APPENDIX IX.2

SUMMARY OF 2001 HYDROGEOLOGICAL DRILL PROGRAM

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1.0 INTRODUCTION

This appendix summarizes the hydrogeologic testing and groundwater quality sampling undertaken as part of the advanced exploration program (AEP) at the Snap Lake Diamond Project. Eight holes were drilled and tested in the AEP workings from May 2001 to August 2001. The purpose of this testing was to obtain hydraulic conductivity and storativity data of the hangingwall and footwall rocks, and the Snap and Crackle Faults. The data from these tests were provided to Hydrological Consultants Inc. (HCI) for analyses of hydraulic conductivity. In addition, water was collected from the drillholes to determine baseline geochemistry of the metavolcanic and granitic rocks.

2.0 HYDROGEOLOGICAL DRILLHOLES

The specific purpose of each of the drillholes is summarized in Table IX.2-1 and the location of each is presented in Figure IX.2-1. All of the drillholes were drilled from the AEP underground workings. A surface casing was installed and sealed over the first 6 m approximately of each drillhole. As the drillhole was advanced in front of this surface casing, any groundwater encountered in the drillhole would report as flow at the drillhole collar, where it could be measured to assess flow rates. Shut-in tests to determine hydraulic conductivity values of the rock mass were conducted at approximately 25-metre (m) intervals over the length of seven of the eight drillholes. Underground drillhole 106 (UG-106), the coverhole for the decline extension completed in 2001, was tested less frequently.

Table IX.2-1
Hydrogeological Drillholes

Drillhole	Collar Coordinates			Azimuth (°)	Inclination (°)	Length (m)	Purpose
	Northing (m)	Easting (m)	Elevation (m)				
UG-45	7053362.7	507457.2	328.99	090	-5	301.14	K_{xz} of metavolcanics and granite, *K* of contact zone. Geochemistry of the granites.
UG-83	7053372.1	507453.5	329.31	360	-2	350.22	K_{yz} of metavolcanics, *K* of Snap and Crackle Faults and other faults. Geochemistry of the metavolcanics.
UG-84	7053372.1	507454.6	329.31	020	-2	395.92	K_{yz} of granites, *K* of Snap and Crackle Faults and other faults. Geochemistry of the granites.
UG-106	7053147.9	507348.1	304.35	90	-4	342.90	K_{xz} of granite. Decline extension cover hole.
UG-173	7053119.0	507774.8	281.31	340	+4	100.89	K_{yz} of hangingwall granite. AEP #2 north drift cover hole. Geochemistry of the granites.
UG-174	7053093.0	507762.9	280.85	200	+6	97.54	K_{yz} of hangingwall granite. AEP #2 south drift cover hole. Geochemistry of the granites.
UG-175	7053115.0	507778.5	281.32	090	0	295.96	K_{xz} of hangingwall granite. Geochemistry of the granites.
UG-176	7053116.0	507777.2	285.14	090	+70	82.30	K_{xy} of hangingwall granite. Geochemistry of the granites.

Notes: K_{yz} indicates high angle joints/fractures in the *y-z* plane (*i.e.*, east-west trending).
K_{xz} indicates high angle joints/fractures in the x-*z* plane (*i.e.*, north-south trending).
K_{xy} indicates high angle joints/fractures in the *x-y* plane (*i.e.*, horizontal).
AEP = advanced exploration program.

Figure IX.2-1 Locations of Hydrogeological Boreholes – Advanced Exploration Program

3.0 HYDROGEOLOGICAL TESTING PROCEDURES

Shut-in tests to determine rock hydraulic conductivity were conducted in seven of the eight drillholes after the eighth drill run (approximately 24.4 m), or where there was a significant increase in flow volume, *i.e.*, an increase of greater than approximately 10 US gallons per minute (US gpm). Shut-in tests on the eighth drillhole, UG-106, were conducted less frequently due to difficulties with access.

In addition to the above testing, a flow recession test was performed on the Snap Fault between drillholes UG-83 and UG-84. This consisted of allowing one drillhole to flow (the pumping well) while the response to this flowing was measured in an adjacent shut-in well.

The following section provides further detail on the testing procedures.

