APPENDIX C

Third Party Review Documents:

APPENDIX C.1

Water Modelling Third-Party Review of the Touquoy Gold Project Site Modifications Environmental Assessment Registration

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Memorandum

To	**Barb Bryden** **Atlantic Mining NS Inc.**	File no	**TE211058**
From	**Simon Gautrey**	cc	**Bruce Fraser** **Mario Bianchin** **Brad Markham** **Veera Rajasekaram** **Niko Finke**
Date	**7 January 2022**		

Subject: Water Modelling Third-party Review of the Touquoy Gold Project Site Modifications – Environmental Assessment Registration

1.0 Introduction

Wood Environmental & Infrastructure Solutions, a Division of Wood Canada Limited (Wood) is pleased to provide Atlantic Mining Nova Scotia Inc (AMNS), a subsidiary of St Barbara Limited (the Client) with a Third-party peer review of the water modelling presented and referenced in the Touquoy Gold Project Site Modifications Environmental Assessment Registration Document (EARD). Wood understands that AMNS was requested by the Nova Scotia Department of Environment and Climate Change (NSECC) to retain a third party to complete a review of water modelling submitted to the NSECC in support of modifications to the previously approved Touquoy Gold Project.

The NSECC provided the Client with a scope of work, which was forwarded to Wood and forms the basis of this review. The NSECC scope of work requested the peer review of water modelling provided in Appendix D and Appendix A of the Touquoy Gold Project Site Modifications EARD and focus on the adequacy of the modelling to predict potential environmental effects from the proposed changes to mine operations. Wood's peer review does not include a review of environmental effects from the previously approved project, although the adequacy of the models presented by the proponent to simulate existing conditions was considered. Potential impacts considered by Wood, which have already been approved under the previous project description, include drawdown effects from the open pit, as well as impacts from groundwater seepage and surface water runoff from existing site facilities such as the existing Waste Rock Storage Facility (WRSF), Tailings Management Facility (TMF), plant site, water storage ponds, roads, etc. Furthermore, an assessment of the regulatory criteria used to evaluate discharge from the proposed facilities and possible technologies for treatment of discharge from the facilities were not part of the peer review.

As Wood understands, the purpose of the Touquoy Gold Project Site Modifications – EARD is to support modifications to the existing project to allow for: 1) disposal of tailings into the open pit, and 2) allow for a slight expansion of the Waste Rock Storage Facility (WRSF). To this end, the following Appendices of the *Touquoy Gold Project Site Modifications – Environmental Assessment Registration Document (EARD) were provided for review:*

- *Appendix A Technical Reports – Project Description.*
- *Appendix D.1 Groundwater Flow and Solute Transport Modelling to Evaluate Disposal of Tailings in Touquoy Open Pit.*
- *Appendix D.2 Waste Rock Storage Area Groundwater Modelling Update, Touquoy Gold Mine.*
- *Appendix D.3 Water Quality Predictions for Scraggy Lake and Watercourse No. 4, Touquoy Gold Mine.*
- *Appendix D.4 Touquoy Gold Mine – WRSA and TMF Geochemical Source Terms.*
- *Appendix D.5 Touquoy Gold Project, Assimilative Capacity Study of Moose Rover – Touquoy Pit Discharge.*

Three specialists from Wood completed the review of the provided documents relative to their field expertise, as follows:

- Hydrology: Veera Rajasekaram, Ph.D., P.Eng. (Alberta), 20 years' experience, Senior Water Resources Engineer.
- Geochemist: Niko Finke Ph.D., 20 years' experience, Environmental Geochemist.
- Groundwater Modelling: Brad Markham, M.Sc., P.Geo. (Ontario), 16 years' experience, Senior Hydrogeologist.

These reviewers each reviewed those documents provided that relate to their specialty under the supervision of Mr. Gautrey, M.Sc., P.Geo., a Principal Hydrogeologist from Wood with over 25 years' experience. Resumes for the staff involved in the peer review are included in Attachment 1.

This letter and accompanying attachments are intended to document the Third Party Review of water models competed by Wood. The letter is intended to provide an overview of the comments, while specific comments from the individual reviewers are provided in a table in Attachment 2. Further, more detailed comments on the groundwater models are provided in Attachment 3.

2.0 Significance of Environmental Risks from Proposed Project Changes

The key environmental risks assessed by the proponent using the models presented in Appendix A and Appendix D of the EARD relate to, a) the potential for increased runoff and seepage from the expansion of the WRSF, and b) the creation of a potential new contaminant source area by the subaqueous deposition of tailings in the open pit, which were previously planned to be directed to the existing TMF.

Generally speaking, the proponent's request for a small expansion of the WRSF is not expected to significantly change the environmental impacts of the project because of the limited size of the requested expansion relative to the previously approved project and the general similarity of conditions under the expansion to the existing WRSF. Contamination from the WRSF is expected to be present in surface runoff and groundwater seepage from the WRSF, however the proponent expects surface water runoff is anticipated to be captured by perimeter ditches and directed to ponds, treated if necessary, and discharged either to Watercourse #4 or the existing Tailings Management Facility (TMF) for treatment. Some groundwater seepage is captured by the perimeter ditches but seepage is also predicted to flow to either Watercourse #4 or the upper reaches of the Fish River or tributaries of these rivers. An assimilation capacity report for Watercourse #4 provided by the proponent (Appendix D.3 of the EARD), indicates that water quality within Watercourse #4 could be maintained below applicable guidelines or at concentrations similar to background concentrations without further mitigation.

Because the existing WRSF has been in operation for several years, it was possible to make a qualitative assessment of the predicted environmental impacts of the facility from a review of available environmental monitoring reports. It is clear from these reports that there are incidents of either runoff or groundwater seepage reaching Watercourse #4 from the WRSF. However, it is also understood that there are measures being put in place to control these releases, and for the purpose of this review, Wood has assumed that both these measures will be successful and any lessons learned from the effectiveness of these measures will be applied to WRSF extension. Therefore, Wood anticipates there will be no significant additional environmental impact from the proposed expansion of the WSRF compared to the previously approved project.

With respect to the deposition of tailings in the open pit during flooding, this is not expected to significantly alter the environmental impacts of the project at a regional scale, as both the open pit and existing TMF, which would otherwise hold the tailings, are located within the Fish River watershed. At a local scale, however, the use of the open pit for tailings storage will potentially introduce contaminants to the Moose River, upstream of its confluence with the Fish River, which under the existing project would have otherwise not received potentially tailings impacted discharge. The placement of tailings in the pit lake therefore potentially introduces contamination to a new subwatershed. This might be seen as doubling the environmental liabilities of the site and as such is a change to the project that represents a potentially significant environmental risk.

The potential effect of contamination of the Moose River from the introduction of tailings to the open pit area has been assessed by the proponent through an assimilation capacity assessment report provided by the proponent in Appendix D.5 of the EARD. This report calculates the available assimilation capacity of the Moose River, which will receive both direct surface water discharge through a proposed spill way and groundwater seepage from the open pit to the river. This report concludes that based on the limited predicted groundwater discharge rate (from groundwater modelling in Appendix D.1 of the EARD), the predicted surface water discharge rate and source water chemistry in the open pit (from Appendix D.4 of the EARD), that the Moose River has sufficient assimilation capacity to reduce contaminant concentrations below applicable guidelines. Furthermore, the report notes that should water chemistry within the open pit be more deleterious than expected, there is the potential for the proponent to batch treat the open pit lake water within the open pit or treat discharge via a theoretical water treatment plant to meet the applicable guidelines.

The reduction in tailings discharge to the TMF, which would be a consequence of using the open pit for tailings, is not discussed in the appendices of the EA report prepared by the proponent, but presumably would result is less groundwater seepage from the TMF due to the slightly lower head build up within the facility and more rapid move to closure conditions for this facility, which is assumed to be a benefit to the environment.

3.0 Primary Recommendations Related to Proposal to Expand the WRSF

From a common sense perspective, it is not expected that a slight increase in the size of the WRSF should result in a significant change in environmental impact. Assimilation calculations from the proponent for the WRSF (Appendices D.3 and D.4 of the EARD) support a conclusion where the small expansion of the WRSF does not result in significant changes in runoff quality.

Concerning for the WRSF environmental assessment is the record of the performance of the WRSF seepage ditches to intercept contamination as existing information suggests that some contaminants are breaking out beyond the ditches to Watercourse #4. This does not appear to have been predicted by the proponent during the EA for the existing facilities, and the application for modification of the project relies heavily on previous work. This strongly indicates that remedial measures are required to capture contaminant. These remedial measures will be required whether the WRSF expansion occurs or not and therefore may not be relevant to the proposal, but do indicate that either the modelling done for the WRSF is not simulating groundwater conditions with sufficient accuracy or the designed mitigation measures (i.e. the seepage collection ditches) are not working as intended. It is understood that additional measures are being undertaken by the proponent to address seepage issues, which were not reviewed by Wood.

Specific comments and recommendations on the groundwater model used to support the WRSF are provided in Attachment 3. In general, the documentation provided by the proponent to support the groundwater modelling lacks sufficient detail to enable a detailed review. The groundwater model appears to be a regional model, and likely not sufficiently detailed to assess the potential success of the ditches which are the primary mitigation measure for the facility. However, further modelling work is unlikely to change the determination that the expansion will not significantly increase the environmental impact of the project above existing conditions and is not required to support the modified Environmental Assessment. It is, however, recommended that continued progress be made on remedial measures to arrest the movement from the existing WRSF to the environmental, and where possible, lessons learned from the operation of the WRSF be incorporated into the design of the WRSF expansion. Other recommendations and comments with respect to the WRSF are included in Attachments 2 and 3 but need only be considered for information.

