Kinetic Testing of Waste Rock and Ore from the Doris Deposits, Hope Bay

Prepared for

TMAC Resources Inc.

Prepared by

SRK Consulting (Canada) Inc.
1CT022.002
June 2015

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Technical Summary

TMAC acquired the Hope Bay project in early 2013 from Hope Bay Mining Ltd. (HBML) a wholly owned subsidiary of Newmont Mining. The previous owner, HBML, with assistance from SRK Consulting (Canada) Inc. (SRK) and Newmont Metallurgical Services (NMS), completed a comprehensive geochemical characterization program of waste rock and ore associated with the Doris deposits and a number of other gold deposits in the Hope Bay Belt. The characterization work was in support of ongoing feasibility, environmental assessment and permitting studies.

TMAC are now advancing plans for underground mining of the Doris deposits and have asked SRK to complete an evaluation of the ML/ARD potential for waste rock and ore that would be produced as part of the proposed mining activities. This report presents the findings of the kinetic testing program, including humidity cell tests and field barrel tests. Static testing and mineralogical characterization has also been completed and is presented in a companion report (SRK 2015a).

The kinetic test program for Doris included 21 humidity cell tests (HCTs) and five barrel tests. Four HCTs were operated by Rescan (2001) and the remaining 17 tests were from more recent geochemical characterization programs by SRK in collaboration with Newmont Metallurgical Services (NMS). Sample selection was based on lithology, economic classification (ore or waste), and ABA characteristics. Trace elements (i.e. arsenic) were a secondary consideration.

The leachates from all samples were neutral to alkaline. Stable sulphate release rates were low and ranged between the limit of analytical detection (0.4 mg/kg/week) to 6 mg/kg/week. Samples with higher total sulphur contents tended to exhibit higher stable sulphate release rates. Generally, trace element concentrations were low in the HCT leachates. One of the late gabbro samples with elevated sulphur levels had elevated concentrations of arsenic, while a number of samples had elevated concentrations of aluminum and copper.

All samples were predicted to be not-potentially acid generating (non-PAG) on the basis of acid potential (AP) and neutralization potential (NP) depletion times and/or low stable sulphate release rates (less than 6 mg/kg/week).

Leachate concentrations from the barrel tests were comparable to the HCTs.

The data from the kinetic test program has been used to validate inputs used for the water quality predictions from waste rock and ore. In general, the stable trace element release rates are less than those used to predict source concentrations from the waste rock, indicating that the input data used in the predictions are conservative.

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List of Abbreviations

ABA	acid base accounting
AP	acid potential
DL	detection limit
EC	electrical conductivity
HCT	humidity cell test
ICP-MS	inductively coupled plasma mass spectrometry
ICP-OES	inductively coupled plasma optical emission spectrometry
MLA	mineral liberation analysis

ML/ARD	metal leaching and acid rock drainage
NCV	net carbonate value
NMS	Newmont Metallurgical Services
NP	neutralization potential
NWB	Nunavut Water Board
ORP	oxidation-reduction potential
PAG	potentially acid generating
QA/QC	quality assurance/ quality control
SEM	scanning electron microscope
TIC	total inorganic carbon
XRD	x-ray diffraction

1 Introduction

1.1 Scope

TMAC Resources Inc. (TMAC) is advancing plans for underground mining of the Doris deposits at Hope Bay. TMAC acquired the Hope Bay project in early 2013 from Hope Bay Mining Ltd. (HBML) a wholly owned subsidiary of Newmont Mining. The previous owner, HBML, with assistance from SRK Consulting (Canada) Inc. (SRK) and Newmont Metallurgical Services (NMS), completed a comprehensive geochemical characterization program of waste rock and ore associated with the Doris deposits and a number of other gold deposits in the Hope Bay Belt. The characterization work was in support of ongoing feasibility, environmental assessment and permitting studies.

SRK was asked to compile all of the relevant kinetic testing results used to evaluate the metal leaching and acid rock drainage (ML/ARD) potential of waste rock and ore that would be produced as part of the proposed underground mining activities at Doris, and to compile those results in a technical report. Static testing and mineralogical testing has also been completed on a number of samples from these deposits, and findings of that work are presented in a separate report (SRK 2015a). The geological context and development concept on which this study was based are presented in Sections 1.2 and 1.3 of SRK (2015a).

1.2 Overview of Previous Kinetic Testing

The historic Doris testing programs included four humidity cell tests on waste rock material. Of these samples, three were from Doris Central and one was from Doris North. On the basis of results from these tests, metal leaching was not considered to be a concern (Rescan 2001, AMEC 2005). However, detection limits were high for numerous parameters. Further discussion of these samples is presented in this report.

2 Methods

The geochemical kinetic database compiled for the Doris project consists of both humidity cell and barrel tests. Details on the tests and testing methods used for these tests are presented below.

2.1 Humidity Cell Tests

There are a total of 21 humidity cell tests (HCTs) from the Doris deposit. Geochemical characterization programs conducted by SRK and NMS established 17 of the HCTs. The remaining 4 were part of historic testing programs (Rescan 2001).

2.1.1 Historic Humidity Cell Program

Four humidity cell tests of waste rock and ore samples from Doris were operated for 39 weeks using the Price (1997) method. Three samples were from Doris Central and the fourth was from Doris North (Table 2.1). The tests were operated by BC Research, in Vancouver, BC under the direction of Rescan. Operational details and data are provided in Rescan (2001).

Table 2.1: List of Historic Humidity Cell Tests

HCT ID	Zone	Lithology Code	Rock Type	No. of Cycles
DOP #12	North	1	Mafic volcanic	39
DUMV #5	Central			
DUG #6		10a	Late gabbro	
DUQ #1		12q	Quartz vein	

SRK completed a quality assurance/ quality control (QA/QC) review of the methods and results, and determined the following:

Missing/inadequate Information:

- The Standard Sobek neutralization potential (NP) method was used to characterize samples prior to testing. Consequently, ratios of NP to acid potential (AP) for these historic humidity cell samples are likely overestimated due to the presence of iron carbonates and/or buffering contributed by silicate minerals.
- The suite of analyzed trace elements did not include mercury.
- Mineralogy was not determined.
- The rationale for sample selection was not documented.

Detection Limits:

- For all results below the detection limit, concentrations were assumed to be half the limit. This assumption was used by Rescan and adopted by SRK during raw data transcription.

- Until cycle 37, detection limits were high for many trace elements (e.g. aluminum, antimony and arsenic were 0.2 mg/L; copper and cadmium were 0.01 mg/L). Results were typically below detection limits and, therefore, not very meaningful.
- Selected parameters (e.g. iron, manganese and zinc) were sometimes present in detectable concentrations; however, detectable concentrations tended to be sporadic and anomalously high, suggesting contamination or analytical error.
- For cycle 38 and 39, low level detection limit analyses were conducted for selected parameters, including aluminum, arsenic, cadmium, copper, iron, lead, molybdenum, nickel, selenium, silver and thallium.

Ion Balances:

- Alkalinity was only analyzed every second week; therefore, ion balances could not be assessed for half of the humidity cell test cycles.
- For all weeks with alkalinity data, ion balances for samples DUMV #5 and DUQ #1 were acceptable. For sample DUG #6, there was an ion imbalance for one week.
- Ion balances for sample DOP #12 were not acceptable for almost all weeks due to relatively low anion content. This may be related to overestimation of cationic charge, specifically from sodium and potassium, which had levels below the detection limit (2 mg/L) for many cycles. When levels were below the detection limit, concentrations were assumed to be half the limit, likely an overestimation.

In Section 3.1.1, the characteristics of these four samples relative to the Doris acid base accounting (ABA) database are discussed. SRK concluded that the historic HCTs should only be used for determination of NP and AP depletion rates. However, data from the final two cycles of each test, which were completed using lower detection limits, are suitable for representing sulphate and metal release rates from more mineralized rock.

2.1.2 SRK/NMS Humidity Cell Program

Program Design

The objective of the Doris geochemical kinetic program was to characterize the significant lithologies representing waste rock and ore. Samples were selected for a total of 17 HCTs in 2008, 2009, and 2011 by SRK. Sample intervals are listed in Appendix A of SRK (2015b). Samples were selected from Doris North and Doris Central for the following reasons:

- The sample set for the Connector zone was smaller or not represented for some rock types.
- Overall, sulphur content for Connector samples was statistically between those from the North zone and those from the Central zone.

The specific sample selection criteria differed each year, as discussed below.

Selection Rationale

2008 Humidity Cell Test Sample Selections

Two samples were selected by SRK in 2008, HC-6 and HC-7 (Table 2.2). They are sub-samples of the barrel tests that were established in 2008 at the Hope Bay project site. Static testing data were not available in 2008, so the selected barrel test intervals were specific lithologies with sufficient lengths of accessible core.

