Atlantic Minerals Limited
Quarry Extension,
Groundwater Monitoring Plan

Lower Cove Quarry

Prepared for:
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Final Report

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1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by Atlantic Minerals Limited (AML) to prepare a Groundwater Monitoring Plan (GWMP) for the Lower Cove Quarry Extension. The Extension Area for the Quarry is shown on Figure 1 in Appendix A. Stantec understands that this work has been requested by the Newfoundland Department of Municipal Affairs and Environment (MAE) as a condition of release from provincial Environmental Assessment to monitor ambient background water quality conditions prior to commencing the undertaking, and to assess potential changes to groundwater quality during construction, operation, and decommissioning of the undertaking.

This document outlines the recommended GWMP and provides:

1. The location of proposed monitoring wells;
2. Procedures for drilling and constructing the monitoring wells;
3. Chemical and physical groundwater parameters to be monitored;
4. Frequency of sampling/monitoring;
5. Methodology for groundwater sampling/monitoring; and
6. Reporting requirements.

This GWMP should be submitted to the MAE for their review and acceptance prior to executing the associated activities at the site.

2.0 PROPOSED GROUNDWATER MONITORING PLAN

The proposed GWMP consists of drilling monitoring well locations around the Extension Area; two on the north/northeast boundary, and two along the southern boundary. Routine water level and water quality sampling at these monitoring wells is also proposed.

2.1 Monitoring Well Drilling

2.1.1 Locations

The Extension Area is in the uplands of the surface watershed containing Harry Brook, which flows northeast and discharges to West Bay at the community of West Bay Centre (see Figure 1 in Appendix A). Watershed boundary analysis based on topographic data shows that the Extension Area is less than one kilometre from the watershed for the Falls Brook, which flows south and discharges to St. George's Bay at Sheaves Cove (see Figure 1 in Appendix A). Uplands near a topographic divide are typically recharge areas for the groundwater system. The surface of the water table is generally a subdued expression of ground surface topography on the larger scale, and groundwater and surface water divides are often assumed to be coincident. However, they may not be coincident on the local scale, especially in bedrock aquifers where groundwater flow is controlled by the presence and interconnectivity of preferential pathways, such as discrete fractures and dissolution voids, as is expected at the Extension Area. There is currently no data available to assess the groundwater flow direction near the Extension Area or the presence of a downward hydraulic gradient indicative of a flow divide and recharge area.

The proposed monitoring well locations are presented on Figure 1 in Appendix A. Two shallow monitoring wells (17MW01 and 17MW02-S) are located between the southern boundary of the Extension Area and the surface water divide. A deeper monitoring well (17MW02-D) is co-located with 17MW02-S to allow for the observation of water level and water chemistry in the deeper groundwater system, and the evaluation of the vertical gradient proximal to the surface water divide.

Two additional shallow monitoring wells (17MW03 and 17MW04) are proposed along the northeast extent of the Extension Area in the downgradient direction.

The water level and water quality data obtained from these monitoring wells will allow for an evaluation of the shallow groundwater flow direction, the quantification of the horizontal and vertical hydraulic gradients, the observation of water quality, and the assessment of the spatiotemporal variability of these datasets.

2.1.2 Drilling Methods

Stantec recommends that the monitor wells be installed by coring an HQ-size (96-mm diameter) boreholes using a track-mounted rig (depending on accessibility constraints). HQ-size holes are preferred to allow for the installation of 50-mm-diameter monitoring wells, which are common for environmental investigations. The core should be logged in the field by a technician with geological/geotechnical experience. Attention should be given to identifying the location of natural fractures and dissolution voids, both of which may act as a preferential pathway for groundwater flow. It is expected that the overburden is thin at the proposed sites. The field technician should record the overburden thickness, but no auguring or split spoon sampling is warranted.

The designations of “shallow” and “deep” monitoring well are relative. For this purpose of this exercise, a shallow monitoring well is one that is screened close to the water table, as observed during drilling. The deeper monitoring well would be screened at 15 m below the bottom of the co-located shallow monitoring well. Typically, the deep interval is drilled first to evaluate the subsurface conditions and locate the position of the water table. This information is then used to establish the target depth for that borehole with consideration for the design of the shallow interval to be drilled adjacent to it. The final depths of the boreholes should be determined based on field conditions by the field technician in consultation with the drillers and the project hydrogeologist. Shallow well depth and screen length should consider the expected water table fluctuation range, both from natural factors and site activities.