3.1 Hydraulic Conductivity Testing Procedures

A sealed, surface casing, approximately 6 m in length, was installed at each drillhole. The casing was pressure tested to 600 pounds per square inch (psi) to ensure that no leaks around the casing were evident. Drilling commenced once the stuffing box, hydraulic bladder, and brass valve assembly were connected to the surface casing.

3.1.1 Flow Measurements

Each of these drillholes was drilled from the AEP workings into areas with higher hydraulic head than the drill collar. Consequently, groundwater encountered in each drillhole would report as outflow from the drillhole collar.

After each drill run (approximately 3 m), the water outflow at the drillhole collar was measured. One drill rod was removed to expose the test zone, and the hydraulic bladder was closed to seal the casing or drill rod annulus. The flow of water exiting the drill rods was determined by the amount of time to fill a 1-litre (L) plastic bottle, a 20-L pail, or a 205-L drum, depending on the observed flow rate. At least two flow measurements were recorded per run. Dry zones were recorded as “no flow” zones. If the flow of water exiting the drill rods was less than approximately 100 litres per minute (L/min) (25 US gpm), then the drill rod that had been previously removed was replaced, and drilling of the next run commenced.

Where the flow rate was greater than 100 L/min, or where the change in flow rate from the previous interval was greater than 40 L/min (10 US gpm), a shut-in test was performed. If the flow rate remained below 100 L/min, then a shut-in test was performed on every eighth drill run, or approximately every 25 m.

3.1.2 Shut-In Test

During the shut-in test, eight drill rods were removed to expose the interval to be tested. If a discrete zone was being tested, only one drill rod was removed. The hydraulic bladder was closed to seal the casing or drill rod annulus. The drill string remained sealed by leaving the water swivel attached to the drill rods.

3.1.2.1 Measurement of Initial Shut-In Pressure

Prior to the start of each shut-in test, the initial shut-in pressure in the drillhole was measured. A pressure transducer and datalogger assembly was connected to the brass value at the end of the drill string. The datalogger was programmed to record pressure readings every second.

Once the shut-in pressure reached a stable level, its value was recorded. The valve was then opened, and the discharge test commenced.

3.1.2.2 Discharge Test

During the discharge test, initial measurements of water flow were recorded as the time to fill a 200-L drum, recorded in 20-L increments. Following that, flow measurements were taken every five minutes for the first 30 minutes, and then at 10-minute intervals up to 60 minutes. After the one-hour flow period, the valve was closed and the recovery test begun.

3.1.2.3 Recovery Test

The recovery test was performed for up to 60 minutes or longer, depending on the well recovery rate. The shut-in period was long enough such that the entire drillhole was re-filled with water and the formation was re-pressurized to at least 70 percent (%) of the initial shut-in pressure.

The pressure transducer and datalogger assembly was connected to the brass valve at the end of the drill string, and it continued to record pressure readings every second.

After the shut-in test period was complete, the valve and hydraulic bladder were opened. If during the discharge test, the flow rate remained below 100 L/min, the drill rods were replaced and drilling continued. However, if the flow rate exceeded 100 L/min, the drillhole was grouted, and allowed to set prior to further advancement of the drillhole.

A summary of the intervals over which shut-in tests were performed is presented in Table IX.2. Included on this table are the rock types encountered over the testing intervals.

Table IX.2-2
Summary of Shut-In Test Intervals

Drillhole	Shut-In Test Interval		Interval Rock Type
	From (m)	To (m)	
UG-45	5.79	39.01	HKBC/HKV/MTVC/WRK/HKD/HKM/MG
UG-45	39.01	58.00	MG
UG-45	58.00	83.00	MG/FLT
UG-45	83.00	109.00	MG/FLT
UG-45	109.00	132.00	MG/PEG/MTVC
UG-45	132.00	158.00	MG/FLT
UG-45	152.00	167.00	MG/FLT/MGF
UG-45	167.00	191.00	MG/FLT/MGF
UG-45	173.00	198.00	MG/FLT/MGF
UG-45	198.00	208.00	MG
UG-45	208.00	213.00	MG
UG-45	208.00	234.00	MG
UG-45	235.00	258.00	MG
UG-45	258.00	283.00	MG/PEG
UG-45	277.00	301.00	MG
UG-83	22.86	47.24	HKBC/HKM/WRK/MTVC
UG-83	47.24	71.63	WRK/MTVC/HKBR
UG-83	71.32	95.71	HKBR/MTVC
UG-83	91.44	103.63	MTVC/MG
UG-83	106.07	109.42	MTVC
UG-83	103.63	120.40	MTVC/MGF
UG-83	135.64	148.74	MGF/MTVC/MG/FLT
UG-83	150.27	174.65	MTVC
UG-83	174.65	199.64	MTVC/MG
UG-83	199.64	219.46	MTVC/FLT
UG-83	219.46	243.84	MTVC/MGF
UG-83	243.84	268.22	MTVC
UG-83	268.22	294.13	MTVC
UG-83	294.13	320.04	MTVC
UG-83	320.04	350.52	MTVC
UG-84	28.65	53.03	MTVC/WRK