Table 2.2: 2008 Humidity Cell Test Selections

HCT ID	Zone	Lithology Code	Rock Type	Preliminary Economic Classification
HC-6	Central	7a mixed	early gabbro	mixed
HC-7	North	1	mafic volcanic	waste

The humidity cell samples were obtained during barrel set-up. Each barrel test core interval was laid out in sequential order and 3 to 5 kg sub-samples were taken by compositing small (~10 cm) pieces of core from the middle of every third row of drill core (representing approximately 4.5 m of core). The sub-samples were submitted to Maxxam Analytics in Burnaby, BC for kinetic and static test work. The analytical program is described in detail later in this section.

2009 Humidity Cell Test Sample Selections

The most comprehensive selection of samples for Doris humidity cell tests was conducted in 2009. Fourteen samples were selected from an ABA database of 638 samples from the Doris deposit. The static dataset included data from various sources including previous studies, samples recently characterized by SRK, and data generated internally by NMS – details are provided in SRK (2015a). The various static testing campaigns used different analytical and data interpretation methods. A comparison was done to reconcile the different analytical methods and surrogate parameters were selected for assessment of ARD potential and HCT sample selection.

The fourteen HCT samples were selected based on rock type, economic classification (ore or waste), and the statistical distribution of sulphur, NP, and TIC. The statistical distribution of specific trace elements (e.g. arsenic) was a secondary consideration. Rock types were assigned to each sample using geology logs and HBML's 2008 standard lithology codes. Economic classifications were assigned to each ABA sample by HBML geologists using a nominal open pit assay grade cut-off of 0.5 g/t.

For waste and ore samples of each rock type, the objective was to select samples containing either "typical" or "high" sulphur levels, and "typical" levels of NP, TIC and trace element content. "Typical" was defined as between the 40th and 60th percentiles (P40 and P60). "High" was defined as between P90 and P95. For NP, TIC, and trace element content, the percentiles were calculated for each rock type using data from both the Doris North and Central zones. For sulphur, the assessment varied depending on the size of the sample set for each rock type (as described in Table 2.3). For rock types with larger sample sets (e.g. mafic volcanic), the

assessment was separate for each zone (North or Central). For some rock types (e.g. diabase), sulphur content was consistently low and the difference in sulphur content between "typical" and "high" was small. Some of the classifications of "typical" and "high" sulphur later changed when the ABA database was expanded; revised percent ranks are discussed in Section 3.1.1.

Some of the HCT samples were obtained from jaw crushed splits in storage at either Maxxam Analytics (Maxxam) in Burnaby, BC or NMS in Englewood, Colorado. The remaining samples were obtained from drill core by HBML geologists under the direction of SRK. Samples were either a half- or quarter-round split of drill core. The complete list of samples selected in 2009 is provided in Table 2.4.

Static data was available for all of the samples; however, those characterized by NMS were analyzed using internal methods referred to as net carbonate value (NCV). Samples selected for HCTs with NCV data were also analyzed for ABA at Maxxam. The analytical program is described in detail later in this section.

Table 2.3: 2009 Humidity Cell Test Selection Rock Type Considerations

Rock Type	Consideration for Selecting "Typical" and "High" Sulphur Samples
mafic volcanic (1)	Sufficient number of samples from North and Central zones to select "typical" and "high" sulphur samples according to zone. Statistically, samples from the Central zone had the highest sulphide content; however, this may be a sampling bias as samples are typically proximal to the ore body where the sulphides are higher. The Connector zone sample set is small with statistical distribution of sulphur similar to that found in the North zone. Samples from the North and Central zones are assumed to be representative of that found in the Connector zone.
mafic volcanics with quartz vein (1 with 12q)	Small sample set. Selections according to overall Doris sample set.
late gabbro (10a) and diabase (11c)	No samples from the Doris Connector zone. Sulphur levels lower for samples from the North zone than those from the Central zone and a high proportion of North zone samples are distal to the deposit area. Samples were selected based on Central zone statistics. Small variations in sulphur content for diabase.
quartz vein (12q)	40^{th} to 60^{th} percentile distribution of sulphur for Doris deposit approximates North, Connector and Central zones. 95^{th} percentile values higher for the Central zone.

Table 2.4: 2009 Humidity Cell Test Selections

HCT ID	Zone	Lithology Code	Rock Type	Preliminary Economic Classification	Selection Rationale[1]
HC-42	North	1	mafic volcanic	waste	Typical S
HC-43	North	1	mafic volcanic	waste	High S
HC-49	Central	1	mafic volcanic	waste	High S
HC-50	Central	1	mafic volcanic	waste	High S
HC-44	North	1 w. 12q	mafic volcanic w. quartz vein	waste	Typical S
HC-45	Central	1 w. 12q	mafic volcanic w. quartz vein	ore	High S
HC-46	Central	10a	late gabbro	waste	Typical S
HC-51	Central	10a	late gabbro	waste	High S
HC-47	Central	11c	diabase	waste	Typical S
HC-48	Central	11c	diabase	waste	High S
HC-53	Central	12q	quartz vein	waste	Typical S (Doris)
HC-54	Central	12q	quartz vein	ore	Typical S (North)
HC-52	Central	12q	quartz vein	ore	Typical S (Central) / High S (North)
HC-36	Central	12q	quartz vein	ore	High S (Central)

[1] these classifications were assigned during selection and have since been revised upon expansion of the ABA database

2011 Humidity Cell Test Sample Selections

In 2011, sample coverage was reassessed in light of revised mine plans. It was determined that the HCT program did not adequately represent the range of characteristics observed for late gabbro, which was identified as a significant rock type in the vicinity of the Doris North decline. Consequently, one sample of late gabbro (HC-65) was added to the program (Table 2.5). Since that time, some of the material that was originally classified as late gabbro has been re-interpreted as a low NP variant of the mafic volcanics (i.e. low NP basalt) that occurs in close proximity to the diabase dyke as a result of heat from contact metamorphism. HC-65 is considered to be representative of the low NP basalt. However, a systematic revision of drilling logs has not yet been completed. Therefore, in the context of this report, the low NP basalt is identified and grouped according to the original nomenclature “late gabbro”, unless the reference is specific to HC-65 or static testing that was specific to the low NP basalt.

The 29 ABA samples of late gabbro from the vicinity of the Doris North decline had both low TIC and sulphur content, with maximum concentrations of 5 kg $CaCO_3$/t and 0.13%, respectively (SRK 2007). As a result of this low TIC content, the late gabbro samples are typically classified as

potentially acid generating (PAG); however, the risk for substantial ARD is considered low due to the low sulphur content, which limits the amount of acidity produced. The sample HC-65 was selected for kinetic testing to help verify these assumptions.

As described for the 2009 humidity cell program, the sample was selected based on the statistical distribution of ABA parameters for the Doris North late gabbro sample set (SRK 2007). The selected sample was on the upper end of sulphur content (0.1% S, P85) to ensure sulphate production rates would be above analytical detection limits.

Table 2.5: 2011 Humidity Cell Test Selections

HCT ID	Zone	Lithology Code	Rock Type	Preliminary Economic Classification
HC-65	North decline	10a	late gabbro (reclassified as low NP basalt)	waste

Analytical Program

All HCT samples were submitted to Maxxam for static and kinetic testing. The static test work included paste pH, total sulphur, sulphate sulphur, TIC and trace element content by aqua regia digestion and inductively coupled plasma mass spectrometry (ICP-MS) as per the methods outlined in SRK (2011). Sulphide was calculated as the difference between total sulphur and sulphate. Total carbon was also analyzed for the 2008 samples at the request of NMS.

Mineralogy was determined at NMS and analyses included x-ray diffraction (XRD) with Rietveld refinement and whole pattern fitting, and mineral liberation analysis (MLA). For the carbonate minerals with detectable levels of ferroan dolomite ($Ca(Fe,Mg)CO_3$) and magnesium-rich siderite ($(Fe,Mg)CO_3$), as determined by XRD, the iron content for each sample was determined by NMS using a scanning electron microscope (SEM). A SEM was not used for HC-47, HC-48, and HC-65 because iron carbonate minerals were below the level of detection, as indicated by XRD. Mineralogy was also determined using optical methods (by Kathryn Dunne, PGeo) for samples HC-50, HC-51, HC-52 and HC-53.

The humidity cell tests were initiated at Maxxam Analytics using the ASTM (2001) method. Initiation dates are listed in Table 2.6 and the list of analytes and frequency of analysis is provided in Table 2.7. Kinetic data were provided to SRK on a monthly basis and each data report underwent QA/QC analysis by SRK.