4.0 Primary Recommendations on the Proposed Disposal of Tailings in the Open Pit

The disposal of tailings in the open pit will create a new area of potential contamination and potentially a requirement for additional treatment and piping facilities. As such this part of the modified project represents the much greater change in terms of environmental effect than the expansion of the WRSF. These changes need to be weighed against some of the key advantages over disposal within the existing TMF including greater geochemical stability of tailings and long term water coverage of greater depth than the existing tailings facility.

The proposal to use the open pit as a second tailings management facility calls for a pit lake to form within the open pit to an elevation of 108 m asl, and to discharge tailings such that there are at least several meters of water cover over the tailings. At 108 m asl, the level of the open pit lake is understood to be a few meters above the Moose River where it flows next to the lake, and groundwater flow from the pit lake to the Moose River is expected.

One overarching comment on the documentation provided by the proponent to support the groundwater modelling is that it lacks sufficient detail to enable a thorough review. Another issue is the amount of subsurface characterization work, which particularly between the open pit and the Moose River, is not commiserative with the potential significance of the risk posed by the facility. For instance, there is insufficient information provided by the proponent to understand whether the pit lake will remain completely within bedrock, or whether there is a potential for groundwater seepage from the pit lake through the much more permeable overburden. It is also not clear what the resulting head gradient from the open pit lake to the river will be, and there are relatively few field measurements of hydraulic conductivity of the geologic units expected to provide containment of the contaminants within the pit lake. Wood therefore recommends that additional drilling and other work be undertaken in the area between the open pit and Moose River to refine the stratigraphy (particularly the bedrock contact), to provide additional measures of hydraulic conductivity of the key units, and to better define river stage levels. Wood recommends that this information be used to update the conceptual model of the site in this area, and if determined to be significantly different than the one used in the transport groundwater model for the open pit (Appendix D.1 of the EARD), develop a refined groundwater model for reevaluation of groundwater flows from the flooded pit lake to the Moose River. Wood also recommends that the proponent evaluate scenarios where a deeper bedrock-overburden allows for some groundwater seepage through the overburden from the open pit to the Moose River, and present potential mitigation measures.

The transport groundwater model appears to predict that groundwater concentrations of contaminants that originate within the open pit should be diluted by a factor of one million along the less than 100 m flow path from the open pit to the Moose River (sulfate decreases from 897 mg/L in tailings pore water, which is used to represent the source, to 0.0015 mg/L in groundwater adjacent to the pit lake). This is a questionable conclusion, as there would be almost no attenuation along such a short flow path of many parameters if the flow path is through largely inert till and bedrock. Almost no or only limited attenuation is being seen in a similar setting at the WRSF and the TMF for many parameters, where sampling in monitoring wells downgradient of the existing TMF report sulphate at concentrations of several hundred mg/L (Figure 2.4 of Appendix D4 of the EARD). Wood recommends that the proponent reexamine the groundwater modelling work and provide additional detail to support their conclusions of limited transport of potential contaminants from the pit lake to the Moose River through groundwater.

Source terms of the pit lake discharge in Appendix D.5 are different from those in Appendix D.1 for tailings pore water as one might expect, but the explanation given for how the pit lake source terms were derived lacks supporting calculations (for example sulfate in tailings pore water as determined by Lorax (2018) is 897 mg/L in Appendix D.1 and this is used as the source term for groundwater flow in both Appendix D.1 and D.5. The source term for sulfate in the pit lake in Appendix D5 is 69 mg/L, but sufficient explanation of how this was derived is not provided). Appendix D.5 does indicate that dilution is considered but does not explain how the pit lake concentrations were calculated or describe how assumptions used were considered reasonable. Wood recommends that the proponent provide further explanation of how these calculations were completed and the assumptions used.

In addition to the above comments, it appears that source terms for the Touquoy mine tailings (Appendix D.1 of the EARD, which were used in the assimilation report from Appendix D.5) were taken from a study for the Beaver Dam project (Lorax, 2018). This maybe a valid approach if the tailings are actually from the Touquoy mine, but some support should be provided to support this decision. Wood further recommends that the proponent present information to validate predicted tailings pore water quality and predicted open pit lake discharge water quality against equivalent waters from the existing TMF.

Due to the uncertainty in the presentation of the results of the open pit groundwater model results, Wood suggests the proponent may wish to consider that the assimilative capacity report be supplemented with a scenario where there is no attenuation of contaminant concentrations in groundwater along the flow path be provided to support the attenuation rates predicted in the EARD.

In addition to the above, Wood recommends that an additional contingency measure be considered for the project to provide hydraulic containment of contaminants within the pit lake by lowering the pit lake below the level at which runoff or groundwater seepage moves from the pit lake towards the Moose River. This measure could be a long-term option or a short-term option to allow time for the proponent to evaluate treatment options.

Wood further recommends that trigger thresholds be developed that would initiate treatment studies should future monitoring or re-assessment of the pit lake models indicate that pit lake concentrations or groundwater flows from the open pit be higher than predicted in the EARD. Financial commitments for reserves to support closure of the open pit may also need to be revised.

Additional specific comments and recommendations regarding the proposal to use the pit lake for tailings disposal in Attachments 2 and 3. The proponent should consider the comments in the attachments for information when addressing the primary comments described above.

Summary

In summary, the expansion the WRSF proposed by the client is not expected to change the significance of the environmental effects from the existing WRSF. The modelling lacks sufficient detail to support a detailed peer review and there appears to be issues with seepage from the existing WRSF, however, these are unlikely to be made significantly worse by the proposed expansion, and the proponent has indicated that remedial measures are already being taken to address these issues.

The request to utilize the open pit for tailings disposal will create a second source area of potential contamination, which may require treatment. The modelling documents submitted by the proponent in support of tailings disposal in the open pit lack sufficient detail to confirm the conclusions of these studies that the effects will not be significant. There are also some questions about how accurately the groundwater model for the open pit is predicting the concentrations of potential contaminants that will eventually reach the Moose River, which the proponent should address. Ultimately, however, the proponent can fall back on treatment as a workable solution given sufficient notice of an issue. Further work is recommended to provide additional information to support the proposal and to establish trigger thresholds at which point mitigation measures such as treatment or hydraulic containment should be initiated. Financial commitments for reserves to support closure of the open pit may also need to be revised.

Should you have any questions, or concerns, please do not hesitate to contact the undersigned.

Respectfully submitted,

Wood Environment & Infrastructure Solutions,
a Division of Wood Canada Limited

Prepared by:

Simon Gautrey, M.Sc., MBA, P.Geo (ON)
Principal Hydrogeologist

Reviewed by:

Mario Bianchin, PhD., P.Geo (BC/AB)
Principal Hydrogeologist

Attachment 1

Resumes

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Simon Gautrey, M.Sc., M.B.A., P.Geo., F.G.C.

Principal Hydrogeologist

Professional Summary

Mr. Gautrey has 25 years of experience as a hydrogeologist specializing in projects related to mining and groundwater resource assessments. His areas of expertise include groundwater characterization projects for engineering and environmental assessments for mine projects, karst feature investigations, participation in ITRB's, peer reviews, and assessments of impacts on surface water features. Mr. Gautrey has worked at mine sites across Canada and in South America and Australia.

In addition to his consulting experience, Mr. Gautrey was a co-chair of a MECP working group, which is Ministry organized stakeholder group reviewing updates to Ontario's rules and regulations concerning groundwater extraction. He also chaired a PGO team of five leading hydrogeologists to peer review a government report on groundwater takings for bottled water in Ontario. In 2021, Mr. Gautrey was made a Fellow of Geoscientists Canada.

Qualifications

Education

- B.Sc. Geology, Concordia University, Montreal, 1992
- M.Sc. Hydrogeology, University of Waterloo, Waterloo, 1996
- M.B.A., Wilfrid Laurier University, Waterloo, 2002

Project Experience

Mining, Nuclear and Resource related projects

Senior Hydrogeologist

Independent review of groundwater work at the Red Chris open pit mine for Newcrest Red Chris Mining Limited, British Columbia, $112,000, 2021 to present

In late 2021, Wood was retained to conduct an independent review of groundwater models and characterization work at the Red Chris Mine in British Columbia, with a particular focus on the efficiency of groundwater seepage collection systems intended to capture seepage from the mine TMF to regulatory requirements.

Years of Experience

25 (16 with Wood)

Office of Employment

Burlington, Ontario

Languages

- English

Professional Associations

- Professional Geoscientist, Ontario, #0461
- National Groundwater Association
- International Association of Hydrogeologists
- Ontario Water Works Association
- American Academy of Environmental Engineers and Scientists

Core Skills

- Hydrogeology Baseline Characterization for mining and large-scale dewatering projects
- Studies to support permit applications for water takings
- Pre-feasibility and feasibility reports
- Groundwater water supply
- Environmental Assessments for mine dewatering and tailings facilities

Lead Hydrogeologist

OMGM2012S, Baseline and EA Groundwater investigations for the Goldlund and Goliath properties, Dryden, Ontario for Treasury Metals, $1,293,767, 2021 to present

In early 2021, Wood was retained to guide and complete groundwater investigations in support of baseline and environmental assessments for the Goliath and Goldlund properties, located north of Dryden for Treasury Metals. The project involves as an assessment of impacts dewatering from five pits on local surface water features at the Goldlund property and an assessment of seepage impacts from the TMF at Goliath. The work will be used to help navigate these projects through the EA process.

Lead Hydrogeologist

ONS2104, Hydrogeological Environmental Assessment for the Springpole Lake project site, First Mining Gold, $3,510,195, 2021 to present

In early 2021, Wood was asked to take over completion of hydrogeological aspect of Environmental Assessment work for the Springpole Lake project site, located north of Sioux Lookout. Work involves an extensive field program. groundwater modelling, dealing with regulators and other stakeholders, peer reviews and assisting with Feasibility Studies.