2.1.3 Monitoring Well Construction

The final construction of the monitoring wells will depend on site conditions, and should be specified by the field technician to the driller in consultation with the project hydrogeologist.

2.1.3.1 Well Screen

The shallow monitoring wells should be constructed with a 50-mm-diameter, 3-m-long, 20-slot (or similar) PVC screen placed at the bottom of the borehole with solid PVC riser pipe extending to a minimum of 0.6 m above ground surface.

2.1.3.2 Sand Pack

A sand pack should be placed around the screen and should extend a minimum of 0.3 m above the top of the screen. The sand must be clean silica suitable for environmental applications with a grain size that is compatible with the screen slot. No. 2 sand and a 10- or 20-slot screen is common in practice. In the case of a bedrock well, the sand pack is typically not needed to retain the natural geologic material (unless extensive weathering has occurred) as would be required in unconsolidated deposits. The sand should be poured slowly to avoid bridging, and a weighted tape should be used to routinely locate the top of the sand and confirm that the minimum height above the top of the screen has been achieved.

2.1.3.3 Annular Seal

The annular space above the top of the sand pack must be sealed to hydraulically isolate the screened interval. The minimum annular seal thickness is 0.3 m, as measured immediately after placement without allowance for swelling. The annular seal will be composed of commercially available bentonite pellets or chips approved for environmental use. Coated pellets should be used if there is a long distance between the water table and the desired depth in the borehole. The coating delays hydration and allows the pellets to settle before they swell and become sticky. Bentonite slurry seals should be used when bentonite pellets or chips cannot be placed in the annulus and the slurry should have a batter-like consistency. Slurry seals will be emplaced using the tremie method above the sand pack and will have a maximum placement thickness of 1.5 m. If bentonite pellets or chips are used, about 4 litres of water (of known chemistry) per 0.3 m of pellets or chips will be added as needed to initiate hydration of the bentonite if no water is present in the well at time of installation.

2.1.3.4 Grout

The annular space above the annular seal must be grouted to within 0.4 m of the surface. Ideally, this would be done using a grout mixture of high-yield bentonite, and placed using a tremie pipe from the bottom up. Alternatively, the placement of bentonite chips or pellets by hand may be more cost effective and still protective of groundwater from surface contamination. Chips and pellets must be hydrated during placement using the method described above.

2.1.3.5 Surface Seal and Completion

A surface seal should then be installed by filling the annual space from 0.4 m below grade to surface. A protective steel casing with a lockable steel cap should be installed over the monitoring well casing and set 0.6 m into the ground through the concrete, leaving about 0.6 m above the ground. The top of the PVC riser pipe should be a maximum of 0.1 m below the top of the protective steel casing to allow for water level measurements.

Each PVC riser pipe should be fitted with a j-plug and a mark should be made on the PVC to indicate the reference point for water level measurements and the elevation survey. The protective casing should be fitted with keyed-alike padlocks.

2.1.3.6 Survey

The spatial coordinates and ground surface and top of PVC casing elevations should be surveyed after well construction. A vertical accuracy of <1 cm is recommended to provide more confidence in water level measurements and the interpretation of flow direction.

2.1.4 Well Development, Testing, and Monitoring Equipment Deployment

2.1.4.1 Well Development

Following the completion of drilling, each monitoring well should be developed using a submersible pump capable of high flow rates and handling turbid water. The volume of the water in the casing should then be calculated based on the depth of the well, the depth to the static water level, and the pipe diameter. For a 50-mm-diameter well, one casing volume is equivalent to the height of the water in the well multiplied by a factor of 2 L/m.