Table 2.6: Inventory of Static Test Work and Mineralogical Data for SRK Humidity Cell Tests

Selection Year	Sample ID	Static[1]					Kinetic
		ABA & ICP-MS	XRD	SEM	MLA	Petrography	Initiated
2008	HC-6	x	x	x	x	-	Feb 2009
	HC-7	x	x	x	x	-	Feb 2009
2009	HC-36	x	x	x	x	-	Jan 2010
	HC-42	x	x	x	x	-	Jan 2010
	HC-43	x	x	x	x	-	Jan 2010
	HC-44	x	x	x	x	-	Jan 2010
	HC-45	x	x	x	x	-	Jan 2010
	HC-46	x	x	x	x	-	Jan 2010
	HC-47	x	x	n/a	x	-	Jan 2010
	HC-48	x	x	n/a	x	-	Jan 2010
	HC-49	x	x	x	x	-	Jan 2010
	HC-50	x	x	x	x	x	Jan 2010
	HC-51	x	x	x	x	x	Jan 2010
	HC-52	x	x	x	x	x	Jan 2010
	HC-53	x	x	x	x	x	Jan 2010
	HC-54	x	x	x	x	-	Apr 2010
2011	HC-65	x	x	n/a	x	-	Feb 2011

[1] See text for details
n/a = not applicable

Table 2.7: Analytical Frequency of SRK Humidity Cell Tests

General Parameters	Frequency
pH, conductivity, SO_4	weekly
low-level SO_4	last 2 cycles[2]
alkalinity, acidity	weekly
oxidation-reduction potential	weekly
Metals	
ICP-MS (trace elements)	0, 1, 2, 4, 8, 12, 16 …, 40, 48, 56 etc.
ICP-OES suite[1]	weekly
Hg by cold vapor (CV) method	0, 1, 2, 4, 8, 12, 16 …, 40, 48, 56 etc.
Ions and Nutrients	
F, Cl, P, total dissolved solids	0, 1, 2, 4, 8, 12, 16 …, 40, 48, 56 etc.
NO_2, NO_3, NH_3	0, 1, 2, 4, 8, 12, 16 …, 40, 48, 56 etc.

[1]Al, Ca, Cu, Fe, Mg, K, Na, Zn by inductively coupled plasma optical emission spectrometry (ICP-OES)
[2]HC-43, HC-51, HC-53, HC-54, and HC−65 only

After the HCTs were considered complete, the last two cycles of HC-43, HC-51, HC-53, HC-54, and HC−65 were analyzed for low level sulphate (analytical detection limit of 0.06 mg/L) at SGS in Lakefield, Ontario (SGS). The regular detection limit for sulphate at Maxxam was 0.5 mg/L. The objective of the low level analysis was to determine if sulphate leaching was occurring at levels less than the limit of detection provided by Maxxam.

Upon completion of each humidity cell test, the remaining material (residue) was geochemically characterized for ABA and trace element content using the same methods described above, except that total carbon was not analyzed.

Evaluation for Completion of Humidity Cell Tests

The HCT results were periodically assessed to determine when any tests could be stopped. The assessment included evaluation of the data in terms of stability of sulphate and metals loadings, pH, and rock type. All tests were completed by the end of January 2012 and ABA analyses were conducted at Maxxam on the HCT residues.

2.1.3 Humidity Cell Test Database Summary

The HCT sample set for the Doris deposit is summarized in Table 2.8.

Table 2.8: Summary of Doris Humidity Cell Tests

Sample ID	Lithology Code	Rock Type	Preliminary Economic Classification	Cycles
DOP #12	1	mafic volcanic	waste	39
DUMV #5				39
HC-7				104
HC-42				57
HC-43				108
HC-49				57
HC-50				57
HC-44	1 w. 12q	mafic volcanic w. quartz vein	waste	57
HC-45			ore	57
HC-53	12q	quartz vein	waste	108
DUQ #1			ore	39
HC-36				57
HC-52				57
HC-54				94
HC-47	11c	diabase	waste	57
HC-48				57
DUG #6	10a	late gabbro (including low NP basalt)	waste	39
HC-46				57
HC-51				108
HC-65*				49
HC-6	7a mixed	early gabbro	mixed	104

Notes: *HC-65 represents late gabbro that has been reclassified as low NP basalt in the vicinity of the decline, while HC-46 and HC-51 represent more typical late gabbro elsewhere in the deposit area.

2.2 Barrel Tests

There are five barrel tests from the Doris deposit area operating at the Hope Bay site (Table 2.9). Barrel test sample intervals are presented in Appendix A of SRK (2015b). In addition, there is an empty barrel test set up to provide a test blank for QA/QC.

These barrel tests were set-up in 2008 and 2009 in the now-defunct northern core storage area near the closed Windy camp. Windy camp is within the Madrid deposit area, located approximately 10 km south of the Doris deposit. The location of the tests was chosen based on proximity of the Doris drill core, all of which was stored at the Windy camp. Additionally, given this camp is closed, and the location is sufficiently remote, it is unlikely to be disturbed or influenced by dust. In July 2012, all of the barrel tests were moved from the northern core area into the Windy camp itself. After the last 2012 sampling event in August, the leachate collection buckets were removed. No samples were collected in 2013. The collection bucket for the late gabbro barrel (W13) was replaced and two leachate samples were taken in 2014.

Table 2.9: Inventory of Barrel Samples

Barrel ID	Rock Code	Rock Type	Program	Sampling Events
W1[a]	1	mafic volcanic	2008	8
W5[b]	7a	early gabbro		5
W9	12q with 1	quartz vein with mafic volcanic	2009	8
W10	11c	diabase		7
W12	Blank	blank		4
W13	10a	late gabbro		10

[a] Same sample material as HC-7
[b] Same sample material as HC-6

2.2.1 Sample Selection and Characterization

Two of the barrel tests were established in 2008, the remaining three in 2009. Geochemical characterization work was done for all of the tests.

2008 Barrel Sample Selections

Two barrel tests were set-up in 2008. Sub-samples of the material from each test were submitted for humidity cell tests (HC-6 and HC-7) as described in Section 2.1.2. Static testing data were not available in 2008, so intervals were selected on the basis of specific lithologies with sufficient lengths of core that were easily accessible.

As stated in Section 2.1.2, geochemical characterization of the samples included ABA, TIC, and trace element content by aqua regia digestion with ICP-MS finish and mineralogy by XRD with Rietveld refinement and whole pattern fitting. NMS also determined the iron content of the iron carbonate minerals (i.e. ferroan dolomite ($Ca(Fe,Mg)CO_3$) and magnesium-rich siderite ($(Fe,Mg)CO_3$)) for each sample using an SEM.

2009 Sample Selection Rationale

In 2009, three additional barrels were set up to represent rock types present in the Doris deposit area. Samples were selected based on obtaining sufficient volumes of material from drillholes characterized as part of SRK's static geochemical program (SRK 2015). Quartz vein material occurs in narrow intervals (on the order of metres) and available volumes were insufficient for exclusive testing. Consequently, the quartz vein material was combined with the surrounding country rock (mafic volcanic) for barrel testing.

Samples were obtained from the core boxes for static geochemical characterization by obtaining chip samples along the barrel sample interval. Samples were submitted to Maxxam for modified ABA, TIC and trace elements analyses. Mineralogy by XRD was determined at NMS.

2.2.2 Leachate Sampling and Analytical Program

Barrel tests are large scale kinetic tests. Each of the Hope Bay barrels was loaded with hundreds of kilograms of broken drill core and allowed to weather under site climatic conditions. Leachate from each barrel was allowed to accumulate in collection buckets and was collected approximately once per month during the unfrozen season. Field measurements included leachate volume, pH, electrical conductivity (EC), and oxidation-reduction potential (ORP). After sampling, any excess leachate was removed and the bucket rinsed with deionized water. The samples were submitted to ALS Laboratory in Vancouver, BC for analysis of the following parameters:

- pH, EC, alkalinity, sulphate;
- bromide, chloride, fluoride;
- ammonia, nitrate, nitrite; and
- dissolved trace elements by ICP-MS (30 parameters). Trace element analytical detection limits were higher than for the humidity cell tests.

For each sampling event, one sample duplicate and one sample blank were collected as part of the QA/QC program. These samples were in addition to sampling of the blank barrel test. QA/QC of the data was performed by SRK.

3 Results and Discussion

The North, Connector, and Central zones of the Doris deposit are from the same vein system. On the basis of geology, barrel and HCTs from any of the Doris zones are assumed to be representative of Doris North, Connector, or Central for the purpose of water quality predictions. Statistically, sulphur content was lowest for the Doris North and highest for the Doris Connector HCT samples (see Figure 3.2 in SRK (2015a)).

