constant annual basis which is considered conservative. When these predictions are coupled with the seasonal hydrograph, elevated loads occur during spring runoff and other high flow events which are commonly observed at mine sites. Total metals concentrations were calculated for selected mining facilities to allow for comparisons of predicted water quality for end-of-pipe discharge.

Table 3-1 provides a list of the source terms developed for this project, including a description of the source, the expected timing of the source, and the type of source term. The following are not listed in Table 3-1, and therefore are not included in this report for the reasons described as follows:

- The Boston underground mine is completely within permafrost; therefore, there will be no intercepted groundwater to manage in the Boston Mine (SRK 2016d) and a source term is not required for the Boston underground mine.
- The scope of this report includes source terms from geologically-sourced materials. Derivation of source terms for drilling brines, explosives residues, surface and groundwater quality, and water treatment plant effluent are presented in SRK (2016e).

Table 3-1: Key Assumptions Related to Source Term Estimates

Component	Mine	Description	Type of Source Term
Waste Rock and Ore Stockpiles (Operations)	Madrid North, Madrid South & Boston	Interaction of precipitation with non-PAG waste rock or ore temporarily stockpiled on surface. At closure all waste rock will be placed as backfill underground and all ore will be processed in the mill.	Unsaturated
Tailings Facilities (Operations and Closure)	Doris	Interaction of precipitation with unsaturated beach area of non-PAG flotation tailings from the Project. Madrid North flotation tailings have the highest metal leaching levels (SRK 2016a) and as a conservative approach are assumed to be on surface at closure. Depth of oxidation for operations and closure is 10 and 5 cm, respectively, based on saturation within the TIA (SRK 2016i). Depth of oxidation is shallower (5 cm) at closure due to placement of quarry rock cover. At closure, loads from the quarry rock cover are based on the pads and infrastructure source term.	Unsaturated
	Boston	Interaction of precipitation with unfrozen non-PAG flotation tailings in drystack facility. Depth of oxidation for operations and closure is 2.48 and 1.67 m, respectively, based on thermal modelling of the TMA (SRK 2016g). Cover system placement at closure (geosynthetic membrane and protective quarry rock layer) will reduce depth of oxidation and contact factor. Loads from the quarry rock cover are based on the pads and infrastructure source term.	Unsaturated
Process Water from Mill (Operations)	Doris	Combined flotation and detoxified tailings process water from all deposits discharged from the mill, and also detoxified process water from Boston	Metallurgical Process
	Boston	Flotation tailings process water from Boston ore discharged from the mill.	Water Chemistry
Underground Mine (Operations)	Doris, Madrid North and Madrid South	Interaction of mine intercepted water with backfill placed in stopes outside of permafrost zones. Source term does not include the load from groundwater intercepted by the mine - this is addressed in water and load balance (SRK 2016e). Permafrost distribution and mine inflow rates derived from groundwater modelling (SRK 2015d and 2016f). New source term developed for Doris to address updated backfill material volumes (total volume is the same as the Type A application (TMAC 2015) but proportion of tailings and waste rock has changed). Backfill material types for each mine include: -Doris: non-PAG waste rock from Doris and non-PAG detoxified tailings from the Project. -Madrid North: non-PAG waste rock from Doris and Madrid, quarry rock and non-PAG detoxified tailings from the Project. -Madrid South: non-PAG waste rock from Madrid South	Unsaturated
Reflooded Underground Mine (Closure)	Doris, Madrid North and Madrid South	At closure, all mine workings will be allowed to flood. When the mine is reflooded, all backfill will be either submerged or within permafrost, and therefore not oxidizing. The reflooded source terms represent pore water chemistry in the mine "pool" or flooded portion of the mine workings when the water level is first allowed to recover, and oxidation products that have accumulated on the backfill material are released into the porewater. Loadings from mine walls are insignificant compared to the backfill and are therefore not addressed. Reflood times are based on groundwater modelling (SRK 2015d and 2016f) and pore water volumes were calculated based on available void space. Source term does not include the load from groundwater intercepted by the mine - this is addressed in the water and load balance (SRK 2016e). New source term developed for Doris to address updated backfill material volumes (total volume is the same as the Type A application (TMAC 2015) but proportion of tailings and waste rock has changed). Backfill at closure according to mine includes: -Doris: same as operations -Madrid North: same as operations, except 100% of the detoxified tailings are assumed to be PAG at closure. -Madrid South: same as operations	Reflooded
Pads and Infrastructure (Construction through Closure)	Madrid North, Madrid South & Boston	Runoff from Phase 2 construction material based on seepage data set from existing pads and infrastructure at Doris and Madrid.	Unsaturated
Tailings Quarry Rock Cover (Closure)	Doris & Boston	As per Pads and Infrastructure. For the Doris TIA, the maximum concentration from the Quarry rock or underlying tailings are used as the source term from the tailings beach area at closure. For the Boston TMA, the maximum concentration from the Quarry rock or underlying tailings are used as the source term from the tailings dry stack at closure.	Unsaturated
Total Metals Content in Total Suspended Solids (TSS) (Operations)	Doris TIA & Doris Infrastructure	Total metals concentrations in tailings contact water from Doris TIA during operations and closure represented by Madrid North flotation tailings trace element content. This source term is also used in the model to represent total metals concentrations from Doris infrastructure and is considered conservative.	Solid-phase metal levels
	Boston TMA, Boston Water Treatment Plant Effluent, and Boston infrastructure	Total metals concentrations in tailings contact water from Boston TMA during operations and closure represented by Boston flotation tailings trace element content. This source term was also applied in the model to represent the total metals concentration in the effluent from the Boston water treatment plant and contact water from Boston infrastructure during operations and closure. In the case of infrastructure, the application of this source term is considered conservative.	
	Doris and Madrid Underground Mines	Total metals content in TSS from backfill contact water during operations. Values derived from Madrid North waste rock and detoxified tailings trace element content.	

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3.2 Calculation Methods

3.2.1 Unsaturated Sources

Unsaturated source terms apply to the waste rock and ore stockpiles, the exposed tailings and backfill in the underground mines prior to flooding at closure. Loadings from pads and infrastructure are also unsaturated but source term development is presented in Section 3.2.4 because a different method was used.

Rock Stockpiles, Tailings Areas and Underground Backfill

Base and upper case source terms for unsaturated rock stockpiles, tailings areas and underground backfill were calculated using scaling methods to convert laboratory measured weathering rates to field scale, followed by calculation of load released based on waste scheduling (Section 3.3.2) and a final calculation of concentrations based on climactic information or mine inflow (Section 3.3.4).

Key steps in the calculation were:

1. Determine laboratory release rates for each parameter from each of the humidity cell tests and estimate the stable laboratory release rate for each test (Appendix A).

2. Calculate the laboratory release rates for each material type (Section 3.3.1).

3. Estimate the field release rate for each material type by adjusting laboratory rates to account for differences in temperature, particle size distribution and contact effects between the test and field conditions (Section 3.3.3).

4. Calculate the potential mass load that could be released from the material type by multiplying the field release rates by the total mass of rock or tailings. The total mass load from the source is then calculated as the sum of the loads from the individual materials in that source.

5. Calculate the potential concentrations that would occur when the total mass load is dissolved into flows that are in contact with the source (Section 3.3.4). For surface sources, the flows were based on the estimated infiltration rates, while for the underground sources, flow rates were estimated based on groundwater modelling. For the underground, source terms for both average and low flow scenarios were calculated.

6. Establish solubility controls on concentrations through data from site day from Hope Bay and analogous sites (Section 3.4).

3.2.2 Reflooded Sources

The tunnels and stopes within the underground workings will be flooded or contained within permafrost at closure. The chemistry of the reflooded mine “pool” will be influenced by the dissolution of oxidation products from backfilled tailings, waste rock and quarry within each mine. Key steps in the calculation of source terms for each reflooded mine were:

1. Using data from Steps 1 and 2 from the unsaturated conditions, calculate the overall weighted average laboratory release rates for each source.

2. Estimate the field release rates for each source by adjusting the laboratory rates to account for differences in temperature, particle size distribution and contact effects between the test and the field conditions. The key difference between this and the calculations for the unsaturated source terms is that the contact factor, which represents the amount of oxidation products that would be flushed from the waste material under unsaturated flow conditions, is changed to represent the amount of oxidation products that would accumulate within the source during the period that they were exposed. Under flooded conditions, it was assumed that all of the oxidation products that accumulated during oxidation would be released into the porewater. Therefore, the accumulation factor was one minus the flushing factor. For backfilled waste rock that was stockpiled on surface, two accumulation factors were calculated to account for the period of time that waste rock was on surface in the stockpile (contact factor of 0.5) and underground as backfill (contact factor of 0.15).

3. Calculate the potential mass load that could be released from each source by multiplying the field release rates by the total mass of rock or tailings. Where waste rock, tailings and/or quarry rock were present, separate calculations were completed and the mass loads added together. Similarly, separate calculations were completed for waste rock that had different contact factors (e.g. stockpiled waste rock). The total mass load was multiplied by the time that the materials would be exposed to oxidation prior to flooding. To account for the duration of time that stockpiled materials oxidized on surface with a different contact (accumulation) factor, the following assumptions were made:

    - Time on surface of all stockpiled waste rock was assumed to be the lifetime of the stockpile from which it was sourced. For example, the surface oxidation period of Madrid South waste rock placed as backfill in the Madrid North Mine was calculated from the initial and final dates of the Madrid South stockpile.
    - Quarry rock and detoxified tailings would be placed in the stockpile prior to being placed underground. For source term calculations, it was assumed that these materials are only placed as backfill.
    - For all backfill, the period of oxidation ends once the reflooding of the mine is complete.

4. Calculate the potential concentrations that would occur when the total mass load is dissolved into the volume of water that would be in contact with the source. For these calculations, the volume of water reflects the total volume of voids within the mine.

5. Solubility controls on concentrations were not applied, which resulted in unrealistically high concentrations for most parameters. These results are therefore overly conservative, however levels were not changed because a sensitivity analysis on the receiving water lakes (SRK 2016e) indicated that even with this highly conservative assumption, there would be essentially no detectable change in concentrations in the overlying lakes.

3.2.3 Process Water

Source term estimates for process water from Madrid and Boston ores at the Doris mill are based on two types of metallurgical tailings data sets for Madrid North and Boston (SRK 2016a): i) process water quality of flotation and detoxified tailings or a combination of the two, referred to as mixed tailings and ii) oxic aging tests conducted on separate streams of flotation and detoxified tailings metallurgical process water. The Boston data set was used as a proxy for Madrid South, owing to the absence of data for Madrid South, and Boston being the most appropriate geochemical analog (SRK 2016a). Upon review of the compiled process water chemistry, it was noted that incomplete cyanide detoxification was achieved in the Boston detox tailings, leading to elevated levels of cyanide, its degradation products and also any metals that may complex with cyanide in the Boston detox tailings and Boston mixed tailings process water samples, and to a lesser extent in corresponding aging tests.

The same derivation method for Doris process water (SRK 2015a) was applied. Key steps in the calculation of process water from the Doris mill were:

1. Compile/calculate relevant data sources as follows:
    a) Mixture of the maximum flotation and detoxified tailings process waters at the ratios used in the metallurgical testwork (95% flotation and 5% detoxification). In the absence of Madrid North detoxified tailings process water and incomplete detoxification at Boston, Doris detoxified tailings process water was used to calculate the mixture.
    b) Process water data for mixed tailings (maximum result).
    c) Mixture of maximum flotation and detoxified tailings data from oxic aging tests at the ratios used in the metallurgical testwork (95% flotation and 5% detoxification). In the absence of aging test data for Madrid North detox tailings, fresh Doris detoxified tailings process water data were used to calculate the mixture.
    d) Aging test data for mixed tailings (maximum result)
2. Compare the calculated values from step 1a to 1d and select the maximum value.
3. For parameters affected by detection limits, incomplete data or incomplete detoxification, an alternative data source were selected on a case-by-case basis, with specific rational recorded in each of the data sheets.

For process water at the Boston processing plant, the maximum value of all the Boston flotation process water samples was selected. Cyanide and its degradation products were not included for the Boston process water source term because cyanide is not used in the flotation circuit, and accordingly these parameters were not analyzed in the flotation tailings.

Base case and upper case scenarios were not derived for process water because the source terms were based on the maximum values.

3.2.4 Total Metals Content in Total Suspended Solids

The source terms generally reflect dissolved concentrations resulting from geochemical reactions as water comes into contact with each of these geological materials. However, guidelines for receiving water quality are based on total metals concentrations. Therefore, an estimate of total metals concentrations was also required for discharges at Doris (Doris Creek and the Marine Mix Box) and Boston (water treatment plant).

At Doris, total metals content in total suspended solids (TSS) source terms were derived for contact water from the Doris TIA (operations and closure) and Madrid North underground (operations only). The Marine Mix Box concentrations were calculated based on a blend of these waters. At Boston, TSS source terms were derived for contact from the Boston TMA (operations and closure).

The basic calculation approach was to estimate the suspended metal concentrations based on an assumption of total suspended sediment (TSS) concentrations, and the trace element content of the suspended particles that could be present, and adding this to the dissolved concentrations.

For the Doris TIA, the prediction assumes that the effluent contains 5.5 mg/L TSS (the maximum background TSS level in Doris Lake outflow at TL-2) comprised of flotation tailings solids. Total metals concentrations of those solids were calculated as the median of the solid-phase trace element content for Madrid North flotation tailings (SRK 2016a). In the water and load balance model (SRK 2016e), this source term was also applied to contact water runoff from Doris infrastructure.

For the Boston TMA, the prediction assumes that the effluent contains 5.5 mg/L TSS comprised of Boston flotation tailings solids. Total metal concentrations of those solids are equivalent to the solid-phase element content for the one sample of Boston flotation tailings (SRK 2016a). In the water and load balance model (SRK 2016e), this source term was also applied to contact water runoff from Boston infrastructure and the effluent for the Boston water treatment plant, however for the water treatment plant, the effluent is assumed to contain 15 mg/l TSS, which is the maximum allowed under MMER. For Boston infrastructure, the application of the Boston TMA source term is considered conservative.

For mine water from Doris and Madrid, the prediction assumed 5.5 mg/L TSS with a composition similar to that of Madrid North underground backfill. Key steps in the calculation were:

1. Calculate median levels of solid-phase trace element content for Madrid North waste rock (SRK 2016b). Quarry rock and Doris and Madrid South waste rock were conservatively assigned the same composition as Madrid North waste rock.
2. Calculate median levels of solid-phase trace element content for Madrid North detoxified tailings (SRK 2016a).
3. Calculate trace element concentrations for backfill based on the proportions of backfilled rock and detoxified tailings at closure.

Base case and upper case scenarios were not derived for total metals content in TSS because the source terms derivation was considered conservative in the context of the overall model.

3.2.5 Pads/Infrastructure and Cover for Tailings Areas

Quarry rock is the construction material for surface pads/infrastructure and the rock covers placed on the tailings areas at closure. The extensive geochemical data set for quarries from the Project suggest that construction rock from quarries at Madrid and Boston have similar geological and geochemical characteristics to the quarries at Doris (SRK 2016k). The approach was based on site-specific data so that water quality estimates were based on reality as much as possible, rather than relying on scaling of laboratory data.

The data set for infrastructure and pads is comprised of seepage data measured in 2013 and 2014 at non-waste rock impacted locations along the Doris to Madrid road and Doris infrastructure (SRK 2014, SRK 2015b). Concentrations for surface infrastructure areas such as roads and mill pads were derived based on the 95th percentile and maximum concentrations (base case and upper case, respectively). The data set included samples that represented surface runoff and not true seeps (contact water) from pads and infrastructure, therefore higher statistics (e.g. 95th percentile as base case) was selected. This is consistent with the method used for the Doris water and load balance (SRK 2015a).

3.3 Input Assumptions

3.3.1 Laboratory Release Rates

Humidity cell tests for waste rock, ore and tailings were classified as non-PAG with the exception of detoxified tailings (SRK 2015c, 2016a, 2016c and 2016d). Laboratory release rates for waste rock, quarry rock (backfill only) and tailings were calculated form the stable loading rates measured in humidity cell tests. Appendix A presents a summary of the stable loading rates from individual kinetic tests, Appendix B presents the considerations in selecting the geochemical data set for the base and upper cases and Table 3-2 presents a summary of laboratory release rates by material type and sample set.

Table 3-2: Summary of Laboratory Release Rates for Source Terms (mg/kg/week)

Material Type	Sample Set	Scenario	SO_4	Alkalinity	F	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Co	Cu	Fe
Waste Rock	Madrid North	Base	2.2	9.8	0.0092	0.031	0.00049	0.051	0.00026	0.0000095	0.023	0.0000041	3	0.000073	0.00035	0.00031	0.0049
		Upper	4.4	20	0.018	0.062	0.00098	0.1	0.00051	0.000019	0.046	0.0000082	5.9	0.00015	0.0007	0.00062	0.0098
	Madrid South	Base	1	9.9	0.0063	0.025	0.00033	0.056	0.00074	0.0000046	0.023	0.0000025	2.7	0.000046	0.00087	0.00039	0.0013
		Upper	2.1	20	0.013	0.05	0.00066	0.11	0.0015	0.0000092	0.046	0.000005	5.4	0.000092	0.0017	0.00078	0.0026
	Boston	Base	5.5	8.2	0.0072	0.0095	0.0009	0.11	0.00046	0.0000062	0.024	0.0000029	3.2	0.000063	0.00058	0.00026	0.0048
		Upper	11	16	0.014	0.019	0.0018	0.22	0.00092	0.000012	0.047	0.0000057	6.4	0.00013	0.0012	0.00052	0.0095
Ore	Madrid North	Base	14	9.6	0.009	0.032	0.00063	0.098	0.00024	0.0000093	0.023	0.0000046	4.7	0.00007	0.00038	0.00033	0.0051
		Upper	28	19	0.018	0.063	0.0013	0.2	0.00049	0.000019	0.046	0.0000091	9.5	0.00014	0.00077	0.00065	0.01
	Madrid South	Base	11	9.9	0.013	0.025	0.0009	0.11	0.00074	0.000027	0.024	0.0000052	7.4	0.000072	0.00087	0.00039	0.0048
		Upper	21	20	0.026	0.05	0.0018	0.22	0.0015	0.000053	0.047	0.00001	15	0.00014	0.0017	0.00078	0.0095
	Boston	Base	11	9.2	0.013	0.0095	0.0009	0.11	0.00046	0.000027	0.024	0.0000052	7.4	0.000072	0.00058	0.00032	0.0048
		Upper	21	18	0.026	0.019	0.0018	0.22	0.00092	0.000053	0.047	0.00001	15	0.00014	0.0012	0.00064	0.0095
Flotation Tailings	All	Base	1.3	33	0.0063	0.015	0.00038	0.025	0.02	0.0000056	0.025	0.0000044	6.5	0.00016	0.000047	0.0002	0.0045
		Upper	4	38	0.01	0.018	0.00046	0.031	0.03	0.000016	0.025	0.0000053	7	0.00023	0.000059	0.00073	0.0052
	Boston	Base	0.94	43	0.011	0.0017	0.00014	0.0012	0.00054	0.000019	0.018	0.0000048	7	0.00023	0.000051	0.00022	0.0041
		Upper	1.3	43	0.011	0.014	0.00014	0.0082	0.0012	0.000019	0.024	0.0000048	7	0.00023	0.000051	0.00022	0.0045
Detoxified Tailings (pH Neutral)	Doris	Base & Upper	380	30	0.029	0.014	0.0007	0.004	0.0068	0.0000074	0.037	0.00006	110	0.000074	0.029	0.0011	0.0042
	All	Base & Upper	380	30	0.029	0.014	0.0007	0.004	0.0018	0.0000074	0.037	0.0000094	110	0.000074	0.029	0.0011	0.0041
Detoxified Tailings (Acidic)	All	Base & Upper	380	0.42	0.029	0.31	0.0007	0.004	0.0068	0.000022	0.11	0.0004	63	0.0023	0.029	0.014	1.7
Quarry Rock	All	Base	0.76	14	0.011	0.063	0.000069	0.0019	0.00023	0.000019	0.024	0.0000038	3.1	0.000075	0.000031	0.00025	0.0046
		Upper	1.5	14	0.011	0.063	0.000069	0.0019	0.00023	0.000019	0.024	0.0000038	3.1	0.000075	0.000031	0.00025	0.0046

Material Type	Sample Set	Scenario	Pb	Li	Mg	Mn	Hg	Mo	Ni	Se	Ag	Tl	U	V	Zn	Acidity
Waste Rock	Madrid North	Base	0.00003	0.00046	1.3	0.0027	0.0000057	0.00031	0.00041	0.000085	0.0000042	0.0000043	0.000011	0.00062	0.0018	--
		Upper	0.00006	0.00092	2.5	0.0054	0.000011	0.00061	0.00082	0.00017	0.0000084	0.0000085	0.000022	0.0012	0.0036	--
	Madrid South	Base	0.000027	0.00033	1.3	0.0024	9.4E-07	0.00016	0.00058	0.000079	0.0000023	0.00000099	0.00004	0.00017	0.00036	--
		Upper	0.000054	0.00066	2.6	0.0048	0.0000019	0.00032	0.0012	0.00016	0.0000046	0.000002	0.00008	0.00034	0.00072	--
	Boston	Base	0.000027	0.00025	1.7	0.0039	0.0000053	0.00023	0.00071	0.00012	0.000003	0.0000036	0.000017	0.0002	0.00036	--
		Upper	0.000054	0.00049	3.3	0.0077	0.000011	0.00046	0.0014	0.00023	0.000006	0.0000072	0.000033	0.0004	0.00071	--
Ore	Madrid North	Base	0.000039	0.00042	2.5	0.0041	0.0000055	0.00038	0.0013	0.000086	0.0000037	0.0000039	0.00001	0.00068	0.0018	--
		Upper	0.000079	0.00083	5	0.0083	0.000011	0.00077	0.0026	0.00017	0.0000074	0.0000077	0.000021	0.0014	0.0037	--
	Madrid South	Base	0.000031	0.00034	3	0.0039	0.0000065	0.00023	0.00071	0.00012	0.0000088	0.000004	0.00004	0.0002	0.00039	--
		Upper	0.000061	0.00069	5.9	0.0077	0.000013	0.00046	0.0014	0.00023	0.000018	0.000008	0.00008	0.0004	0.00079	--
	Boston	Base	0.000031	0.00034	3	0.0039	0.0000065	0.00023	0.00071	0.00012	0.0000088	0.000004	0.000017	0.0002	0.00039	--
		Upper	0.000061	0.00069	5.9	0.0077	0.000013	0.00046	0.0014	0.00023	0.000018	0.000008	0.000033	0.0004	0.00079	--
Flotation Tailings	All	Base	0.000017	0.00059	5.6	0.0052	0.0000013	0.00055	0.00022	0.00008	0.0000031	0.0000035	7.1E-06	0.00014	0.00048	--
		Upper	0.000026	0.00071	5.9	0.014	0.0000018	0.001	0.00033	0.00012	0.000006	0.0000045	0.000011	0.0004	0.0007	--
	Boston	Base	0.00002	0.00038	7	0.0011	0.0000012	0.0011	0.00029	0.000093	0.0000069	0.0000035	0.000011	0.000081	0.00056	--
		Upper	0.00002	0.00044	7	0.0052	0.0000013	0.0011	0.00029	0.000093	0.0000069	0.0000035	0.000011	0.00014	0.00056	--
Detoxified Tailings (pH Neutral)	Doris	Base & Upper	0.000019	0.019	39	0.55	0.0000015	0.00059	0.11	0.012	0.0000037	0.000069	0.000049	0.0002	0.0097	--
	All	Base & Upper	0.000019	0.0023	30	0.26	0.0000015	0.00059	0.11	0.0016	0.0000037	0.000028	0.000013	0.0002	0.00069	--
Detoxified Tailings (Acidic)	All	Base & Upper	0.0022	0.019	16	0.55	0.0000015	0.000093	0.11	0.00049	0.000011	0.000069	0.000049	0.00044	0.045	21
Quarry Rock	All	Base	0.000026	0.00044	1.8	0.0063	0.0000067	0.000079	0.000048	0.000076	0.000007	0.0000032	9.7E-06	0.00033	0.00044	--
		Upper	0.000026	0.00044	1.8	0.0063	0.0000067	0.000079	0.000048	0.000076	0.000007	0.0000032	9.7E-06	0.00033	0.00044	--

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3.3.2 Distribution and Quantity of Materials

As described in Section 2.1, a monthly schedule for ore and waste rock production, stockpile volumes, backfill requirements and ore processing was provided by TMAC (2016). Table 3-3 presents the material quantities used to develop the source terms.

Waste Rock and Ore Stockpiles

The metal leaching and acid rock drainage properties of waste rock and ore are largely unrelated to rock type (SRK 2016c, 2016d and 2016h). Waste rock and ore on surface is non-PAG and arsenic leaching at neutral pH is of concern. Accordingly, the distribution or proportions of the rock types that would be brought to surface were not considered in derivation of the source terms. All rock was considered to be reactive due to an assumption of convective movement of oxygen through the stockpile.

Tailings Impoundment Areas

In contrast to waste rock, the physical properties of the tailings are expected to greatly limit the amount of oxygen that reaches the tailings surfaces both during operations and closure. Therefore, in addition to estimating the total quantity of tailing in each of the source areas, it is necessary to estimate the amount of tailings that will oxidize. The following assumptions were made:

- For the Doris TIA, the reactive or oxidized mass of tailings was calculated per unit hectare area of tailings beach surface, assuming a 10 cm thick reactive layer of tailings during operations and a placed density of 1.3 t/m^3. At closure the depth of oxidation is shallower due to the placement of a rock cover, and is assumed to be 5 cm. The physical control on oxidation depth is saturation within the tailings and depths were based on a water balance for the TIA, presented in Appendix C.
- For the Boston TMA, the reactive or oxidized mass of tailings was calculated per unit hectare area of drystack tailings, assuming a 2.48 m thick reactive layer of tailings during operations and a placed density of 1.8 t/m^3. At closure, the placement of a cover system (geosynthetic membrane and protective quarry rock cover) will reduce the depth of oxidation in the tailings to 1.67 m. The physical control on oxidation depth is freeze back within the TMA and depths were based on thermal modelling (SRK 2016g).

Table 3-3: Distribution and Quantities of Materials by Source Area

Source Term	Phase	Mine	Component	Quantity (tonnes)	Comment
Waste Rock Stockpile	Operations	Madrid North	Madrid North waste rock	645,556	Life-of-mine maximum stockpile volume.
		Madrid South	Madrid South waste rock	649,890	Life-of-mine maximum stockpile volume.
		Boston	Boston waste rock	627,862	Life-of-mine maximum stockpile volume.
Ore Stockpile	Operations	Madrid North	Madrid North ore	302,000	Life-of-mine maximum stockpile volume.
		Madrid South	Madrid South ore	5,400	No ore stockpile anticipated at Madrid South because ore will be directly transported to Doris for processing. Volume assumed for the purposes of source terms and represents a scenario where there is an ore stockpile overflow at Doris.
		Boston	Boston ore	2,000	Life-of-mine maximum stockpile volume.
Tailings Areas	Operations	Doris	Flotation tailings (all deposits)	1,300	Reactive mass per unit hectare area of tailings beach.
		Boston	Flotation tailings (Boston)	44,568	Reactive mass per unit hectare area of dry stack tailings.
	Closure	Doris	Flotation tailings (all deposits)	650	Reactive mass per unit hectare area of tailings beach.
		Boston	Flotation tailings (Boston)	30,060	Reactive mass per unit hectare area of dry stack tailings.
Underground Mine	Operations	Doris	Doris waste rock	938,338	End of mine backfill volumes adjusted according to proportion of mine not intersected by permafrost.
			Detoxified tailings (pH neutral)	154,127	
		Madrid North	Doris waste rock	63,948	
			Madrid North waste rock	2,653,437	
			Madrid South waste rock	509,417	
			Quarry rock	901,985	
			Detoxified tailings (pH neutral)	587,060	
		Madrid South	Madrid south waste rock	554,960	
Reflooded Underground Mine	Closure	Doris	Doris underground waste rock	543,162	End of mine backfill volumes adjusted according to proportion of mine not intersected by permafrost. Provenance of waste rock differentiated because higher flushing (contact factor) of oxidation products for waste rock in stockpile than backfill that is sourced directly from underground.
			Doris waste rock stockpile	395,176	
			Detoxified tailings (pH neutral)	154,127	
		Madrid North	Madrid North underground waste rock	2,285,472	End of mine backfill volumes adjusted according to proportion of mine not intersected by permafrost. Provenance of waste rock differentiated because higher flushing (contact factor) of oxidation products for waste rock in stockpile than backfill that is sourced directly from underground.
			Madrid North waste rock stockpile	367,965	
			Madrid South waste rock stockpile	509,417	
			Doris waste rock stockpile	63,948	
			Quarry rock stockpile	901,985	
			Detoxified tailings (pH neutral)	0	Volume of acidic tailings based on delay to onset of ARD and age of detoxified tailings at closure.
			Detoxified tailings (acidic)	587,060	
		Madrid South	Madrid South underground waste rock	554,960	End of mine backfill volumes adjusted according to proportion of mine not intersected by permafrost.