Project Manager and Lead Hydrogeologist

SCB1912026, Detailed Hydrogeological characterization for High Level Nuclear Waste Deep Geological Repository, Ignace, Ontario, $22,333,527, 2019 to present

In early 2019, Wood was awarded a project to complete detailed characterization of three 1 km deep boreholes at a proposed site for a Deep Geological Repository for high level radioactive waste, near Ignace Ontario. Work involves using highly sophisticated techniques of for borehole fluid tracing, packer testing and downhole geophysics, combined with detailed sampling and lab work. Mr. Gautrey is the project manager for this project, which is scheduled to be completed in mid 2021.

Lead Hydrogeologist

OMEMA2005Z, Kiena Mine Prefeasibility hydrogeology study, Quebec, $348,815, 2020

In 2020, Mr. Gautrey prepared a prefeasibility level hydrogeological report for the Kiena Mine, an underground mine located beneath a lake near Val d'Or, Quebec. More recently Simon has been involved in assessing the migration of cyanide from the TMF.

Senior Reviewer

OMGM2018S, McEwen Grey Fox PEA level hydrogeology Study, Ontario, $486,659, 2020

Mr. Gautrey was senior reviewer for hydrogeological aspects of a PEA study for McEwen Mining's Grey Fox project.

Lead Hydrogeologist

TC180316, Cote Gold Project, Gogama, Ontario, $13,561,693, 2019 to present

Since early 2019, Mr. Gautrey has been leading a hydrogeological study to prepare a 3-D groundwater seepage model for a proposed tailings facility for the Cote Gold project near Gowgama, Ontario. Work has included model development and field program of drilling and packer testing to characterize fault zones beneath the facility, and participation in meetings with Cote Gold management. The work is supporting permitting of the Cote Gold project.

Lead Hydrogeologist

1720194034, Asarco Mining., Elder Gulch Dam Raise karst review, Ray Mine, Arizona, $231,515, 2019

In 2019, Mr. Gautrey participated in a hydrogeological assessment of karst features as a senior reviewer of a proposal by Asarco to raise the Elder Gulch dam tailings facility at the Ray copper Mine in Arizona. At issue was how raising the height of the tailings facility above a level where karstic limestone is exposed. The work involved a site visit, project meetings and report reviews. Further review work is expected as the project develops.

Lead Hydrogeologist

TC180502, Argonaut Gold, Magino Project, Ontario, $4,537,690, 2019 to present

Since 2019, Mr. Gautrey has been provided hydrogeological support for the proposed Magino project in northern Ontario. The primary focus of the work has been supporting the groundwater aspects of permitting the TMF.

Lead Hydrogeologist

TC180323, Wesdome Mines Ltd., Eagle River Mine, Ontario, $5,210,231, 2019

Mr. Gautrey undertook a review of water inflow issues related to the underground development at the Eagle River Mine, and prepared hydrogeological reports to support the use of a former open pit for temporary storage of water from the tailings facility. Work has involved background review, data analysis and meetings with regulators.

Peer Reviewer

TB174002, BHP Billiton, Peer review of karst assessment reports, Olympic Dam Mine, Australia, $50,000. 2018

Mr. Gautrey was asked to act as a peer reviewer for proposals and the subsequent reports prepared to assess the role of sinkholes and karst features at the Olympic Dam mine in southern Australia. The work has included the review of proposals and work for two separate initiatives, the first to undertake a geophysics' program to locate vertical karst pipes near a proposed Tailings Storage Facilities (TSF) and hidden by the overburden, and the second to assess the efficiency of a groundwater contaminant system of capturing groundwater from karst features in the subsurface beneath an existing TSF.

Lead Hydrogeologist

TC170503, Barrick Gold Inc., Williams Operating Corporation, Barrick Hemlo, Eagle River Mine, Ontario, $1,491,310, 2019

Mr. Gautrey was the lead hydrogeologist for a preliminary evaluation of how a proposed tailings dam raise at Barrick Hemlo might change groundwater patterns from the facility and change the water table position within the facility.

Lead Hydrogeologist

TC180201, Ontario Ministry of Natural Resources, Steep Rock Mine Closure, Ontario, $4,000,000 2018

Steep Rock Mine is an abandoned iron mine that is the responsibility of the Province of Ontario. The site is the largest liability in the Province, with an estimated rehabilitation cost of approximately $850M. Wood's role is to conduct multidisciplinary geoscience and engineering studies to assess the site mine water volume and quality and to develop a mine waste and mine water management approach that can be implemented to reduce the potential environmental impacts and reduce the financial liabilities associated with the site. Mr. Gautrey is leading the hydrogeological aspects of the project.

Lead Hydrogeologist

TB174002, BHP Billiton, Member of the Geotechnical Stewardship Board, Karst specialist, Olympic Dam Mine, Australia, $70,000, 2017 to present

Mr. Gautrey has been a member of the Geotechnical Stewardship Board (GSB) for the Olympic Dam Mine in southern Australia, where he has applied his knowledge as a karst expert with mining experience. The main concerns at this mine were the occurrence of sinkhole above karst features, and their impact on the stability of the Tailings Storage Facilities (TSF), as well as their role as potential conduits for groundwater flow from the TSF to either nearby mine portals or offsite. The work involved two five-day site visits to the mine site in Australia (in 2017 and 2019), interviewing of mine staff, review of the reports, and the preparation of comments. The work identified a large number of karst features, previously unknown to the managers of the TSF. Mr. Gautrey returned to the site in 2019, and additional follow up work as a member of the GSB is expected to continue until 2022.

Lead Hydrogeologist

TC140504, De Beers, Victor Diamond Mine karst sinkhole investigation, James Bay lowlands, Ontario, $73,000, 2015 to present

The Victor open pit Diamond Mine is located within karstic limestone within one of the world's largest wetlands, and close to a kilometer-wide river. The mine required continuous dewatering at rates of greater than 70,000 m^3/day from 2008 to 2019, when mining ended. The resulting drawdown triggered the creation of sinkholes as far as 5 km from the mine, including some in proximity of local rivers and beneath onsite mine infrastructure, including Tailings Management Areas. Mr. Gautrey has been involved at the site from 2006 to the present day. As part of this work, he completes annual surveys of sinkholes and karst features within and around the open pit, including around the TMA's, to satisfy regulatory requirements. In 2015, Mr. Gautrey presented a paper on the results of this investigation at the 2015 IAH karst conference in Birmingham, UK. Dewatering at the mine ended in early 2019, however the sinkhole monitoring continues during the recovery period, with Mr. Gautrey completing annual surveys of karst and sinkhole features.

Lead Hydrogeologist

TC150506, Newmont. Hydrogeology section of NI-43-101 Report, Borden Gold Project. Chapleau, Ontario, $5,997,962, 2019

Mr. Gautrey was retained to complete the hydrogeological section of an NI-43-101 report for the Borden Gold Project. This work was based on work completed by Wood during permitting and did not require additional investigation.

Lead Hydrogeologist

TX18005801, Canada Cobalt Works, Hydrogeological support for the Castle Silver Mine, Gowganda, Ontario, $430,652, 2018

Mr. Gautrey oversaw site work to provide in initial assessment of groundwater conditions at the former Castle Silver workings near Gowganda. Work included profiling water quality of the flooded shaft and a preliminary assessment of nearby surface water features.

Lead Hydrogeologist

TB184003, IKO, PTTW renewal for open pit quarry, Madoc, Ontario, $35,781, 2018 to present

Mr. Gautrey completed a hydrogeological investigation to support renewal of groundwater taking from a quarry at IKO's Madoc, Ontario facility. This work built on investigation work undertaken by Mr. Gautrey in 2008 to secure the initial PTTW to support dewatering and demonstrated how past modelling efforts had effectively predicted groundwater inflow and drawdown from the facility and remained valid to predict future impacts.

Lead Hydrogeologist

VE52699, Yukon Geological Survey, Ross River, Geothermal investigation, Yukon Territory, $135,000, 2018

Wood was retained to supervision the installation of a string of 30 thermistors in a 500 m deep borehole near Ross River, Yukon. The purpose of the borehole was to explore the potential of faults within the Tintina Trench to be a potential source of geothermal power. The work involved work at a remote location and careful consideration of winter conditions. Mr. Gautrey was the lead hydrogeologist for this project.

Lead Hydrogeologist

TV173009, BHP Billiton, Hydrogeological Investigation in support of closure of the Selbaie Mine, Quebec, $1,437,117, 2018

Wood was awarded a multi-year project to evaluate closure options for the former Selbaie Mine, north of Rouyn-Noranda in Quebec. As part of this work, Mr. Gautrey lead the hydrogeological investigation of the site that includes a review of background materials, drilling, an onsite flow assessment and numerical modelling. The work was completed in 2020, with follow up work continuing into 2021.

Lead Hydrogeologist

TC150506, Goldcorp/Newmont, Hydrogeological Investigation in support of Borden Underground Mine EA, Ontario, $5,997,972, 2015 to present

Since 2015 Wood was retained to complete an Environmental Assessment in support of a proposed new underground mine at the Borden property near Chapleau, Ontario. The proposed mine will be located adjacent to and beneath Borden Lake, and there are concerns of groundwater inflows through a fault zone located on the north shore of the lake. For this investigation, Wood has used a combination of downhole geophysics (temperature and conductivity logging), downhole televiewer surveys, packer testing and modelling, to analysis the structures in concert with the rock mechanics and geotechnical drilling programs, and a numerical model to evaluate the inflows to the underground workings along the fault structure. The model was also the basis of predictive modelling for the EA. Mr. Gautrey is the lead hydrogeologist for this project and continues to assist the project through the completion of annual reporting.