3.1 Humidity Cell Tests

3.1.1 Sample Characterization

The basic geochemical characteristics of the humidity cell samples, including mineralogy, ABA and trace element composition are described in the following text. The humidity cell tests were managed by SRK, Apppendix B of SRK (2015b) presents mineralogical data and Appendix C of SRK (2015b) presents ABA and trace element data. A selection of ABA data is also presented in Table 3.2. The complete data compilation for the historic humidity cell tests is presented in Rescan (2001).

Mineralogy

Mineralogy data are available for the SRK samples only. Mineralogy was determined using four methods: XRD for bulk mineralogy, MLA for trace level mineralogy with an emphasis on carbonates and sulphides, SEM to determine the stoichiometric formulas of iron carbonate minerals, and optical methods to determine mineralogical associations and textures (Appendix B of SRK (2015b)).

XRD Results

The HCT sample XRD results corroborate the results from XRD analyses of all samples in the SRK/NMS static geochemical characterization program for the Doris deposit:

- Carbonate content was generally high, predominantly in the form of iron carbonates (specifically ferroan dolomite ($Ca(Mg_{(x-1)}Fe_x)CO_3$) and magnesium-rich siderite ($(Mg_{(x-1)}Fe_x)CO_3$).
- The presence of calcite ($CaCO_3$) as a secondary carbonate mineral in the HCT samples was confirmed. Specifically, samples of mafic volcanic (HC-42), mafic volcanic mixed with quartz vein (HC-44), and early gabbro mixed with mafic volcanic (HC-6) had high levels of calcite (greater than 90th percentile levels), with mineral levels comparable to ferroan dolomite.
- The exceptions were both diabase samples (HC-47 and HC-48), one quartz vein sample (HC-53), and the late gabbro (low NP basalt) sample (HC-65), which had low levels of carbonate minerals (below or slightly above analytical detection (1%)).
- Sulphides, in the form of pyrite, were only detected in samples with high total sulphur levels, as indicated by ABA (Table 3.1).

Table 3.1: Comparison of Sulphur Content from ABA, XRD, & MLA Assessments

HCT ID	Lithology Code	Rock Type	Preliminary Economic Classification	Total Sulphur (%S)		
				XRD	MLA	ABA
HC-7 (chip)	1	mafic volcanic	waste	<DL	0.15	0.11
HC-7 (pulp)				<DL	0	0.17
HC-42				<DL	0.13	0.1
HC-43				0.53	0.6	0.52
HC-49				<DL	0.05	0.17
HC-50				1.6	1.03	1.78
HC-44	1 w. 12q	mafic volcanic w. quartz vein	waste	<DL	0.53	0.31
HC-45			ore	1.07	2.51	2.37
HC-53	12q	quartz vein	waste	<DL	0.15	0.09
HC-36				1.07	3.3	6.03
HC-52				1.6	2.12	1.69
HC-54				0.53	1.04	0.61
HC-47	11c	diabase	waste	0.53	0.02	0.1
HC-48				0.53	0.05	0.12
HC-46	10a	late gabbro (including low NP basalt)	waste	<DL	0.13	0.29
HC-51				0.53	0.94	1.19
HC-65*			decline	<DL	0.12	0.1
HC-6	7a mixed	early gabbro	mixed	<DL	0.08	0.13

DL – detection limit
*HC-65 represents late gabbro that has been reclassified as low NP basalt in the vicinity of the decline, while HC-46 and HC-51 represent more typical late gabbro elsewhere in the deposit area.

MLA Results

The MLA method can quantitatively identify thousands of mineral grains at submicron and trace levels. Selected samples of mafic volcanic combined with the quartz veins (HC-44 and HC-45), early gabbro (HC-51), and diabase (HC-47 and HC-48) contained detectable levels of chalcopyrite ($CuFeS_2$). Pyrrhotite ($Fe_{(1-x)}S$) was also present in HC-44 and HC-55. Other sulphides identified, but at levels less than analytical detection (0.01 to 0.001%), included gersdorffite ((Fe,Co,Ni)AsS), galena (PbS), cobaltite (CoAsS), sphalerite (ZnS), and tetrahedrite (Cu_3SbS).

SEM Results

The iron content in ferroan dolomite ($CaFe(CO_3)_2$) and magnesium-rich siderite ($(FeMg)CO_3$) was determined for fourteen HCT samples using a SEM. The iron content was stoichiometrically up to 0.56 of the iron+magnesium content of the ferroan dolomite. Similarly, the iron content was upwards of 0.78 of the iron+magnesium content of the siderite.

Acid-Base Accounting

ABA data is presented in Table 3.2 and Appendix C1 of SRK (2015b). The two sets of ABA data for HC-7 represent the different sampling methodologies for ABA test work (chip sample vs. assay pulps). For each HCT sample, the percentile rank of the ABA parameters was recalculated according to rock type and economic classification using the updated 2011 ABA sample set (Table 3.3). For sulphur, comparisons were made to the overall sample set (referred to as Doris) and also each specific zone (North, Connector and Central). For NP and TIC, comparisons were to the overall Doris sample set. For HC-6 (early gabbro or 7a), a statistical comparison was not performed as early gabbro has since been determined to be volumetrically insignificant at the Doris deposit.

ABA data for the overall Doris sample set are discussed in SRK (2015a). Compared to this dataset, the historic humidity cell tests contained high sulphur levels, with all samples above the 80th percentile (P80). The ABA data for the SRK/NMS HCT samples were consistent with the findings of SRK (2015a). More than half of the HCT samples contained sulphur levels in the 20th to 60th percentile range (P20 to P60). Samples typically contained high NP and TIC levels (greater than 100 kg $CaCO_3$ eq/t) and were classified as non-PAG.

Nine HCT samples were classified as uncertain or PAG. The basis for these classifications was related to the geochemical characteristics of the individual samples:

- Mafic volcanic (1): an uncertain classification was made for one sample (DUMV#5), which had an anomalously high sulphur content of 6.5% (P99).
- Mafic volcanic mixed with quartz vein (1 with 12q): an uncertain classification was made for one sample (HC-45), again due to high sulphur content of 2.4% (P86).
- Diabase (11c): an uncertain classification was made for one sample (HC-48), which had low sulphur (median levels less than 0.1%) and TIC levels, and to a lesser degree, low NP.
- Late gabbro (10a): an uncertain classification was made for one sample (DUG#6), which contained anomalously high levels of sulphur (P100 or 1.9%) and NP and TIC (~P80 or 78 and 130 kg $CaCO_3$ eq/t, respectively).
- Late gabbro/Low NP basalt: HC-65 had low levels of sulphur (0.1 %) and TIC (0.5 kg $CaCO_3$ eq/t), and to a lesser degree, NP (19 kg $CaCO_3$ eq/t) and was classified as PAG having a TIC/AP ratio of 0.1.
- Quartz vein (12q): most of these samples were classified as uncertain or PAG due to either high sulphur (at least 1.9%) or low NP and TIC levels (less than 30 kg $CaCO_3$ eq/t), as observed for samples HC-53, DUQ#1, HC-36, and HC-54.

Levels of total sulphur determined by ABA were typically similar to those determined by XRD and MLA (Table 3.1). When detected, sulphide levels by XRD were typically lower than those by MLA or ABA. For samples containing quartz vein (12q and 1 with 12q), sulphur by MLA was typically higher. Conversely, sulphur by ABA was generally highest for all other samples.

Table 3.2: ABA Data, Doris Humidity Cell Tests

HC #	Rock Type[1]	Preliminary Economic Classification	Sample Type	Paste pH	Total Sulphur %S	Sulphate %S	Fizz Test	Total C	NP[2]	TIC	NP/AP	TIC/AP
								%	(kgCaCO3/t)			
DOP #12	1	waste	n/a	9.4	1.68	n/a	n/a	-	337	386	6.4	74
DUMV #5				8.9	6.57	n/a	n/a	-	229	264	1.1	1.3
HC-7			chip	8.4	0.11	<0.01	Strong	3.19	161	259	46.8	75.3
			pulp	8.3	0.17	0.01	n/a	2.98	173	244	33.4	46.9
HC-42				8.4	0.10	<0.01	Strong	-	165	178	52.9	56.8
HC-43				8.8	0.52	<0.01	Strong	-	188	254	11.6	15.6
HC-49				9.2	0.17	<0.01	Strong	-	176	331	33.1	62.2
HC-50				8.8	1.78	<0.01	Strong	-	202	336	3.6	6.0
HC-44	1 w. 12q	waste	pulp	8.7	0.31	<0.01	Strong	-	194	216	20.0	22.3
HC-45		ore		8.9	2.37	<0.01	Strong	-	161	233	2.2	3.1
HC-53	12q	waste	pulp	8.5	0.09	<0.01	Slight	-	3	3	1.0	1.2
DUQ #1		ore	n/a	8.8	1.87	n/a	n/a	-	68	93	1.2	1.6
HC-36			pulp	8.3	6.03	0.01	Strong	1.99	120	156	0.6	0.8
HC-52				9.0	1.69	<0.01	Strong	-	173	302	3.3	5.7
HC-54				8.8	0.61	<0.01	Moderate	-	20	28	1.1	1.5
HC-47	11c	waste	pulp	9.5	0.10	<0.01	Moderate	-	28	18	8.9	5.6
HC-48				9.2	0.12	<0.01	Slight	-	19	10	5.2	2.8
DUG #6	10a	waste	n/a	8.3	1.85	n/a	n/a	-	78	130	1.3	2.2
HC-46			pulp	8.8	0.29	<0.01	Strong	-	116	142	12.8	15.6
HC-51				9.0	1.19	<0.01	Strong	-	246	417	6.6	11.2
HC-65*		decline	pulp	9.1	0.10	0.01	None	0.00	19	0.5	6.1	0.1
HC-6	7a mixed	mixed	chip	8.6	0.13	<0.01	Strong	1.94	128	156	31.6	38.5