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Underground Mine

Backfill volumes were calculated using the following assumptions:

- Material quantities were based on volumes at closure assuming bulk densities of 1.8 and 1.7 m^3/t for waste rock and detoxified tailings, respectively. It was assumed that materials in permafrost would not oxidize therefore material volumes for loading calculations were adjusted based on the proportion of the mine that does not intersect permafrost.
- Consistent with the surface rock stockpiles, the distribution or proportions of waste rock lithologies were not considered in derivation of the underground mine source terms.
- Detoxified tailings will be placed on the surface waste rock stockpile before being trucked underground with the waste rock. All rock and tailings with areas of the mine not in permafrost were considered to be reactive due to an assumption of convective movement of oxygen through the backfilled material.
- The reflooded source term load is calculated from the soluble products that have accumulated for each material type. Accordingly, rock backfill volumes were delineated according to provenance in order to account for the different amount of residual soluble products from backfill that was sourced directly from the underground versus rock that was temporarily stockpiled on surface before being transported back underground. Rock on surface interacts with a relatively uniform distribution of precipitation over the stockpile and as a result will have a higher contact factor (more soluble products flushed) than waste rock backfill. In contrast, water infiltrating backfill is expected to flow along the sides of the stopes, interacting with backfill as localized inflows.
- On the basis of an acidic detoxified tailings humidity cell test, the onset to ARD for detoxified tailings is projected to be on the order of 20 years (SRK 2015e). The quantities of tailings assessed to be pH neutral or acidic was based on the age of the tailings when all backfill is flooded (year 2021 and 2052 for Doris and Madrid North, respectively). All backfill in the Doris Mine will be flooded prior to the detoxified tailings becoming acidic. For Madrid North, at closure all detoxified tailings will be acidic.
- At Madrid South, all backfill will be flooded by 2042.

3.3.3 Scaling Factors

Scaling factors that were considered in the calculations of field release rate included temperate, particle size distribution and contact effects between the test and field conditions. For the rock stockpiles, site-specific scaling factors were developed and ultimately applied in the calculations for waste rock at Madrid and Boston. This section presents the method for developing the site-specific scaling factors and the scaling factors used for each source term.

Site-Specific Scaling Factor

For the Doris site-wide water and load balance (SRK 2015a), source terms for waste rock were calculated using chemistry monitoring data and flow estimates associated with the 192,400 tonnes of Doris waste rock and ore stockpiled. ST-2 is a water license station that monitors contact water from the waste rock stockpile and other pads located within the contact water pond. Results from this location represent run-of-mine rock that has weathered under climatic conditions for the Project. As such, this approach is considered to be more accurate than extrapolating from small-scale laboratory tests to full scale field conditions using the temperature, particle size and contact effects scaling factors described later in this section.

For the Phase 2 waste rock and ore stockpile source terms, a site-specific scaling factor for each parameter was calculated using the SRK (2015a) waste rock source term and stable rates for the 17 Doris waste rock and ore humidity cell tests (HCT, SRK 2015c). This site specific scaling factor was then used in conjunction with laboratory results from Madrid and Boston to derive source terms for waste rock and ore from these other areas. Key steps in the calculation were:

1. Calculate the scaling factor for each parameter (SF_X).
    a. For each Doris HCT and parameter, calculate ratio of Doris waste rock stockpile loading rate to HCT stable rate (SRK 2015a);
    b. For each parameter, calculate median value based on the 17 Doris HCT samples.
2. Select the scaling factor for the overall waste rock stockpile (SF_{WR}) based on parameters that exhibit geochemically conservative behaviour, including sulphate, magnesium, calcium and selenium. SF_{WR} was calculated as the median value of the scaling factors for selenium and magnesium, using the method outlined in step 1. The calculated value of SF_{WR} was 0.09. Sulphate was not selected due to high detection limits in the humidity cell test. Similarly, calcium was also omitted because calcium chloride from drilling brines is present in the waste rock stockpile runoff, but not the HCT samples.
3. Parameters with high HCT detection limits had artificially high values of SF_X, including sulphate, beryllium, boron, cadmium, calcium, chromium, iron, lithium, mercury, silver, thallium, uranium and vanadium. For these parameters, the SF_{WR} was adopted.
4. Parameters with values of SF_X less than SF_{WR} indicate that leaching of that parameter was determined to be appreciably higher than the overall scaling factor (e.g. SF_{WR}), including barium, cobalt, manganese, and nickel. For these parameters, SF_{WR} was assumed. For parameters with values of SF_X greater than SF_{WR}, notably aluminum, arsenic, antimony, copper and lead, the value of SF_X was adopted. The difference between SF_{WR} and SF_X in this latter group of parameters is attributed to attenuation reactions that are occurring in the Doris waste rock stockpile.

A scaling factor for each parameter was calculated using the following steps and are presented in Appendix D.

Source Term Scaling Factors

For the waste rock and ore stockpiles, site-specific scaling factors were calculated for source term calculations, as described above. This section presents scaling factors used in the absence of site-specific data. For the stockpiles, scaling factors presented below are for the purpose of comparison. The scaling factors used for this project are summarized and explained as follows:

- *Temperature:* For the rock stockpiles, tailings areas and underground mine, a scaling factor of 0.2 was used. Using the Arrhenius Equation and assuming pyrite is the dominant sulphide mineral, this corresponds to an average internal temperature of 1°C compared to average ambient temperatures of the site of -11°C.
- *Particle Size:* The following assumptions were made for the different source areas:
  - For stockpiled rock and backfilled rock, the particle size factor was set at 0.5 based on experience to account for differences between the grain-size distributions used in the laboratory tests compared to blasted rock.
  - For tailings, a scaling factor of 1 was used, because laboratory testing was performed on samples of tailings generated from metallurgical testing with a particle size distribution that is very close to eventual production values.
- *Contact Effects:* Contact effects refer to the development of preferential flowpaths and other factors that physically limit flushing of soluble oxidation products from the waste materials under unsaturated flow conditions. Conversely, when those materials are later flooded, as will be the case for backfill in the underground mine, the accumulated soluble load remaining is assumed to be fully flushed into the porewater. The following assumptions were made for the different source areas:
  - A factor of 0.5 was used for unsaturated flow conditions through rock stockpiles. Conversely, a factor of 0.5 was applied to determine the amount of accumulated load that would be flushed from waste rock backfill that was sourced from a surface stockpile.
  - A factor of 1 (full flushing) was used for flotation tailings in the Doris TIA (operations and closure) and Boston TMA (operations only). In these scenarios, there is no management of water infiltration.
  - A factor of 0.04 was used for flotation tailings in the Boston TMA at closure, indicating that 4% of the tailings will be flushed. This value is based on the flow through the geosynthetic cover, which assumes 0.4% of operational infiltration and a spreading factor of ten times (SRK 2016j).
  - A factor of 0.15 was used for backfilled rock and tailings based on the assumption of focused inflows in the underground mine. Conversely, a factor of 0.85 was applied to determine the amount of accumulated load that would be flushed from waste rock that is never transported to surface prior to being backfilled, and also tailings. Equivalent values were selected for waste rock and tailings because they will be co-disposed in the underground and accordingly there will be no preferential water flow according to material.
- *Overall scaling factor adjustment:* For the backfilled rock, an additional adjustment was applied to account for the difference between site specific scaling factors derived for geochemically mobile parameters in the waste rock (i.e. 0.09), and the overall scaling factor that would have been used in lieu of a site specific correction (i.e. 0.05). This additional adjustment of 1.8 (i.e. 0.09/0.05) was applied to the sum of all other scaling factors used for backfill.

3.3.4 Estimates of Infiltration, Groundwater Flow and Permafrost Distribution

Infiltration volumes to the waste rock and ore stockpile areas were calculated based on the mean annual precipitation (MAP) of 210 mm (SRK 2016b) and the footprint of each of these facilities.

Infiltration rates to the tailings areas at Doris and Boston (operations only) were calculated based on an annual runoff of 102 mm (SRK 2016e) and a one hectare unit area. At closure, the infiltration rate through the Boston TMA was calculated based on a rate of 32 L/ha/day through the geosynthetic membrane and assuming precipitation four months of the year (SRK 2016j).

Table 3-4 presents average and low flow groundwater inflow rates for each mine and base case mine reflood times. Rates and reflood times were based on predictive numeral groundwater models for each mine, which considered zones of permafrost relative to the mine plan (SRK 2015d and 2016f). A low flow scenario source term scenario was also presented because higher flow rates are conservative from a water management perspective, but are non-conservative from a geochemical perspective. For Madrid North and Madrid South, reflood times represent flooding to the maximum elevation of the stopes. After this point in time, the workings will continue to be flooded, however there will be no backfill in these areas. Source loading contributions from underground mine walls are considered insignificant compared to that from the backfill due to limited surface area.

Table 3-4 also presents the proportion of the workings that are expected to be within permafrost. Backfilled materials in those areas are expected to freeze and are not expected to contribute flows or geochemical loadings during operations or at closure.

Table 3-4: Underground Mine Inflow Rates, Reflood Times and Distribution of Permafrost

Mine	Inflow Rate (m^3/day)	Reflood Time* (days)	Proportion in Permafrost
Doris	5,000	243	0.36
Madrid North	910	6,867	0.43
Madrid South	450	3,470	0.16

*Base case scenario with backfill

3.4 Solubility Controls

3.4.1 Basis

Solubility limits were established based on the assumption that each parameter is controlled by various processes such as secondary mineral precipitation, adsorption or co-precipitation, and that these controls would be similar at other sites with similar geochemical characteristics. Monitoring data from Hope Bay and analogous sites were used as a basis to establish geochemical limits for the Hope Bay source terms.

3.4.2 Analog Database

Equilibrated concentrations were compared to an analog database to assess whether any further reductions in concentrations were appropriate. Data that were included in the analog database were from sampling sites located as near as possible to the source material so that data points may come close to representing contact water. It is recognized that the majority of mine site drainages can be influenced by non-contact waters to some degree due to local runoff, source runoff and groundwater inflows to monitoring points, though by compiling water from many sources, direct contact water has a high likelihood of being represented.

A global search for mines of low-sulphide gold-quartz vein deposits using United States Geological Survey, BC MINFILE and Geological of Survey of Canada websites resulted in identification of 19 candidate sites and five mining districts in Alaska that each contained numerous small mines that were studied collectively. Field-scale water chemistry data were found for 12 mines, including Con Mine (NWT), Giant (NWT), Detour Gold (Ontario), Discovery (NWT), Colomac (NWT), Seabee (Saskatchewan), Bralorne (BC), Congress (BC), Wayside (BC), Ashanti (Ghana), Polaris-Taku (BC), Hope Bay (NU) and five Alaskan mining districts ((Fairbanks, Willow Creek, Juneau, Nuka Bay and McKinley Lake).

Review of the datasets obtained indicated that Giant (NWT), Detour Gold (Ontario), Discovery (NWT), Colomac (NWT), Seabee (Saskatchewan), Bralorne (BC), Congress (BC), Wayside (BC), Ashanti (Ghana), Polaris-Taku (BC), and four Alaskan mining districts had relevant data for near contact water chemistry for waste rock and/or tailings. Drainage from the Con Mine had limited value due to the influence of aerial deposition of arsenic trioxide on water samples. Data from the Nuka Bay mining district were limited.

Table 3-5 summarizes the types of samples used from each site. Small scale field tests from Hope Bay were included in the analog database because comparison of results from similar scale tests with full scale under controlled conditions have shown that, for non-acidic conditions, the small scale tests can show similar solubility constraints as the full scale.

To develop the solubility constraints for development of source terms, the following procedure was used:

- Scatter plots of pH vs concentrations for each parameter were evaluated to determine if expected solubility relationships existed. Only pH neutral data were included. Plots are presented in Appendix E.
- Each plot was reviewed to assess for the presence of an upper bound in the overall data set and the distribution of the data relative to Hope Bay site data.
- The solubility constraint selected was typically either the upper bound of analog concentrations or upper limit (95th percentile or maximum) of Hope Bay site data.
- Each parameter was assessed if the upper limit could be applied the rock stockpiles and tailings areas, based on geochemical processes. For arsenic, a limit was applicable to the

Boston TMA at closure, at which time water inflow will be very limited by the cover system and as a result concentrations elevated.

Results of the assessment of the analog database are presented in Table 3-5.

Table 3-5: Sites in the Low-Sulphide Quartz Vein Analog Database

Mine or District	Type of Data
Ashanti	Porewater from anaerobic and aerobic soil mixed with tailings
Bralorne	Drainage from adit and within underground workings
Colomac	Tailings pore water and surface water quality
Detour Gold	Seepage from waste rock and ore stockpiles
Fairbanks District, Alaska	Drainage from tailings piles, collection ponds, mine adits and seeps from placer tailings
Giant	Open pit and stockpile seeps
Giant	Surface water from open pits
Hope Bay	Boston - ore and waste rock seepage
Hope Bay	Doris, Madrid North, Madrid South, Boston - onsite barrel tests
Hope Bay	Doris - seepage from infrastructure and pads
Hope Bay	Doris - seepage and drainage from waste rock stockpile (ST-2)
Juneau Gold Belt, Alaska	Flooded pit and drainage from tailings and mine portal
McKinley Lake District, Alaska	Drainage from adits and shaft
Polaris-Taku	Portal drainage and seeps, and pumped water from underground flooded workings
Seabee	Seepage from waste rock dumps and drainage from underground
Wayside	Adit drainage
Willow Creek District, Alaska	Drainage from tailings piles and mine portals

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Table 3-6: Assessment on Controls on Element Mobility

Parameter	Rationale	Rock Stockpiles	Doris & Boston Tailings Areas[1]	Boston TMA (closure)[2]	Analog Value
SO_4	Upper bound of analog concentrations not approaching gypsum solubility, therefore use of analog inappropriate.	N	N	N	970
Alk	Equilibrium controls on alkalinity therefore site data appropriate. Use P50 of Hope Bay waste rock data.	Y	Y	Y	89
F	Analog data set suggest upper equilibrium limit. There are some scatter of site specific data above this apparent limit. Apply upper limit of analog.	Y	Y	Y	0.59
Al	Distribution of analog data suggests an equilibrium limit. Apply upper limit of analog.	Y	Y	Y	0.1
Sb	Antimony behavior similar to arsenic. Use of analog appropriate for waste rock samples. Apply upper limit of analog.	Y	N	N	0.036
As	Large range of arsenic concentrations from Hope Bay barrel sample set, with highest values greater than any mine site data. Do not use analog data set. Address upper limits by using site specific scaling factor except for Boston TMA at closure.	N	N	Y	3.8
Ba	Equilibrium controls on barium (solubility of barite or adsorption to hydroxides). Use analog limit. Maximum of analog data set selected because highest range of values from Doris and Boston.	Y	Y	Y	0.29
Be	Detection limit issues with overall data set. No samples above detection limits from Hope Bay. Select lowest Hope Bay detection limit.	Y	N	N	0.0001
B	Distribution of analog data suggests an equilibrium limit. Apply upper limit of analog.	Y	N	N	1.8
Cd	Detection limit issues with overall data set. Used P95 of Hope Bay waste rock data set because i) lower detection limits compared to other data sets and ii) some samples above detection limits	Y	N	N	0.00022
Ca	Drilling brines affect Hope Bay waste rock data so these data sets omitted. Doris seepage data set also has subset that is waste rock influenced. Choose upper limit from non-Hope Bay sites.	Y	Y	Y	204
Cr	Chromium generally insoluble. Detection limit issues with overall data set. Used P95 of Hope Bay waste rock data set because i) lower detection limits compared to other data sets and ii) some samples above detection.	Y	Y	Y	0.02
Co	Distribution of analog data suggests an equilibrium limit. Apply upper limit of analog.	Y	N	N	0.1
Cu	Equilibrium controls on copper (copper hydroxides) at neutral pH. Apply upper limit of analog data set.	Y	Y	Y	0.017
Fe	Equilibrium controls on iron (iron hydroxides) at neutral pH. Apply upper limit of analog data set.	Y	Y	Y	0.22
Pb	Equilibrium controls on lead (precipitation, adsorption, co-precipitation) Apply upper limit of analog data set.	Y	Y	Y	0.003
Li	No weathering products at low solubility. Large range of data for Hope Bay sample set, with a scatter of Hope Bay data higher than all other sites. Use P95 of Hope Bay waste rock data.	Y	Y	Y	0.42
Mg	Upper limit of analog.	Y	Y	Y	103
Mn	Upper limit of analog. Some scatter of data points above this limit collected from Hope Bay.	Y	Y	Y	0.54
Hg	Detection limit issues with overall data set. No samples above detection from Hope Bay. Select lowest Hope Bay detection limit.	Y	Y	Y	0.00005
Mo	Geochemical controls on molybdenum (e.g. adsorption. Use upper limit of analog.	Y	Y	Y	0.03
Ni	Geochemical controls on nickel. Use analog value. Upper limit of analog takes into account high values of Boston seep data.	Y	Y	Y	0.3
Se	Geochemical controls on selenium inferred by analog data set. Use upper limit of analog value.	Y	N	N	0.014
Ag	Detection limit issues with overall data set. Selected highest detection limit from Hope Bay sample set.	Y	Y	Y	0.0004
Tl	Detection limit issues with overall data set. Selected highest detection limit from Hope Bay sample set.	Y	Y	Y	0.001
U	Analog data set suggest upper equilibrium limit. Hope Bay data distribution within range of other analog sites. Use upper bound of analog value.	Y	Y	Y	0.0018
V	Detection limit issues with overall data set. Selected highest detection limit from Hope Bay sample set.	Y	Y	Y	0.03
Zn	Equilibrium and other geochemical controls on zinc. Use upper limit of analog data set.	Y	N	N	0.15

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[1] Operations for Doris and Boston tailings areas and Closure for Doris TIA only.

4 Prediction Results and Discussion

Table 4-1 and Table 4-2 present the base case and upper case source terms, respectively, for the waste rock and ore stockpiles, tailings areas, pads and infrastructure and underground mines. The parameter acidity is presented only for the Madrid North reflooded underground mine source term because acidic materials are exclusively present at closure in this facility. Table 4-3 and Table 4-4 present the source terms for process water and total metals content in TSS, respectively. These represent both base and upper cases as these source terms are considered appropriately conservative for both scenarios (Section 3.2).

4.1 Surface Stockpiles and Pads

The base case source term concentrations for all waste rock and the Madrid North ore stockpiles were roughly equivalent and tended to have higher levels than the Madrid South and Boston ore stockpiles. These latter ore stockpiles have arsenic levels approximately an order of magnitude lower than the other stockpiles. Sulphate, antimony, cobalt, copper, nickel and zinc are similarly lower for the Madrid South and Boston ore stockpiles. The same trends were observed for the upper case source terms for waste rock and ore stockpiles. During operations, any runoff will be collected in contact water ponds, which will be managed as contact water at Doris and Boston. At closure, during operations, all waste rock will progressively be placed underground as backfill, therefore there will be no waste rock on surface at closure.

The base and upper case source term concentrations for pads and infrastructure were significantly lower than the base case concentrations for the waste rock and ore stockpiles, owing to pad construction from quarry rock material. This source term also represents the quarry rock cover on the tailing areas at closure.

4.2 Tailings Impoundment Areas

For operations and closure, both base and upper case source term concentrations for the Boston TMA were generally higher than the Doris TIA. One noteworthy exception was arsenic for the operations base case scenario only, for which concentrations for both tailings areas were roughly equivalent. Boston TMA contact waters will undergo water treatment during operations and two years after operation. At closure, the Doris and Boston tailings areas will have quarry rock covers and the Boston TIA will also be covered with a geosynthetic membrane.

4.3 Underground Mine

There is no underground source term for Boston because the mine will be completely encapsulated within permafrost resulting in no groundwater inflow. As previously discussed, solubility constraints were not placed on the underground mine source terms, therefore these source terms are considered overly conservative for selected parameters such as aluminum and iron (Section 3.2.2).

During operations, the base and upper case Madrid North mine source term concentrations were higher than Madrid South, which were higher than Doris. Exceptions included sulphate, manganese, nickel and selenium which were higher at Doris than Madrid South, and cobalt, which was roughly equivalent for Doris and Madrid South.

At closure, the reflooded source terms for Madrid North underground mine included acidity, because all detoxified tailings underground are projected to be acidic. The overall drainage from Madrid North is projected to be neutral, based on higher source term alkalinity concentrations compared to acidity. The detoxified tailings in the Doris underground are projected to be pH neutral at closure.

The base and upper case reflooded Madrid North Mine source term concentrations were significantly higher, owing to the higher metal leaching levels from the acidic tailings. Some noteworthy observations are noted as follows:

- Arsenic: for the base and upper case scenarios, reflooded arsenic levels for Madrid North were approximately four times higher than Madrid South and approximately three orders of magnitude higher compared to Doris.
- Selenium: for the upper case, Madrid North levels were comparable to the other mines.
- Source term concentrations for Madrid South were typically higher than Doris with the exception of sulphate, cadmium, cobalt, manganese, nickel, selenium and zinc, which had roughly equivalent or higher levels for Doris.

4.4 Process Water

The Boston mixed tailings process water was used as an analog for Madrid South, therefore any discussion of the Boston process water from the Doris mill is also representative of Madrid South.

A comparison of the mixed tailings process waters from the Doris mill indicated that the mixed tailings process waters from all deposits were roughly equivalent with the following exceptions:

- Arsenic levels for Madrid North and Boston were approximately two orders of magnitude higher than Doris, with concentrations from Madrid North slightly higher than Boston.
- Madrid North and Boston were higher than Doris for the following parameters: sulphate, chromium, selenium (Madrid North only), and vanadium (Boston only).
- Detection limits for were high for selected testwork, which resulted in high source term concentrations that represent analytical methods, rather than process water data. This applies to barium, beryllium and selenium (Boston), uranium (Madrid North and Boston), and vanadium (Madrid North).
- Doris had the highest levels of manganese and silver.
- The high aluminum and iron concentrations for Boston and Doris, respectively, may reflect colloids in the samples.

Compared with the Boston detoxified tailings process water, the Boston mixed tailings had higher levels of copper and vanadium, and roughly equivalent or lower levels of ammonia, barium, beryllium, boron, cadmium, chromium, lithium, and zinc.

The chemistry of the Boston processing plant flotation tailings and Doris mixed tailings process waters is roughly equivalent for all parameters, with the exception of antimony, arsenic and vanadium, which are approximately an order of magnitude higher for Boston.

4.5 Total Metals Content in TSS

Total metals content in TSS from the Doris TIA and Boston TMA were roughly equivalent with the following exceptions: aluminum, arsenic, cobalt, and nickel were three to five times higher for the Doris TIA and cadmium, molybdenum and zinc were two to three times higher for the Boston TMA. Madrid North flotation tailings have the highest metal content and as a conservative approach, were assumed to be on top at closure.

Total metals content in TSS from the Madrid North Mine are typically higher than the Doris TIA, owing to the presence of detoxified tailings in the underground, which are enriched in metals relative to the flotation tailings. Proportionally there is more waste rock than detoxified tailing in the Madrid North underground but the detoxified tailings contain higher metal levels.

Table 4-1: Base Case Water Quality Estimates for Stockpiles, Tailings Areas, Underground Mines and Pads

Component	Mine	SO4	Alkalinity	F	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Li
Waste Rock Stockpile	Madrid North	770	89	0.59	0.1	0.036	1.5	0.13	0.0001	1.8	0.00022	204	0.02	0.1	0.017	0.22	0.003	0.21
	Madrid South	480	89	0.59	0.1	0.036	2.2	0.29	0.0001	1.8	0.00022	204	0.02	0.1	0.017	0.22	0.003	0.21
	Boston	1700	89	0.59	0.1	0.036	2.8	0.14	0.0001	1.8	0.00022	204	0.019	0.1	0.017	0.22	0.0027	0.21
Ore Stockpile	Madrid North	5700	89	0.59	0.1	0.036	3.4	0.13	0.0001	1.8	0.00022	204	0.02	0.1	0.017	0.22	0.003	0.21
	Madrid South	200	89	0.4	0.036	0.0049	0.17	0.13	0.0001	0.44	0.000097	140	0.005	0.016	0.0059	0.088	0.00018	0.21
	Boston	250	89	0.4	0.017	0.0061	0.21	0.13	0.0001	0.54	0.00012	170	0.005	0.013	0.0059	0.11	0.00022	0.21
Pads & Infrastructure; Quarry Rock Covers on Tailings Areas	All	27	86	0.053	0.06	0.00013	0.002	0.0077	0.0001	0.047	0.000018	33	0.00038	0.00024	0.014	0.14	0.00013	0.0027
Tailings Areas (Operations)	Doris	17	89	0.084	0.1	0.005	0.33	0.26	0.000075	0.34	0.000059	86	0.0021	0.00063	0.0027	0.059	0.00023	0.0079
	Boston	430	89	0.59	0.1	0.062	0.56	0.25	0.0086	8.4	0.0022	200	0.02	0.023	0.017	0.22	0.003	0.17
Tailings Areas (Closure)	Doris	8.7	89	0.042	0.099	0.0025	0.17	0.13	0.000037	0.17	0.000029	43	0.001	0.00031	0.0013	0.03	0.00011	0.0039
	Boston	3100	89	0.59	0.1	0.45	3.8	0.29	0.062	60	0.016	200	0.02	0.17	0.017	0.22	0.003	0.42
Underground Mine (Operations)	Doris	50	4.1	0.0044	0.0019	0.000093	0.00053	0.0011	0.0000027	0.0051	0.000008	15	0.000018	0.0039	0.00015	0.0006	0.0000027	0.0028
	Madrid North	1100	89	0.22	0.1	0.0077	0.63	0.0097	0.0001	0.46	0.000084	200	0.0013	0.087	0.0077	0.078	0.00049	0.013
	Madrid South	4.3	42	0.027	0.1	0.0014	0.24	0.0031	0.000019	0.097	0.000011	11	0.00019	0.0037	0.0016	0.0055	0.00011	0.0014
Reflooded Underground Mine (Closure)	Doris	3500	280	0.29	0.14	0.0064	0.037	0.069	0.00013	0.35	0.00055	980	0.001	0.27	0.011	0.062	0.00019	0.18
	Madrid North	34000	5300	7.1	46	0.25	20	0.74	0.0073	21	0.037	6900	0.24	2.7	1.4	150	0.21	1.9
	Madrid South	89	860	0.55	2.2	0.029	4.9	0.064	0.0004	2	0.00022	240	0.004	0.076	0.034	0.11	0.0024	0.029

Component	Mine	Mg	Mn	Hg	Mo	Ni	Se	Ag	Tl	U	V	Zn	Acidity
Waste Rock Stockpile	Madrid North	103	1	0.00005	0.03	0.14	0.014	0.0004	0.001	0.0018	0.03	0.15	--
	Madrid South	103	1	0.00005	0.03	0.27	0.014	0.0004	0.00047	0.0018	0.03	0.15	--
	Boston	103	1	0.00005	0.03	0.22	0.014	0.0004	0.001	0.0018	0.03	0.11	--
Ore Stockpile	Madrid North	103	1	0.00005	0.03	0.3	0.014	0.0004	0.001	0.0018	0.03	0.15	--
	Madrid South	71	1	0.00005	0.005	0.013	0.0022	0.00016	0.0001	0.001	0.0037	0.041	--
	Boston	71	1	0.00005	0.0051	0.016	0.0027	0.0002	0.0001	0.001	0.0046	0.041	--
Pads & Infrastructure; Quarry Rock Covers on Tailings Areas	All	6.5	0.066	0.00001	0.001	0.0024	0.0003	0.00001	0.00001	0.00033	0.0011	0.0051	--
Tailings Areas (Operations)	Doris	74	0.069	0.000018	0.0072	0.0029	0.0011	0.000041	0.000046	0.000093	0.0019	0.0064	--
	Boston	100	0.51	0.00005	0.03	0.13	0.014	0.0004	0.001	0.0018	0.03	0.15	--
Tailings Areas (Closure)	Doris	37	0.034	0.0000088	0.0036	0.0014	0.00053	0.00002	0.000023	0.000047	0.00093	0.0032	--
	Boston	100	0.54	0.00005	0.03	0.3	0.014	0.0004	0.001	0.0018	0.03	0.15	--
Underground Mine (Operations)	Doris	5.2	0.075	0.00000028	0.000087	0.014	0.0015	0.00000066	9.3E-06	0.0000075	0.000028	0.0014	--
	Madrid North	100	0.54	0.00005	0.0053	0.3	0.0057	0.00008	0.00013	0.00026	0.0082	0.022	--
	Madrid South	5.5	0.01	0.000004	0.00067	0.0024	0.00033	0.0000097	4.2E-06	0.00017	0.00072	0.0015	--
Reflooded Underground Mine (Closure)	Doris	360	5.1	0.00002	0.0057	0.99	0.11	0.000035	0.00064	0.00052	0.0019	0.09	--
	Madrid North	2000	50	0.0028	0.13	9.7	0.083	0.0032	0.0078	0.011	0.29	4.6	1800
	Madrid South	110	0.21	0.000082	0.014	0.051	0.0069	0.0002	0.000086	0.0035	0.015	0.031	--