Table IX.2-2
Summary of Shut-in Test Intervals (Continued)

Drillhole	Shut-In Test Interval		Interval Rock Type
	From (m)	To (m)	
UG-84	53.34	71.62	WRK/HKD/MTVC/MG
UG-84	77.42	101.80	HKBC/HKBR/MG/MGF
UG-84	101.80	123.14	MG
UG-84	123.14	147.52	MG/PEG
UG-84	147.52	173.43	MG/MGF
UG-84	173.43	185.62	MGF
UG-84	185.62	211.53	MGF
UG-84	211.53	235.92	MGF/FLT
UG-84	235.92	254.20	FLT/MTVC
UG-84	254.20	280.11	MTVC
UG-84	280.11	304.50	MTVC/MGF
UG-84	304.50	328.88	MGF
UG-84	327.36	351.74	MGF/MG
UG-84	351.74	375.51	MG
UG-84	375.51	395.94	MG
UG-106	164.00	172.00	MG
UG-106	184.00	209.00	MG
UG-106	275.83	300.21	MG
UG-173	3.05	36.88	HKD/MG
UG-173	36.88	55.17	MG
UG-173	55.17	80.00	MG
UG-173	80.00	100.00	MG
UG-174	0.00	24.40	HKD/MG
UG-174	24.40	48.80	MG
UG-174	48.80	73.20	MG
UG-174	73.20	97.50	MG
UG-175	24.40	48.80	HKD/HKM/MG
UG-175	52.10	75.90	MG
UG-175	76.50	99.40	MG/MGF
UG-175	99.40	122.20	MG
UG-175	122.20	146.60	MG
UG-175	146.60	171.00	MG
UG-175	171.00	183.20	MG
UG-175	183.20	207.60	MG
UG-175	207.60	232.00	MG
UG-175	232.00	241.10	MG
UG-175	241.10	265.50	MG

Table IX.2-2
Summary of Shut-in Test Intervals (Continued)

Drillhole	Shut-In Test Interval		Interval Rock Type
	From (m)	To (m)	
UG-175	265.50	289.90	MG
UG-176	21.33	45.72	MG
UG-176	3.05	56.31	MG
UG-176	56.39	62.48	MG
UG-176	60.96	82.29	MG

Notes:
HKM: hypabyssal macrocrystic kimberlite
HKD: kimberlite dykelet
HKV: carbonate veined hypabyssal kimberlite
HKBC: contact kimberlite breccia
HKBR: macrocrystic kimberlite breccia
MG: multiphase magnetic granitoids
MGF: fault related multiphase magnetic granitoids
MTVC: metavolcanic unit
WRK: kimberlite veining into wallrock
PG: muscovite pegmatite
FLT: fault zone

3.2 Flow Recession Test Protocol

A flow recession test was performed between drillholes UG-83 and UG-84 to provide hydraulic conductivity and storativity data on the Snap Fault. Prior to the intersection of the Snap Fault, procedures for drilling, hydraulic conductivity testing, and grouting if required were followed.

The Snap Fault zone was intersected in UG-83, at approximately 200 m. Drilling through the zone was continued to a depth of 243.83 m, where flows sometimes exceeded 100 L/min, until tighter rock was encountered past the fault zone. The drill rods were removed from drillhole UG-83, and the drillhole was shut-in with the brass valve installed on the casing. UG-83 had previously been grouted to a depth of 167.63 m.