Lead Hydrogeologist

TC170501, Goldcorp/Newmont, Hollinger Mine, Receiving water assessment and numerical groundwater model, Timmins, Ontario, $31,412, 2017

Wood was retained by Goldcorp to complete a receiving water assessment and groundwater modelling for the Hollinger open pit mine in Timmins Ontario. This work was triggered by a condition in the mine's discharge permit upon expiry of the existing PTTW for the mine. Mr. Gautrey completed a groundwater monitoring plan component of the work, which involved reviewing pumping and groundwater level data from monitoring wells and local private wells and comparing the results to predictions made by a previous numerical groundwater model. The review determined that observed dewatering effects were within the range of predictions made in 2011 when changes in the timing of mining and the mine plan are considered.

Lead Hydrogeologist

TC160502, Glencore, Kidd Creek Mine, Groundwater investigation and numerical model for TMA, Timmins, Ontario, $4,912,426, 2016 - 2017

Wood was retained by Glencore to complete a hydrogeological investigation in support of closure of the tailings facility at the Kidd Creek mine. The work involved drilling, packer testing and groundwater modelling. Mr. Gautrey was the senior reviewer for the groundwater aspects of the project. Follow up work continued through to 2017.

Senior Hydrogeologist

TC111504, New Gold, Rainy River Mine project, Groundwater investigation and numerical model for EA, Rainy River, Ontario, $19,110,740, 2011 - 2015

Starting in 2011 and continuing for several years, Mr. Gautrey was the senior hydrogeologist for an ongoing hydrogeology study at the Rainy River project site in northern Ontario, supporting the Environmental Assessment for a developing gold mine. The mine is located in an area where tight clays create artesian conditions in a deep aquifer used by local wells and there are expected issues related to dewatering. The study also considered leakage from the proposed TMA, and potential impacts to the nearby Pinewood River. The study has involved packer testing, monitoring well installation, sampling, pumping tests and numerical modelling. Ongoing work has involved the development of a dewatering plan for the mine, ongoing assessment of dewatering effects on local aquifers and the preparation of annual reports for submission to the MECP.

Lead Hydrogeologist

TC261521, De Beers, Victor Diamond Mine groundwater reporting for EA and annual reporting, Ontario, $9,149,962, 2005 to present

Mr. Gautrey has been involved in the groundwater reporting at the Victor Diamond Mine since before development of the mine in 2005. From 2005 to 2009 this included participating in the groundwater aspects of the EA and project management of drilling and sampling programs. Since 2009, Mr. Gautrey has prepared annual groundwater reports for the mine. This long-term history with the project has provided an opportunity to assess the initial predictions and develop relationships with regulators responsible for approving groundwater permits for mining in northern Ontario.

Lead Hydrogeologist

TX15001803, Glencore, Hydrogeological Hazard and Permafrost investigation at the Raglan Mine, Quebec, $365,800, 2015

Mr. Gautrey led the hydrogeological and permafrost components of an investigation in 2015 into hydrogeological and permafrost conditions at a proposed 700 m deep underground mine at Glencore's Raglan Mine in northern Quebec. The work involved deep packer testing and instrumentation in adverse conditions to help identify hydrogeological hazards.

Lead Hydrogeologist

TC121511, De Beers, Victor Mine Expansion EA, Ontario, $413,289, 2013-2014

In 2013, Wood was retained to complete in EA in support of expansion of the DeBeers Victor Mine to include an open pit at a second kimberlite. For this project, Mr. Gautrey led the hydrogeology portion of the EA, which is particularly challenging at this site due to the karstic aquifer setting, the large quantities of dewatering expected (~100,000 m^3/day) and the site's proximity to rivers and surface water features.

Senior Reviewer

TC160516, Treasury Metals, Goliath Project, Groundwater investigation and numerical model for EA, Dryden, Ontario, $2,354,239, 2013 - 2018

Wood was retained to complete a hydrogeological study to support the EA process, and then revise the EIS. The hydrogeological work relied on data provided by others and involved numerical modelling and report preparation. Mr. Gautrey is the senior reviewer for this project.

Lead Hydrogeologist

TB8106901, IKO, Groundwater investigation and numerical model for EA, Madoc, Ontario, $66,606, 2012

IKO requested Mr. Gautrey to undertake work to address regulator concerns about a proposed deepening of an andesite pit at IKO's Madoc Ontario facility. The facility is located within a spur of andesite that extends into a karstic limestone area. The work relied on data collected over the last several years and developing a monitoring plan to the satisfaction of regulators.

Senior Reviewer

TC131503, Labrador Iron Mines, Labrador, $66,714, 2012

Wood was retained by Labrador Iron Mines to complete a scoping level study for a proposal to construct a mine at the Julienne Lake site. The work involved applying Wood's hydrogeological experience from Wabush to the proposed site to estimate groundwater inflows and prepare a plan for further hydrogeological investigation of the site.

Senior Hydrogeologist

PhosCan project, Groundwater investigation and numerical model for feasibility studies, Ontario, $346,486, 2012

Mr. Gautrey was the senior hydrogeologist for a hydrogeology study at a proposed mine site in karstic terrain in northern Ontario. The objective of the study is to determine whether dewatering of the mine is feasible given the karst setting and high permeability's reported for the bedrock. The work involved large diameter well drilling, multi-day pumping tests, and numerical modelling. The study determined that pumping at up to 30,000 m^3/day would be required to dewater the mine and included recommendations for dewatering strategies and treatment.

Senior Hydrogeologist

TC113916, Quest Mine project, Quebec, $1,315,408, 2012

Mr. Gautrey has been the senior hydrogeologist for a hydrogeologic investigation in support of the design of an open pit mine in northern Quebec, adjacent to a lake. Work to date has involved drilling, well installations and hydraulic testing. Hydrogeologic issues being investigated include the role of intermittent permafrost in controlling groundwater flow, the presence of open fractures in the mineral bearing zone, and the proximity to the lake, which is separated from the mine by an esker ridge.

Review Team

New Millennium Iron Corp., LabMag Iron Ore Project, Labrador, 2012

Mr. Gautrey was part of a review team retained by New Millennium to review hydrogeological investigations and work plans associated with the proposed LabMag Iron Ore project, and comment on an appropriate path forward.

Senior Reviewer

TF1143013, IOC, Carol Lake project, Labrador, $165,836, 2012

Mr. Gautrey was part of a team retained to undertake a hydrogeological investigation to assess the potential for expansion of the Carol Lake project to interfere with Labrador City's back up water supply, which was located downgradient of the proposed pit. The work involved installing and testing a groundwater well, and planning for additional phases of work.

Senior Hydrogeologist

Detour Gold, Detour Lake Project, Groundwater investigation and numerical model for EA, Ontario, 2011 - 2012

Mr. Gautrey was the senior hydrogeologist for groundwater related EA, feasibility and permit application studies, and for estimating groundwater inflow rates into a proposed 3 km long, and 500 m deep open pit in Northern Ontario. Work involved the review of previous consultant reports, drilling and packer testing, interacting with regulators, and numerical modelling to estimate groundwater inflows, the potential impacts in local creeks, and the effectiveness of other groundwater control methods.

Senior Hydrogeologist

TC93902, Guyana Gold, Groundwater investigation and numerical model for feasibility studies, Guyana, $1,850,227, 2010 - 2011

Mr. Gautrey was the senior hydrogeologist for a dewatering study for an open pit mine adjacent to a major river in southern Guyana. Work has involved drilling, packer testing, numerical modelling, with pumping tests to assess the hydraulic connection between the river and the proposed open pit mine.

Senior Reviewer

TF1073901, Teck Resources, Duck Pond, Newfoundland, $2,862,752, 2010

Mr. Gautrey oversaw the completion a hydrogeological investigation to estimate groundwater inflow rates into an open pit mine at Duck Pond. The work involved groundwater modelling, packer testing and estimating dewatering effects on nearby surface water features.

Lead Hydrogeologist

TC81525, Goldcorp, Hollinger Project, Groundwater investigation and numerical model for EA, Ontario, $1,835,263, 2009 - 2011

Mr. Gautrey completed a hydrogeology study in support of a PTTW application for dewatering of the Hollinger open pit for Goldcorp. The work involved predicting potential environmental impacts from mine development. The work included drilling and packer testing, a local assessment of private water wells, groundwater modelling, and report writing.

Senior Reviewer

TC101514, Wesdome Gold Mines Ltd., Mishi Pit Project, Ontario, $175,782, 2011

Amec completed a follow up study to expand and extend the PTTW for the Mishi Pit. Mr. Gautrey had previously completed a PTTW application for dewatering of the Mishi Pit in 2006, and for this second project, was the senior review. Much like the first project, the hydrogeological assessment completed in 2011 included field work, the preparation of a numerical groundwater model, and reporting.

Senior Reviewer

TC101503, Northgate Minerals Corporation, Young-Davidson property, $4,348,980, 2012

Senior reviewer of a hydrogeology feasibility study to estimate inflows into a new open pit mine and to examine potential environmental impacts from mine development.

Senior Hydrogeologist

Shoregold, Saskatchewan, 2008

Mr. Gautrey was the senior hydrogeologist for an Environmental Impact Study for a proposed open pit diamond mine near Prince Albert Saskatchewan. Work involved an assessment of impacts on water supply wells and local creeks over a large area in rural Saskatchewan. Dewatering rates into the proposed open pit mine are expected to exceed 100,000 m^3/day, and a series of deep dewatering wells has been proposed to dewater the mine. Key regulatory issues have been impacts to local private wells and to the nearby Saskatchewan River.

Senior Hydrogeologist

VA06709, PCS Rocanville, Saskatchewan, $92,032, 2008

Mr. Gautrey was the senior hydrogeologist for a groundwater exploration program to locate a water supply for an expanded Potash Mine near Rocanville. Work involved drilling test wells, aquifer testing, water quality sampling, and reporting.