Table 4-2: Upper Case Water Quality Estimates for Stockpiles, Tailings Areas, Underground Mines and Pads

Component	Mine	SO4	Alkalinity	F	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Li
Waste Rock Stockpile	Madrid North	1500	89	0.59	0.1	0.036	3	0.18	0.0001	1.8	0.00022	204	0.02	0.1	0.017	0.22	0.003	0.32
	Madrid South	960	89	0.59	0.1	0.036	4.4	0.29	0.0001	1.8	0.00022	204	0.02	0.1	0.017	0.22	0.003	0.31
	Boston	3400	89	0.59	0.1	0.036	5.6	0.28	0.0001	1.8	0.00022	204	0.02	0.1	0.017	0.22	0.003	0.21
Ore Stockpile	Madrid North	11000	89	0.59	0.1	0.036	6.7	0.2	0.0001	1.8	0.00022	204	0.02	0.1	0.017	0.22	0.003	0.34
	Madrid South	400	89	0.43	0.073	0.0099	0.34	0.13	0.0001	0.87	0.00019	204	0.005	0.032	0.0089	0.18	0.00036	0.21
	Boston	490	89	0.53	0.034	0.012	0.42	0.13	0.0001	1.1	0.00022	204	0.005	0.026	0.009	0.22	0.00045	0.21
Pads & Infrastructure; Quarry Rock Covers on Tailings Areas	All	31	92	0.053	0.068	0.00017	0.0024	0.0078	0.0001	0.048	0.000031	40	0.0004	0.00025	0.015	0.15	0.00014	0.003
Tailings Areas (Operations)	Doris	53	89	0.13	0.1	0.006	0.41	0.29	0.00021	0.34	0.00007	93	0.003	0.00078	0.0096	0.068	0.00035	0.0094
	Boston	600	89	0.59	0.1	0.063	3.7	0.29	0.0086	11	0.0022	200	0.02	0.023	0.017	0.22	0.003	0.2
Tailings Areas (Closure)	Doris	26	89	0.067	0.1	0.003	0.21	0.2	0.0001	0.17	0.000035	46	0.0015	0.00039	0.0048	0.034	0.00017	0.0047
	Boston	4300	89	0.59	0.1	0.45	3.8	0.29	0.062	79	0.016	200	0.02	0.17	0.017	0.22	0.003	0.42
Underground Mine (Operations)	Doris	51	4.2	0.005	0.0019	0.000094	0.00053	0.0013	0.0000044	0.0053	0.0000082	15	0.000027	0.0039	0.00016	0.00065	0.0000028	0.003
	Madrid North	1100	89	0.22	0.1	0.0077	0.63	0.0097	0.0001	0.46	0.000084	200	0.0013	0.087	0.0077	0.078	0.00049	0.013
	Madrid South	8.6	83	0.053	0.1	0.0028	0.47	0.0062	0.000039	0.19	0.000021	23	0.00039	0.0073	0.0033	0.011	0.00023	0.0028
Reflooded Underground Mine (Closure)	Doris	3500	280	0.31	0.13	0.0064	0.037	0.076	0.0002	0.35	0.00055	1000	0.0013	0.27	0.011	0.042	0.00018	0.19
	Madrid North	35000	11000	12	64	0.44	40	0.89	0.013	32	0.039	8400	0.27	2.9	1.5	150	0.22	2.1
	Madrid South	180	1700	1.1	4.4	0.058	9.8	0.13	0.0008	4	0.00044	470	0.008	0.15	0.068	0.23	0.0047	0.058

Component	Mine	Mg	Mn	Hg	Mo	Ni	Se	Ag	Tl	U	V	Zn	Acidity
Waste Rock Stockpile	Madrid North	103	1	0.00005	0.03	0.29	0.014	0.0004	0.001	0.0018	0.03	0.15	--
	Madrid South	103	1	0.00005	0.03	0.3	0.014	0.0004	0.00093	0.0018	0.03	0.15	--
	Boston	103	1	0.00005	0.03	0.3	0.014	0.0004	0.001	0.0018	0.03	0.15	--
Ore Stockpile	Madrid North	103	1	0.00005	0.03	0.3	0.014	0.0004	0.001	0.0018	0.03	0.15	--
	Madrid South	81	1	0.00005	0.0082	0.026	0.0043	0.00033	0.00015	0.0015	0.0074	0.041	--
	Boston	100	1	0.00005	0.01	0.032	0.0053	0.0004	0.00018	0.001	0.0092	0.041	--
Pads & Infrastructure; Quarry Rock Covers on Tailings Areas	All	8.5	0.12	0.00001	0.0012	0.0032	0.00033	0.00001	0.00001	0.00056	0.0015	0.011	--
Tailings Areas (Operations)	Doris	78	0.19	0.000024	0.013	0.0043	0.0016	0.000079	0.000059	0.00015	0.0053	0.0093	--
	Boston	100	0.54	0.00005	0.03	0.13	0.014	0.0004	0.001	0.0018	0.03	0.15	--
Tailings Areas (Closure)	Doris	39	0.095	0.000012	0.0067	0.0022	0.00082	0.00004	0.00003	0.000073	0.0027	0.0046	--
	Boston	100	0.54	0.00005	0.03	0.3	0.014	0.0004	0.001	0.0018	0.03	0.15	--
Underground Mine (Operations)	Doris	5.3	0.077	3.6E-07	0.000095	0.014	0.0015	0.00000083	0.0000095	0.0000086	0.000029	0.0015	--
	Madrid North	100	0.54	0.00005	0.0053	0.3	0.0057	0.00008	0.00013	0.00026	0.0082	0.022	--
	Madrid South	11	0.02	0.0000079	0.0013	0.0049	0.00067	0.000019	0.0000083	0.00034	0.0014	0.003	--
Reflooded Underground Mine (Closure)	Doris	360	5.2	0.00002	0.006	0.99	0.11	0.000046	0.00064	0.00053	0.0019	0.097	--
	Madrid North	2700	52	0.0054	0.24	9.9	0.12	0.0055	0.0096	0.018	0.54	5.2	1800
	Madrid South	230	0.42	0.00016	0.028	0.1	0.014	0.0004	0.00017	0.007	0.03	0.063	--

Source: P:\01_SITES\Hope.Bay\1CT022.004_Phase 2 DEIS - Engineering Support\Task 240_Geochemistry & Source Terms\Reports\Source Term Report\Tables\[SourceTermPredictionsTables_1CT022-004_Rev02_LNB.xlsx]

Note: All concentrations in mg/L

Table 4-3: Doris Mill and Boston Processing Plant Process Water Quality Estimates

Parameter	Doris Mill					Boston Processing Plant
	Doris Mixed	Madrid North Mixed	Madrid South Mixed	Boston Mixed	Boston Detoxified	Boston Flotation
SO_4	130	490	670	670	710	120
Alk	180	230	350	350	110	230
F	0.39	0.12	0.15	0.15	0.15	0.35
Total CN	0.52	0.63	0.63	0.63	3.8	0
WAD CN	0.27	0.63	0.63	0.63	3.8	0
SCN	30	30	30	30	220	0.1
NH_3	0.4	3	11	11	7.3	1
NO_3	0.099	0.14	0.33	0.33	0.6	0.06
NO_2	0.15	0.12	0.26	0.26	0.5	0.04
Al	0.15	0.13	1	1	0.058	1.2
Sb	0.019	0.039	0.12	0.12	0.63	0.0029
As	0.0079	0.87	0.26	0.26	1.2	0.011
Ba	0.2	0.03	0.028	0.028	0.023	0.0087
Be	0.00049	0.0026	0.02	0.02	0.0002	0.0001
B	0.23	0.18	0.18	0.18	0.18	0.18
Cd	0.00049	0.00045	0.00056	0.00056	0.0003	0.00043
Ca	130	150	160	160	76	45
Cr	0.0039	0.014	0.01	0.01	0.005	0.0045
Co	0.0096	0.0096	0.0096	0.0096	1.5	0.0096
Cu	0.027	0.031	0.022	0.022	0.0095	0.012
Fe	4.3	0.68	0.43	0.43	0.01	0.34
Pb	0.0027	0.00051	0.002	0.002	0.0025	0.0007
Li	0.021	0.013	0.013	0.013	0.013	0.013
Mg	17	100	120	120	29	27
Mn	0.16	0.057	0.075	0.075	0.11	0.029
Hg	0.000079	0.000079	0.0000094	9.4E-06	0.0001	0.000037
Mo	0.12	0.15	0.17	0.17	0.33	0.16
Ni	0.013	0.07	0.045	0.045	0.18	0.0057
Se	0.0048	0.013	0.01	0.01	0.02	0.0012
Ag	0.0024	0.0022	0.0023	0.0023	0.016	0.00017
Tl	0.00044	0.0003	0.00066	0.00066	0.0002	0.00029
U	0.00039	0.001	0.002	0.002	0.0022	0.0001
V	0.0027	0.01	0.024	0.024	0.0007	0.024
Zn	0.04	0.021	0.058	0.058	0.04	0.036

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All units mg/L. Alkalinity expressed as mg/L as $CaCO_3$.

-- denotes not analyzed. See Section 5 for details.

Table 4-4: Estimates of Total Metals Content in TSS

Parameter	Unit	Doris TIA[1]	Boston TMA[2]	Madrid North Underground[3]
Ag	ppm	0.1	0.1	0.29
Al	%	1.1	0.31	2.5
As	ppm	320	86	550
B	ppm	20	20	20
Ba	ppm	14	10	15
Ca	%	8.1	6.5	6.3
Cd	ppm	0.1	0.2	0.24
Co	ppm	34	13	81
Cr	ppm	180	110	200
Cu	ppm	31	31	250
Fe	%	6	5	8.5
Hg	ppb	10	10	20
Mg	%	4.2	3.1	3.1
Mn	ppm	1700	1600	1400
Mo	ppm	0.9	2.6	1.7
Na	%	0.011	0.01	0.044
Ni	ppm	290	62	220
Pb	ppm	2.5	2.2	8.6
Sb	ppm	0.4	0.4	0.76
Se	ppm	0.5	0.5	2
Tl	ppm	0.1	0.1	0.1
U	ppm	0.1	0.1	0.1
V	ppm	60	20	130
Zn	ppm	37	68	68

[1] Also applied to Doris infrastructure contact water.

[2] Also applied to Boston water treatment plant effluent and Boston infrastructure contact water.

[3] Also applied to Doris and Madrid South underground mine water.

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5 Summary and Conclusions

Base and upper case geochemical source terms (contact water chemistry) were estimated for the following Phase 2 mine facilities:

- Madrid and Boston waste rock and ore stockpiles;
- Madrid and Boston pads and infrastructure;
- Doris and Boston tailings areas;
- Quarry rock covers on the tailings areas at closure;
- Surface pads and infrastructure;
- Doris and Madrid underground mines (including reflooded closure scenario); and
- Doris mill and Boston processing plant.

Source terms for drilling brines, explosives residues surface and groundwater quality and water treatment plant effluent are presented in SRK (2016e).

Base and upper case source term estimates were based on a combination of scale-up calculations from the geochemical characterization programs[1], monitoring data from existing facilities at Hope Bay, and extrapolation of monitoring data from geologically similar mine sites.

The results are a key input to the water and load balance used to predict discharge and receiving water quality for Phase 2 of the Project, for use in the effects assessment (SRK 2016e). The source terms generally reflect dissolved concentrations resulting from geochemical reactions as water comes into contact with each of these geological materials. However, guidelines for receiving water quality are based on total metals concentrations. Therefore, an estimate of suspended metal concentrations was also required for discharges to Doris Creek and the Marine Mix Box. At Boston, contact water from the mining facilities will undergo water treatment, and the water treatment plant effluent is considered to be representative of total metals.

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[1] SRK (2015c), SRK (2016c), SRK (2016d), SRK (2016h), SRK (2015a), SRK (2015e), SRK (2016a), SRK (2008), SRK (2015f), SRK (2016k), SRK (2014), SRK (2015b)

This report, “Geochemical Source Term Predictions for the Proposed Madrid North, Madrid South and Boston Mines, Hope Bay Project”, was prepared by SRK Consulting (Canada) Inc.

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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Appendix A – Summary of Humidity Cell Tests Stable Rates

Appendix A:
Summary of Humidity Cell Tests Stable Rates

Test ID	Deposit Area	Rock Type[1]	SO4	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Li	Mg	Mn
HC-3	Madrid North	1	0.75	0.032	0.000031	0.0008	0.0002	0.000023	0.018	8.4E-06	3.4	0.000075	0.000033	0.0003	0.0045	0.000029	0.00024	0.53	0.0016
HC-8	Madrid North	1	2.2	0.0072	0.000097	0.013	0.00068	4.5E-06	0.022	2.2E-06	1.5	0.000068	0.000029	0.00017	0.0045	6.9E-06	0.00022	0.92	0.00085
HC-9	Madrid North	1	0.66	0.053	0.00004	0.00023	0.00016	0.000035	0.018	6.5E-06	3.4	0.000079	0.000036	0.00032	0.01	0.000031	0.00027	0.56	0.0013
HC-24	Madrid North	1	3.1	0.015	0.0011	0.16	0.00018	4.7E-06	0.023	2.3E-06	1.9	0.00007	0.00025	0.00043	0.0044	0.000018	0.00037	1.1	0.0048
HC-25	Madrid North	1	2.1	0.013	0.00071	0.065	0.000088	4.6E-06	0.023	2.3E-06	2	0.000061	0.00047	0.00019	0.005	0.000021	0.00025	1.1	0.0029
HC-26	Madrid North	1	25	0.003	0.000061	0.0067	0.00013	4.5E-06	0.023	3.8E-06	8.7	0.000045	0.0003	0.00016	0.0042	0.000054	0.00023	4.6	0.002
HC-27	Madrid North	1	1.3	0.011	0.0013	0.16	0.000075	4.5E-06	0.025	2.5E-06	2	0.000058	0.00062	0.00019	0.003	0.000014	0.00025	0.94	0.0032
HC-28	Madrid North	1	10	0.025	0.00039	0.077	0.00011	4.6E-06	0.023	2.3E-06	3.4	0.000069	0.00055	0.00024	0.0047	8.3E-06	0.00025	1.8	0.0039
HC-17	Madrid North	1aj	1.7	0.015	0.000046	0.00032	0.00027	4.4E-06	0.022	2.6E-06	2.3	0.000052	0.000022	0.00035	0.0037	0.00006	0.0005	1.3	0.0025
HC-4	Madrid North	2pg	1.1	0.03	0.000027	0.00021	0.00017	0.000023	0.02	6.8E-06	2.5	0.00007	0.000028	0.00029	0.0061	0.000026	0.00035	0.29	0.0013
HC-18	Madrid North	2pg	0.8	0.059	0.000065	0.0073	0.00026	0.000011	0.024	2.8E-06	3.1	0.000079	0.000029	0.00024	0.0048	0.000022	0.00065	0.75	0.0032
HC-19	Madrid North	2pg mixed	4.8	0.027	0.000015	0.00032	0.00011	4.5E-06	0.022	4.8E-06	5	0.000045	0.000055	0.00024	0.0041	0.000073	0.00033	0.22	0.0018
HC-20	Madrid North	5	2.9	0.0052	0.0018	0.33	0.00025	4.4E-06	0.022	3.4E-06	2.7	0.000044	0.0015	0.000088	0.0041	0.000084	0.00022	1.5	0.0027
HC-21	Madrid North	5	41	0.003	0.000064	0.00018	0.001	4.5E-06	0.023	2.7E-06	15	0.000045	0.0001	0.00037	0.0041	0.000042	0.00023	5.3	0.0027
HC-40	Madrid North	7a	1.1	0.037	0.00009	0.0022	0.00011	7.9E-06	0.023	2.5E-06	1.3	0.000049	0.000017	0.00022	0.0081	0.000012	0.00042	1	0.0016
HC-41	Madrid North	7a	1.6	0.03	0.00099	0.27	0.00022	4.7E-06	0.023	2.3E-06	1.8	0.00011	0.00041	0.00025	0.0097	0.000016	0.0006	1.3	0.0027
HC-22	Madrid North	11c	2.2	0.024	0.000033	0.00062	0.00012	4.4E-06	0.022	2.2E-06	1.1	0.000058	0.000017	0.00036	0.0039	0.00001	0.00085	0.29	0.0014
HC-23	Madrid North	11c	1.5	0.033	0.000017	0.0013	0.00017	4.5E-06	0.022	2.2E-06	1.6	0.000052	9.3E-06	0.00026	0.004	0.000026	0.0004	0.72	0.00082
HC-5	Madrid North	13a	0.87	0.013	0.00027	0.037	0.00036	0.000033	0.021	0.000006	1.9	0.000076	0.00029	0.00026	0.0047	0.000028	0.00027	1.1	0.0023
HC-29	Madrid North	13a	1	0.012	0.00077	0.065	0.00014	4.4E-06	0.024	2.2E-06	1.2	0.000062	0.00064	0.00019	0.0043	0.000016	0.00022	0.97	0.0019
HC-39	Madrid North	13a	1.7	0.0038	0.00016	0.0029	0.000093	4.6E-06	0.023	2.3E-06	2.4	0.000046	0.000056	0.00018	0.0012	0.000021	0.00023	1.2	0.00018
HC-30	Madrid North	13a	4.1	0.0066	0.000077	0.00016	0.00015	4.4E-06	0.022	2.2E-06	2.8	0.000051	0.000017	0.00055	0.0039	8.7E-06	0.00061	2	0.003
HC-63	Madrid South	1	0.57	0.018	0.00028	0.00048	0.00034	4.7E-06	0.023	2.5E-06	1.8	0.000047	0.000013	0.00013	0.00084	0.000024	0.00033	1.1	0.0018
HC-61	Madrid South	1	1.1	0.0071	0.0005	0.056	0.0001	4.6E-06	0.023	2.3E-06	2.7	0.000046	0.0011	0.00039	0.0021	0.00003	0.00025	1.3	0.0024
HC-62	Madrid South	7ac mixed	23	0.031	0.00014	0.00046	0.0085	4.4E-06	0.022	2.5E-06	24	0.000044	0.000017	0.00043	0.00079	0.000027	0.00044	1.9	0.0069
HC-60	Madrid South	9	0.48	0.025	0.00022	0.0025	0.00074	4.5E-06	0.025	2.3E-06	1.8	0.000045	0.000028	0.0003	0.0013	0.000023	0.00024	0.96	0.0013
HC-64	Madrid South	9	1	0.0091	0.00033	0.097	0.000089	4.4E-06	0.022	2.2E-06	2.4	0.000044	0.00087	0.00022	0.0013	0.000013	0.00022	1.2	0.0023
HC-31	Boston	1	1.1	0.00016	0.00033	0.032	0.00013	4.4E-06	0.022	2.2E-06	1.5	0.000065	0.00031	0.00016	0.004	0.000022	0.00022	1	0.0022
HC-55	Boston	1	1	0.0085	0.0006	0.023	0.00028	4.8E-06	0.024	2.5E-06	2.9	0.000058	0.00027	0.00026	0.0038	0.000021	0.00024	1.7	0.0041
HC-12	Boston	1	0.9	0.0072	0.00062	0.08	0.00048	0.000034	0.017	6.2E-06	2.1	0.000078	0.00065	0.00035	0.0049	0.000034	0.00038	1.3	0.003
HC-10	Boston	1 mixed	0.84	0.013	0.00087	0.023	0.00077	0.000036	0.016	6.6E-06	1.8	0.0001	0.000078	0.00033	0.033	0.000033	0.00024	1.1	0.0039
HC-32	Boston	1oj	2.2	0.0074	0.00083	0.13	0.00015	4.4E-06	0.022	2.3E-06	1.5	0.000063	0.00055	0.00018	0.0042	0.000013	0.00022	1	0.0036
HC-33	Boston	1oj	1.8	0.0067	0.0011	0.18	0.00016	4.5E-06	0.023	2.3E-06	1.8	0.000059	0.0006	0.00018	0.0045	0.000023	0.00023	1.1	0.0035
HC-11	Boston	5	12	0.0019	0.00012	0.0002	0.00015	4.5E-06	0.023	0.000003	5.6	0.000045	0.000027	0.00009	0.0039	6.6E-06	0.00023	2.9	0.00051
HC-35	Boston	5	1.1	0.018	0.00034	0.0063	0.00051	4.5E-06	0.022	2.7E-06	3.5	0.000062	0.00017	0.00026	0.0041	0.000071	0.00023	1.6	0.0017
HC-34	Boston	5	6.1	0.0092	0.00071	0.00081	0.0003	4.5E-06	0.027	2.7E-06	2.2	0.000064	0.00012	0.00024	0.004	0.00002	0.0003	1.6	0.0016
HC-37	Boston	12q	4.8	0.0037	0.0026	0.14	0.00044	4.4E-06	0.022	2.2E-06	2.4	0.000051	0.00083	0.00019	0.004	0.000016	0.00022	1.2	0.0041
HC-38	Boston	12q	14	0.0022	0.00014	0.0012	0.00035	4.6E-06	0.023	2.3E-06	9.2	0.000054	0.00017	0.00023	0.001	0.00002	0.00023	3.5	0.0007

[1] Rock codes: 1 - mafic metavolcanics; 1aj/1oj - mafic metavolcanics with sediments; 2pg - pale green pillow; 5 -sedimentary units; 7a - early gabbro; 9 - late porphyry granitoids; 11c - diabase; 12q - quartz vein; 13a - deformation zone

*All rates expressed as mg/kg/week

Test ID	Deposit Area	Tailngs Type	SO4	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Li	Mg	Mn
HC-57	Doris	Flotation	1	0.016	0.00014	0.0027	0.00049	4.6E-06	0.023	5.4E-06	6.1	0.000066	0.000031	0.005	0.0043	0.000028	0.00023	2.7	0.016
HC-1	Doris	Flotation	5	0.0064	0.000048	0.00048	0.0022	0.000024	0.0096	0.000024	3.1	0.00024	0.00074	0.0009	0.0095	0.00054	0.00048	2.3	0.009
HC-66	Doris	Flotation	4.8	0.028	0.00011	0.016	0.0018	6.2E-06	0.031	3.1E-06	8	0.000062	0.000062	0.00019	0.0053	0.000015	0.0066	4	0.021
HC-56	Madrid North	Flotation	2.2	0.018	0.00062	0.048	0.035	4.8E-06	0.024	3.5E-06	7.1	0.00012	0.000048	0.00041	0.004	0.000011	0.00081	6.2	0.00072
HC-14	Madrid North	Flotation	1.9	0.011	0.00024	0.015	0.00046	4.6E-06	0.023	3.2E-06	4.5	0.00023	0.000034	0.000087	0.0042	5.7E-06	0.00039	5.2	0.0012
HC-13	Boston	Flotation	0.94	0.0017	0.00014	0.0012	0.00054	0.000019	0.018	4.8E-06	7	0.00023	0.000051	0.00022	0.0041	0.00002	0.00038	7	0.0011
HC-1b	Doris	Detoxified Tailings	310	0.31	0.000044	0.00019	0.0042	0.000022	0.11	0.0004	87	0.0023	0.012	0.014	1.7	0.0022	0.0019	16	0.091
HC-67	Doris	Detoxified Tailings	290	0.0023	0.000056	0.00095	0.0068	4.7E-06	0.023	0.00006	63	0.000047	0.0073	0.00021	0.0042	0.000019	0.019	39	0.55
HC-58	Madrid North	Detoxified Tailings	380	0.014	0.00014	0.004	0.0018	7.4E-06	0.037	8.5E-06	110	0.000074	0.029	0.0011	0.0041	0.000013	0.0023	30	0.26
HC-2	Boston	Detoxified Tailings	160	0.0025	0.0007	0.0017	0.00085	5.8E-06	0.029	9.4E-06	64	0.000074	0.0015	0.00038	0.0041	0.000019	0.00059	24	0.0078

*All rates expressed as mg/kg/week

Appendix A:
Summary of Humidity Cell Tests Stable Rates

Test ID	Deposit Area	Rock Type[1]	Hg	Mo	Ni	Se	Ag	Tl	U	V	Zn	Alkalinity	F	Acidity
HC-3	Madrid North	1	0.0000055	0.000052	0.000055	0.000057	0.0000079	0.0000035	0.000014	0.00033	0.00055	9.6	0.014	--
HC-8	Madrid North	1	0.0000069	0.00039	0.00012	0.000081	0.0000022	0.0000009	0.0000075	0.00043	0.00045	7	0.0091	--
HC-9	Madrid North	1	0.0000078	0.000039	0.000065	0.000054	0.000011	0.000005	0.000017	0.00089	0.00031	11	0.016	--
HC-24	Madrid North	1	0.0000042	0.00063	0.001	0.00013	0.0000023	0.000002	0.0000054	0.00065	0.0018	7.1	0.0047	--
HC-25	Madrid North	1	0.0000024	0.000099	0.00076	0.000088	0.0000023	0.00000093	0.000011	0.0002	0.0019	7	0.0046	--
HC-26	Madrid North	1	0.0000009	0.0003	0.0021	0.000071	0.0000023	0.000003	0.0000037	0.0001	0.00033	8.7	0.0045	--
HC-27	Madrid North	1	0.000005	0.000048	0.00055	0.00013	0.0000022	0.000001	0.0000059	0.00042	0.0018	8.5	0.0054	--
HC-28	Madrid North	1	0.0000026	0.00018	0.00089	0.000065	0.0000023	0.00000099	0.0000022	0.00018	0.0019	9.3	0.0046	--
HC-17	Madrid North	1aj	0.000005	0.0014	0.00003	0.000052	0.0000022	0.0000039	0.0000031	0.00012	0.00098	9.5	0.0061	--
HC-4	Madrid North	2pg	0.0000055	0.000043	0.00011	0.000053	0.0000078	0.0000046	0.000011	0.00047	0.00047	6.9	0.012	--
HC-18	Madrid North	2pg	0.0000062	0.000049	0.000045	0.00013	0.0000048	0.0000024	0.0000069	0.001	0.00075	12	0.0079	--
HC-19	Madrid North	2pg mixed	0.00000089	0.00007	0.00022	0.000058	0.0000022	0.0000037	0.0000018	0.00019	0.00075	7.6	0.0045	--
HC-20	Madrid North	5	0.00000089	0.00012	0.018	0.000065	0.0000022	0.0000027	0.0000016	0.0002	0.0004	9.5	0.0044	--
HC-21	Madrid North	5	0.0000009	0.00069	0.00019	0.00024	0.0000023	0.00006	0.000011	0.00009	0.00036	12	0.0045	--
HC-40	Madrid North	7a	0.0000059	0.00013	0.00003	0.000058	0.0000036	0.0000016	0.000003	0.0013	0.0018	8.9	0.0093	--
HC-41	Madrid North	7a	0.0000055	0.000076	0.00092	0.000042	0.0000023	0.0000069	0.0000087	0.00055	0.0018	8.9	0.0085	--
HC-22	Madrid North	11c	0.0000026	0.000073	0.00012	0.000048	0.0000022	0.00000088	0.0000021	0.00069	0.0018	5.8	0.0044	--
HC-23	Madrid North	11c	0.0000027	0.000045	0.000019	0.000054	0.0000022	0.00000089	0.0000016	0.0013	0.0019	10	0.0045	--
HC-5	Madrid North	13a	0.0000077	0.00058	0.00019	0.000072	0.000011	0.0000047	0.000019	0.00016	0.00029	9.1	0.015	--
HC-29	Madrid North	13a	0.0000049	0.00016	0.00053	0.000043	0.0000022	0.00000089	0.000006	0.00017	0.0018	7.7	0.0044	--
HC-39	Madrid North	13a	0.00000093	0.00047	0.00029	0.000024	0.0000023	0.00000093	0.000025	0.0001	0.00024	8	0.0046	--
HC-30	Madrid North	13a	0.0000024	0.00022	0.00003	0.00009	0.0000022	0.00000088	0.00000088	0.00012	0.0019	11	0.0044	--
HC-63	Madrid South	1	0.00000094	0.00007	0.000032	0.000035	0.0000023	0.00000093	0.0000014	0.00012	0.00036	9.4	0.0072	--
HC-61	Madrid South	1	0.0000011	0.000081	0.00058	0.000079	0.0000023	0.00000099	0.0000017	0.00017	0.00033	11	0.0051	--
HC-62	Madrid South	7ac mixed	0.0000009	0.00016	0.00005	0.000046	0.0000025	0.000002	0.00004	0.000089	0.00027	9.1	0.0056	--
HC-60	Madrid South	9	0.0000009	0.00036	0.000034	0.000019	0.0000023	0.0000009	0.0001	0.00012	0.0005	9.4	0.0063	--
HC-64	Madrid South	9	0.00000091	0.000041	0.00072	0.000088	0.0000022	0.00000089	0.0000012	0.00026	0.00024	9.9	0.005	--
HC-31	Boston	1	0.0000023	0.000046	0.00018	0.000099	0.0000022	0.00000087	0.00000087	0.00017	0.00027	8.1	0.0044	--
HC-55	Boston	1	0.000001	0.000087	0.00042	0.000071	0.0000024	0.00000097	0.0000014	0.00012	0.00042	6.2	0.0048	--
HC-12	Boston	1	0.000008	0.000041	0.00059	0.00013	0.000011	0.0000049	0.000016	0.00019	0.00025	9.5	0.016	--
HC-10	Boston	1 mixed	0.000008	0.000039	0.0003	0.000065	0.000011	0.000005	0.000017	0.00014	0.00028	8	0.016	--
HC-32	Boston	1oj	0.0000033	0.000076	0.00085	0.000048	0.0000022	0.00000088	0.0000065	0.00028	0.00024	6.5	0.0044	--
HC-33	Boston	1oj	0.0000026	0.000058	0.00089	0.0001	0.0000023	0.0000018	0.0000029	0.00023	0.00013	7.8	0.0045	--
HC-11	Boston	5	0.000001	0.00027	0.000062	0.000075	0.0000023	0.0000024	0.000013	0.000091	0.00033	8.3	0.0045	--
HC-35	Boston	5	0.0000015	0.0017	0.00026	0.000023	0.0000024	0.000001	0.000082	0.000095	0.00038	9.4	0.0045	--
HC-34	Boston	5	0.0000035	0.0019	0.00029	0.00018	0.0000022	0.0000043	0.00003	0.00009	0.0002	5.1	0.0083	--
HC-37	Boston	12q	0.0000027	0.00019	0.0023	0.00004	0.0000022	0.0000029	0.0000068	0.00015	0.00015	6.8	0.0044	--
HC-38	Boston	12q	0.000002	0.00018	0.00029	0.000075	0.0000023	0.0000012	0.0000049	0.000091	0.00044	8.1	0.0046	--