[1] Rock types: 1=mafic volcanics; 1 w. 12q=mafic volcanics mixed with quartz vein; 7a mixed=early gabbro mixed; 10a=late gabbro (including low NP basalt); 11c=diabase; 12q=quartz vein

[2] Standard NP method used for samples DOP #12, DUMV #5, DUG #6, HC-65 and DUQ #1. Modified method (MEND 1991) used for all other samples

*HC-65 represents late gabbro that has been reclassified as low NP basalt in the vicinity of the decline, while HC-46 and HC-51 represent more typical late gabbro elsewhere in the deposit area.

Table 3.3: Percentile Rank of Total Sulphur, NP and TIC for Humidity Cell Tests

Humidity Cell #	Rock Type[1]	Preliminary Economic Assessment	Sample Type	Total Sulphur									NP		TIC		ARD Classification	
				%S	All Zones		North		Connector		Central		(kgCaCO3/t)	All Zones	(kgCaCO3/t)	All Zones	NP/AP	TIC/AP
					%Rank	n	%Rank	n	%Rank	n	%Rank	n		%Rank		%Rank		
DOP #12	1	waste	n/a	**1.68**	94%	361	96%	168	>100%	51	91%	142	**337**	99%	**386**	94%	non-PAG	non-PAG
DUMV #5				**6.54**	99%	361	100%	168	>100%	51	99%	142	**22**	1%	**264**	50%	PAG	Uncertain
HC-7*			chip	**0.11**	26%	361	34%	168	30%	51	16%	142	**161**	39%	**259**	49%	non-PAG	non-PAG
HC-42			pulp	**0.17**	59%	361	71%	168	61%	51	45%	142	**173**	50%	**244**	45%	non-PAG	non-PAG
HC-43				**0.10**	21%	361	27%	168	22%	51	13%	142	**165**	43%	**178**	27%	non-PAG	non-PAG
HC-49				**0.52**	85%	361	90%	168	96%	51	75%	142	**188**	63%	**254**	47%	non-PAG	non-PAG
HC-50				**0.17**	60%	361	72%	168	62%	51	45%	142	**176**	53%	**331**	70%	non-PAG	non-PAG
HC-44	1 w. 12q	waste	pulp	**1.78**	95%	361	97%	168	>100%	51	91%	142	**202**	71%	**336**	73%	non-PAG	non-PAG
HC-45		ore	pulp	**0.31**	29%	8	25%	5	--	1	7%	2	**194**	86%	**216**	10%	non-PAG	non-PAG
HC-53	12q	waste	pulp	**2.37**	86%	15	>100%	5	54%	2	80%	6	**161**	59%	**233**	20%	Uncertain	non-PAG
DUQ #1		ore	n/a	**0.09**	50%	27	67%	13	#N/A	0	38%	14	**3**	9%	**3**	13%	Uncertain	Uncertain
HC-36			pulp	**1.87**	82%	52	95%	20	91%	11	65%	21	**68**	76%	**93**	73%	Uncertain	Uncertain
HC-52				**6.03**	100%	52	>100%	20	>100%	11	100%	21	**120**	86%	**156**	82%	PAG	PAG
HC-54				**1.69**	76%	52	92%	20	90%	11	55%	21	**173**	88%	**302**	95%	non-PAG	non-PAG
HC-47	11c	waste	pulp	**0.61**	49%	52	57%	20	53%	11	40%	21	**20**	50%	**28**	56%	Uncertain	Uncertain
HC-48				**0.10**	95%	41	>100%	33	>100%	1	67%	7	**28**	60%	**18**	64%	non-PAG	non-PAG
DUG #6	10a	waste	n/a	**0.12**	98%	41	>100%	33	>100%	1	83%	7	**19**	57%	**10**	63%	non-PAG	Uncertain
HC-46			pulp	**1.85**	100%	60	>100%	41	>100%	7	100%	12	**78**	77%	**130**	79%	Uncertain	Uncertain
HC-51				**0.29**	92%	60	94%	41	>100%	7	82%	12	**116**	82%	**142**	84%	non-PAG	non-PAG
HC-65*		decline	pulp	**1.19**	98%	60	>100%	41	>100%	7	91%	12	**246**	95%	**417**	100%	non-PAG	non-PAG
HC-6*	7a mixed	mixed	chip	**0.10**	58%	60	65%	41	80%	7	65%	12	**19**	52%	**0.5**	24%	non-PAG	PAG
				0.13	--	0	--	0	--	0	--	0	**128**	--	**156**	--	non-PAG	non-PAG

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Statistical analysis was done by rock type and economic classification. For HC-6, this rock type is not in the Doris database.

* Denotes samples are barrel test samples

[1] Rock types: 1=mafic volcanics; 1 w. 12q=mafic volcanics mixed with quartz vein; 7a mixed=early gabbro mixed; 10a=late gabbro (including low NP basalt); 11c=diabase; 12q=quartz vein

[2] Standard NP method used for samples DOP #12, DUMV #5, DUG #6, HC-65 and DUQ #1. Modified method used for all other samples

*HC-65 represents late gabbro that has been reclassified as low NP basalt in the vicinity of the decline, while HC-46 and HC-51 represent more typical late gabbro elsewhere in the deposit area.

Trace Elements

Solid content trace element data for the HCT samples are presented in Appendix C2 of SRK (2015b). Trace element data for the overall Doris sample set are discussed in SRK (2015a). For eight HCT samples, arsenic levels were elevated relative to ten times the average crustal abundance for basalt, 20 ppm (Price 1997). These samples were characterized as having “high” sulphur content (though not all samples with “high” sulphur content contained elevated levels of arsenic). All rock types except early gabbro (7a) and diabase (11c) had at least one sample with elevated arsenic.

Arsenic levels for each HCT sample were statistically compared with the ABA samples corresponding to the equivalent rock type and economic classification in the static testing database for Hope Bay (Table 3.4). The exception was HC-6 because early gabbro (7a) is not a significant rock type at Doris. HCT samples with arsenic levels greater than ten times the average crustal abundance for basalt had at least 60th percentile levels of arsenic.

3.1.2 Humidity Cell Leachate Data

There are a total of 21 HCTs. Four were operated by Rescan (2001) and 17 by SRK/NMS. Operational details for all 21 HCTs are presented in Table 2.7 and Table 2.8 including analytical schedule and test duration. Figures showing trends from the SRK and Rescan HCTs are provided in Appendix D1 and D2 of SRK 2015b. Appendix E of SRK 2015b contains tabulated results from the SRK HCTs, including a summary of key data, stable release rates, depletion calculations, low-level sulphate data from SGS, and the complete raw concentration dataset.

Concentrations and Trends

For the HCTs, maximum concentrations and pHs were typically highest during the initial leaching stages, after which they decreased with time and levelled out. For all HCTs, the pHs were neutral to alkaline for the duration of the test. Overall, the pHs from the quartz vein samples tended to be the lowest (minimum 7.3), with the exception of the late gabbro (low NP basalt) sample (HC-65). pH levels in leachate from HC-65 were decreasing at a faster rate than any of the other cells, pH was around 9 at the start of testing and decreased to around 7 in just over 40 weeks.

Sulphate concentrations were initially high and decreased rapidly to levels consistently below 20 mg/L (or 5 mg/kg/week) after cycle 15. Stable sulphate release rates were low and ranged between the limit of analytical detection (0.4 mg/kg/week) to 5.5 mg/kg/week (Figure 3.1). Samples with higher total sulphur content exhibited higher stable sulphate release rates.