Senior Hydrogeologist

TG71032, Wesdome Mines Ltd., Eagle River Mine, Ontario, $10,000, 2007

Mr. Gautrey was the senior hydrogeologist for a hydrogeological assessment to support groundwater permitting for pumping from an underground mine and water taking from a surface intake near Wawa, Ontario.

Senior Reviewer

TC96221, Wesdome Gold Mines Ltd., Mishi Pit Project, Ontario, $83,199, 2006

Mr. Gautrey completed a PTTW application for dewatering of the Mishi Pit. The work involved a hydrogeological assessment, the preparation of a numerical groundwater model, and reporting. A second phase of the project was completed in 2011 using a similar approach. Mr. Gautrey was the senior reviewer for this.

Senior Reviewer

Tc63915, WallBridge Mining Company, Broken Hammer Open Pit Project, $161,975, 2006

Senior reviewer of a hydrogeology feasibility study in 2006 to estimate inflows into a new open pit mine and to examine potential environmental impacts from mine development.

Senior Reviewer

TY660121, Liberty Mines, McWatters Mine Project, $25,309, 2006

Senior reviewer of a hydrogeology feasibility study to estimate inflows into a new open pit mine and to examine potential environmental impacts from mine development.

Senior Hydrogeologist

TY66020, Porcupine Joint Venture, Porcupine (Timmins), Ontario, $11,020, 2005 - 2006

Mr. Gautrey was the senior hydrogeologist for an assessment of potential impacts of mine dewatering on a nearby headwater lake, which was to be partially displaced by the open pit. The work involved meetings with regulators and developing a path forward with Federal reviewers to: install more than 20 monitoring wells; establish a groundwater and surface water monitoring program and complete a detailed assessment of the local hydrogeology. Follow up work confirmed no impact to the lake.

Lead Hydrogeologist

SW1051013, St Marys Cement, St. Marys, Ontario, $39,220, 2006

In 2006, Mr. Gautrey completed a hydrogeological investigation at SMC's St Marys facility in order to support an application for a PTTW for the quarries at this facility. The work involved an assessment of impacts to area wells, including local monitoring supply wells, monitoring well installation, and downhole geophysics. Since 2006, Mr. Gautrey has remained involved with the quarry, preparing or reviewing annual groundwater monitoring reports.

Professional History

- Principal Hydrogeologist, Wood Environment & Infrastructure, Oakville, Ontario, 2021 to present.
- Senior Associate Hydrogeologist, Wood Environment & Infrastructure, Hamilton, Ontario, 2015 to 2021.
- Associate Hydrogeologist, Wood Environment & Infrastructure, Hamilton, Ontario, 2011 to 2015.
- Senior Hydrogeologist, Wood Environment & Infrastructure, Hamilton, Ontario, 2004 to 2011.
- Senior Hydrogeologist, Lotowater Ltd., Paris, Ontario, 2002 to 2004.
- Project Hydrogeologist, Geosyntec Consultants, California and Ontario, 2000 to 2002.
- Project Hydrogeologist, Conor Pacific Inc., Mississauga, Ontario, 1999 to 2000.
- Contract Hydrogeologist, Ontario MOE (MECP), Hamilton, Ontario, 1999.
- Staff Hydrogeologist, Lotowater Ltd., Paris, Ontario, 1995 to 1999.

Additional Qualification

Publications / Presentations

- "Dipping a toe into the Nestle Groundwater conflict, looking beyond a technical solution". Presented at the Geoethics session of the Professional Geoscientists of Ontario AGM, Toronto (online). July 2020.
- "Evaluating public opinion on groundwater extraction from public comment submission and Google Trends". Presented at Geoethics and Groundwater Management Congress, Porto Portugal (online). May 2020.
- "Freelton GUDI Study: A comparison of the new and old GUDI Terms of Reference to a bedrock water supply well North of Hamilton". S. Gautrey and M. Christie. Presented at the 2019 OWWA Annual Conference in Ottawa, Ontario. May 2019.
- "What to expect from the updated GUDI guidance document for treatment requirements of Municipal Wells" S. Gautrey. Presented at the 2019 OWWA Source Water Protection Workshop in Mississauga, Ontario. February 2019.
- "A comparison of predicted groundwater impacts to observed effects at the Victor Diamond Mine, 11 years after the start of dewatering". S. Gautrey. Presented at the Mine Water Solutions Conference, in Vancouver, BC, June 2018.
- "Public perceptions of groundwater takings for bottled water in Ontario: a source of public pressure on policy makers". S. Gautrey. Presented at the Resources for Future Generations Conference, in Vancouver, BC, June 2018.
- "Progress of the MOECC's Water Quantity Protection External Working Group on a Review of Ontario's Water Resources and Regulations". S. Gautrey. Presented at the OWWA annual conference in Niagara Falls, Ontario, May 2018.
- "Groundwater Basics". S. Gautrey. Presented at the 2018 OWWA groundwater workshop in Mississauga Ontario, March 2018.
- "Contrasting public participation in two recent groundwater governance initiatives: insights into public opinions about groundwater". S. Gautrey. Annual Conference of Canadian Geotechnical Society, GeoOttawa, 2017, Ottawa, ON, Canada, 2-5 October 2017, 8pp., October 2017.
- "New permitting processes for construction and bottled water takings in Ontario". S. Gautrey. Presented at the 2017 OWWA groundwater workshop in Mississauga Ontario, February 2017.

- "New permitting process for construction water taking in Ontario". S. Gautrey. Annual Conference of Canadian Geotechnical Society, GeoVancouver 2016, Vancouver, BC, Canada, 2-5 October 2016, ID004162, 7pp., October 2016.
- "In Situ Characterization and Deep Borehole Instrumentation to Identify Permafrost Zones at Raglan Mine, Nunavik, QC, Canada." Annual Conference of Canadian Geotechnical Society, GeoVancouver 2016, Vancouver, BC, Canada, 2-5 October 2016, ID003918, 9pp. Cabot E., Gautrey S., Coulson A.L., Choquet F., Anderson M., Drob T., Caumartin R., Thivierge S-E. and Bréhé J-M. October 2016.
- "A review of predicted impacts to the Nayshkootayaow River by dewatering at the Victor Diamond Mine: when is there enough data to be certain and the case for ending supplementation flows". S. Gautrey and D. Ott. Presented at a joint CWRA-IAH conference in Montreal, Quebec, May 2016.
- "Changes to the Permit To Take Water process for construction dewatering". S. Gautrey. Presented at the OWWA annual conference in Windsor, Ontario, March 2016.
- Session Chair for the Mining and Groundwater session at the Canadian IAH 2015 conference in Waterloo, Ontario. Session Chair for a Groundwater Issues session at the Canadian IAH 2017 conference in Ottawa, Ontario
- "A review of key groundwater issues, eight years after the start of the dewatering at the Victor Diamond Mine, James Bay Lowlands, Ontario". S. Gautrey. Presented at the IAH-CNC conference in Waterloo, October 2015.
- "The proposed Ontario Permit To Take Water changes, what do they mean for the practicing hydrogeologist?". S. Gautrey. APGO Field Notes, May 28th, 2015 issue.
- "Relative importance of lithologic, stratigraphic and structural controls on karst conduit development at the Victor Diamond Mine, James Bay Lowlands, Ontario Canada". S. Gautrey, D. Cowell, P. Rummel and B. Steinback. Presented at International Conference on Groundwater in Karst, Birmingham, UK, June 2015.
- "Drawdown-induced karst at an open pit diamond mine". D. Cowell, S. Gautrey and B. Steinback. Presented at International Conference on Groundwater in Karst, Birmingham, UK, June 2015.
- "Multi-layer stratification of groundwater temperatures in Ordovician and Silurian aquifers at the Victor Diamond Mine, as evidence of limited groundwater recharge and circulation in James Bay Lowlands, Ontario." S. Gautrey, P. Rummel and B. Steinback. Presented at the joint AGU-GAC-MAC-CGU Joint Assembly in Montreal, May 2015.
- "Current Permitting Processes and challenges for new mines and re-opening old mines". S. Gautrey. Presented at Water Management for Mining session, March 2014, Toronto.
- Session chair for the OWWA groundwater and source water protection sessions at the OWWA annual conferences in Collingwood, Niagara Falls, Ottawa, London, Toronto and Windsor between 2010 and 2017.
- "Successful Application of new Groundwater Resource Mapping Approaches in the Search for Municipal Groundwater Supply in Paleozoic Aquifers Near Acton Ontario". S. Gautrey, M. Situm, and F. Brunton. Presented at the joint AGU-GAC-MAC Annual conference Toronto, May 2009
- "The role of buried bedrock valleys on the development of karstic aquifers in flat-lying carbonate bedrock: insights from Guelph, Ontario, Canada". J. Cole, M. Coniglio and S. Gautrey. IAH Hydrogeology Journal (2009) 17: 1411-1425.
- Regional Distribution and Development of Porosity in Karstic Aquifers in the Guelph Area of Southern Ontario: Implications for Groundwater Resources, J. Cole, M. Coniglio & S. Gautrey. Presented at the GAC-MAC conference, Halifax, 2005.
- Evidence to Support Pre or Early Wisconsinan Genesis of a Productive Karst System Beneath the City of Guelph". S. Gautrey. Presented at the GAC-MAC conference, Ste. Catharines, Ontario 2004

Veerakcuddy Rajasekaram, Ph.D., P.Eng.

Senior Water Resources Engineer

Professional Summary

Mr. Gautrey has 25 years of experience as a hydrogeologist specializing in projects related to mining and groundwater resource assessments. His areas of expertise include groundwater characterization projects for engineering and environmental assessments for mine projects, karst feature investigations, participation in ITRB's, peer reviews, and assessments of impacts on surface water features. Mr. Gautrey has worked at mine sites across Canada and in South America and Australia.