[1] Rock codes: 1 - mafic metavolcanics; 1aj/1oj - mafic metavolcanics with sediments; 2pg - pale green pillow; 5 -sedimentary units; 7a - early gabbro; 9 - late porphyry granitoids; 11c - diabase; 12q - quartz vein; 13a - deformation zone

*All rates expressed as mg/kg/week

Test ID	Deposit Area	Tailngs Type	Hg	Mo	Ni	Se	Ag	Tl	U	V	Zn	Alkalinity	F	Acidity
HC-57	Doris	Flotation	0.0000019	0.00041	0.00000016	0.000031	0.0000031	0.000001	0.0000045	0.000092	0.00033	25	0.0073	--
HC-1	Doris	Flotation	0.0024	0.0029	0.00022	0.0003	0.000024	0.0000048	0.0000096	0.00048	0.001	13	0.000048	--
HC-66	Doris	Flotation	0.0000012	0.00068	0.00000041	0.00013	0.0000031	0.0000056	0.000017	0.00056	0.00029	35	0.014	--
HC-56	Madrid North	Flotation	0.00000099	0.00049	0.00000049	0.000081	0.0000026	0.0000059	0.0000044	0.0002	0.0007	39	0.0071	--
HC-14	Madrid North	Flotation	0.0000011	0.00036	0.00039	0.000069	0.0000025	0.0000023	0.0000032	0.0001	0.00051	29	0.0047	--
HC-13	Boston	Flotation	0.0000012	0.0011	0.00029	0.000093	0.0000069	0.0000035	0.000011	0.000081	0.00056	43	0.011	--
HC-1b	Doris	Detoxified Tailings	0.00000087	0.00011	0.01	0.00072	0.000011	0.000013	0.000019	0.00044	0.045	0.42	0.0087	21
HC-67	Doris	Detoxified Tailings	0.00000093	0.000093	0.0059	0.012	0.0000023	0.000069	0.000049	0.000093	0.0097	30	0.016	--
HC-58	Madrid North	Detoxified Tailings	0.0000015	0.00059	0.11	0.0016	0.0000037	0.000011	0.000013	0.00015	0.00048	26	0.029	--
HC-2	Boston	Detoxified Tailings	0.0000012	0.00016	0.015	0.00049	0.0000031	0.000028	0.0000039	0.0002	0.00069	12	0.0062	--

*All rates expressed as mg/kg/week

Appendix B – Humidity Cell Test Data Set Considerations

Material Type	Source Term	Sample Set	Considerations
Waste Rock	Madrid and Boston Stockpiles, Madrid Underground Backfill	Madrid North	Ore samples exhibited higher rates of sulphate and nickel release. Waste rock stockpile data set only includes HCTs classified as waste. Similarly, ore stockpile data set only includes HCTs classified as ore. Base case statistic is 75th percentile (P75) levels and the upper case is two times P75 values. P75 levels were selected rather than P50 because for selected parameters such as arsenic at Madrid North, there could be an order of magnitude difference in leaching rates between different rock types. The upper case scenario is based on a best-judgement scenario.
		Madrid South	All HCTs classified as waste. Used full Madrid South HCT sample set. Base and upper cases are P75 and two times P75, respectively.
		Boston	Includes HCTs classified as both ore and waste because no difference in release rates between the sample sets. Base and upper cases are P75 and two times P75, respectively.
Ore	Madrid and Boston Stockpiles	Madrid North	Ore samples exhibited higher rates of sulphate and nickel release. Ore stockpile data set only includes HCTs classified as ore. Base and upper cases are P75 and two times P75, respectively.
		Madrid South	No Madrid South HCT samples containing ore. Comparison of tailings data suggests Boston is best analog for Madrid South (SRK 2016a). For each parameter and scenario, data set is maximum statistical value of two data sets (e.g. P75 for base case): 1) Madrid South waste rock samples and 2) Boston ore samples. Base and upper cases are P75 and two times P75, respectively.
		Boston	For each parameter and scenario, data set is maximum statistical value of two data sets (e.g. P75 for base case): 1) all Boston HCTs (waste and ore) and 2) Boston ore samples. Base and upper cases are P75 and two times P75, respectively.
Flotation Tailings	Doris TIA	All	Deposition of flotation tailings from Doris, Madrid and Boston. All flotation tailings classified as non-PAG, however arsenic is a metal leaching concern and sulphide and arsenic content vary by deposit (SRK 2016a). Madrid North has the highest sulphide and arsenic levels and according to the mining schedule will be on surface at closure. Base and upper cases are P50 and P75, respectively. For the base case, the flotation tailings data set was derived as follows: 1) calculate P50 for all (Doris, Madrid and Boston) flotation tailings humidity cell tests, 2) calculate P50 for all Madrid North flotation tailings humidity cell tests, and 3) take the higher P50 value from data sets 1 and 2. The same steps were followed for the derivation of the data set for the upper case.
	Boston TIA	Boston	Deposition of Boston flotation tailings only. Only one flotation tailings humidity cell test from Boston (HC-13). Base case is data from HC-13. To create an upper case, data from the other deposits were considered. Upper case is P50 levels, calculated using the same steps as for the Doris TIA, however the data sets considered were 1) HC-13 and 2) all flotation tailings humidity cell tests.
Detoxified Tailings (pH neutral)	Doris Underground Backfill	All	Deposition of Doris and Phase 2 detoxified tailings. Geochemistry of detoxified tailings from the Project is overall homogeneous though solid-phase arsenic levels at Doris are lower (SRK 2016a). To be conservative, all pH neutral detoxified tailings humidity cell test samples combined into one sample set and maximum value selected. This data set represents both the base and upper cases.
	Madrid North Underground Backfill	Madrid North and Boston	Deposition of Phase 2 detoxified tailings. Geochemistry of Phase 2 detoxified tailings is homogenous (SRK 2016a). To be conservative, all pH neutral Phase 2 detoxified tailings humidity cell test samples combined into one sample set and maximum value selected. This data set represents both the base and upper cases.
Detoxified Tailings (Acidic)	Madrid North Underground Backfill (Closure only)	All	One detoxified tailings humidity cell test from the Project developed acidic conditions (SRK 2015e). To be conservative, the sample set was comprised of all detoxified tailings humidity cell tests, including the acidic and pH tests, and maximum value selected. This data set represents both the base and upper cases.
Quarry rock	Madrid North Underground Backfill	Doris	Sample set comprised of Doris waste rock humidity cell tests with equivalent geological and geochemical characteristics as Madrid quarry samples (SRK 2008 and SRK 2015f). P75 arsenic levels two orders of magnitude higher than median levels, therefore P75 levels selected as base case and two times P75 as the upper case.

Appendix C – Calculation of Oxidation Layer Thickness for Doris TIA at Closure Memo

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Memo

To:	Project File	**Client:**	TMAC Resources Inc.
From:	Iozsef Miskolczi, MASc, PEng	**Project No:**	1CT022.004
Reviewed By:	Maritz Rykaart, PhD, PEng	**Date:**	December 9, 2016
Subject:	Hope Bay Project: Calculation of Oxidation Layer Thickness for Doris TIA at Closure		

1 Introduction

1.1 Background

The Hope Bay Project (the Project) is a gold mining and milling undertaking of TMAC Resources Inc. The Project is located 705 km northeast of Yellowknife and 153 km southwest of Cambridge Bay in Nunavut Territory, and is situated east of Bathurst Inlet. The Project is comprised of three distinct areas of known mineralization plus extensive exploration potential and targets. The three areas hosting known mineral resources are Doris, Madrid, and Boston.

The Project consists of two phases; Phase 1 (Doris deposit), and Phase 2 (all remaining deposits). Ore processing includes cyanidation and flotation, with two separate streams of tailings. Cyanidation tailings will undergo cyanide destruction, and the subsequent tailings will be filtered and disposed underground with waste rock backfill. At the Doris and Madrid processing facilities, the flotation tailings will be deposited in the Doris TIA, and at the Boston processing facility these tailings will be filtered and deposited in the Boston TMA.

At closure, contact water quality flowing from the covered tailings surface at the Doris TIA will be dependent on the depth of oxidation within the tailings. This memo describes how that depth of oxidation has been calculated.

2 Conceptual Model

2.1 Processes

2.1.1 Tailings Oxidation

Geochemically, dissolved metals are released to the tailings pore water during oxidation of the residual sulphide minerals, or by dissolution of the metals in the case of neutral metal leaching. While sulphide oxidation and production of secondary minerals and metals loading occurs continually, the rate at which this occurs is greatly influenced by temperature and the availability of oxygen. For the Doris TIA, this means that oxidation can be considered negligible when the tailings are frozen, or when they are at least 85% saturated.

2.1.2 Transfer of Tailings Pore Water

Transfer of the tailings pore water with elevated concentrations of metals into the surface run-off can occur at the surface of the tailings and to a lesser degree in the unsaturated zone of the thawed tailings. This transfer cannot occur while the tailings are frozen.

Transport of the metals from the pore water to the receiving environment occurs through lateral flow of the pore water, or by mixing and dilution into the surface run-off. Since the tailings have a very low hydraulic conductivity, the contaminant pathway is likely to be dominated by run-off transport. Lateral transport cannot occur while the tailings are frozen, and a frozen surface effectively seals off the tailings, even if some of the tailings below are not yet frozen.

2.1.3 Permafrost and Active Layer

The Project is located in the continuous permafrost region of Canada, with the permafrost depth extending to 500 m below ground surface (SRK 2016a). The active layer thickness (ALT) which freezes and thaws seasonally is approximately 1 m, depending on ground conditions, with moisture content, soil type and color dominating local differences in the ALT.

2.1.4 The Vadose Zone

The vadose zone is the near-surface layer of tailings that will undergo changes in water content as a result of the interaction with the climate in the form of precipitation and evaporation. At time of deposition as well as after precipitation or snow melt events, the tailings will experience elevated moisture contents nearing saturation. Conversely, during extended dry periods, the moisture content will gradually decrease, predominantly as a result of evaporative forcing. Gravity flow, i.e. downward seepage is relatively unimportant, due to the high capillarity typically exhibited by fine grained tailings, as well as the presence of an aquitard resulting from permafrost that develops within the tailings mass.

2.2 Approach

The objective is to calculate the depth of oxidation within the tailings surface considering the processes described above. This is best defined by calculating the water mass balance within a unit dimensional layer of unfrozen tailings. Since the extent of freezing varies temporally, the calculation needs to be temporal, and a resolution of monthly time-step has been adopted. Figure 1 illustrates the conceptual model.

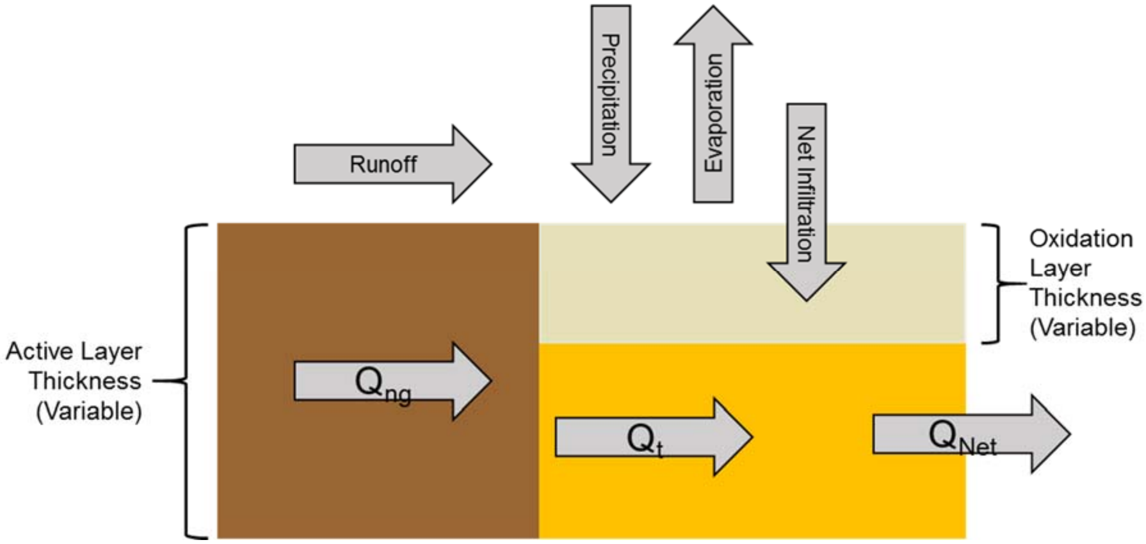

Figure 1. Conceptual Tailings Oxidation Thickness Calculation Model

The oxidation layer thickness is calculated in monthly time steps using either equation (1) or (2) below depending on the degree of saturated chosen.

$$OLT_{100} = \frac{\sum \Delta S_{Lost}}{\varphi_t} \qquad (1)$$

$$OLT_{85} = \frac{\sum \Delta S_{Lost}}{\varphi_t \times 0.85} \qquad (2)$$

Where:

$$\Delta S_{Lost} = \Delta S_{Available} - \Delta S_{Remaining}$$

$$\Delta S_{Remaining} = \Delta S_{Available} - NI - Q_{Net}$$

$$\Delta S_{Available} = ALT_t \times \varphi_t$$

$$NI = R + P - E$$

$$Q_{Net} = Q_t - Q_{ng}$$

$$Q_t = k_t \times i_t \times A_t$$

$$Q_{ng} = k_{ng} \times i_{ng} \times A_{ng}$$

$$A_t = ALT_t \times \varphi_t$$

$$A_{ng} = ALT_{ng} \times \varphi_{ng}$$

And:

$OLT_{100} = Oxidation\ layer\ thickness\ at\ 100\%\ saturation\ (cm)$

$OLT_{85} = Oxidation\ layer\ thickness\ at\ 85\%\ saturation\ (cm)$

$\Delta S_{Lost} = Loss\ in\ storage\ volume\ within\ active\ layer\ (m^3)$

$\Delta S_{Remaining} = Remaining\ storage\ volume\ within\ active\ layer\ (m^3)$

$\Delta S_{Available} = Available\ storage\ volume\ within\ active\ layer\ (m^3)$

$NI = Net\ infiltration(m^3)$

$Q_{Net} = Net\ active\ layer\ flux\ in\ tailings\ (m^3)$

$Q_t = Active\ layer\ flux\ through\ tailings\ (m^3)$

$Q_{ng} = Active\ layer\ flux\ from\ surrounding\ natural\ ground\ (m^3)$

$ALT_t = Tailings\ active\ layer\ thickness\ (m)$

$ALT_{ng} = Surrounding\ natural\ ground\ active\ layer\ thickness\ (m)$

$\varphi_t = Tailings\ porosity\ (\%)$

$\varphi_{ng} = Surrounding\ natural\ ground\ porosity\ (\%)$

$R = Freshet\ runoff\ (m)$

$P = Total\ precipitation\ (mm) = Rainfall + Snow\ water\ equivalent$

$k_t = Tailings\ saturated\ hydraulic\ conbductivity\ ({}^{m}/_{s})$

$k_{ng} = Surrounding\ natural\ ground\ saturated\ hydraulic\ conbductivity\ ({}^{m}/_{s})$

$i_t = Tailings\ ground\ hydraulic\ gradient\ ({}^{m}/_{m})$

$i_{ng} = Surrounding\ natural\ ground\ hydraulic\ gradient\ ({}^{m}/_{m})$

$A_t = Tailings\ active\ layer\ thickness\ surface\ area\ (m^2)$

$A_{ng} = Surrounding\ natural\ ground\ active\ layer\ thickness\ surface\ area\ (m^2)$

3 Input Parameters

3.1 Material Properties

Tailings and surrounding natural ground material properties are based on site specific testing documented in SRK (2016a) and SRK (2016b). A summary of the typical material properties used in the oxidation thickness calculation are summarized in Table 1. The “Base Case” analysis assumes average material properties and the minimum and maximum values were used in the sensitivity analysis.

Table 1: Summarized Material Properties

Material	Parameter	Minimum	Average	Maximum
Tailings	Porosity (%)	38%	42%	44%
	Saturated Hydraulic Conductivity (m/s)	6.4×10^{-8}	1.3×10^{-7}	2.1×10^{-7}
	Hydraulic Gradient (m/m)	0.005	0.010	0.020
Surrounding Natural Ground	Porosity (%)	52%		
	Saturated Hydraulic Conductivity (m/s)	3.6×10^{-10}	4.1×10^{-10}	4.6×10^{-10}
	Hydraulic Gradient (m/m)	0.020	0.040	0.060

3.2 Climatic Data

3.2.1 Current Conditions

Comprehensive site specific climate data is available for the Project site, however since these records span a relatively short period, regional data was used to provide an extensive long-term climatic record (SRK 2016c). Average monthly data relevant to the oxidation thickness calculation are presented in Table 2 and Figure 2.

This data demonstrates that although the annual climatic water balance for the site is net positive, it varies seasonally. Between April and July the climatic water balance is net negative as there is significant evaporative forcing; however, during the remainder of the year this does not occur. In reality however, this is an over simplistic consideration of available moisture for two primary reasons; (1) much of the sow will sublimate, and (2) snow that does not sublimate gets discharged over a small time period as freshet flow.

The amount of sublimation that occurs at the Project site is not measured, but past water balance analysis suggest a value of about 50% is reasonable. Furthermore, it is known that freshet flows peak during a short period in the month of June. When considering these refinements it is assumed that snow falling during the summer months does not sublimate but are deemed to melt and flow off as runoff since the mean annual air temperature during those months are positive. Similarly, rainfall that falls during the winter months is assumed to freeze and is therefore subject to sublimation.

Table 2: Average Monthly Climatic Water Balance

Period	Rainfall (mm)	Snow Water Equivalent (mm)	Total Precipitation (mm)	Evaporation (mm)	Climatic Water Balance (mm)
January	0.0	10.0	10.0	0.0	10.0
February	0.0	8.6	8.6	0.0	8.6
March	0.0	10.7	10.7	0.0	10.7
April	0.2	11.3	11.3	26.0	-14.7
May	2.1	12.4	14.5	46.0	-31.5
June	12.5	5.7	18.3	45.0	-26.7
July	28.3	0.2	28.5	35.0	-6.5
August	29.6	1.7	31.3	21.0	10.3
September	14.5	11.1	25.8	19.0	6.8
October	1.9	22.6	24.4	0.0	24.4
November	0.1	15.5	15.6	0.0	15.6
December	0.0	10.6	10.6	0.0	10.6
Annual Total	**89.3**	**120.1**	**209.6**	**192.0**	**17.6**

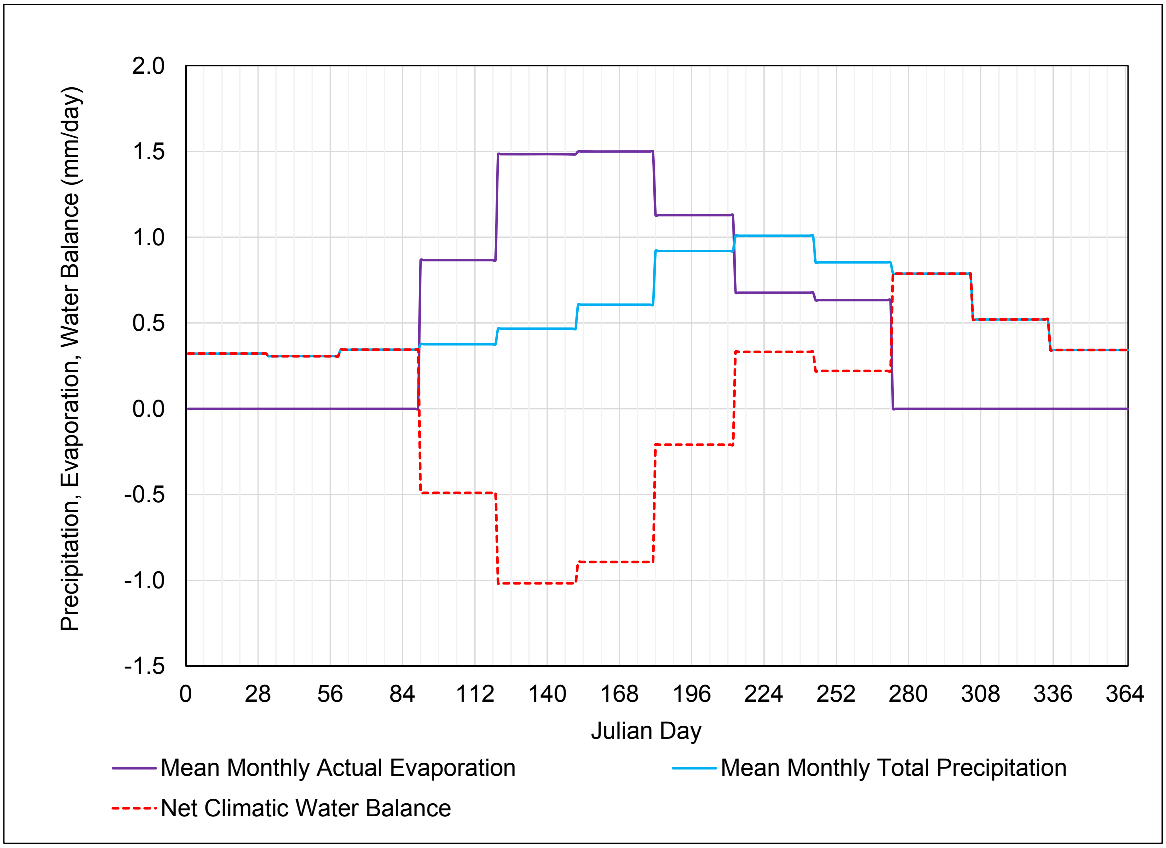

Figure 2. Average Monthly Climatic Water Balance

3.2.2 Climate Change

The oxidation thickness calculation considered climate change, projected to the year 2100 as described in (SRK 2016d) This includes consideration of increased precipitation, evaporation and air temperature.

3.3 Active Layer Thickness

Thermal modeling was conducted to determine the depth of the active layer in the tailings surface (SRK 2016e), as well as the surrounding natural ground (SRK 2016f). These models consider both current conditions, and projects up to the year 2100 inclusive of climate change. Figure 3 illustrates the tailings active layer thickness progression annually for the year 2100. It should be noted that by October, although the active layer is still near its maximum thickness, the ground is starting to refreeze from the surface, and therefore it can no longer contribute towards contaminant transport in the context of the oxidation thickness model.

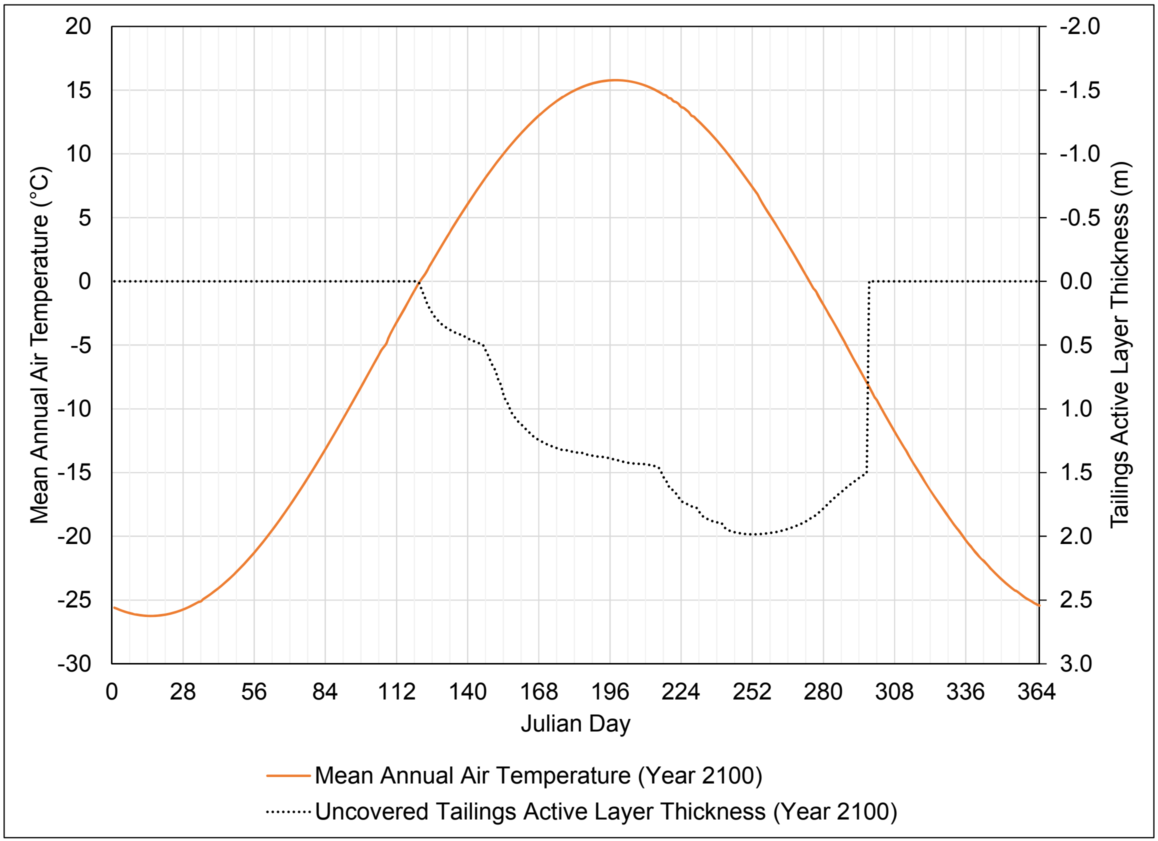

Figure 3. Air Temperature and Active Layer Thickness of Tailings

3.4 Tailings Saturation in the Active Layer

Combining the active layer thickness and the climatic water balance information on an annual timeline facilitates an understanding on the potential saturation state of the tailings surface. This is illustrated in Figure 4. As soon as the active layer develops there is a potential for desaturation of the profile which will lead to oxidation. Based on the evolution of the active zone thickness, desaturation as a result of the net negative climatic water balance can occur from day 122 to day 217. At that time, although the active layer is still increasing in thickness, the climatic water balance turns to net positive and as a result the profile starts to re-saturate. However, by day 273 the ground surface is once again frozen (although the active layer beneath still persists) and this surface freezing effectively seals off the surface to any further infiltration and subsequent re-saturation.

Equation (1) allows for calculation of this state of saturation based on a monthly time step, and the maximum level of desaturation over this period is defined as the expected depth of oxidation. Equation (2), is the same calculation, but considers a saturation level of 85%, as that is recognized as the state of oxidation beyond which further oxidation would be negligible.