High molar ratios of $(Ca+Mg)/SO_4$) were observed in almost all of the samples, which suggests that dissolution of carbonate minerals, and alkalinity production rates, is in response to the addition of deionized water, and not oxidation of sulphides. The notable exception is HC-65 (early gabbro), which consistently had a molar ratio of less than 1.

Table 3.4: Percentile Rank of Arsenic Levels, Humidity Cell Test Samples

HCT ID	Rock Type[1]	Preliminary Economic Classification	Arsenic	
			ppm	%Rank
DOP #12	1	waste	60	91
DUMV #5			166	100
HC-7			1.7	24
			1.8	25
HC-42			1.7	24
HC-43			21	70
HC-49			2.2	29
HC-50			63	92
HC-44	1 + 12q	waste	12	17
HC-45		ore	51	69
HC-53	12q	waste	2.6	14
DUQ #1		ore	10	43
HC-36			26	60
HC-52			42	77
HC-54			7.7	31
HC-47	11	waste	1.4	87
HC-48			3.4	95
DUG #6	10a	waste	4	85
HC-46			7.6	91
HC-51			48	100
HC-65*		decline	1.2	41
HC-6	7a mixed**	mixed	3.2	--
Average crustal abundance for basalt (Price 1997)			2	

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Notes: orange highlight indicates value is elevated above ten times the average crustal abundance for basalt
[1] Rock types: 1=mafic volcanics; 1 w. 12q=mafic volcanics mixed with quartz vein; 7a mixed=early gabbro mixed; 10a=late gabbro (including low NP basalt); 11c=diabase; 12q=quartz vein
*HC-65 represents late gabbro that has been reclassified as low NP basalt in the vicinity of the decline, while HC-46 and HC-51 represent more typical late gabbro elsewhere in the deposit area.
* There were insufficient 7a samples to calculate the percentile rank of this sample relative to the static dataset.

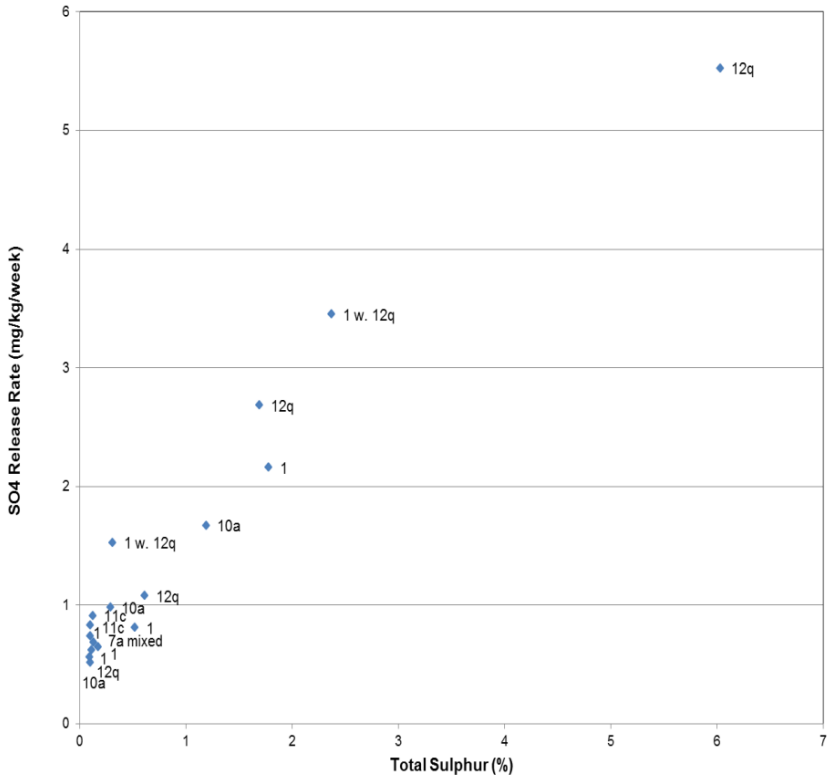

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Figure 3.1: Sulphate Release Rates vs. Total Sulphur Content

Trace element concentrations in the leachates from the 17 HCTs operated by SRK and NMS were typically stable or showed decreasing trends over time. Concentrations of most parameters were very low (Table 3.5). However, selected SRK HCTs had somewhat elevated concentrations of arsenic, aluminum and copper in comparison to screening criteria[1]. Graphs are provided in Appendix D1 of SRK 2015b and the results are described as follows:

- Arsenic concentrations were highest in HC-51 (late gabbro, P98 sulphur), with median[2] levels of 0.012 mg/L. The solid-phase arsenic content of HC-51 (48 mg/kg) is the highest concentration observed in any of the late gabbro samples from Doris. Maximum arsenic concentrations were also elevated for selected samples of mafic volcanic with quartz vein (HC-45) and diabase (HC-47), and the other late gabbro/low NP basalt sample (HC-65), with values ranging from 0.01 to 0.06 mg/L. There was no evident relationship between stable rates for arsenic leaching and pH, solid-phase arsenic or sulphur content. HC-51 also had higher concentrations of antimony and cobalt in comparison to other humidity cell tests.

[1] Screening criteria are based on CCME water quality guidelines for the protection of aquatic life (freshwater; WQG PAL, CCME 2015). These comparisons are used for screening purposes to identify parameters of potential concern for the project. However, concentrations from these tests are not considered representative of field conditions, and actual leachate conditions in the field can be either higher or lower than source concentrations from a waste rock dump depending on scaling factors and other controls on solubility.

[2] Median levels were determined for the duration of the test, and do not necessarily correspond to the stable concentration.

- Aluminum levels were initially elevated for all humidity cell tests, with the exception of the quartz vein samples. Maximum levels ranged from 0.12 to 1.1 mg/L. Median[2] levels were elevated for HC-65 (late gabbro/low NP basalt, P58 sulphur) and HC-49 (mafic volcanic, P60 sulphur). Stable concentrations of aluminum leaching are related to pH, with higher rates corresponding to more alkaline conditions. There was no relationship observed between leaching rates and solid-phase concentrations (aluminum or sulphur).
- Copper levels were initially elevated for all humidity cell tests, except for four mafic volcanic samples (HC-42, HC-43, HC-49 and HC-50, P21 to P95 sulphur) and HC-46 (late gabbro, P92 sulphur). Maximum copper levels ranged from 0.002 to 0.006 mg/L. Stable rates for copper leaching were lower and may be related to solid-phase copper content, but not to pH or sulphur.

For the historic humidity cell tests, the analytical detection limits were high for all cycles except for the last two. The high detection limits precluded any trend analyses. For the last two cycles, low level analyses were conducted for selected parameters (e.g. Al, As, Cu, Mo), but those were still higher than the detection limits achieved for the more recent HCTs.

Data from the earlier (Rescan 2001) testing program were used as the basis for predicting source concentration from the waste rock. A comparison of stable release rates from these earlier tests to rates from the more recent SRK HCTs indicated lower release rates due to improved analytical detection limits (Table 3.5), suggesting that the input data used in the predictions are conservative.

Table 3.5: Median Concentrations from HCT Leachates compared to Screening Criteria