In addition to his consulting experience, Mr. Gautrey was a co-chair of a MECP working group, which is Ministry organized stakeholder group reviewing updates to Ontario's rules and regulations concerning groundwater extraction. He also chaired a PGO team of five leading hydrogeologists to peer review a government report on groundwater takings for bottled water in Ontario. In 2021, Mr. Gautrey was made a Fellow of Geoscientists Canada.

Qualifications

Education

- Ph.D. (Doctor of Engineering, Water Resources Engineering), Asian Institute of Technology, Thailand, 1997
- M.Eng. (Water Resources Engineering), Asian Institute of Technology, Thailand, 1993
- B.Sc. (Civil Engineering) Hons, University of Peradeniya, Sri Lanka, 1981

Project Experience

River Engineering Analysis and Modeling Projects

Technical Lead

Battle River Hydraulic Analysis and Water Quality Modeling, Alberta Environment and Parks, AB (2018 - 2020)

Technical lead, hydraulic modeler, and reviewer for river hydraulic analysis, hydrodynamic modeling and water quality modeling using CE-QUAL-W2 software. Responsibility also included review of hydrological modeling of watershed using SWAT software. Reviewed the project report compiled by other engineers and modelers.

Years of Experience

20 (<1 with Wood)

Office of Employment

Calgary, AB

Languages

- English

Professional Associations

- Member, Association of Professional Engineers and Geoscientists of Alberta (APEGA)

Areas of Expertise

- River Engineering, and Flooding Analysis
- Hydrologic Analysis and Distributed Hydrologic Modeling
- Water Resources, Mine - Site and Environmental System Modeling
- Stormwater and Irrigation Systems Modeling
- Computational Fluid Dynamics/ Hydraulic and Water Quality Modeling

Lead Hydraulic Modeler

Hydrodynamic, Sediment Transport and Gravel Nourishment Analysis and Modeling of Elbow River Below Glenmore Dam, Alberta Environment and Parks, AB (2016)

Provided technical advice on hydrodynamic, sediment transport and gravel nourishment analysis and modelling (using HEC-RAS and CCHE2D software). Artificial gravel piles were planned at strategic locations, and their dispersion during heavy river flow was modelled. Had also been responsible for reviewing the project report.

Lead Hydraulic Modeler

Hydrodynamic and Morphological Assessment of Pipe Crossing Across the Bow River Near Douglas Dale, City of Calgary, AB (2016)

Following the 2013 flood and considerable morphological changes on the Bow River bed, the City of Calgary intended analyzing the safety of pipe crossings across Bow River. Provided technical advice on river flow and hydraulic analysis/ modelling (using HEC-RAS and CCHE2D software), and reporting.

Technical Reviewer

Hydraulic Assessment of Pipe Crossing at Bull Creek, Repsol Oil and Gas, AB (2016)

Provided technical advice on hydraulic modelling and the estimation of scour depth. Guided modelers on the use of CCHE2D software for hydrodynamic modelling. Reviewed the project report.

Hydraulic Modeler

Bank Stability Analysis of Elbow River Near Discovery Ridge, City of Calgary, AB (2015)

Analyzed data, determined extreme events, developed a two-dimensional hydrodynamic/sediment transport model, and analyzed the river bank stability. The two-dimensional hydrodynamic model was developed using CCHE2D software. Also, compiled the technical report.

Hydraulic Modeler

Bank Stability Analysis of Bow River Near Glenmore, City of Calgary, AB (2014)

Responsible for river hydraulic analysis, hydraulic/morphologic modelling (using HEC-RAS and CCHE2D software), and reporting. Applying the statistical extreme events of flooding, the hydraulic/ morphological models yielded design parameters for bank stability considerations.

Hydraulic Modeler

Bank Stability Analysis of Bow River Near Calf Robe, City of Calgary, AB (2014)

Responsibility included river hydraulic analysis, hydraulic/morphologic modelling (using HEC-RAS and CCHE2D software), and reporting. Applying the statistical extreme events of flooding, the hydraulic/ morphological models yielded design parameters for bank stability considerations.

Hydraulic Modeling Lead

Hydraulic Analysis and Water Quality Modeling of Highwood River, Alberta Environment and Parks, AB (2013 – 2014)

Conducted river hydraulic analysis, hydrodynamic modelling, and water quality modelling of Highwood River from High River to the confluence with Bow River. Used CE-QUAL-W2 modelling software. With the base flow and water quality conditions set, impacts of sending a new treated waste-water effluent were analyzed.

Technical Lead

Kananaskis River Bank Protection Analysis and Hydraulic/Morphological Modeling, AltaLink Management Ltd., AB (2014)

Guided river hydraulic analysis, and hydrodynamic/ morphologic modelling of Kananaskis River. Modeling results were used in the bank stability analysis. Also guided on the use of HEC-RAS and CCHE2D modelling software. Compiled modelling and analysis results.

Hydraulic Modeler

Athabasca River Hydraulic Analysis and Modeling Near White Court, Swan Hills Synfuels, AB (2011)

Swan Hills Synfuels had an option for water intake from Athabasca River, thus needed a hydraulic modelling of river at the intake site. Responsibilities included hydraulic analysis, hydraulic modelling (using CCHE2D software), and reporting.

Hydraulic Modeler

Hydraulic Analysis and Modeling of River Water Intake Structure for Kearl Mine, Imperial Oil Canada Ltd., Fort McMurray, AB (2008)

Developed a hydraulic model to analyze options for a river water intake. The three-dimensional hydraulic model was created using ANSYS CFX software. Responsibilities included hydraulic analysis, modelling and reporting.

Project Engineer

Hydraulic Modeling and Design of DD-1 Channel, CNRL, Fort McMurray, AB (2007)

The DD-1 channel reach in Tar River diversion involved design challenge due to the steep slopes. MIKE11 software was used to model the channel flow for varying slope conditions and with structures. Responsibilities included hydraulic analysis/ modelling, design and reporting.

Hydraulic Modeler

Hydraulic Analysis and Modeling of Pump Intake, Shell – Albian Oil Sands Project, Fort McMurray, AB (2006)

A wet-well installed with two intake pumps was investigated for the possibility of adding a third pump. A hydraulic model was developed (using ANSYS CFX software) to analyze the consequences of installing the third pump, including the development of vortices when all three pumps operate at full capacity. Responsibilities: hydraulic analysis, modelling and reporting.

Flooding Analysis and Modeling Projects

Project Engineer

Flooding Assessment of Fish Creek near Priddis, Ghostpine Environmental Services, AB (2014)

Completed the analysis of extreme flooding events by developing a two-dimensional hydraulic/sediment transport model using CCHE2D software. Responsibilities also included estimation of scour depths at critical locations, bank stability computations, and reporting.

Project Engineer

Flooding Analysis of Red Deer River and Clearwater River, AltaLink Management Ltd., AB (2014)

Hydraulic models were developed using CCHE2D software to analyze the selected flooding sites. Tasks also included the analysis of extreme events, estimation of scour depths, analysis of bank stability and reporting.
Project Engineer

Flooding Assessment of Elbow River at Rideau- Roxboro, City of Calgary, AB (2013)

Analyzed the extreme flooding events by developing a two-dimensional hydraulic/sediment transport model using CCHE2D software. Responsibilities also included estimation of scour depths at critical locations, bank stability computations, and reporting.

Project Engineer

Flood Hazard Identification of Bow River Below Ghost Dam, Alberta Environment and Parks, AB (2012)

The flood hazard analysis of a plot below Ghost dam was analyzed. As part of the assessment, a flooding analysis model was developed using HEC-RAS software, flooding simulations carried out, and flood-risk maps were developed. Responsibility also included reporting.

Project Engineer

James River Flooding Analysis and Hydraulic Modeling, Private Client, Red Deer, AB (2011)

Developed a river flood model using HEC-RAS software to investigate the flooding around the client’s property. Responsibilities included hydraulic modelling, floodplain analysis, and reporting.

Project Engineer

Lott Creek Flooding Analysis and Flood Risk Mapping, Rocky View County, AB (2011)

Flooding around the golf course near Lott Creek was analyzed. As part of the assessment, a flooding analysis model was developed using CCHE2D software, flooding simulations carried out, and flood-risk maps were developed. Responsibility also included reporting.

Project Engineer

Evaluation of the Impact of Probable Maximum Flood in Bow River, TransAlta Energy Corp., AB (2009)

Analyzed the impacts of PMF at various locations on the Bow River with alternate combinations of reservoir/dam operations. An operation model was developed using GoldSim software, scenarios analyzed, and results reported.

Project Engineer, Hydraulic Modeler

Dam-breach/ Floodplain Modeling and Analysis of Pantabangan and Masiway Dams, National Irrigation Administration, the Philippines (1996)

A dam-breach and floodplain hydraulic model was developed using MIKE11 software. Various failure modes of dams were analyzed, and dam breach scenarios were simulated for selected extreme flood events. Responsibilities also included statistical analysis of hydrologic data, hydraulic model simulation and reporting.

Hydrology and Mine Water System Projects

Project Engineer, Hydrologic Modeler

Mine Site Water Balance Modeling of Milner #14 Coal Mine, Maxim Power Corp., Grand Cache, AB (2011)

Developed a multi-pond operation model (using GoldSim software) to analyze the water management of mine site. Model also included rules for pump and sluice operation to optimize the water use efficiency. Responsibilities included hydrologic analysis, system modelling, and reporting.

Project Engineer, Hydrologic Modeler

Joslyn North Mine Site Water Balance Modeling, Total E&P Canada Ltd., Fort McMurray, AB (2009)

Analyzed the mine site water balance using HSPF and a VBA-enabled spreadsheet. Responsibilities included hydrologic analysis, mine water system modelling, and reporting.