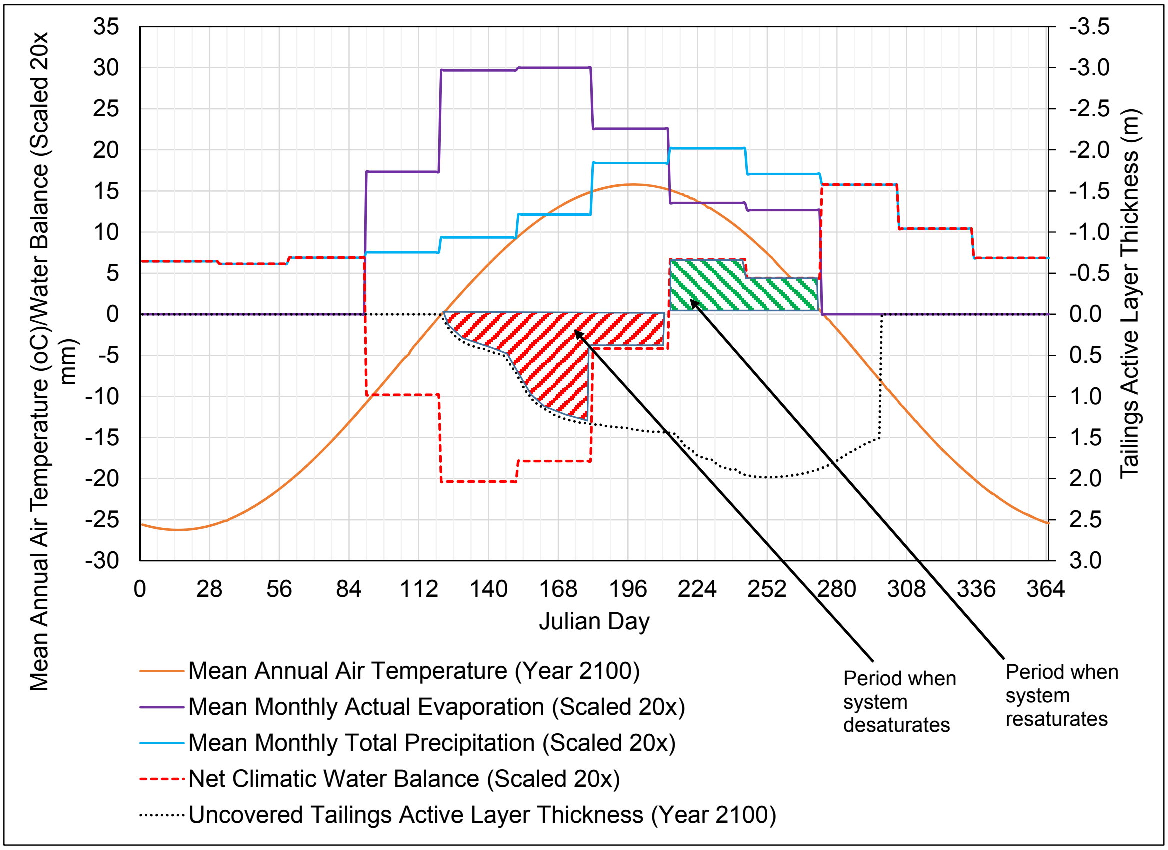

Figure 4: Yearly Evolution of Tailings Saturation in the Active Layer

4 Results

The calculated maximum oxidation depth calculation results are summarized in Table 3. As a result of climate change the maximum oxidation depth increases over time, and ranges from about 10 to 40 cm in depth depending on the conditions assessed. Based on these calculations, the appropriate depth of oxidation to use in tailings source load predictions is about 3 cm; however, conservatively a value of 10 cm is recommended.

At closure, the tailings will be covered with a coarse rock cover. Due to the coarse grained nature of the rock cover, the evaporation form the tailings surface will be reduced and as a result there will be more water available to saturate the tailings surface. In addition, by the year 2100 precipitation is expected to increase substantially due to climate change. The net result is that the depth of oxidation in the tailings will be about 5 cm with a rock cover in place.

Table 3: Calculated Maximum Oxidation Depth

Scenario	Material Properties	Tailings Covered	Cover Evaporation Reduction	Sublimation	Year 2015		Year 2100	
Degree of Saturation					100%	85%	100%	85%
Base Case	Average	No	n/a	50%	2.4	2.9	14.3	16.9
Scenario #1	Average	No	n/a	25%	2.4	2.9	17.5	20.5
Scenario #2	Minimum	No	n/a	50%	1.9	2.3	11.6	13.7
Scenario #3	Maximum	No	n/a	50%	12.8	15.0	32.5	38.3
Scenario #4	Average	Yes	40%	50%	0.0	0.0	4.6	5.4
Scenario #5	Maximum	Yes	40%	50%	6.0	7.0	21.6	25.4
Scenario #6	Maximum	Yes	40%	25%	6.0	7.0	21.6	25.4
Scenario #7	Maximum	Yes	20%	50%	9.4	11.0	27.1	31.9

5 References

SRK Consulting (Canada) Inc. 2016a. Hope Bay Project, Geotechnical Design Parameters and Overburden Summary Report. Report prepared for TMAC Resources Inc. Project No.: 1CT022.004. 2016

SRK Consulting (Canada) Inc., 2016b. Hope Bay Project: Doris, Madrid, and Boston Tailings Geotechnical Properties. Technical memorandum prepared for TMAC Resources Inc. SRK Project No: 1CT022.004. 2016.

SRK Consulting (Canada) Inc. 2016c. Hope Bay Project Climate and Hydrological Parameters Summary. Report prepared for TMAC Resources Inc. Project No.: 1CT022.004. 2016

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SRK Consulting (Canada) Inc. 2016e. Hope Bay Project: Phase 2 Doris Tailings Impoundment Area South and West Dams Thermal Modeling. Memo prepared for TMAC Resources Inc. Project No.: 1CT022.004. 2016

SRK Consulting (Canada) Inc. 2016f. Hope Bay Project: Contact Water Pond Berms Thermal Modeling. Memo prepared for TMAC Resources Inc. Project No.: 1CT022.004. 2016

Appendix D – Site-Specific Scaling Factors

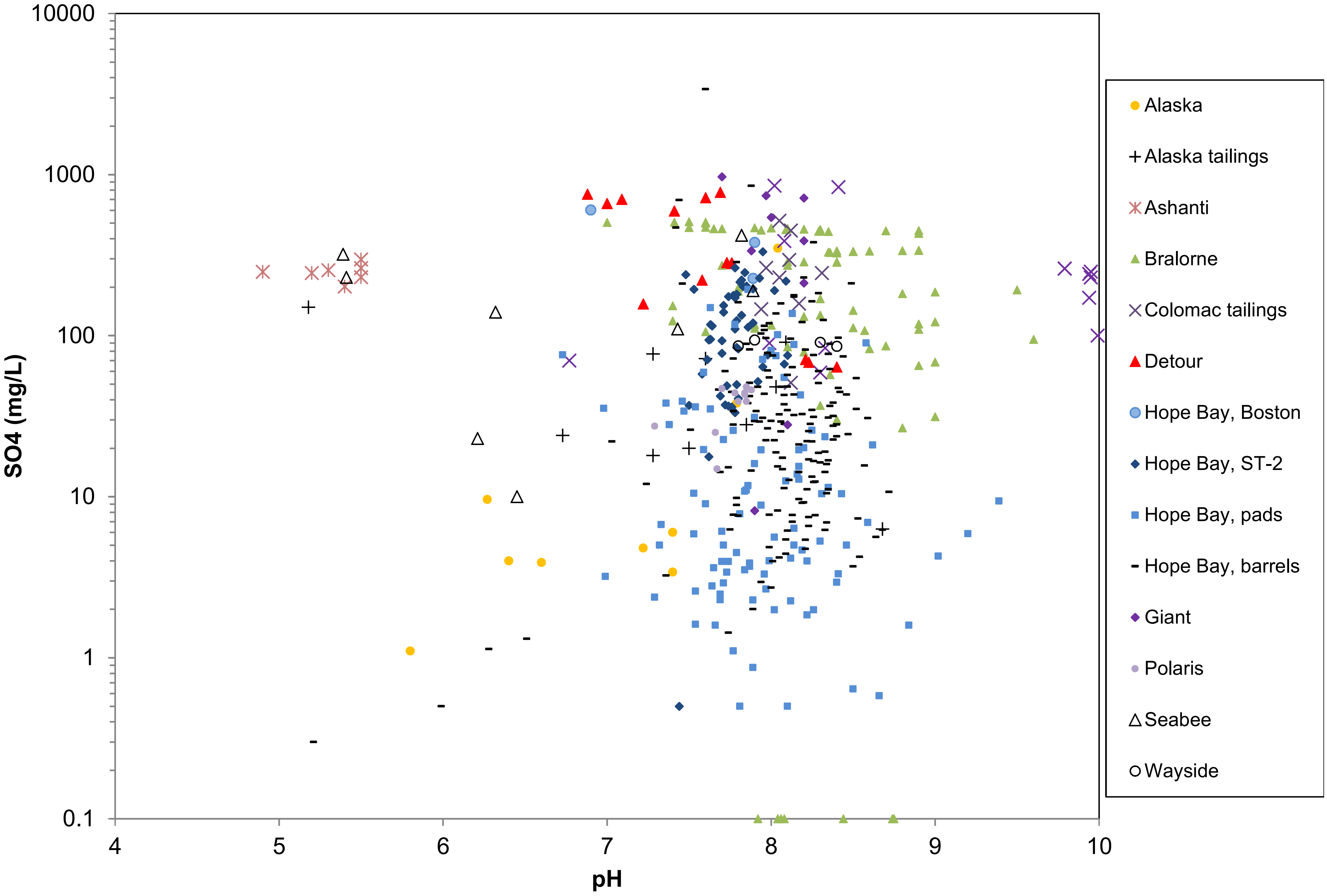
Appendix D:
Site-Specific Scaling Factors

HC ID	Rock Type	SO4	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Li	Mg	Mn	Hg	Mo	Ni	Se	Ag	Tl	U	V	Zn	Alkalinity	F
HC-7	1	0.24	0.01	0.017	0.015	0.61	0.037	0.023	0.026	0.19	0.091	0.17	0.039	0.14	0.012	0.39	0.045	0.24	0.017	0.17	0.14	0.046	0.0024	0.053	0.088	0.031	0.077	0.011	0.033
HC-42	1	0.2	0.004	0.037	0.012	0.74	0.1	0.017	0.065	0.24	0.12	0.47	0.046	0.11	0.028	0.69	0.11	0.12	0.021	0.13	0.24	0.054	0.0047	0.1	0.28	0.031	0.16	0.018	0.056
HC-43	1	0.19	0.01	0.06	0.0069	0.89	0.22	0.016	0.073	0.21	0.14	0.73	0.068	0.33	0.027	0.45	0.048	0.29	0.039	0.16	0.19	0.12	0.0092	0.22	0.61	0.029	0.14	0.015	0.087
HC-49	1	0.23	0.0021	0.0082	0.0088	0.89	0.12	0.014	0.065	0.22	0.12	0.36	0.079	0.13	0.028	0.6	0.051	0.22	0.021	0.041	0.28	0.088	0.0055	0.12	0.34	0.022	0.097	0.012	0.071
HC-50	1	0.068	0.0063	0.0082	0.0019	0.71	0.16	0.015	0.07	0.18	0.1	0.07	0.068	0.23	0.019	0.63	0.057	0.17	0.023	0.079	0.32	0.11	0.0074	0.17	0.46	0.028	0.057	0.014	0.082
HC-46	10a	0.15	0.0065	0.035	0.0012	0.67	0.17	0.016	0.073	0.31	0.14	0.47	0.051	0.12	0.03	0.6	0.086	0.21	0.024	0.069	0.014	0.11	0.0076	0.18	0.58	0.029	0.19	0.02	0.073
HC-51	10a	0.088	0.011	0.0076	0.00075	1.4	0.3	0.016	0.08	0.17	0.15	0.055	0.085	1.1	0.0073	0.66	0.036	0.67	0.15	0.18	0.11	0.098	0.012	0.3	0.93	0.025	0.12	0.011	0.12
HC-65	10a	0.29	0.0017	0.011	0.0044	3.4	0.29	0.015	0.076	19	0.15	0.47	0.044	0.056	0.025	0.45	3.4	13	0.14	0.27	0.25	0.11	0.011	0.28	0.93	0.00068	0.057	0.033	0.082
HC-47	11c	0.18	0.0029	0.025	0.00054	0.74	0.11	0.015	0.065	0.37	0.12	0.44	0.034	0.029	0.027	0.72	0.24	1.2	0.022	0.055	0.22	0.075	0.0051	0.11	0.17	0.0016	0.058	0.015	0.065
HC-48	11c	0.16	0.0038	0.022	0.0021	1.2	0.12	0.014	0.065	0.42	0.12	0.38	0.033	0.033	0.016	0.56	0.17	1.9	0.022	0.13	0.25	0.05	0.0055	0.12	0.19	0.0014	0.097	0.018	0.065
HC-44	1 w. 12q	0.1	0.0043	0.041	0.0011	1	0.17	0.016	0.073	0.19	0.14	0.27	0.043	0.26	0.035	0.31	0.062	0.24	0.023	0.055	0.36	0.064	0.0074	0.17	0.53	0.026	0.31	0.014	0.062
HC-45	1 w. 12q	0.043	0.045	0.025	0.0018	0.96	0.29	0.015	0.076	0.23	0.13	0.055	0.073	0.25	0.028	0.63	0.062	0.27	0.038	0.051	0.076	0.091	0.012	0.29	1.7	0.027	0.042	0.02	0.12
HC-53	12q	0.27	0.058	0.041	0.0088	0.52	0.15	0.016	0.063	0.42	0.13	0.44	0.064	0.5	0.024	0.69	0.17	0.29	0.036	0.11	0.18	0.1	0.0066	0.15	0.46	0.027	0.088	0.027	0.078
HC-36	12q	0.027	0.12	0.055	0.011	1.2	0.27	0.014	0.073	0.19	0.14	0.23	0.049	0.54	0.021	0.6	0.041	0.82	0.028	0.06	0.2	0.091	0.011	0.27	0.32	0.025	0.047	0.015	0.072
HC-54	12q	0.14	0.027	0.013	0.012	0.52	0.29	0.016	0.07	0.17	0.14	0.34	0.057	0.45	0.038	0.66	0.066	0.37	0.04	0.06	0.12	0.11	0.011	0.28	0.61	0.025	0.085	0.015	0.095
HC-52	12q	0.056	0.042	0.027	0.0075	0.74	0.3	0.016	0.08	0.22	0.15	0.71	0.057	0.69	0.046	0.66	0.072	1.3	0.025	0.08	0.2	0.15	0.011	0.3	1.2	0.025	0.069	0.018	0.12
HC-6	7a mixed	0.22	0.0056	0.019	0.012	1	0.04	0.025	0.029	0.19	0.093	0.18	0.035	0.1	0.016	0.5	0.051	0.54	0.017	0.13	0.12	0.046	0.0024	0.055	0.099	0.02	0.045	0.011	0.035

Notes:

Rock types: 1 - mafic metavolcanics, 7a - early gabbro, 10a - late gabbro, 11c - diabase, 12q - quartz vein

Appendix E – Analog Database Scatterplots



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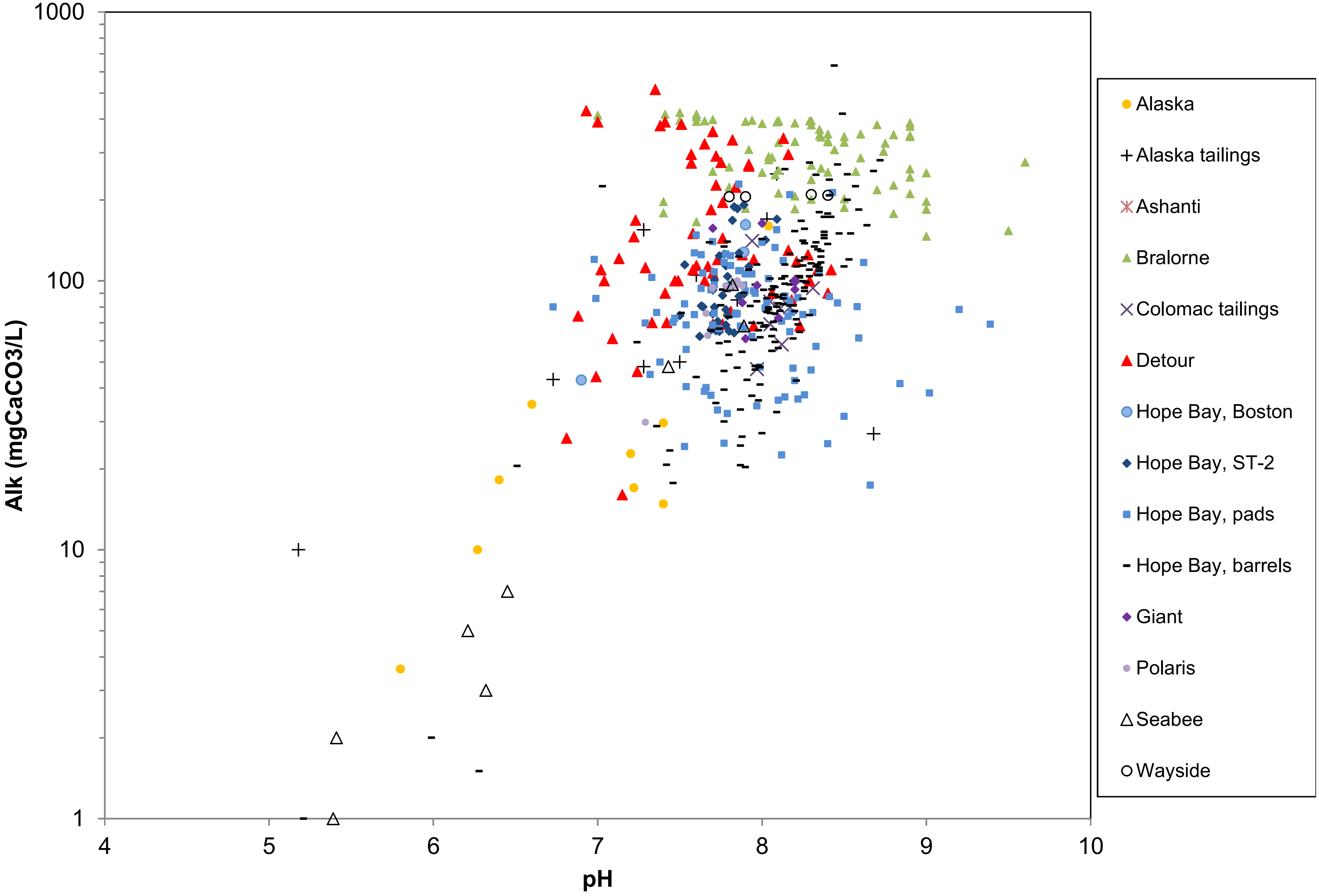
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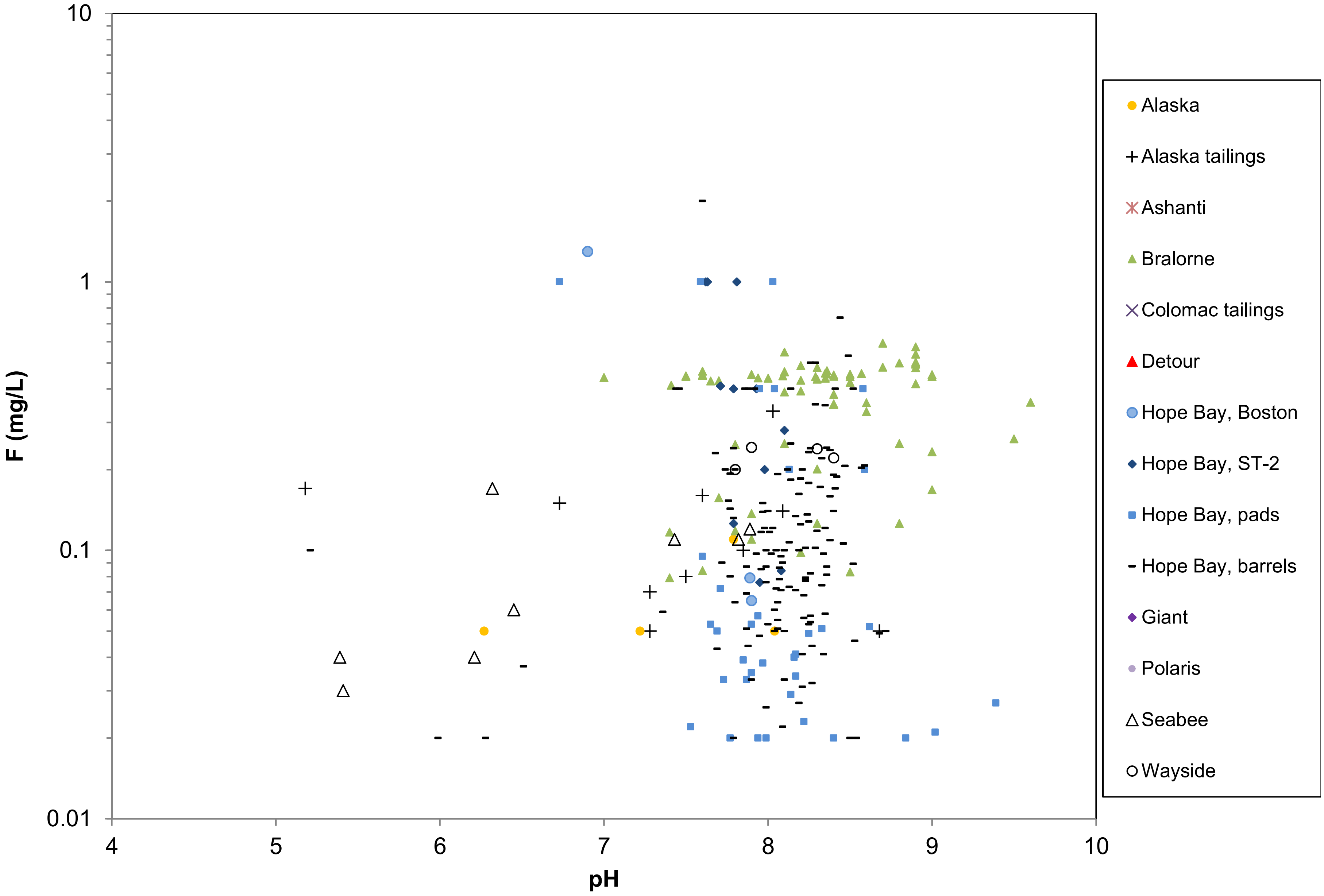
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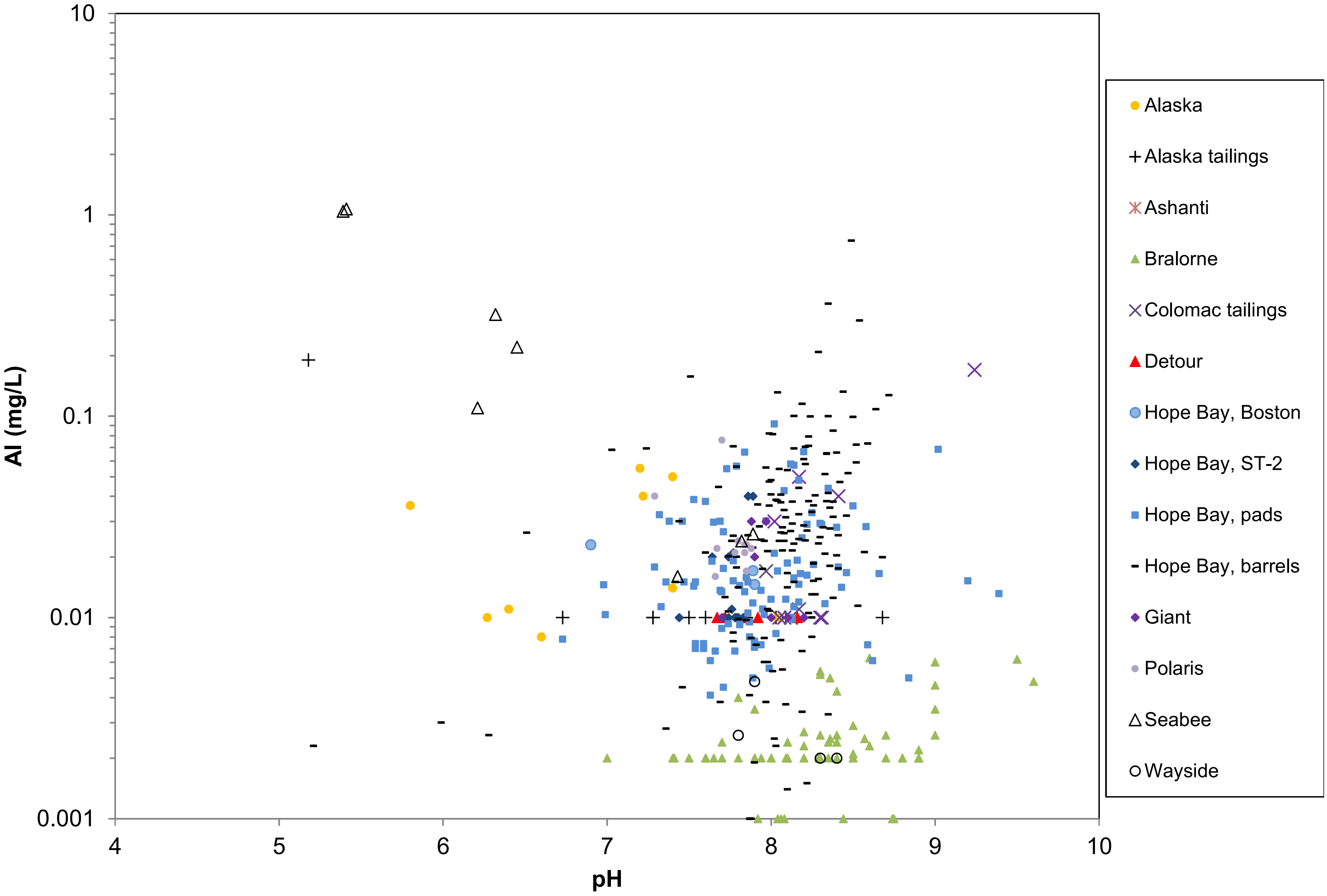
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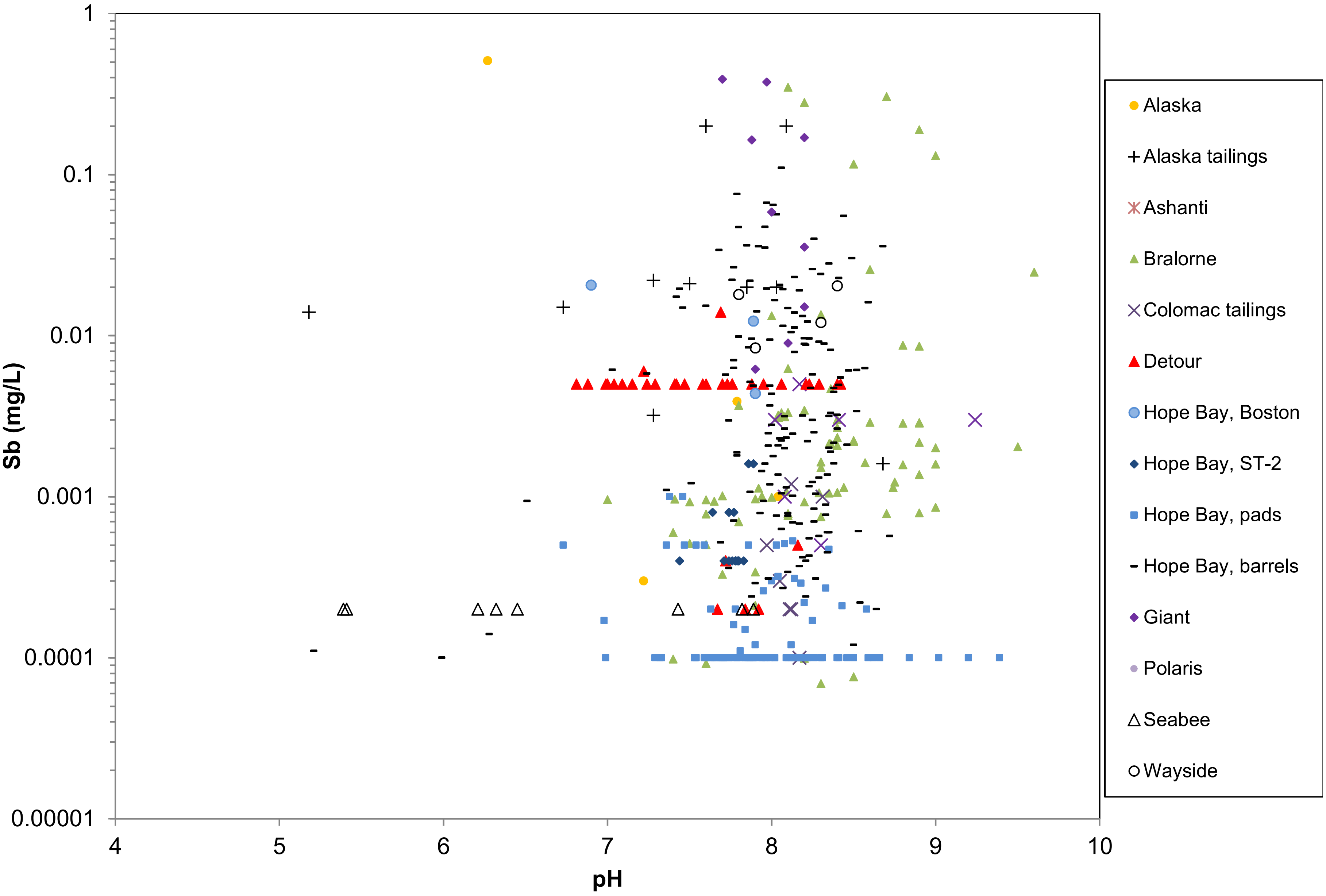
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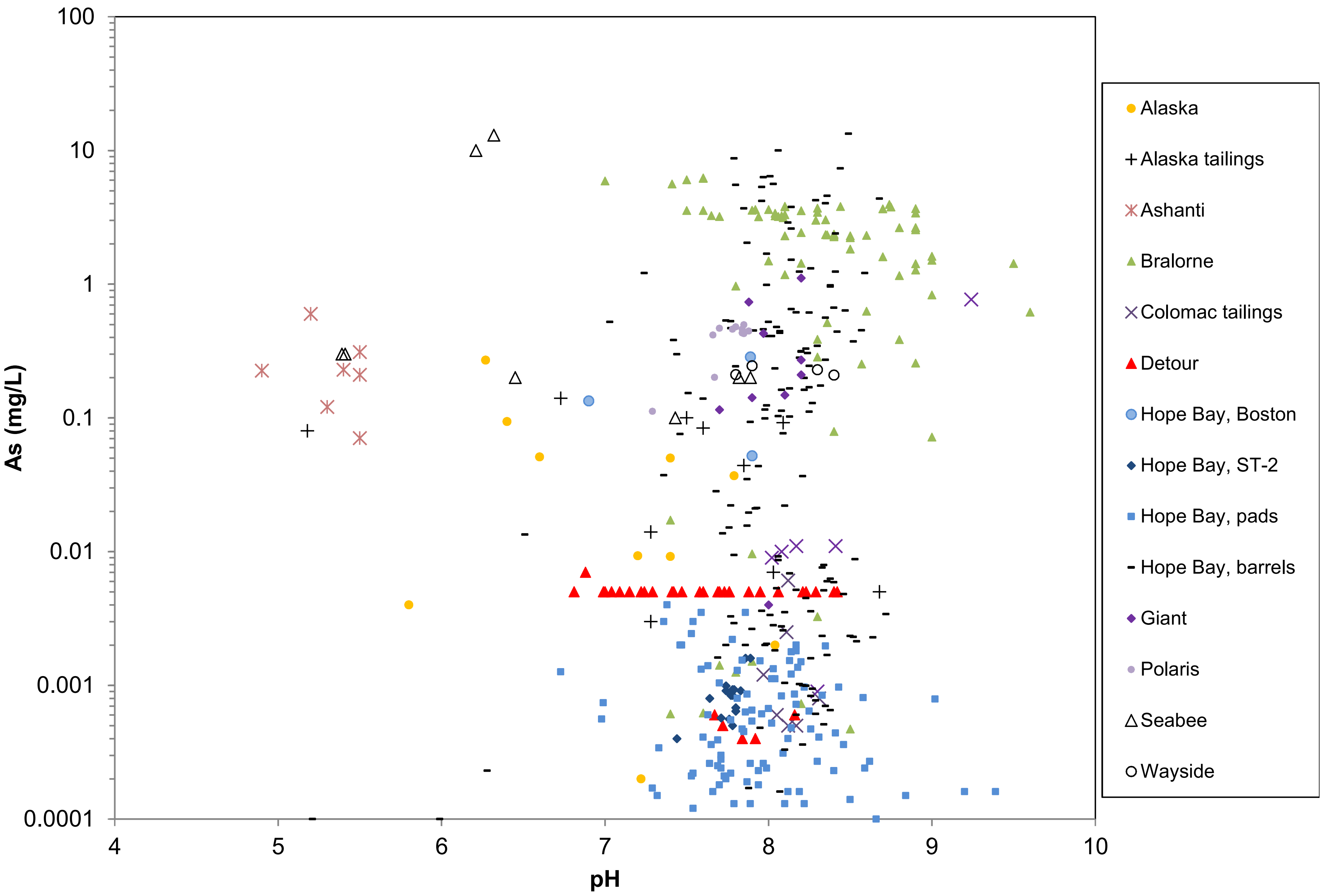
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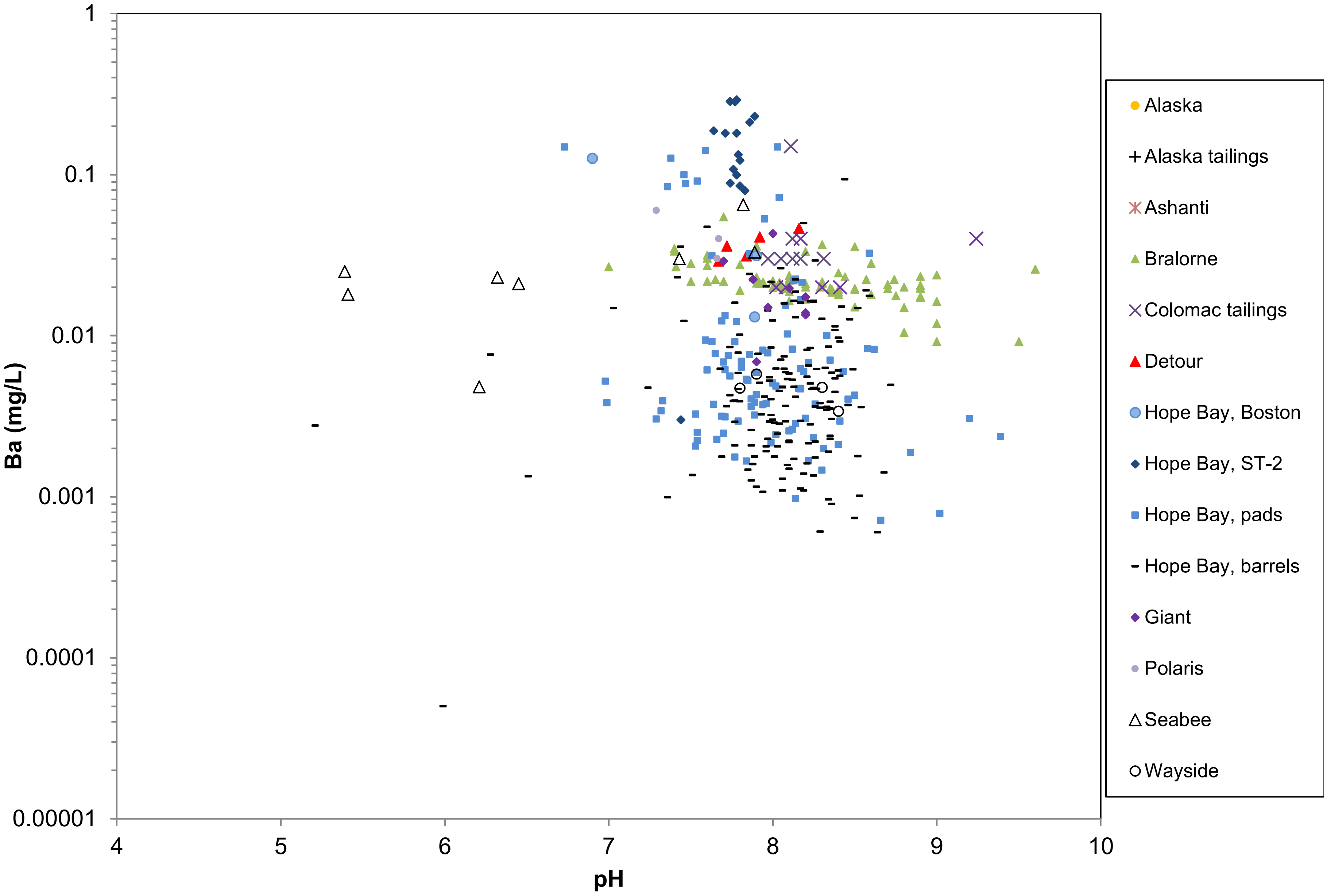
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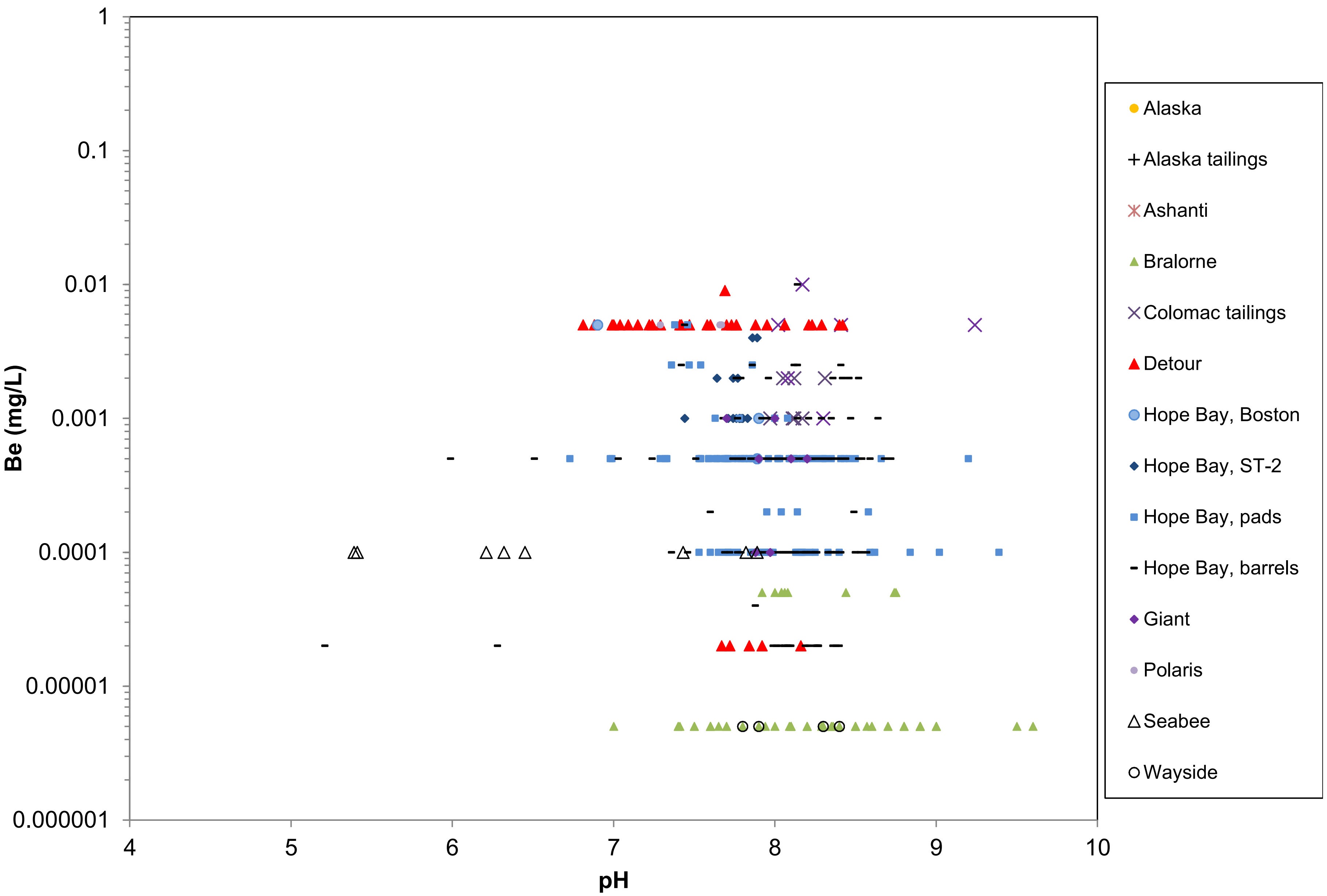