Development should take place across the entire screened interval by raising the pump slowly up the well during the process (i.e., place the pump at the bottom initially and bring to the top of the water column by the time two well volumes have been removed). Development should continue until 10 well volumes has been removed and the water is clear of sediment as is practical and three consecutive readings with 10% of pH/electrical conductivity is achieved. If water is added during drilling, an additional 3 well volumes should be removed (i.e., a minimum total of 13 well volumes). If the monitoring well does not provide sufficient yield to remove 10 well volumes, it should be pumped dry and allowed to recover three times.

2.1.4.2 Slug Testing

Slug testing should be performed at each monitoring well so that the hydraulic conductivity of the aquifer intersected by the screen can be evaluated. This should be performed by an experienced field technician in consultation with the project hydrogeologist. It is recommended that a logging pressure transducer be used to measure and record the water level during the test rather than trying to use a manual water level tape. Note that the slug test method does have limitations for the range of the hydraulic conductivity that can be reasonably interpreted (typically the range is

10^{-8} to 10^{-4} m/s. For this exercise, it is most practical to report "$<10^{-8}$ m/s" or "$>10^{-4}$ m/s" if the data indicates that the hydraulic conductivity is outside of the testable range rather than attempt a retest using another hydraulic testing method.

2.1.4.3 Monitoring Equipment Deployment

Dedicated polyethylene sampling tubing with foot valve (e.g. Waterra™) is recommended for all monitoring wells. New and clean tubing and foot valve should be inserted into the well until it reaches the bottom. The tubing should then be cut long enough to allow for 1.5 m extra. The tubing should then be folded so that the extra portion can be inserted into the well while allowing it to be easily retrieved during sampling.

The use of dedicated water level loggers is recommended at all four monitoring wells along with one barometric pressure logger. This will allow for a better understanding of the temporal variability of aquifer water levels between the manual water level monitoring events. The water level loggers should be hung using braided steel cable, Kevlar cord, or other suitable cable (made from material that doesn't stretch when wet) from the molded plastic loop on the j-plug. The logger should be placed a minimum of 2 m below the static water level. The barometric pressure logger should be deployed inside of any one of the well protectors where it is free to the atmosphere.

2.2 Water Quality and Quantity Monitoring

The following describes the proposed monitoring program.

2.2.1 Parameters

The proposed initial monitoring program consists of measurements of water levels in the monitoring wells and the collection of water samples for the analysis of general chemistry and dissolved metals.

The parameter list should be revisited after the first six monitoring events to determine if it is appropriate. Modifications to the plan may be warranted depending on the development of the Extension Area and if any significant impacts are detected that warrant further investigation.

2.2.2 Frequency

The proposed initial monitoring program should consist of three annual events for manual water level measurement and sample collection. The water level and barometric pressure loggers should be programmed to measure and record every hour on the hour. The field technician should download the data at each field event.

Based on the typical climate conditions, sampling is proposed for April/May, July/August and October/November. Snow pack depth and air temperature could inhibit site access and sampling between November and March. Some flexibility may be warranted based on actual conditions.

Sampling frequency should be revisited after the first six sampling events to determine if it is appropriate. Modifications to the plan may be warranted depending on the development of the Extension Area and if any significant impacts are detected that warrant further investigation.

The first sampling event should be incorporated into the well development effort following drilling.

2.2.3 Methodology

Water levels should be measured during every monitoring event using a water level tape. The measurement should be taken relative to the measurement reference point indicated on the PVC casing. The field technician should record the value of the depth to the static water level and note the time of the measurement. This information is required for compensating the logger data. The datalogger should then be pulled, downloaded, and redeployed.

Each monitoring well should be purged prior to the collection of a sample. The purpose of purging is to remove the water in the well and induce the flow of aquifer water into the well to collect a representative sample of aquifer water. Purging should be conducted until three to five well volumes have been removed and three successive measurements of field parameters are within ±0.1 pH units, ±3% for specific conductance, ±10 mV for oxidation-reduction potential, and ±10% for turbidity and dissolved oxygen, as measured using a multi-parameter sonde in a flow-through cell. At a minimum, pH and specific conductance should be tracked during purging. Ideally, the water level will not be drawn down below the top of the screen during purging. If the well pumps dry and the water level recovers to within about 80% of the static condition in less than 8 hours, the well should be evacuated again at least once before sampling is performed.