Project Engineer

Athabasca River Water Allocation Modeling for Oil Sands Mine Operators, Alberta Oil-Sands Developers Group (OSDG), AB (2007 - 2009)

Developed a VBA-enabled Excel spreadsheet to analyze water allocation from Athabasca River for the oilsands mine operators. Responsibilities included data compilation, tool development, and reporting.

Project Engineer, System Modeler

Beaver Creek Diversion System Operation Modeling, Syncrude Canada Ltd., Fort McMurray, AB (2009)

Developed a system operation model (using GoldSim software) to analyze various options of diverting Beaver Creek to mine site. Responsibilities included hydrologic analysis, system modelling, and reporting.

Project Engineer, System Modeler

Water Management Options Analysis for Base Mine Lake, Syncrude Canada Ltd., Fort McMurray, AB (2008)

Developed a system dynamics lake operation model using GoldSim software. Various water management options were analyzed using the model and results communicated to the client. Compiled technical report.

Project Engineer, Hydrologic Modeler

Distributed Hydrologic Modeling of Reclaimed Area, Total E&P Canada Ltd., Fort McMurray, AB (2008)

Developed a distributed hydrologic model to analyze the interaction between surface and sub-surface flows in a filter-cake like tailings (used MIKE-SHE software). Responsibilities included hydrologic analysis, modelling and reporting.

Project Engineer

Review of Hydrometric and Climate Data for Syncrude Monitoring Stations, Syncrude Canada Ltd., Fort McMurray, AB (2008)

Collected hydrometric and climate data from stations established in the reclaimed mining areas, performed statistical analysis, and compared results with those of the regional monitoring stations. Responsibilities also included reporting.

Project Engineer

Hydrologic Modeling Support for the Design of Compensation Lake and Drainage Channels, Total E&P Canada Ltd., Fort McMurray, AB (2008)

Provided computational support to analyze the modelling results, and organized data for the design of compensation lake and drainage channels. Responsibilities included hydrologic analysis, results analysis and documentation.

Project Engineer

Hydrologic Modeling Support for the Pierre River Mine Development, Shell Canada Ltd., Fort McMurray, AB (2007)

Compiled hydrologic data and used it to simulate hydrologic model developed using HSPF software. Responsibilities included hydrologic analysis, mine system modelling, and reporting.

System Dynamics Modeler

Mine Site Water Quantity and Quality Management Modeling for Alto-Chicama Mine, Minera Barrick Misquichilca S.A., Peru (2007)

Developed a system dynamics model (using GoldSim software) to determine optimal management plans for water quantity and quality. Resulting downstream concentration of various constituents was kept within the allowable limits. Responsibilities included data compilation, analysis and modelling.

Project Engineer

Runoff Estimation of Reclaimed Areas, Syncrude Canada Ltd., Fort McMurray, AB (2007)

Analyzed various approaches to estimate runoff from reclaimed mining areas. Responsibilities included hydrologic data analysis and reporting.

Project Engineer, System Dynamics Modeler

Mine Site Water Balance Modeling for Suncor Voyager South Project, Suncor Energy, Fort McMurray, AB (2006)

Developed a system dynamics-based mine site water balance model (using GoldSim software) to analyze various aspects of mine site water management including drainage from consolidated tailings. Responsibilities included system dynamics modelling and documenting.

Project Engineer, Hydrologic Modeler

Lake Operation Modeling for Fort Hills No-Net Loss Lake, Petro Canada Ltd., Fort McMurray, AB (2006)

Developed a lake operation model (using GoldSim software) to analyze the long-term operation of the proposed no-net loss lake. Responsibilities included development of hydrologic time series, bathymetry data, and reporting of the analysis.

Urban System, Irrigation and Water Management Projects

Technical Reviewer

Water Balance Modeling of Shepard Waste Management Facility, City of Calgary, AB (2017)

Reviewed the water balance and hydraulic analysis conducted by other engineers. The water balance model was created using GoldSim software, with guidance on various model components. Task also included detailed technical review of the project report.

Technical Reviewer

Stormwater and Irrigation Management Various Industrial Lots in Rocky View County, Various Clients, AB (2014 – 2017)

Had been the technical advisor and reviewer for the stormwater management modelling of various industrial lots in the Rocky View County. These models were developed using PCSWMM software and the water balance spreadsheet of the City of Calgary (WBSCC). Task also included technical review of project reports.

Project Engineer

Operation Optimization Modeling of Storm Ponds near 84th Street, Rocky View County, AB (2011)

Developed a water management and ponds operation model using GoldSim software. Various scenario analyses resulted in an optimal operation plan for the ponds. Tasks included presentation of the model to stakeholders and reporting.

Developer

Development of Water Balance Spreadsheet (WBSCC), City of Calgary, AB (2011)

Developed the water balance spreadsheet to incorporate multiple land-uses, ponds, and irrigation system in the analysis of water balance for urban areas. Development included multiple modules of VBA macros, user-interface, and user/reference manuals.

Project Engineer

Watershed Operation Modeling for Vermilion River Basin, North Saskatchewan Watershed Alliance (NSWA), AB (2009)

A system dynamics-based basin-wide operation model was developed (using iThink software). Model included major lakes, surface drainage, and ground water. Responsibilities also included compiling the report.

Project Engineer

Data Analysis Support for Alberta Water Supply- Demand Assessment, Alberta Environment, AB (2008)

In support of assessing the water demand – supply for various basins in Alberta, carried out data compilation, analysis and documentation.

Project Engineer, Dynamic System Modeler

Dynamic Modeling of Optimal Pond Sizing, Bruce Power, Saskatoon, SK (2008)

A system dynamics model was developed using GoldSim software to analyze the water balance of pond operation. The model was also used for determining the optimal model parameters. Responsibilities also included reporting.

Project Engineer, Dynamic System Modeler

Stormwater Management Modeling of Gardner Stormwater System, Western Securities Ltd., AB (2007)

Developed a stormwater management model using GoldSim system dynamics software. Model included rainfall/runoff processes of catchment area and operation of ponds. Water balance analysis was carried out for system operation and optimal irrigation water allocation. Responsibilities also included reporting.

Water Quality / Dispersion Analysis and Modeling Projects

Project Manager, Lead Water Quality Modeler

Estimation of Acceptable Loading Limits to WH Canal and Chestermere Lake, City of Calgary, AB (2018 - 2020)

Guided other engineers/modelers to develop a waterbody water quality model using EFDC and a watershed water quality model using QSWAT. Various pollutant loading scenarios were analyzed and the loading conditions at the lake inlet were evaluated and reported.

Water Quality/ Dispersion Modeler

Water Quality-based Effluent Limits Analysis for Bow River Near Outfall B5, Enmax Corp., AB (2019)

As part of the application to re-locate the effluent into Bow River, a water quality based effluent limit analysis was carried out. A dispersion model was developed using SMS and RMA software, and the extent of dispersion and concentration of various water quality constituents were analyzed and reported.

Project Manager, Dispersion Modeler

Water Quality-based Effluent Limits Analysis for Rosebud River, Symbiotic EnviroTek Inc., AB (2018)

As part of the application to build a new wastewater treatment plant and to direct effluent into Rosebud River, a water quality based effluent limit analysis was carried out. A dispersion model was developed using SMS and RMA software, and the extent of dispersion and concentration of various water quality constituents were analyzed and reported.

Project Manager, Lead Water Quality Modeler

Water Quality Modeling of Weed Lake, Rocky View County, AB (2017)

Guided other engineers/modelers to develop a lake water quality model using EFDC and a watershed water quality model using QSWAT. Various modelling scenarios including establishment of a new wastewater discharge were analyzed and reported.

Project Manager, Lead Hydraulic Modeler

Cooling Water Effluent Heat Dispersion Modeling, AB Mauri Canada Ltd., AB (2016)

As part of the application to discharge the cooling water effluent into Bow River, a temperature dispersion analysis was carried out. A dispersion model was developed using SMS and RMA software, and the extent of dispersion of temperature for various scenarios were analyzed and reported.

Project Engineer, Lead Modeler

Water Quality Modeling of the Plant Wastewater Disposal, Swan Hills Synfuels, AB (2012)

A water quality based effluent limit analysis was carried out to discharge the plant effluent into Athabasca River. As part of the project, a dispersion model was developed using SMS and RMA software, and the resulting concentration of various constituents were determined. Responsibilities also included reporting.

Project Engineer, Hydraulic Modeler

Tailings Pond Temperature and Sediment Dispersion Modeling, Total E&P Canada Ltd., Fort McMurray, AB (2009)

A hydrodynamic and temperature dispersion model was developed to investigate dispersion of temperature due to hot tailings added to a tailings pond. SMS and RMA software were used to develop the model. Tasks included modelling and reporting.

Project Engineer, Hydraulic Modeler

Thermal Plant Outfall Temperature Dispersion Modeling, Minneria Petaquilla S.A., Panama (2009)

The dispersion of a thermal plant effluent in the Caribbean Sea was analyzed and modelled. The model was developed using MIKE21 software with the hydrodynamic and advection/dispersion modules. Dispersion of temperature plumes were developed and reported.

Research and Innovation Projects

Project Manager

Climate Prediction Scenarios and River Water Quality Models for Battle River Basin, Alberta Environment and Parks, AB (2017)

Had the task to direct other engineers to develop the climate data downscaling models, and to predict climate variables in accordance with AR5. Also, reviewed and evaluated various water quality prediction models for the Battle River watershed. Completed technical Review and reporting.

Researcher; Software Developer

Water Resources System Management Software Development, University of Western Ontario, London, ON (2006)

Developed a series of water resources management optimization software. These software were used for linear programming, non-linear programming, evolutionary programming and multi-criteria optimization. Responsibilities also included development of user manuals and software help systems.