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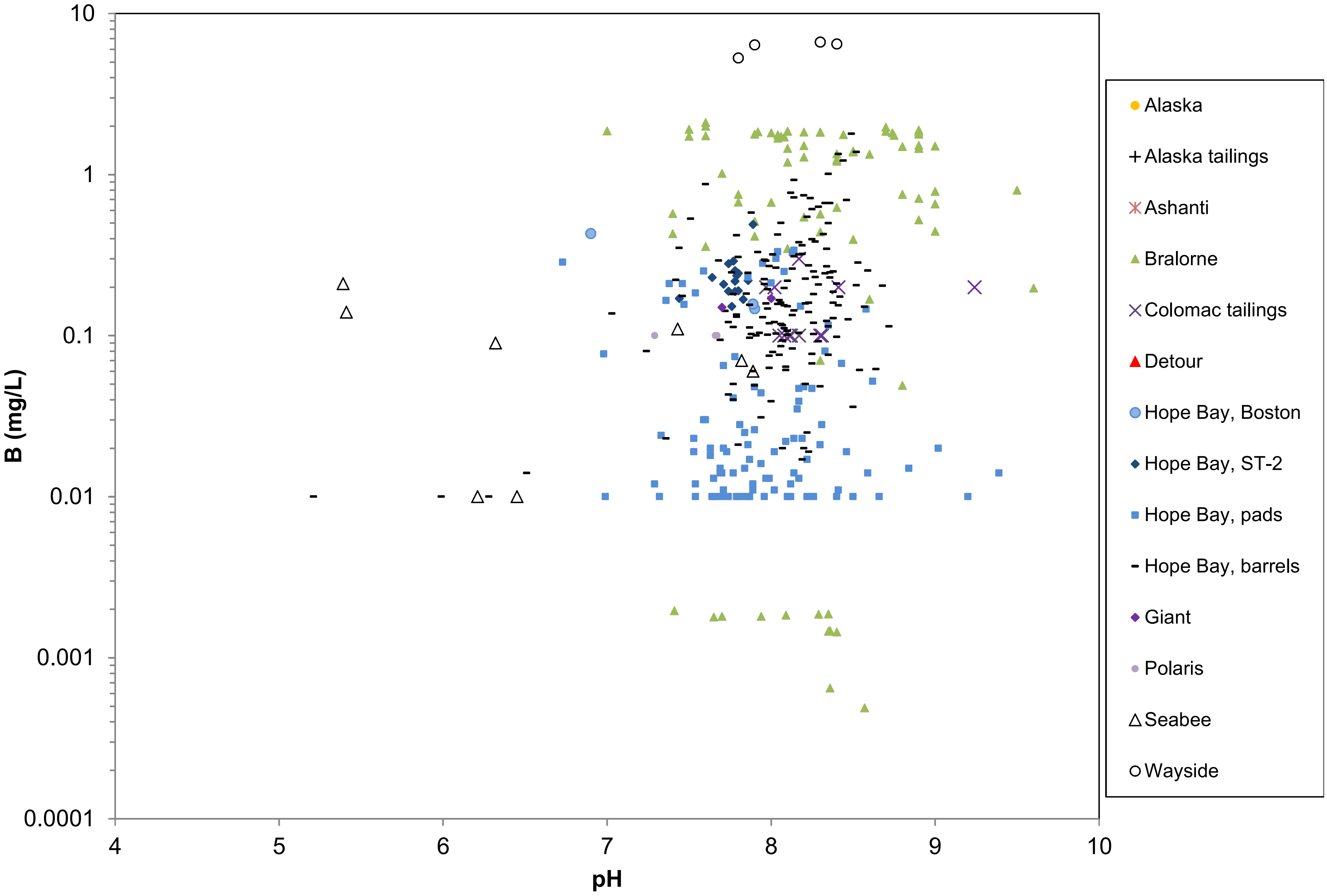
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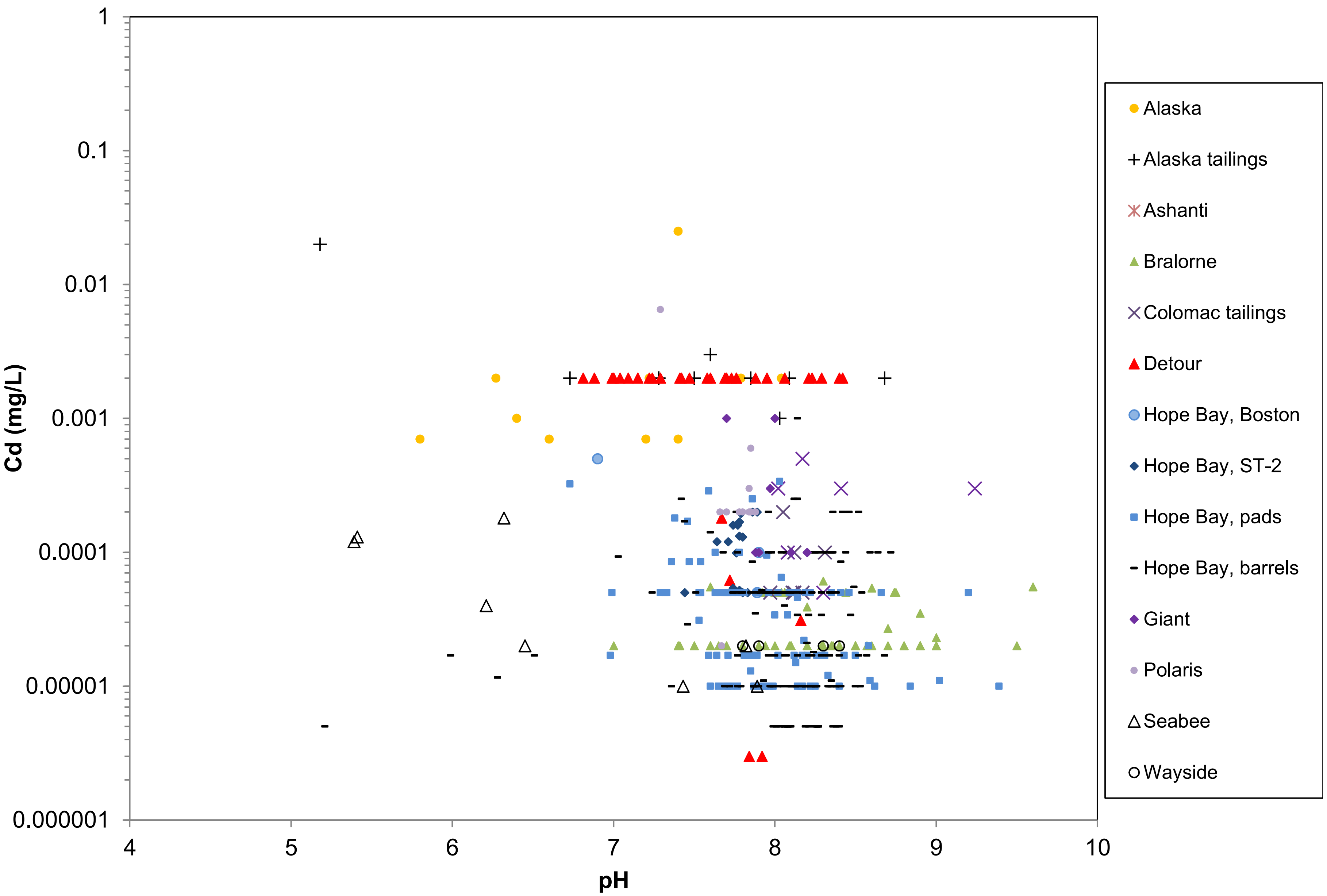

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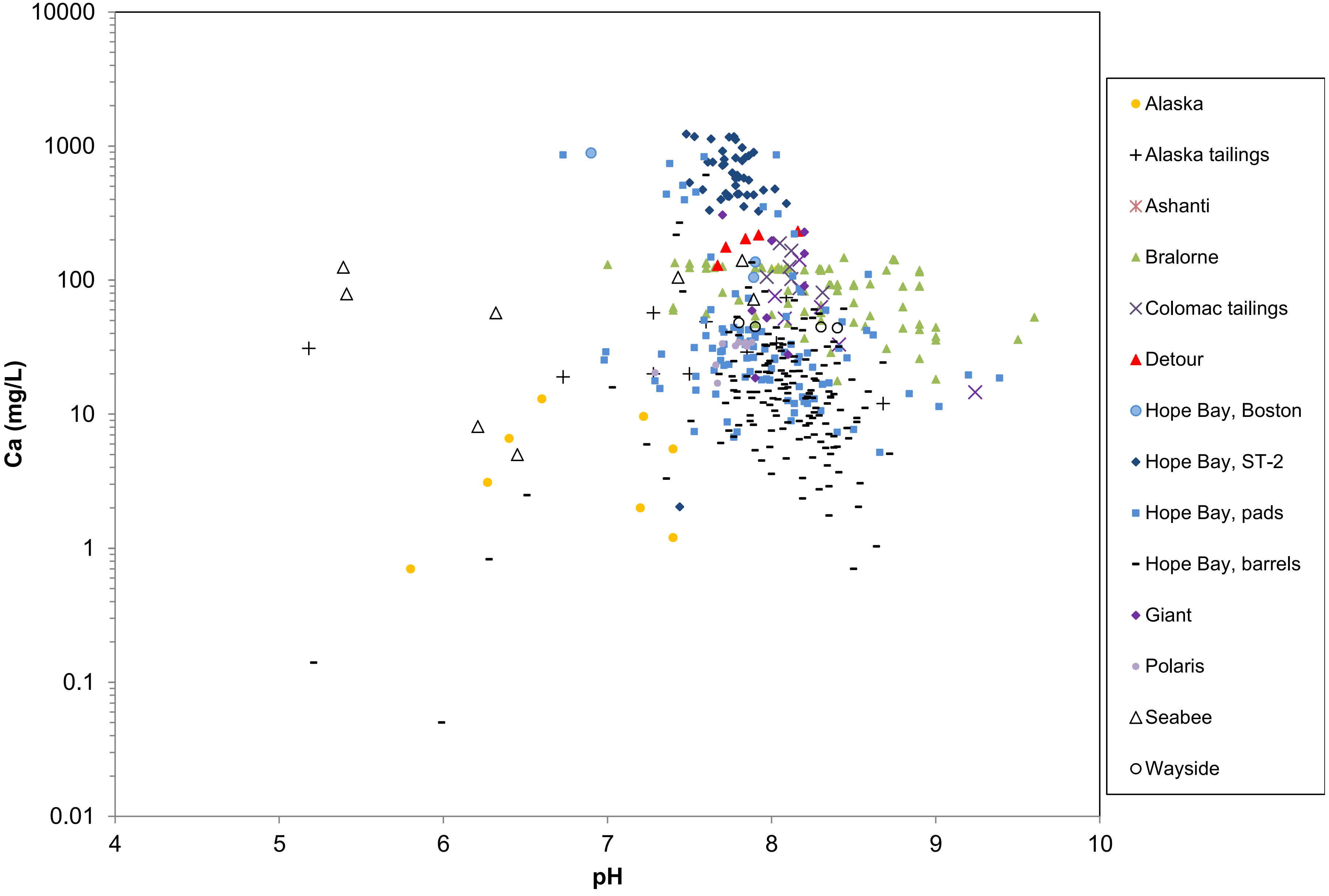

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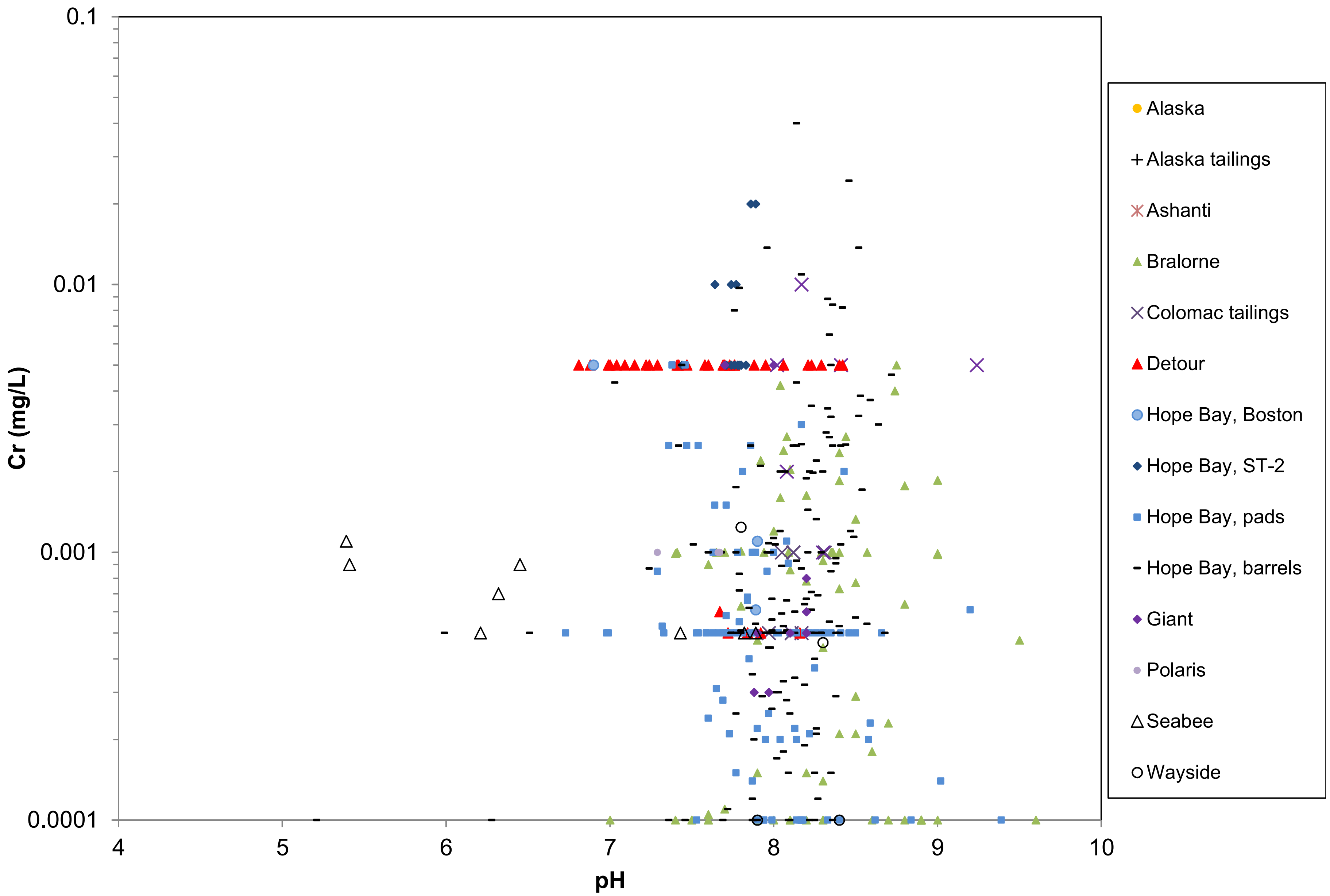

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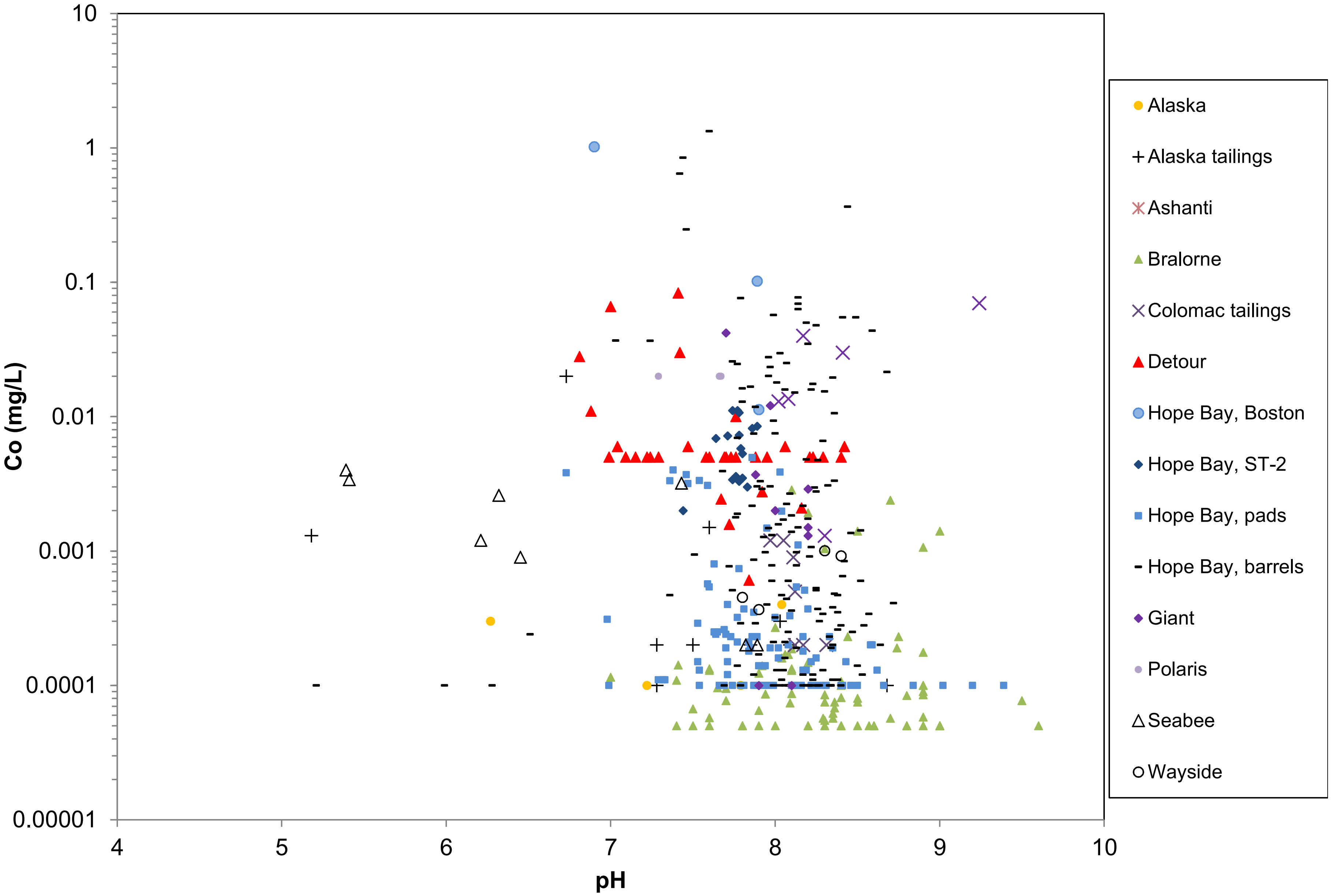