		pH	Hardness	SO4	F	Cl	Al	Sb	As	Cd	Cr	Co	Cu	Fe	Pb	Hg	Mo	Ni	Se	Ag	Tl	U	Zn
HCT ID	**Rock Type[1]**	**-**	**mg $CaCO_3$/l**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**µg/L**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
HC-7	1	8.6	34	1	0.05	0.5	0.08	0.0001	0.0002	0.00001	0.0002	0.0001	0.00072	0.01	0.00005	0.02	0.0001	0.0002	0.0002	0.00004	0.00002	0.00005	0.001
HC-42		8.9	20	1	0.02	0.5	0.08	0.00002	0.00017	0.000005	0.0001	0.000014	0.00051	0.01	0.00005	0.02	0.00009	0.00005	0.00009	0.000005	0.000002	0.000003	0.0003
HC-43		8.3	30	2	0.01	2.7	0.062	0.00002	0.0003	0.000005	0.0001	0.000021	0.0003	0.01	0.000041	0.02	0.0001	0.00008	0.00005	0.000005	0.000002	0.000004	0.0004
HC-49		8.7	29	2	0.01	0.5	0.18	0.00024	0.00027	0.000005	0.0001	0.000031	0.00033	0.02	0.00005	0.02	0.0004	0.00005	0.00004	0.000005	0.000002	0.000005	0.00035
HC-50		8.3	32	5	0.01	0.5	0.08	0.00024	0.0013	0.000005	0.0001	0.0002	0.00034	0.01	0.00005	0.02	0.00024	0.00006	0.00004	0.000005	0.000002	0.000006	0.001
HC-44	1 + 12q	8.9	30	4	0.02	0.5	0.08	0.00005	0.0025	0.000005	0.0001	0.00005	0.00052	0.01	0.000047	0.02	0.0003	0.00005	0.00009	0.000005	0.000002	0.000004	0.0002
HC-45		8	30	9	0.01	0.5	0.032	0.00013	0.0023	0.000005	0.0001	0.00027	0.00048	0.01	0.000044	0.02	0.00053	0.0003	0.00009	0.000005	0.000002	0.000004	0.0005
HC-53	12q	7.5	12	1	0.01	0.5	0.0072	0.00002	0.00021	0.000005	0.0001	0.000025	0.0004	0.003	0.000047	0.02	0.00009	0.00009	0.00004	0.000005	0.000002	0.000002	0.0007
HC-36		8	38	14	0.02	0.5	0.014	0.00006	0.0002	0.000005	0.0001	0.00012	0.00041	0.01	0.00005	0.02	0.0004	0.00014	0.00009	0.000005	0.000002	0.000018	0.0008
HC-52		8.1	28	6	0.01	0.5	0.021	0.00009	0.00036	0.000005	0.0001	0.000035	0.0004	0.01	0.000043	0.02	0.00028	0.00014	0.00004	0.000005	0.000002	0.000004	0.001
HC-54		8.1	29	2.2	0.01	1.6	0.017	0.00013	0.00021	0.000005	0.0001	0.000022	0.00035	0.001	0.000028	0.009	0.00027	0.00007	0.00004	0.000005	0.000002	0.000003	0.0005
HC-47	11	8.7	12	2	0.01	0.5	0.1	0.00007	0.004	0.000005	0.0001	0.000021	0.00074	0.02	0.00005	0.02	0.00024	0.00006	0.00005	0.000005	0.000002	0.000014	0.0007
HC-48		8.7	11	2	0.01	0.5	0.09	0.0001	0.0011	0.000005	0.0001	0.000037	0.001	0.04	0.00005	0.02	0.00018	0.00006	0.00015	0.000005	0.000002	0.000015	0.0003
HC-46	10a	8.6	20	2	0.01	0.5	0.072	0.00004	0.0002	0.000005	0.0001	0.000034	0.0004	0.01	0.00005	0.02	0.0003	0.00005	0.00005	0.000005	0.000002	0.000002	0.0003
HC-51		8.6	40	5	0.01	0.6	0.1	0.00065	0.012	0.000005	0.0001	0.00031	0.00032	0.0095	0.000049	0.02	0.0002	0.00019	0.00008	0.000005	0.000002	0.000002	0.0005
HC-65*		8.1	0.5	1.1	0.02	1.1	0.2	0.00014	0.0005	0.000005	0.0001	0.000029	0.00057	0.02	0.000026	0.002	0.00005	0.00005	0.00005	0.000005	0.000002	0.000002	0.0009
HC-6	7a mixed	8.7	33	2	0.05	0.5	0.09	0.0001	0.0002	0.00001	0.0002	0.0001	0.00048	0.01	0.000055	0.02	0.00011	0.0002	0.0002	0.00004	0.00002	0.00005	0.001
Screening Criteria		**> 6.5**	**-**	**-**	**0.12**	**120**	**0.1**	**-**	**0.005**	**VAR[2]**	**0.001**	**-**	**0.002**	**0.3**	**0.001**	**0.026**	**0.073**	**0.025**	**0.001**	**0.0001**	**0.0008**	**0.015**	**0.03**
Rescan 2001 Program																							
DOP #12	1	9.1	41	3	-	-	0.1	0.1	0.1	0.005	0.005	0.005	0.005	0.015	0.025	-	0.015	0.025	0.1	0.005	0.1	-	0.0025
DUMV #5		9	56	13	-	-	0.1	0.1	0.1	0.005	0.005	0.005	0.005	0.015	0.025	-	0.015	0.025	0.1	0.005	0.1	-	0.0025
DUQ #1	12q	9.3	37	5	-	-	0.1	0.1	0.1	0.005	0.005	0.005	0.005	0.015	0.025	-	0.015	0.025	0.1	0.005	0.1	-	0.0025
DUG #6	10a	8.8	50	15	-	-	0.1	0.1	0.1	0.005	0.005	0.005	0.005	0.015	0.025	-	0.015	0.025	0.1	0.005	0.1	-	0.0025

Note: red highlight indicates value is elevated above the screening criteria, which is based on the long term CCME Water Quality Guideline for the protection of freshwater aquatic life.
[1] Rock types: 1=mafic volcanics; 1 w. 12q=mafic volcanics mixed with quartz vein; 7a mixed=early gabbro mixed; 10a=late gabbro (including low NP basalt); 11c=diabase; 12q=quartz vein
[2]The screening criteria for cadmium is calculated based on average hardness.
*HC-65 represents late gabbro that has been reclassified as low NP basalt in the vicinity of the decline, while HC-46 and HC-51 represent more typical late gabbro elsewhere in the deposit area.

Source: Y:\01_SITES\Hope.Bay\1CH008.005_Geochemistry (Doris, Madrid, Boston)\4.Kinetic program\WR HCs\Calculations\[HB_WR_Loadings.mc.REV09.xlsx]

Depletion Calculations

Depletion calculations are presented in Appendix E3 of SRK 2015b.

Depletion calculations based on stable release rates indicate that a number of humidity cell tests are likely to remain neutral, including HC-7, HC-42 and HC-49 (mafic volcanic, P20 to P60 sulphur), HC-44 (mafic volcanic with quartz vein, P29 sulphur), HC-6 (early gabbro), and HC-46 and HC-51 (late gabbro, P92 and P58 sulphur, respectively).

Depletion calculations for the other samples suggest that NP and/or TIC will be depleted prior to AP, including HC-43 and HC-50 (mafic volcanic, P85 to P99 sulphur), HC-45 (mafic volcanic with quartz vein, P86 sulphur), HC-47 and HC-48 (diabase, P95 and P98 sulphur, respectively), HC-53, HC-36, HC-52 and HC-54 (quartz vein, P49 to P100 sulphur), and HC-65 (late gabbro/low NP basalt, P58 sulphur). However, the generation of net acidic conditions for these samples is considered unlikely because of:

- Low AP depletion rates: sulphate release rates were low (stable rates of <6 mg/kg/week). These rates suggest that acidity production from sulphide oxidation will be limited.
- Overestimated NP depletion rates: at low rates of sulphide oxidation, leaching of calcium and magnesium are due primarily to simple dissolution of the carbonate minerals, rather than to production of acidity from sulphide oxidation. This can result in an overestimation of NP depletion rates, particularly in laboratory scale data where the water to rock ratios are very high. In contrast, under field conditions, where water to rock ratios are much lower, the rate of carbonate dissolution in the waste rock piles will be limited by equilibrium with carbonate minerals. The theoretical ratio of (Ca+Mg) depletion to sulphate generation in samples where Ca+Mg leaching is primarily in response to sulphide oxidation is between 1 and 2. Stable $(Ca+Mg)/SO_4$ values in these samples are between 3 and 14, suggesting that TIC dissolution, and therefore NP depletion, is in response to the weekly addition of water rather than sulphide oxidation. The exception is HC-65 (late gabbro/low NP basalt, P58 sulphur) which had stable $(Ca+Mg)/SO_4$ values below 1.

3.1.3 Post-Test Residue Characterization

After completion of the humidity cell tests, the remaining residues were geochemically analyzed for ABA and trace element content. Data are presented in Appendix F of SRK 2015b.

3.2 Barrel Tests

Characterization data for the barrel test samples are provided in Appendix C of SRK 2015b. As noted previously, humidity cell tests HC-6 and HC-7 were completed on the same samples that were used to charge barrel W1 and W5. Therefore, comparison of results from these two programs provides an indication of some of the types of differences that can be observed between the lab and field.

3.2.1 Sample Characterization

Mineralogy

Mineralogy data for the barrels are presented in Appendix B of SRK 2015b. XRD data is available for all barrel samples. MLA analysis and SEM analysis of the iron carbonates is available for W1 and W5 only.

XRD data are available for all samples characterized in recent testing programs by NMS and SRK (SRK 2011). The XRD results for the humidity cell tests were comparable to those results and showed the following:

- W10 (diabase) did not have any detectable levels of carbonate minerals.
- Carbonate minerals, where present were predominantly present as iron carbonates (ferroan dolomite ($Ca(Mg_{(x-1)}Fe_x)CO_3$) and magnesium-rich siderite ($(Mg_{(x-1)}Fe_x)CO_3$).
- Carbonate mineral levels were comparable to the humidity cell test samples, except for W13 (late gabbro), which contained low levels of ferroan dolomite (4%).
- Calcite was below detection for W1 (mafic volcanic), W10 (diabase) and W9 (quartz vein with mafic volcanic).
- Sulphides were detected in sample W9 only (quartz vein with mafic volcanic). Levels indicated by XRD for that sample were approximately half of those determined by ABA methods.