The drill rig was then set-up on drillhole UG-84 and the procedures for drilling, testing, and grouting if required, were followed until the Snap Fault zone was intersected at approximately 225 m. Drilling through the zone continued to a depth of 254.19 m, where flows sometimes exceeded 100 L/min, until tighter rock was encountered past the fault zone. The drill rods were removed from the drillhole to a depth of 185.61 m, and the drill-hole was shut-in.

UG-83 was designated as the flowing well and UG-84 was designated as the observation well. Previous flow measurements indicated that UG-83 showed the highest flow rates. Once both “wells” were installed within the Snap Fault zone, the flow recession test was conducted.

3.2.1 Measurement of Initial Shut-In Pressures

The collar elevation for both drillholes was recorded. An oil-filled pressure gauge was connected to the valve assembly on drillhole UG-83, while the pressure transducer and datalogger assembly was connected to drillhole UG-84. The datalogger was programmed to record pressure measurements at 20-second intervals. The initial shut-in pressures in both drillholes were recorded.

Once the shut-in pressure for both drillholes reached a stable level, the values were recorded. The brass valve attached to UG-83 was then opened and the discharge test commenced.

3.2.2 Discharge Test

During the discharge test, initial measurements of water flow from UG-83 were taken as the time to fill a 200-L drum, recorded in 20-L increments. Following that, flow measurements were taken every five minutes for the first 30 minutes, and then at ten-minute intervals up to 60 minutes using the 200-L drum. Flow was then measured and recorded every 30 minutes for up to 12 hours. The purpose of the 12-hour flow period was to determine hydraulic conductivity of the Snap Fault zone over a large area rather than the one-hour discussed above.

3.2.3 Recovery Test

After the 12-hour flow period, the valve attached to UG-83 was closed. Pressure measurements from UG-83 were taken using the oil-filled pressure gauge attached to the casing. Measurements were taken approximately every ten seconds for the first two minutes, every minute from two to ten minutes, and every 180 minutes from ten to 720 minutes. The duration of the shut-in period was 12 hours, at which time the UG-83 drill string had re-filled, and the formation had re-pressurized.

3.2.4 Post-test Procedures

Once the Snap Fault flow recession test was complete, drillholes UG-83 and UG-84 were grouted.

Drilling then continued on drillhole UG-83. Drilling and testing of drillhole UG-83 followed the procedures for drilling, testing, and grouting. It was planned to complete a second flow recession test on the Crackle Fault. However, the location of the Crackle Fault was difficult to discern in the drill core, and was not obviously intersected. Consequently, a second flow recession tests was not conducted.

3.3 Hydrogeological Testing Data

All test data collected and amalgamated during the 2001 hydrogeological program at Snap Lake were supplied to HCI for detailed analysis and hydrogeological modelling of the Snap Lake mine.

The analyses performed by HCI and the results of the hydrogeological modelling are presented in Appendix IX.3.

4.0 GROUNDWATER SAMPLING PROGRAM

As part of the geochemical and water-quality characterization programs, groundwater samples were also taken from each of the drillholes. The depth and the rock type from which each water sample was taken are presented in Table IX.2-3. Table E-1 of Appendix IX.1 presents the raw data from the groundwater samples.

Table IX.2-3
Water Sample Locations

Drillhole	Depth (m)	Rock Type
UG-45	158	MGF
	237	MG
	301	MG
UG-83	128	MTVC
	244	MTVC
	350	MG
UG-84	186	MGF
	396	MG
UG-106	172	MG
	343	MG
UG-173	67	MG
	100	MG
UG-174	72	MG
	98	MG
UG-175	122	MG
	296	MG
UG-176	82	MG

Notes: MG: multiphase magnetic granitoids.
MGF: fault related multiphase magnetic granitoids.
MTVC: metavolcanic unit.
m = metres.

Field measurements such as temperature, conductivity, pH, Redox potential, dissolved oxygen, and alkalinity were collected from each water sample. Water samples were then sent to an analytical laboratory for analysis. Samples were analyzed for the following parameter groups: major cations and anions, nutrients, oil and grease, total organic carbon, dissolved organic carbon, total ultra low metals, dissolved ultra low metals. Procedures for the collection of water samples are described in brief below.

4.1 Measurement of Field Parameters

Prior to the collection of water samples from a drillhole, at least two drillhole volumes were allowed to flow through the drill rods. This equated to 0.9 cubic metres (m^3) per 100 m, or 70 US gallons per 30 m of drillhole.