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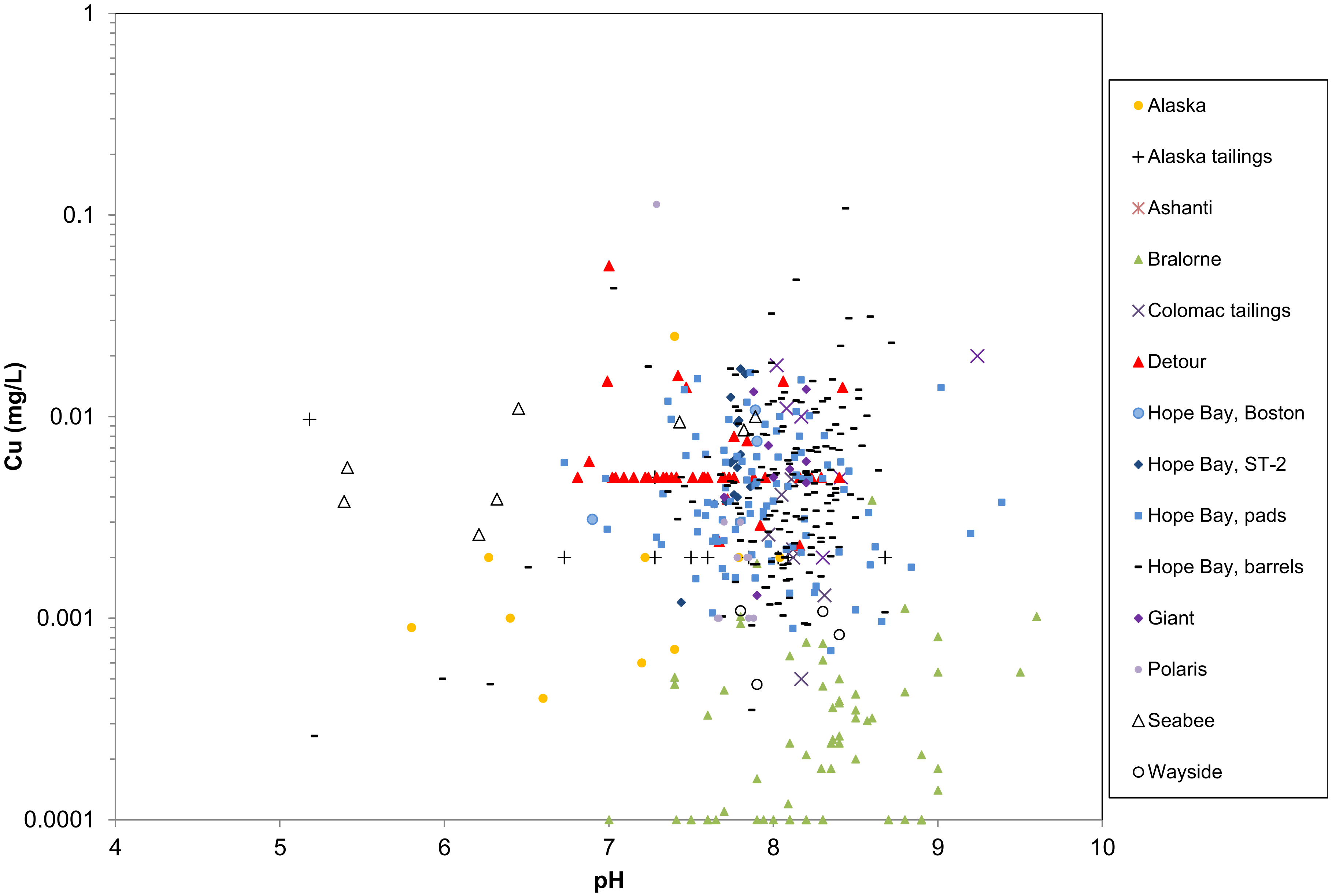
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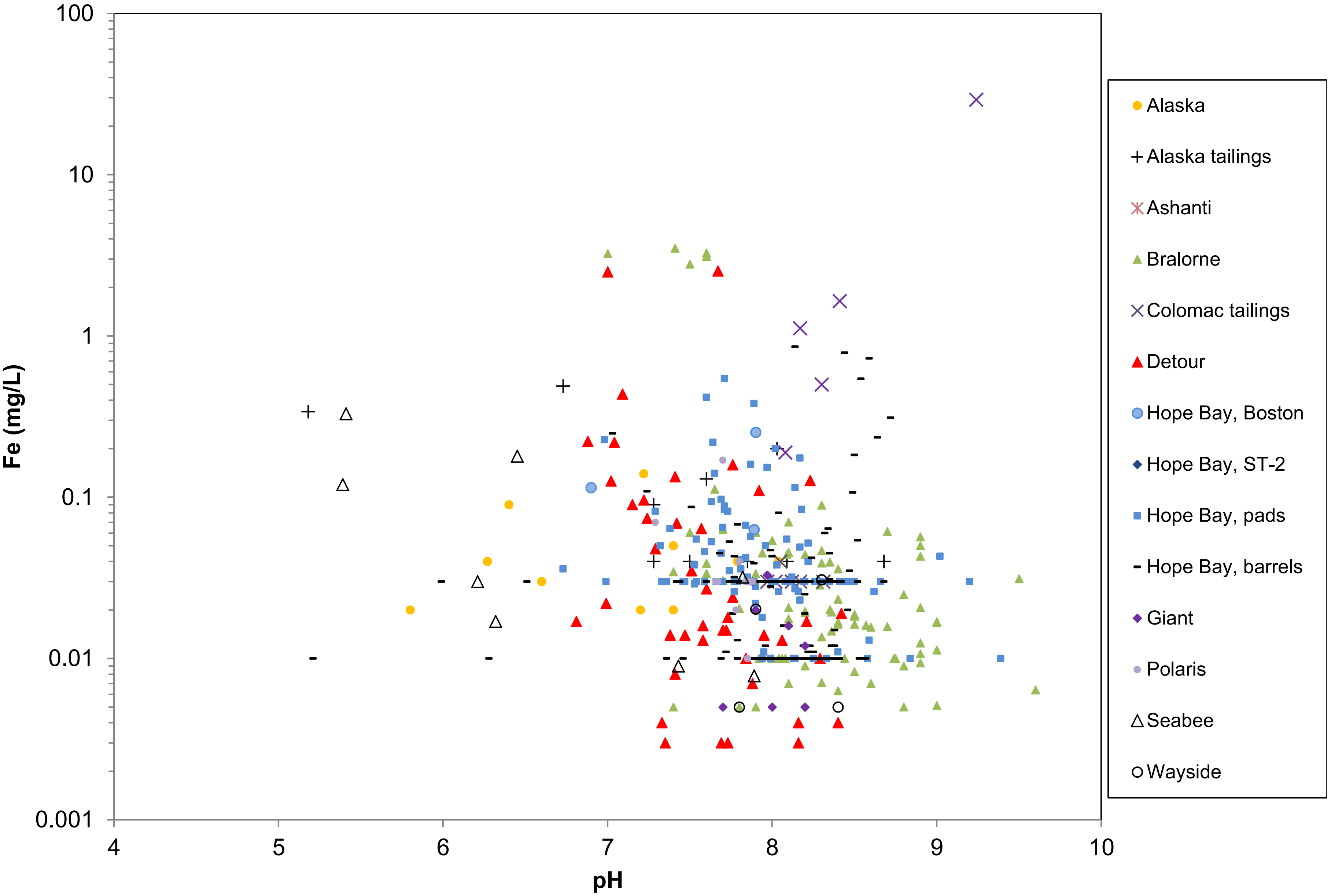

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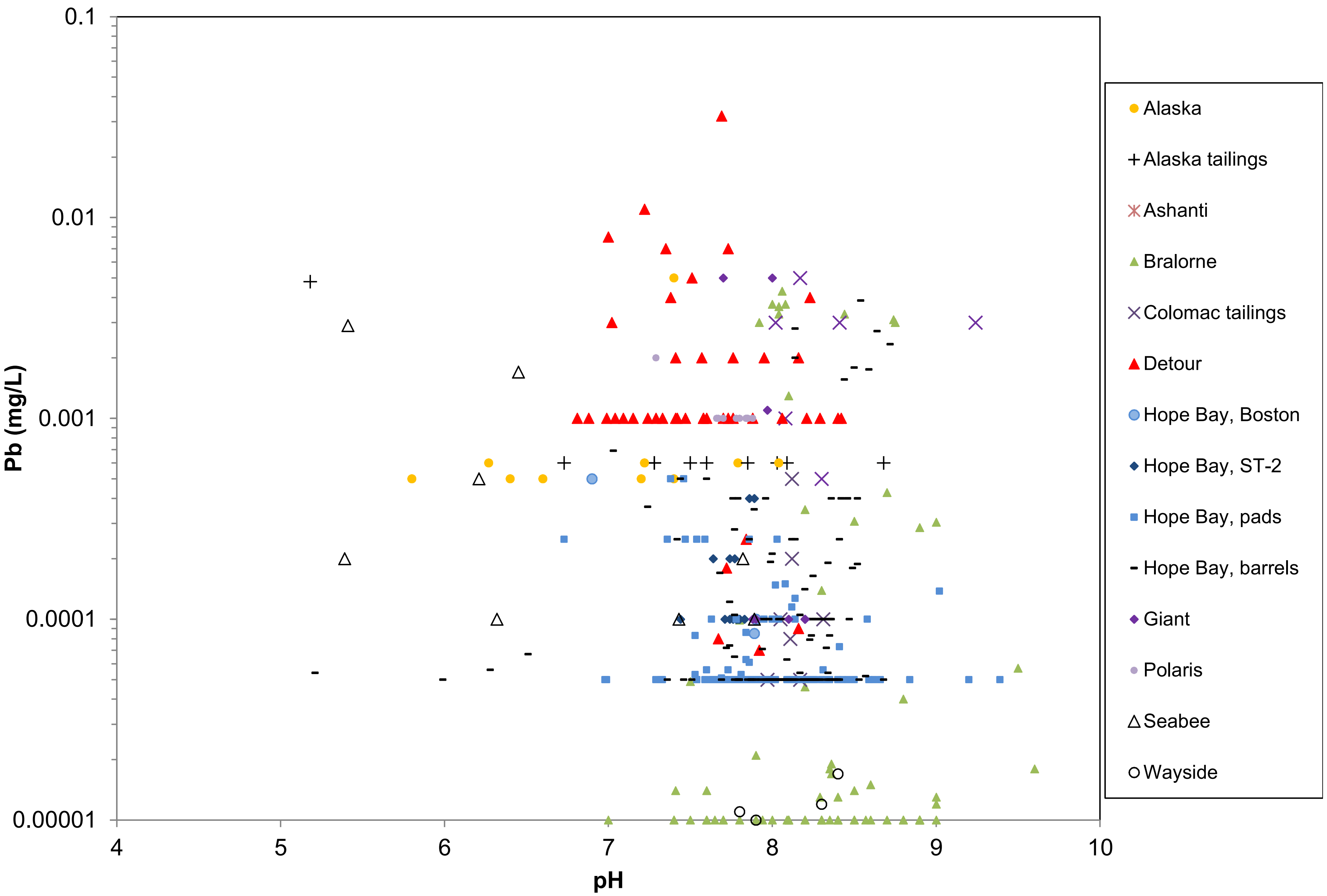

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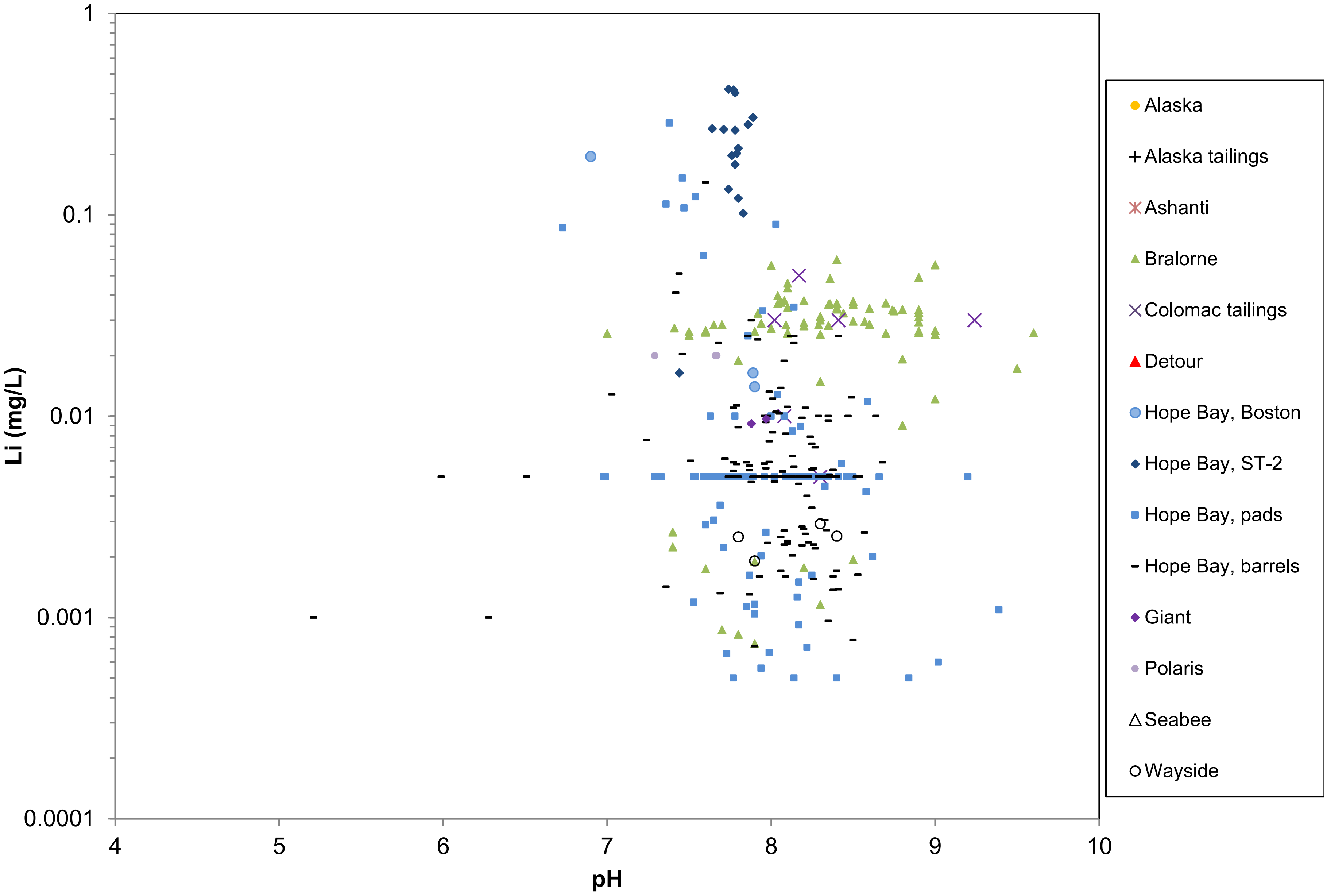
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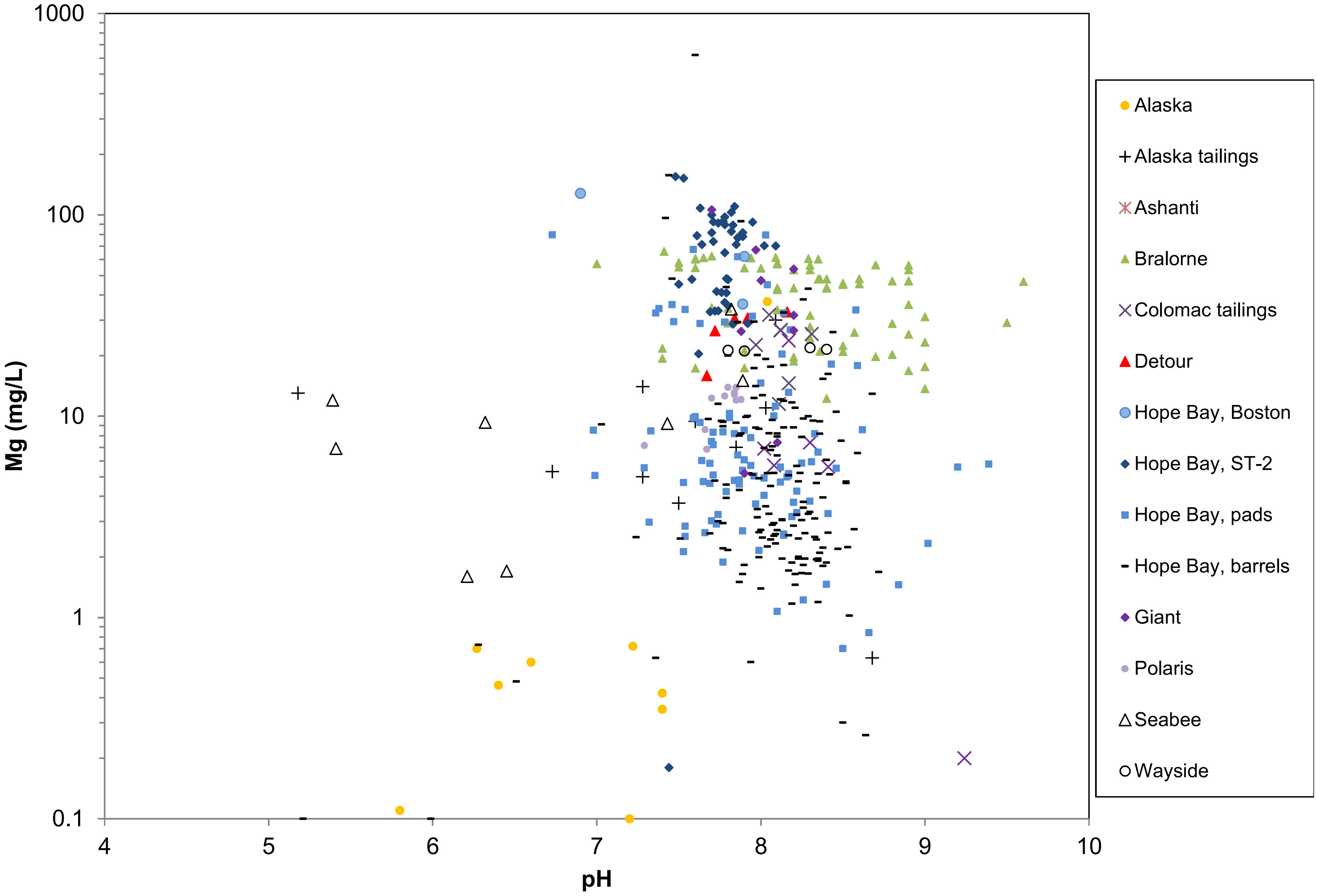
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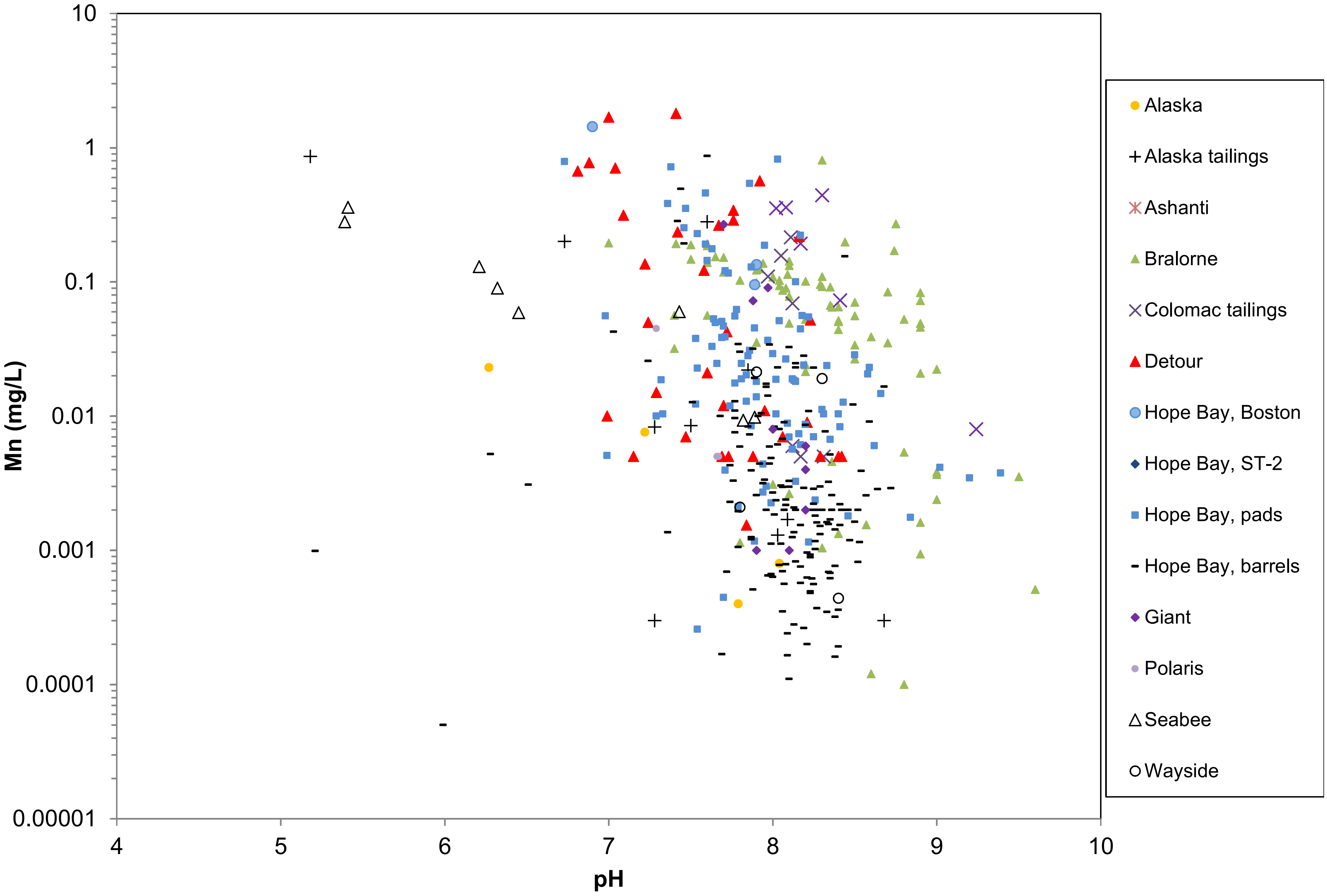
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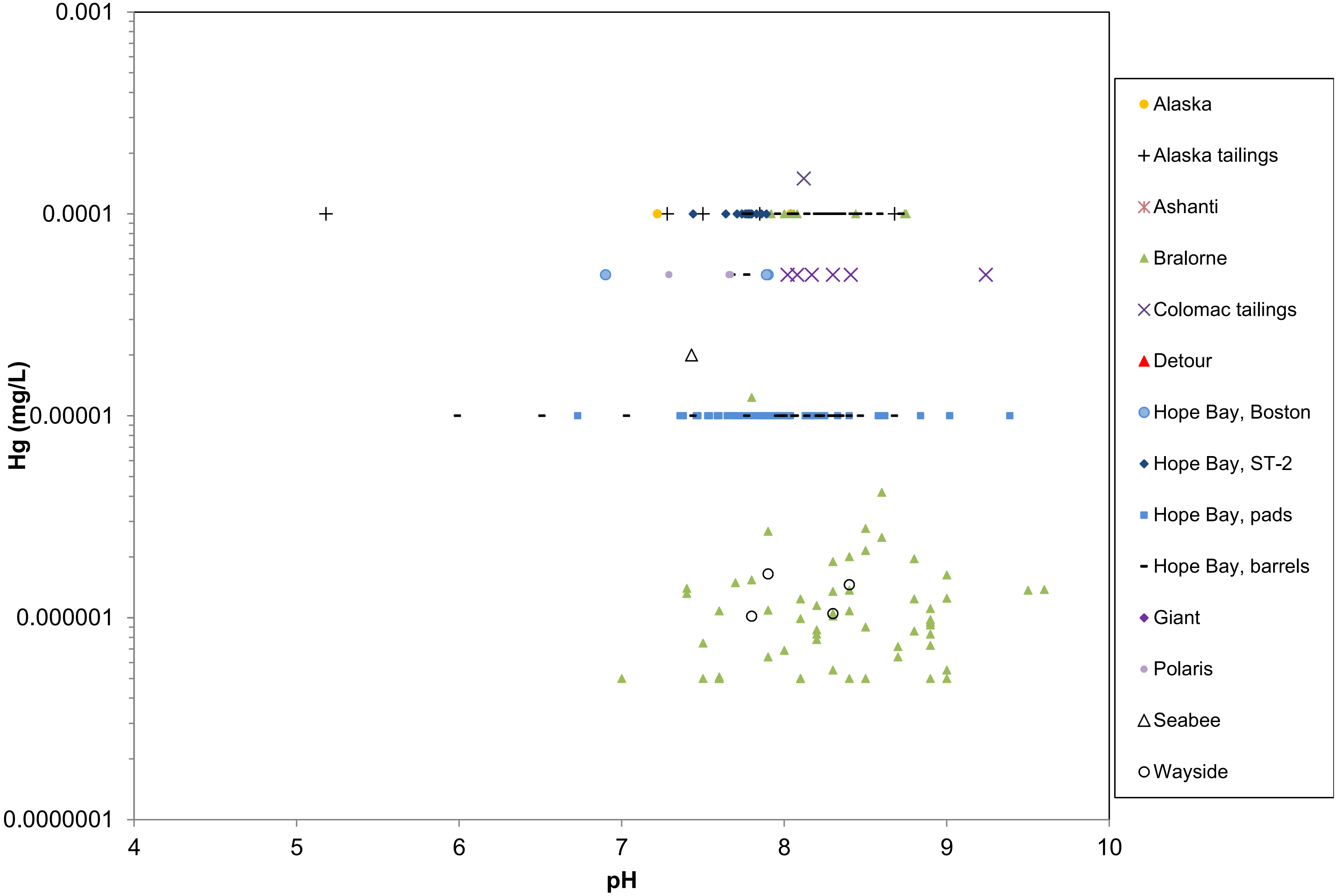