Both purging and sampling can be performed using the dedicated tubing (i.e., inertial lift pump). Alternatively, a variety of other pump types (e.g. bladder, peristaltic, submersible) could be used, if deemed suitable for the analytes. It is not critical to sample using low flow methods for general chemistry and dissolved metals, though care should be exercised to induce the least amount of agitation. The pump intake should be kept at least one metre off the bottom of the well to avoid the disturbance of any fines that may have accumulated.

Upon the completion of purging a well, a sample should then be collected. Samples should be collected directly in clean bottles supplied by the laboratory. The dissolved metals sample needs to be filtered using a 0.45 µm filter. Puck filters can be supplied for this purpose by the laboratory, or a high volume inline filter may be preferred when the turbidity is elevated. The sample bottles should be filled to the top so that there is no headspace and capped tightly. Analytes that require specific preservation have their own bottle preloaded with the appropriate acid for preservation. All samples should be kept on ice in a cooler and/or refrigerated (<4 °C) and submitted to the laboratory within 28 days of collection (unless otherwise specified by the commercial laboratory).

Water level and sampling at all monitoring wells should be conducted in one event to provide a "snapshot" of aquifer conditions.

2.3 Reporting

Monitoring data should be compiled after every field event. A formal review of the monitoring data should be conducted after the first three events to establish the ambient conditions prior to development. It is likely that many parameters will show variable concentrations/values with time in the initial data that reflect natural/ambient conditions, not the influence of anthropogenic activity that can be attributed directly to development of the Extension Area. Over time, the dataset will grow and so will the confidence in defining what may be considered background concentration ranges and expected fluctuations in the water table or hydraulic gradient. The initial data review should be conducted by a qualified hydrogeologist and presented in an internal memo to AML. The rationale is that while there will be data at that point, there is not enough to make a reasonable interpretation of ambient aquifer conditions. The results should be made readily available to MAE upon their request.

A second formal review of the data should be performed by a qualified hydrogeologist after the first six monitoring events. The more extensive dataset will allow for a more confident quantification of typical ambient (if the footprint of the Extension Area development is relatively small at that point) concentration ranges and water level/gradient fluctuations. At a minimum, the review should include:

- Well hydrographs.
- A map presenting groundwater elevation contours from a representative monitoring event.
- Quantification of horizontal and vertical hydraulic gradients.
- A textual description of the conceptual model for groundwater flow.
- Groundwater chemistry presented in table format and screened against an appropriate regulatory guideline(s).
- A discussion of groundwater chemical conditions and the identification of indicator parameters that may be used in the future to identify site-related impacts on groundwater quality.
- Recommendations for the on-going monitoring (parameters, locations, frequency, etc.).

This review should be summarized into a report that is the first submission to MAE. Any proposed changes to the GWMP would require NLDECC approval prior to their implementation.

At a minimum, the subsequent (monitoring event seven and beyond) compiled monitoring data should be reviewed by a hydrogeologist on an annual basis and documented in an internal memo to AML. The frequency of formal reporting needs to be set in consultation with MAE.

3.0 CLOSURE

This report has been prepared for the exclusive use of AML and any use by any third party is prohibited. Stantec assumes no responsibility for losses, damages, liabilities or claims, howsoever arising, from third party use of this report.

The information contained in this report is based on work undertaken by trained professional and technical staff, in accordance with generally accepted engineering and scientific practices current at the time the work was performed. Conclusions made within this report consist of Stantec's professional opinion as of the time of the writing of this report, and are based solely on the scope of work described in the report, the limited data available and the results of the work. This report should not be construed as legal advice.

If any conditions become apparent that differ significantly from our understanding of conditions as presented in this report, we request that we be notified immediately to reassess the conclusions provided herein.

This report was prepared by John Kozuskanich, PhD, M.Pl., P.Geo. and reviewed by Robert MacLeod, M.Sc., P.Geo. We trust that this report meets your present requirements. If you have any questions or require additional information, please contact our office at your convenience.