A 1-L water sample was collected for the measurement of field parameters. Prior to collecting the water sample, a sample bottle was rinsed three times with small amounts (about 5% of the container volume) of the water being sampled. Care was taken to limit exposure of the sample to the atmosphere by allowing the sample container to overflow for approximately a minute before measurements were taken.

Temperature, conductivity, pH, Eh, and dissolved oxygen were collected at the drill rig with a portable meter. The sample bottle was re-filled after the measurement of these parameters, and brought to surface where the sample was filtered and an alkalinity measurement was taken.

4.2 Collection of Water Samples for Analytical Analysis

Following collection of the water sample for the measurement of field parameters, water samples were collected in specific bottles for shipment to EnviroTest Laboratories for analytical testing. The standard technical procedures for collecting water samples were followed (Appendix IX.5). All samples were labelled with the sample identification (*e.g.*, UG-45-158 [underground-drillhole-depth]).

4.3 Quality Assurance/Quality Control

To assure quality assurance/quality control (QA/QC) of the results from the sample program, replicate samples and field equipment blanks were also collected.

5.0 SUMMARY

A summary of the location, geology encountered, hydrogeological tests, groundwater samples, and the maximum water flow encountered in each of the hydrogeological drillholes is presented in Table IX.2-4.

Table IX.2-4
Summary of Advanced Exploration Program Drillhole Hydrogeological Information

Drill hole	North Drift				Kimberlite Drift			
	UG-45	UG-83	UG-84	UG-106	UG-173	UG-174	UG-175	UG-176
Direction	east from north end of north drift	north from north end of north drift.	north-northeast from north end of north drift.	east – decline extension cover hole	north from north- drift cover hole.	south from south drift cover hole	east from drill bay	east at 70 degrees from drill bay
Rock type	kimberlite 0 m to 32 m, granite 32 m to 301.14 m	kimberlite 0 m to 82 m, metavolcanics (some granite) 82 m to 350.22 m	kimberlite 0 m to 84 m, metavolcanics (some granite) 84 m to 395.92 m	entire hole drilled in granite	entire hole drilled in granite	entire hole drilled in granite	kimberlite 0 m to 34 m, granite 34m to 295.96 m	entire hole drilled in granite
Length	301.14 m	350.22 m	395.92 m	342.90 m	100.89 m	97.54 m	295.96 m	82.30 m
Number of shut-in tests	15	16	14	3	4	4	12	4
Approximate Maximum flow	250 L/min (60 US gpm) at 205-m depth	≈450 L/min (115 US gpm) at 99-m depth	180 L/min (45 US gpm) at 184-m depth	120 L/min (30 US gpm) at 107-m depth	130 L/min (32 US gpm) at 54-m depth.	45 L/min (11 US gpm) 84-m depth	120 L/min (40 US gpm) at 177-m depth	200 L/min (55 US gpm)
Fault intersection	n/a	Snap Fault intersected at approximately 200 m Crackle Fault not obviously intersected	Snap Fault intersected at approximately 225 m Crackle Fault not obviously intersected	n/a	n/a	n/a	one fault zone intersected at approximately 90 m – hydrothermally altered zone, no increase in flow	n/a
Number of water samples collected	3	3	2	2	2	2	2	1
Flow-recession tests	none	a 24-hour test; flowing well	a 24-hour test; monitoring well	none		none	none	none

Notes: US gpm = Unites States gallon per minute.
L/min = litres per minute.
n/a – not applicable.

6.0 UNITS AND ACRONYMS

UNITS

L	litre
L/min	litres per minute
m	metre
m^3	cubic metre
%	percent
psi	pounds per square inch
US	United States
US gpm	United States gallons per minute

Acronyms

AEP	advanced exploration program
FLT	fault zone
HKBC	contact kimberlite breccia
HKBR	macrocrystic kimberlite breccia
HKD	kimberlite dykelet
HKM	hypabyssal macrocrystic kimberlite
HKV	carbonate veined hypabyssal kimberlite
HCI	Hydrological Consultants Inc.
MG	multiphase magnetic granitoids
MGF	fault related multiphase magnetic granitoids
MTVC	metavolcanic unit

PG	muscovite pegmatite
QA/QC	quality assurance/quality control
WRK	kimberlite veining into wallrock