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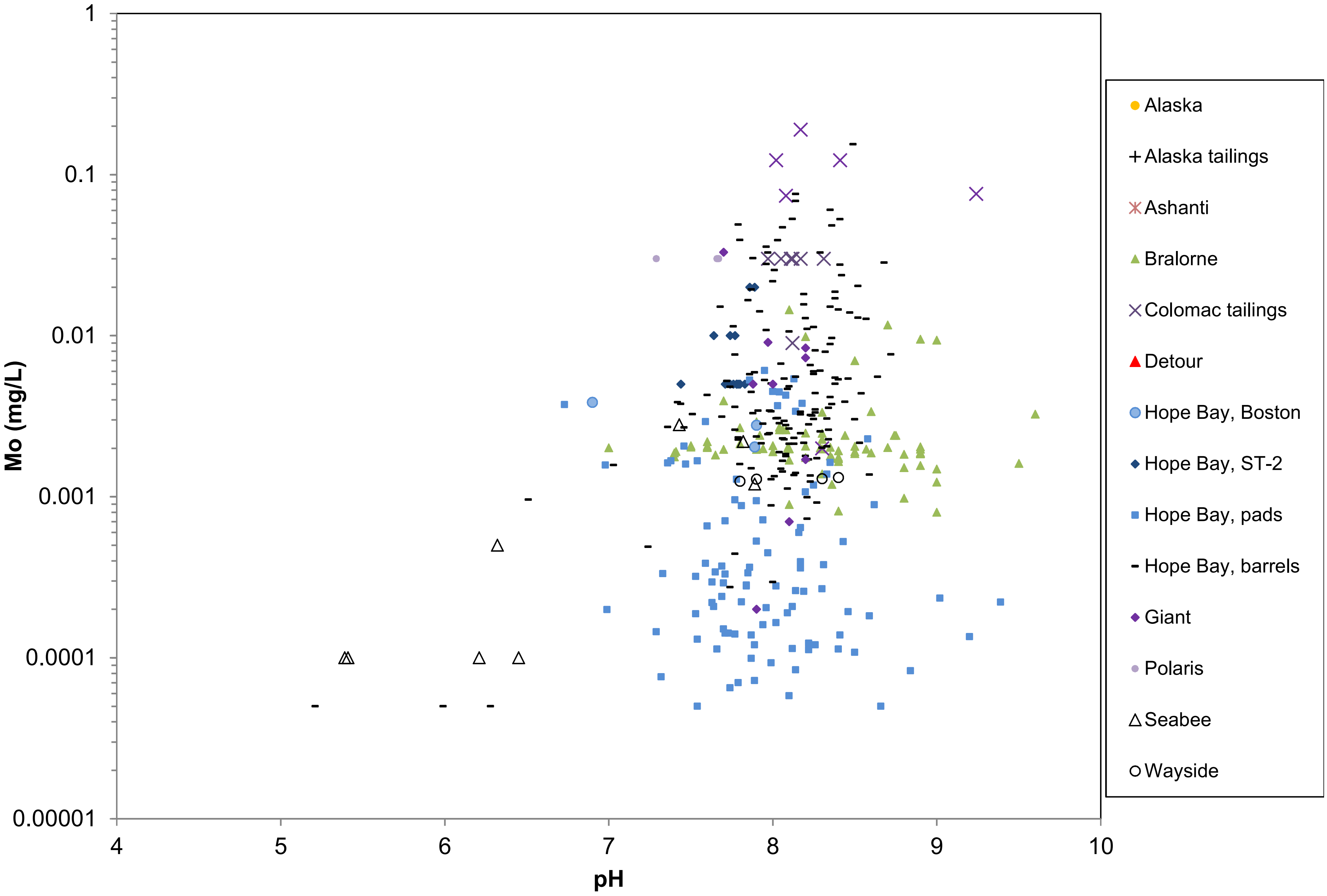
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× Colomac tailings
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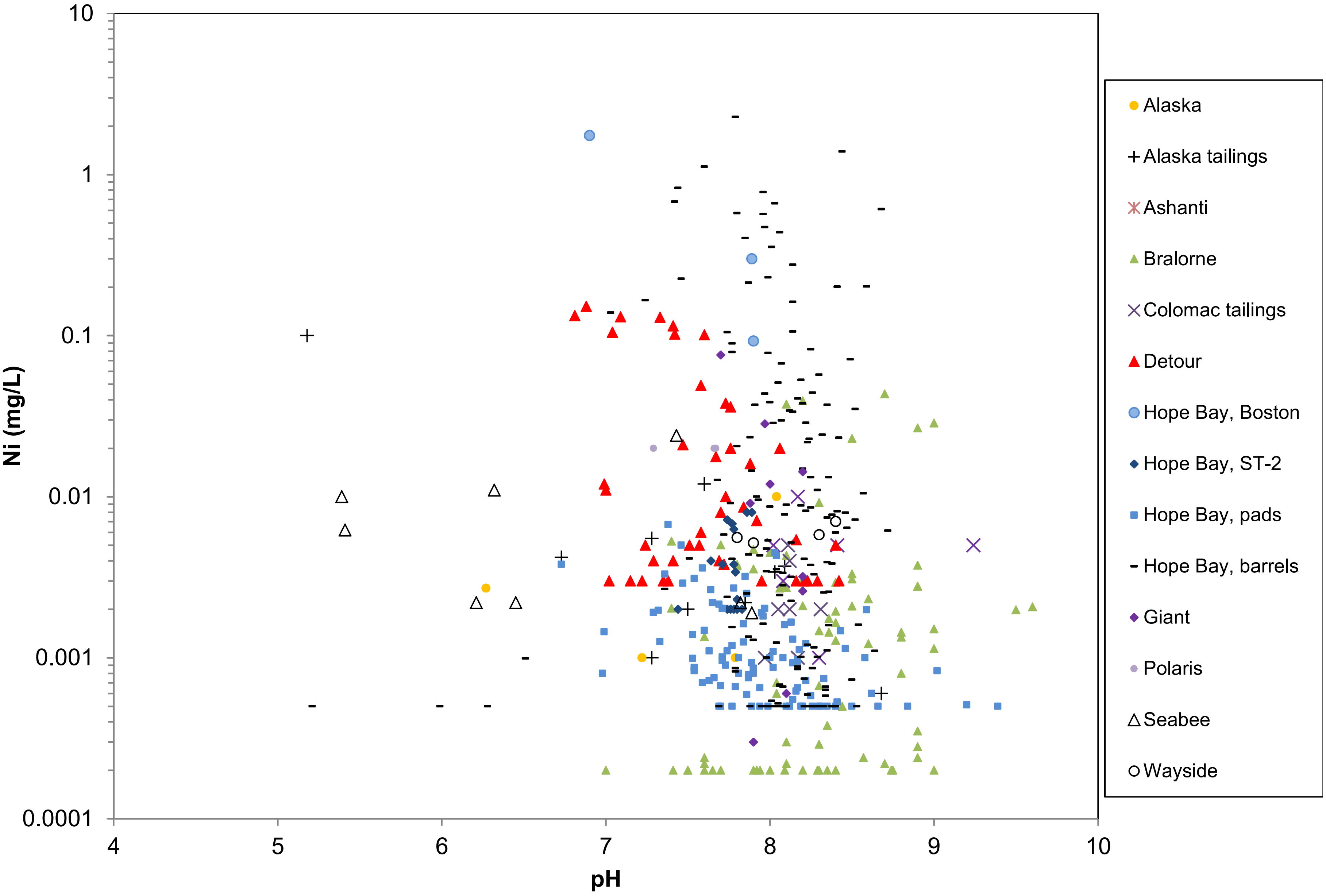
● Hope Bay, Boston
◆ Hope Bay, ST-2
■ Hope Bay, pads
- Hope Bay, barrels
◆ Giant
● Polaris
△ Seabee
○ Wayside



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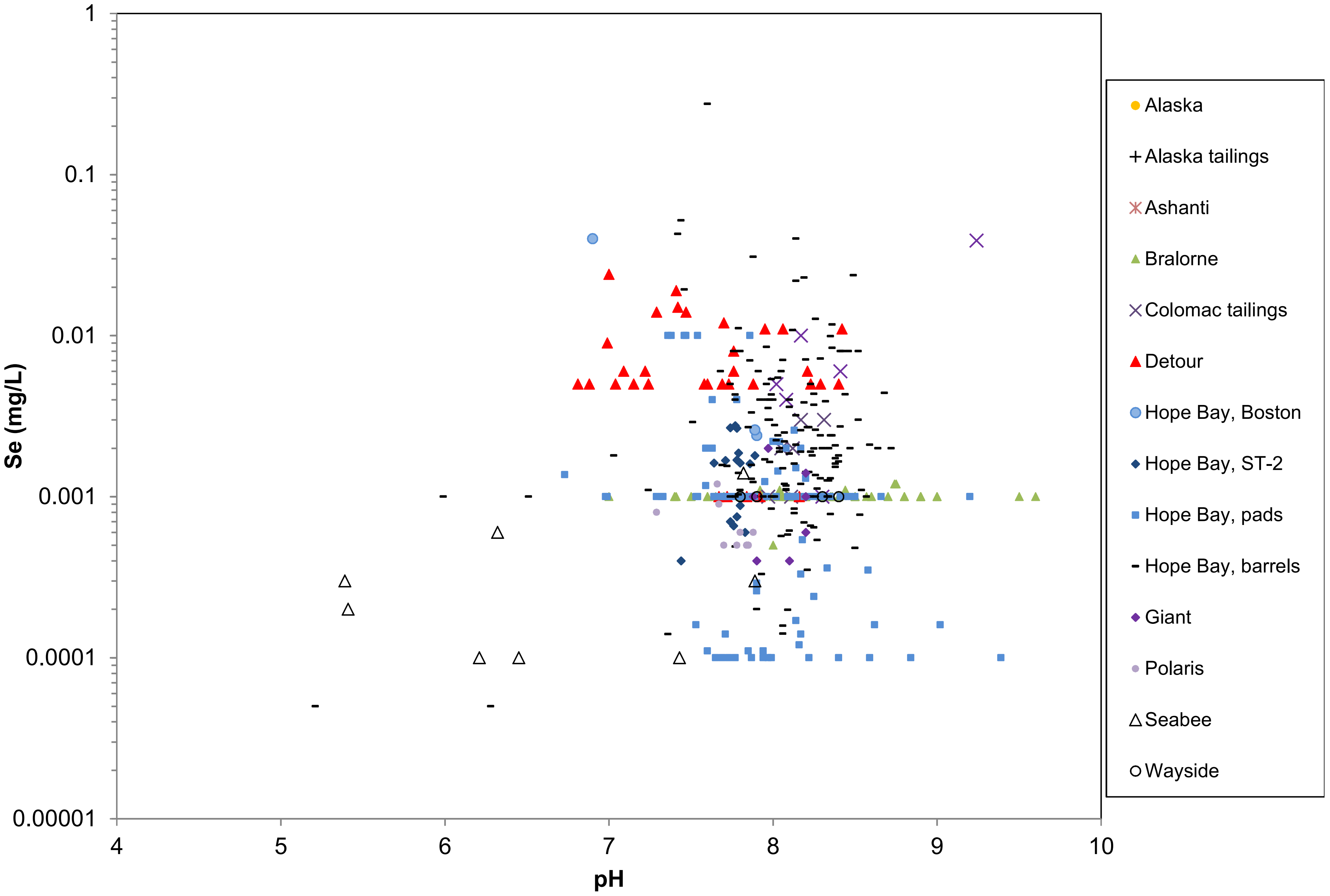
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Se (mg/L)
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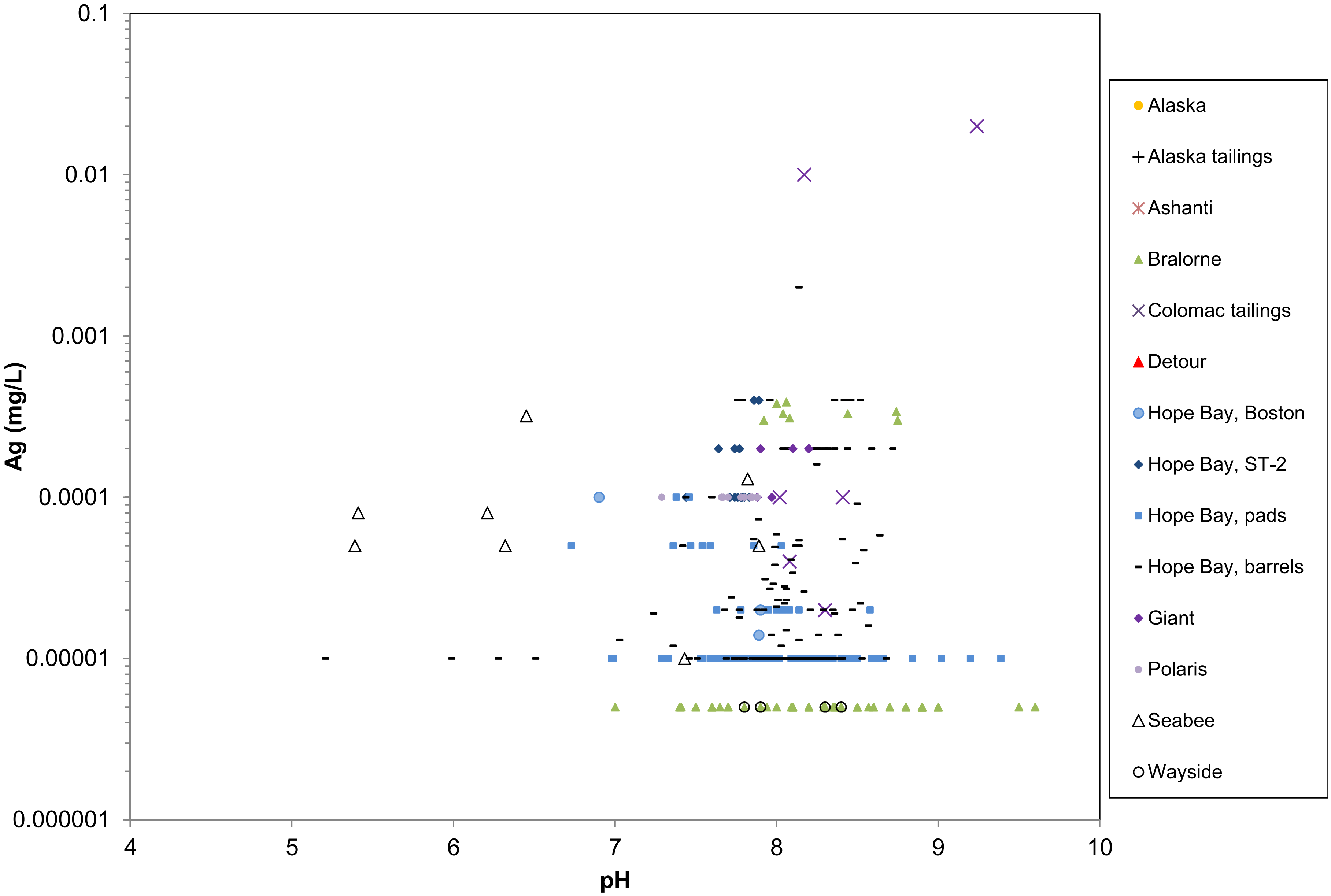
pH
Alaska
Alaska tailings
Ashanti
Bralorne
Colomac tailings
Detour
Hope Bay, Boston
Hope Bay, ST-2
Hope Bay, pads
Hope Bay, barrels
Giant
Polaris
Seabee
Wayside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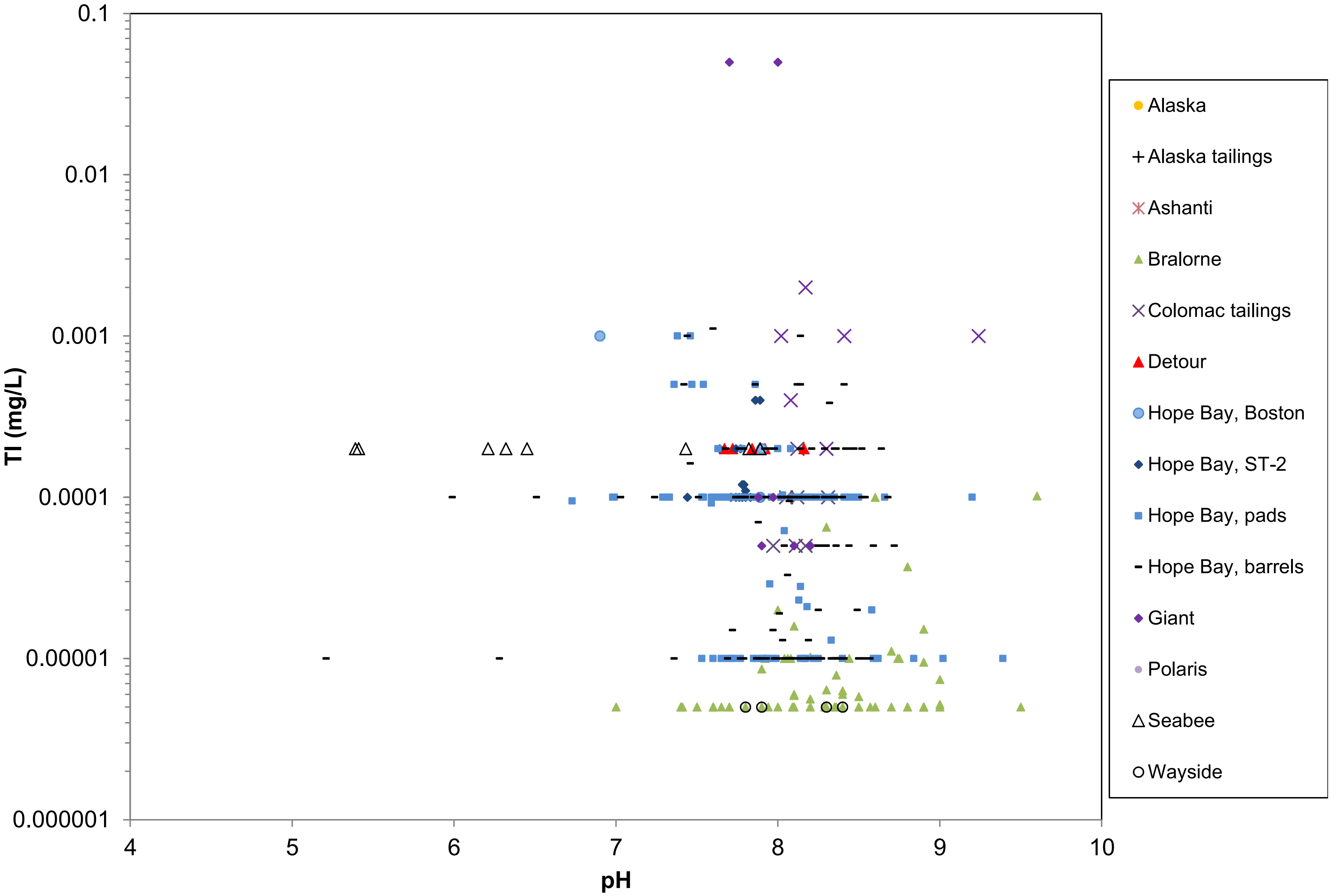
pH
● Alaska
+ Alaska tailings
✳ Ashanti
▲ Bralorne
× Colomac tailings
▲ Detour
● Hope Bay, Boston
◆ Hope Bay, ST-2
■ Hope Bay, pads
- Hope Bay, barrels
◆ Giant
● Polaris
△ Seabee
○ Wayside



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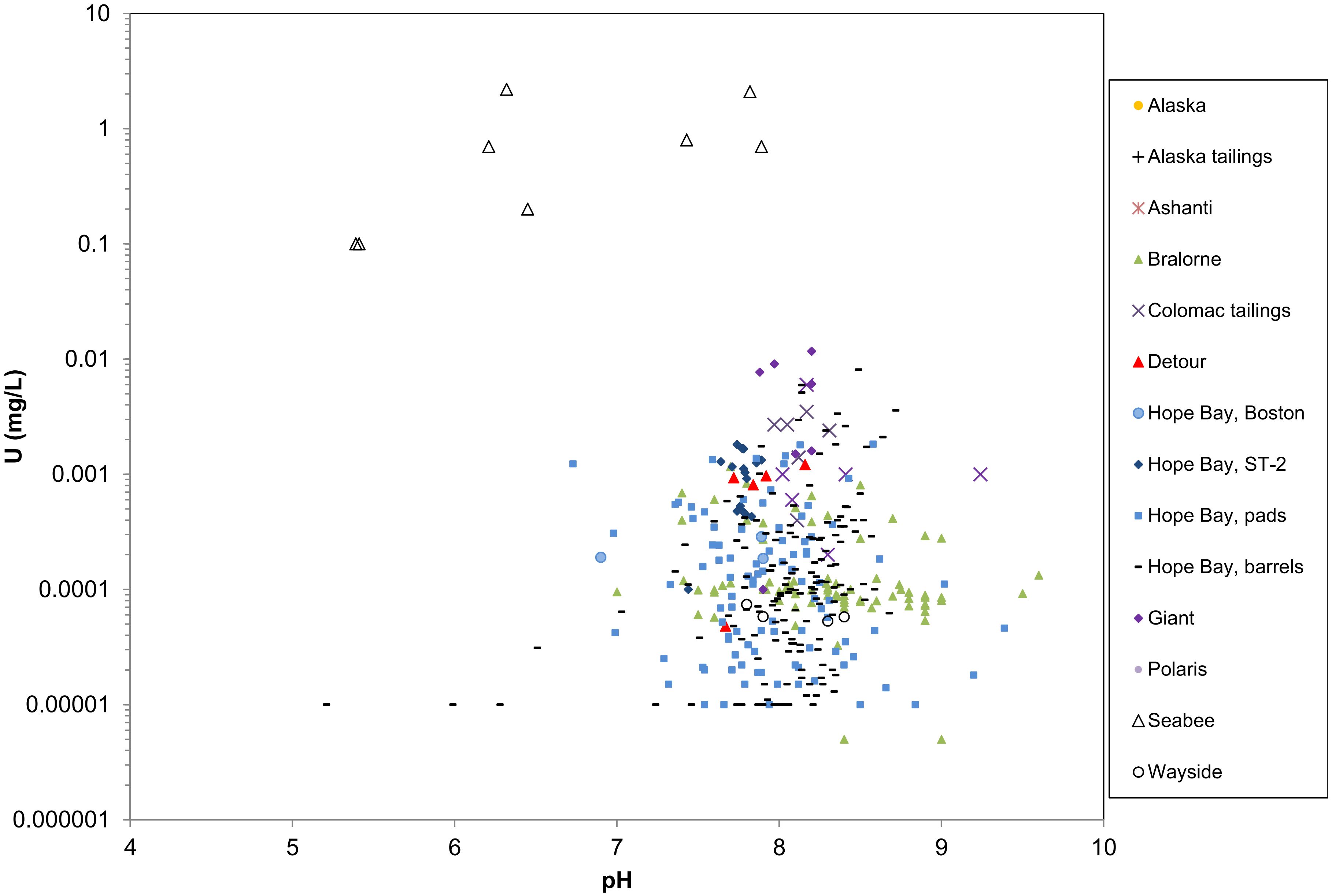

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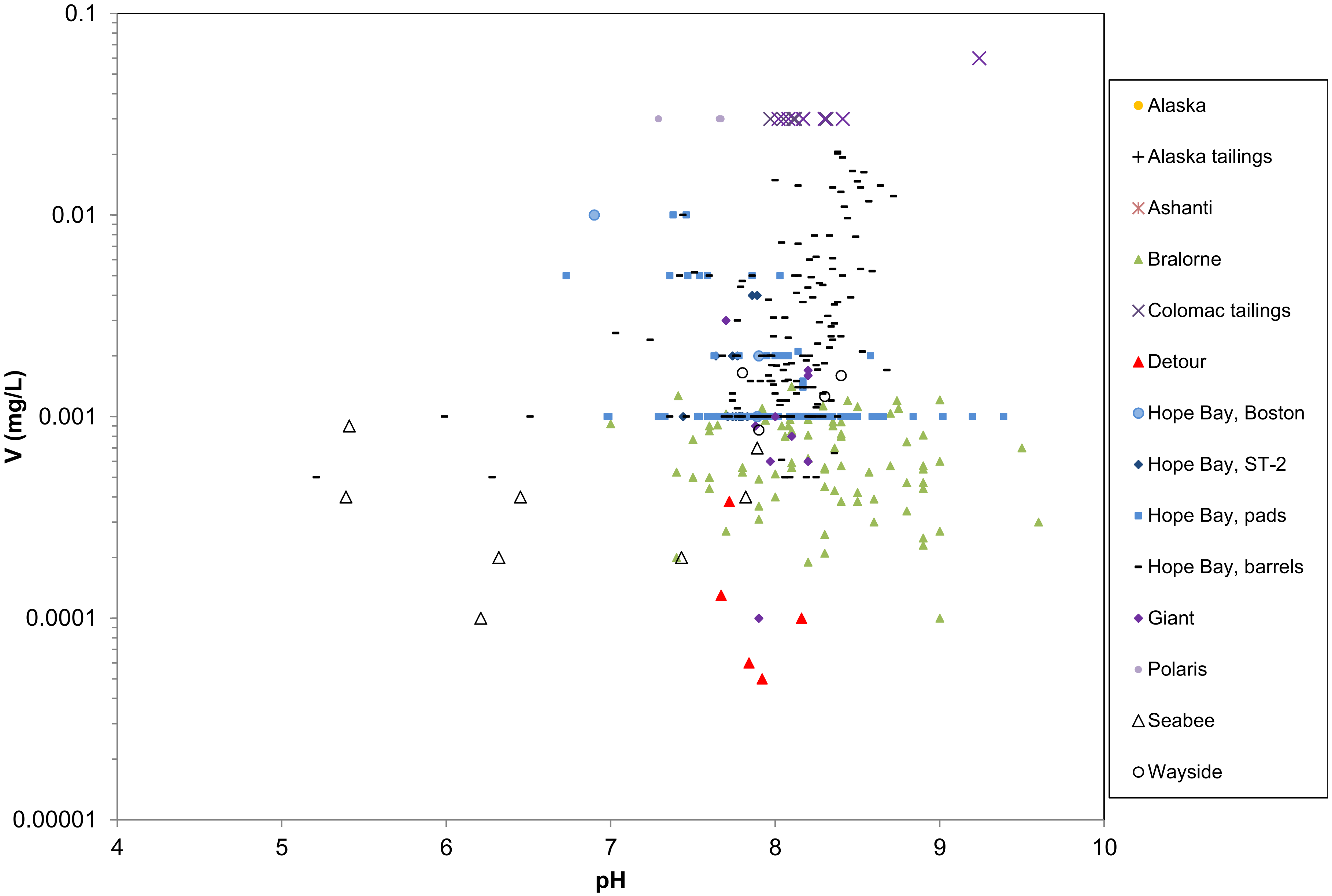

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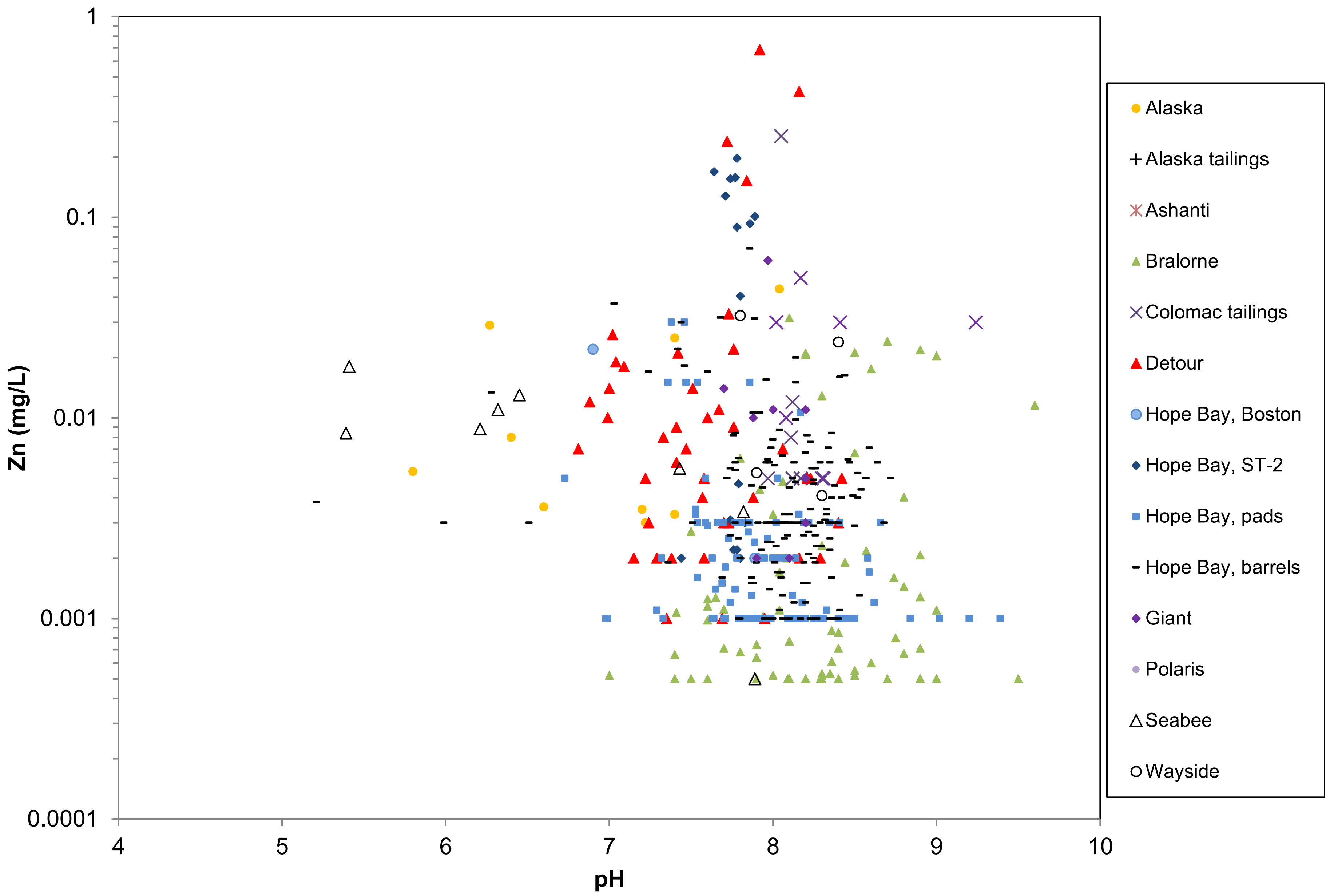
Zn (mg/L)
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● Alaska
+ Alaska tailings
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