Respectfully submitted,

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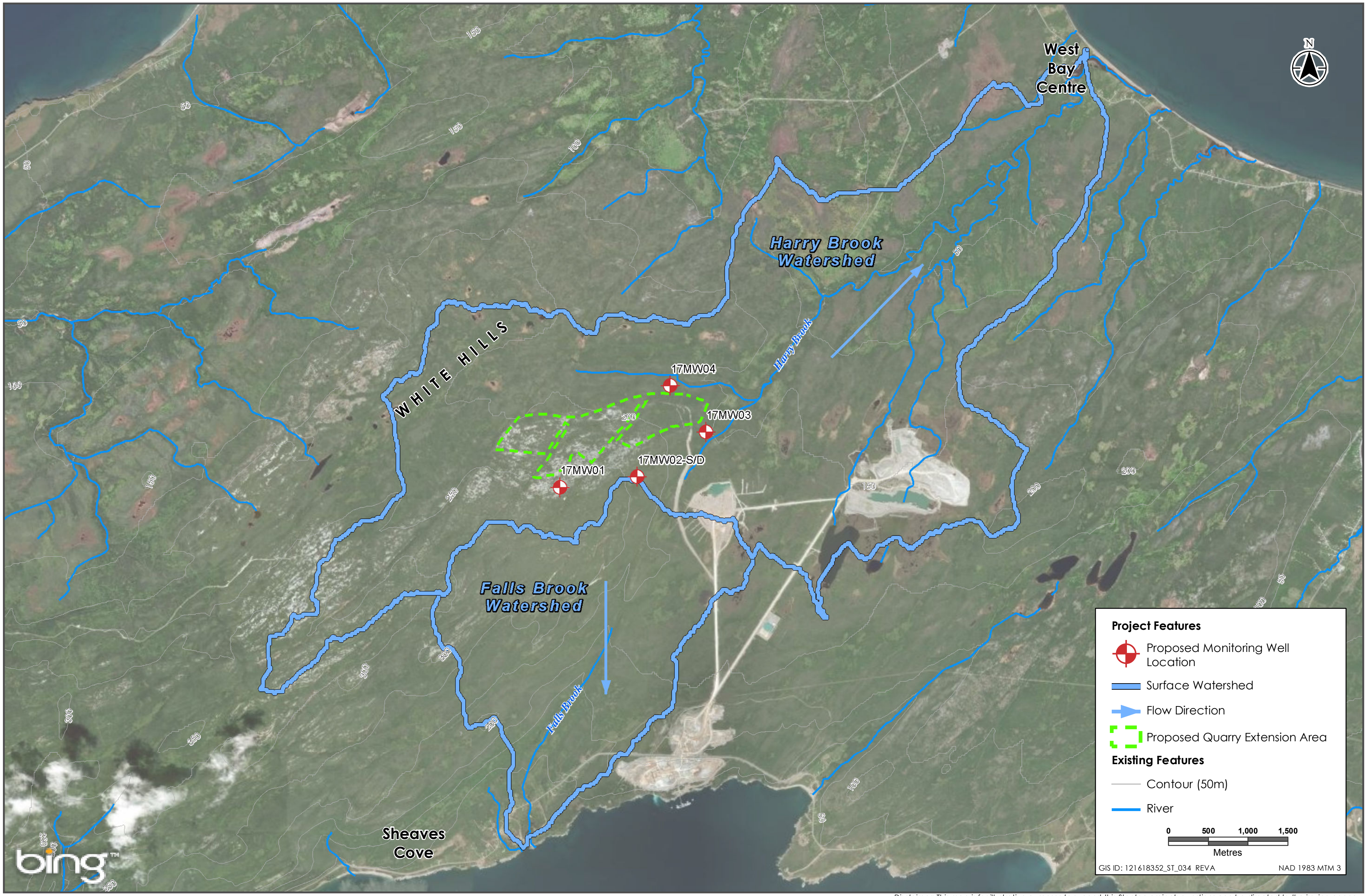
APPENDIX A

Figure 1 Proposed Monitoring Well Locations



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Disclaimer: This map is for illustrative purposes to support this Stantec project; questions can be directed to the issuing agency.

Figure 1 - Proposed Monitoring Well Locations

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