For the W1 and W9, the iron content (or x), as determined by SEM, was stoichiometrically 0.45 of the iron+magnesium content of the ferroan dolomite. Similarly, the iron content was roughly 0.8 of the iron+magnesium content of the siderite.

Acid-Base Accounting

All ABA data for the barrel test samples is provided in Appendix C1 of SRK 2015b, a selection is presented in Table 3.6, and the percentile rank for selected ABA parameters is presented in Table 3.7.

The ABA data for the SRK/NMS barrel test samples were consistent with the findings of SRK (2011). With the exception of sample W9 (quartz vein with mafic volcanic), sulphur content ranged from P26 to P59 with NP and TIC levels ranging from P39 to P75. NP and TIC content for samples W13 (late gabbro) and W10 (diabase) were lower than the other barrel samples with levels ranging from 4 to 80 kg $CaCO_3$ eq/t. For sample W9, the relative sulphur, NP and TIC content were higher than the other samples (P90). Sample W9 was classified as uncertain on the basis of NP to AP ratios, whereas all other samples were classified as non-PAG. The uncertain classification for sample W9 is related to high sulphur content.

Table 3.6: ABA Data for Barrel Samples

Barrel ID	Rock Type[1]	Paste pH	Total Sulphur	Sulphide Sulphur (%S)	NP (kg $CaCO_3$/Tonne)	TIC (kg $CaCO_3$/Tonne)	NP/AP	TIC/AP
W1	1	8.4	0.11	0.11	161	259	46.8	75.3
	1	8.3	0.17	0.16	173	244	35.5	50.0
W5	7a mixed	8.6	0.13	0.13	128	156	31.6	38.5
W13	10a	8.8	0.06	0.05	76	80	40.8	42.5
W10	11c	9.8	0.03	0.03	21	4	22.6	4.1
W9	12q with 1	9.2	2.05	2.04	180	350	2.8	5.5

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[1] Rock types: 1=mafic volcanic; 1 w. 12q=mafic volcanic mixed with quartz vein; 7a mixed=early gabbro mixed; 10a=late gabbro (including low NP basalt); 11c=diabase; 12q=quartz vein.

Table 3.7: Percentile Rank of Total Sulphur, NP and TIC for Barrel Tests

Barrel ID	Rock Type[1]	Total Sulphur									NP		TIC		ARD Classification	
		%S	All Zones		North		Connector		Central		($kgCaCO_3$/t)	All Zones	($kgCaCO_3$/t)	All Zones	NP/AP	TIC/AP
			%Rank	n	%Rank	n	%Rank	n	%Rank	n		%Rank		%Rank		
W1	1	0.11	26%	361	34%	168	30%	51	16%	142	161	39%	259	49%	non-PAG	non-PAG
	1	0.17	59%	361	71%	168	61%	51	45%	142	173	50%	244	45%	non-PAG	non-PAG
W5	7a mixed	0.13	49%	6	#N/A	0	#N/A	0	#N/A	0	128	49%	156	49%	non-PAG	non-PAG
W13	10a	0.06	36%	60	38%	41	>100%	7	15%	12	76	75%	80	74%	non-PAG	non-PAG
W10	11c	0.03	48%	41	>100%	33	>100%	1	17%	7	21	57%	4	61%	non-PAG	non-PAG
W9	12q w. 1	2.05	90%	27	89%	13	#N/A	0	92%	14	180	91%	350	98%	Uncertain	non-PAG

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Statistical analysis by rock type and preliminary economic classification
[1] Rock types: 1=mafic volcanic; 1 w. 12q=mafic volcanic mixed with quartz vein; 7a mixed=early gabbro mixed; 10a=late gabbro (including low NP basalt); 11c=diabase; 12q=quartz vein.

Trace Elements

Trace element data is presented in Appendix C2 of SRK 2015b.

Trace element data are available for the overall Doris sample set, as discussed in SRK (2011). Data were compared with ten times the average crustal abundance for basalt (Price 1997) to determine if any parameters were elevated. Arsenic levels were elevated for W9 only (quartz vein with mafic volcanic), with levels a magnitude higher compared to the other barrel samples. Arsenic levels for each barrel test sample were statistically compared with the ABA samples corresponding to the equivalent rock type and economic classification in the static testing database for Hope Bay (Table 3.8).

Table 3.8: Percentile Rank of Arsenic Levels, Barrel Test Samples

Barrel ID	Rock Type[1]	As	
		ppm	%Rank
W1	1	1.7	24
W5	7a mixed	3.2	2
W13	10a	3	79
W10	11	1.1	80
W9	12q with 1	36.5	82

[1] Rock types: 1=mafic volcanic; 1 w. 12q=mafic volcanic mixed with quartz vein; 7a mixed=early gabbro mixed; 10a=late gabbro (including low NP basalt); 11c=diabase; 12q=quartz vein.

3.2.2 Barrel Leachate Data

Table 2.9 presents details of the five barrel tests from Doris. A complete set of concentration data for the barrel leachate samples is provided in Appendix H of SRK 2015b.

The sampling frequency of each barrel was variable for a number of reasons, including inaccessibility and the absence of leachate. In September 2010, the leachate for some tests was partially frozen and as a result, parameter levels may be higher due to concentration of the leachate.

Both the field and lab pHs for all tests were neutral to alkaline. Sulphate concentrations were lower (4 to 15 mg/L) for the samples of late gabbro (W13) and diabase (W10) as compared with the samples of mafic volcanic (W1), early gabbro (W5) and quartz vein with mafic volcanic (W9) (15 to 46 mg/L).

The following observations were made for concentrations of selected trace elements (see Appendix G of SRK 2015b for graphs of concentration data):

- Antimony levels were similar for all tests and ranged from 0.0001 to 0.01 mg/L. One sample (0.03 mg/L) from the diabase barrel (W10) was not included in this range because it deviated from the trend for that barrel by more than an order of magnitude. Antimony concentrations were generally highest from the late gabbro barrel (W13).

- Arsenic, cobalt and copper levels were variable but generally ranged between 0.0001 and 0.009 mg/L (arsenic), 0.0001 to 0.003 mg/L (cobalt), and 0.001 to 0.01 mg/L (copper). These ranges do not include data points that appeared to be anomalous spikes in concentrations. Excluding these spikes, for arsenic and copper, concentrations were generally highest for W10 (diabase) and W13 (quartz vein with mafic volcanic). For cobalt, concentrations were generally highest for W1 (mafic volcanic) and W0 (quartz with mafic volcanic).
- Aluminum and iron levels were below 0.1 mg/L, except for the diabase barrel (W10), which had concentrations ranging from 0.13 to 0.30 mg/L and 0.2 to 0.5 mg/L, respectively. These elevated levels for W10 suggest colloids may be in the leachate, which would elevate the dissolved levels.
- Lead exhibited a similar trend to aluminum and iron. Concentrations for the diabase barrel (W10) were elevated (0.002 to 0.004 mg/L) relative to the other samples (less than 0.0005 mg/L).

Overall, concentrations are comparable to the HCTs.

4 Conclusions

The kinetic test program for Doris included 21 HCTs and 5 barrel tests. Four HCTs were operated by Rescan (2001) and the remaining 17 samples were from more recent geochemical characterization programs by SRK in collaboration with NMS. Sample selection was based on lithology, economic classification (ore or waste), and ABA characteristics. Trace elements (i.e. arsenic) were a secondary consideration.

The leachates from all samples were neutral to alkaline. Stable sulphate release rates were low and ranged between the limit of analytical detection (0.4 mg/kg/week) to 6 mg/kg/week. Samples with higher total sulphur contents tended to exhibit higher stable sulphate release rates.

Generally, trace element concentrations were low in the HCT leachates. One of the late gabbro samples with elevated sulphur levels had elevated concentrations of arsenic, while a number of samples had elevated concentrations of aluminum and copper.

All samples were predicted to be non-PAG on the basis of AP and NP depletion times and/or low stable sulphate release rates (less than 6 mg/kg/week).

Leachate concentrations from the barrel tests were comparable to the HCTs.

The data from the kinetic test program has been used to validate inputs used for the water quality predictions from waste rock and ore. In general, the stable trace element release rates are less than those used to predict source concentrations from the waste rock, indicating that the input data used in the predictions are conservative.

This report, “Kinetic Testing of Waste Rock and Ore from the Doris Deposits, Hope Bay”, has been 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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