Researcher, Dynamic System Modeler

Dynamic Modeling of Canadian Weather and Environmental Prediction System, CFCAS, University of Western Ontario, London, ON (2005)

A weather and environment assessment model was developed using Vensim (system dynamics) software. The task included identification of key parameters that play vital roles in the weather and environment prediction, and the development of various modelling scenarios. Other tasks included developing technical report and peer-reviewed publications.

Researcher, Dynamic System Modeler

Integrated Water Resources Assessment Modeling for Canada, NSERC, University of Western Ontario, London, ON (2003 - 2004)

An integrated water resources assessment model was developed using Stella (system dynamics) software. In addition to the water sector, the model also included population, climate, environment, energy, and water quality sectors. Other tasks included developing technical report and peer-reviewed publications.

Professional History

- Wood, Water Resources Engineer, Senior Modeler, Calgary, AB (2021 - Present)
- Westhoff Engineering Resources Inc., Water Resources Engineer/ Senior Modeler, Calgary, AB (2011 - 2021)
- Golder Associates Ltd., Water Resources Engineer/ Senior Modeler, Calgary, AB (2006 - 2010)
- University of Western Ontario, Post-doctoral Researcher, London, ON (2001 - 2005)
- Southeast Asia Technology Co. Ltd., Senior Water Resources Engineer, Bangkok, Thailand (1997 - 2001)
- Asian Institute of Technology Post-graduate Student/ Researcher, Bangkok, Thailand (1992 - 1997)
- Irrigation Dept., Irrigation Engineer, Sri Lanka (1982 - 1991)
- University of Peradeniya, Assistant Lecturer, Sri Lanka (1982)

Additional Qualification

Publications / Presentations

- V. Rajasekaram, G.A. McBean and S.P. Simonovic. 2010. A Systems Dynamic Modeling Approach to Assessing Elements of a Weather Forecasting System. Atmosphere-Ocean, Canadian Meteorological and Oceanographical Society, 48(1), 1 - 9.
- McBean, G.A., V. Rajasekaram and S.P. Simonovic. 2007. A Systems Dynamic Modeling Approach to Assessing Elements of a Weather Forecasting System. CMOS-CGU-AMS Congress 2007, Canadian Meteorological and Oceanographical Society. St. John's, NL, Canada. May 28 - Jun. 1.
- Rajasekaram, V. and K.D.W., Nandalal. 2005. Decision Support System for Reservoir Water Management Conflict Resolution. Journal of Water Resources Planning and Management. ASCE, 131(6), 410-419.
- Rajasekaram, V. and S.P. Simonovic. 2005. Impact of Regional Water Quality on Canadian Development Sectors, 17th Canadian Hydrotechnical Conference of the CSCE. Edmonton, Alberta, Aug. 17-19.
- Rajasekaram, V. 2005. Application of Spatial System Dynamics for Watershed Modelling, International Conference on Hydrological Perspectives for Sustainable Development (HYPESD-2005). Roorkee, INDIA, Feb. 23-25.
- Rajasekaram, V. and K.D.W. Nandalal. 2004. System Dynamics-Based Decision Model for Water Management in Walawe Basin, Sri Lanka, International Conference on Sustainable Water Resources Management in the Changing Environment of the Monsoon Region. Colombo, Sri Lanka, Nov. 17-19.
- Simonovic, S.P. and V. Rajasekaram. 2004. Integrated Analyses of Canada's Water Resources: A System Dynamics Approach, Canadian Water Resources Journal. 29(4), 223-250.
- Rajasekaram, V. and K.D.W. Nandalal. 2003. Distributed Watershed Modelling using Object Oriented Programming, 16th Canadian Hydrotechnical Conference of the CSCE. Oct. 21-24.
- Simonovic, S.P. and V. Rajasekaram. 2003. A Model for Assessment of Canadian Water Resources through System Dynamics Simulation, 16th Canadian Hydrotechnical Conference of the CSCE. Oct. 21-24.
- Rajasekaram, V., S.P. Simonovic and K.D.W. Nandalal. 2003. Computer Support for Implementation of a Systematic Approach to Water Conflict Resolution, Water International. 28(4), 454-466.
- Rajasekaram, V., K.D.W., Nandalal and S.P. Simonovic. 2002. A Conflict Resolution Support System for Use in Water Resources Management, International Conference: 'From Conflict to Co- operation in IWRM'. Delft, The Netherlands, Nov. 20-22.

- Patrapanich, M., V. Rajasekaram, and M.A. Habib. 2000. Applications of Hydrodynamic Modelling. National Workshop on Data and Model Inventory organized by Mekong River Commission. Nakorn Ratchasima, Thailand, Aug. 31 - Sep. 1.
- Tingsanchali, T. and V. Rajasekaram. 1997. Reliability-based Optimal Reservoir Operation of the Mae Klong River Basin, 9th World Water Congress, IWRA. Montreal, Canada, Sept. 1-6.
- Tingsanchali, T. and V. Rajasekaram. 1997. Water Resource System Operation Under Hydrologic Uncertainty: the Mae Klong River Basin, Thailand, 27th IAHR Congress. San Francisco, USA, Aug. 10-15.
- Tingsanchali, T. and V. Rajasekaram. 1996. An analytical Model for Flow Routing in Urban Channel Networks, International Conference on Urban Engineering in Asian Cities in the 21st Century. Bangkok, Thailand, Nov. 20-23.
- Tingsanchali, T. and V. Rajasekaram. 1994. Application of HEC-3 Model to Assess Water Resources Availability of the Mae Klong River Basin, Thailand, International Agricultural Engineering Conference. AIT, Thailand, Dec. 6-9.

Software / Skills

- Sound knowledge of MS Office, AutoCAD, ArcGIS, and various modeling software
- Experienced in design of hydraulic structures and various data analysis techniques
- Software and macro authoring using Visual Studio software development tools, Excel VBA and Python

wood.

Application of Modeling Software and Utilities

Category	Software/ Tool	Application Experience
Computational Fluid Dynamics, Flooding Analysis, Hydraulic, Environmental and Water Quality Modeling	EFDC (3-D lake hydrodynamic and water quality modeling)	2 projects
	CE-QUAL-W2 (2-D river hydrodynamic and water quality modeling)	2 projects
	SMS and RMA 10/11 (2-D/3-D hydrodynamic and dispersion modeling)	5 projects
	ANSYS CFX (3-D flow hydrodynamic and heat dispersion modeling)	2 projects
	MIKE 21 (2-D hydrodynamic and environmental transport modeling)	>5 projects; trainer
	CCHE2D (2-D hydrodynamic, sediment transport and morphological modeling)	>10 projects
	HEC-RAS (1-D/2D hydrodynamic modeling)	>10 projects
	MIKE 11 (1-D hydrodynamic and environmental modeling; dam-breach modeling)	>5 projects; trainer
Stormwater Modeling	PCSWMM, XPSWMM	>5 projects
	Custom Stormwater models using GoldSim	>10 projects
	Custom Urban Water Balance Models using MS Excel VBA	>10 projects; developed WBSCC(a)
Distributed Hydrologic/Mine-site Water Balance Modeling	SWAT, QSWAT (Distributed hydrologic modeling)	2 projects
	HSPF (Distributed hydrologic modeling)	>10 projects
	MIKE-SHE (3-D integrated surface and groundwater hydrologic modeling)	1 project
	Mine-site water balance using GoldSim	2 projects
Dynamic Systems Modeling	GoldSim (Stochastic/ deterministic system dynamics modeling)	>10 projects; trainer; beta tester
	iThink/ Stella, Vensim (System dynamics modeling)	>10 projects; trainer
	SDSM (Climate prediction data downscaling)	1 project
Development/ Programming	Visual Studio 2017(VB, C#), VBA	
	Microsoft SQL, MS Access, MySQL, SQLite	
	ArcGIS and QGIS (Geographic information system)	

Technical Training

- Stochastic System Dynamics and Contaminant Transport Modeling using GoldSim, GoldSim Technology Group, Issaquah, WA (Training held at Golder Associates Office, Calgary); 2007
- Groundwater and Surface Water Integrated System Modeling using MIKE-SHE, Danish Hydraulic Institute, Portland, OR (Training held at Golder Associates Office, Calgary); 2007
- 3-D Hydrodynamic Modeling using ANSYS CFX, ANSYS Inc., Waterloo, ON; 2006
- System Dynamics Modeling using STELLA, University of Western Ontario, London, ON; 2002
- Coastal and Estuarine Modeling using MIKE-21 (by DHI staff), Asian Institute of Technology, Thailand; 1998
- Object-oriented and Database Programming using Microsoft Visual Studio, ACECOM, Asian Institute of Technology, Thailand; 1995
- Geographic Information System Development using ArcInfo, Asian Institute of Technology, Thailand; 1995
- Surface Water System Modeling using MIKE11 and NAM (by DHI staff), Asian Institute of Technology, Thailand; 1993
- Hydro-meteorological Measurements and Data Analysis Techniques, Asian Institute of Technology, Thailand; 1991

Niko Finke, PhD

Environmental Geochemist

Professional Summary

Mr. Gautrey has 25 years of experience as a hydrogeologist specializing in projects related to mining and groundwater resource assessments. His areas of expertise include groundwater characterization projects for engineering and environmental assessments for mine projects, karst feature investigations, participation in ITRB's, peer reviews, and assessments of impacts on surface water features. Mr. Gautrey has worked at mine sites across Canada and in South America and Australia.

In addition to his consulting experience, Mr. Gautrey was a co-chair of a MECP working group, which is Ministry organized stakeholder group reviewing updates to Ontario's rules and regulations concerning groundwater extraction. He also chaired a PGO team of five leading hydrogeologists to peer review a government report on groundwater takings for bottled water in Ontario. In 2021, Mr. Gautrey was made a Fellow of Geoscientists Canada.

Qualifications

Education

- Dr. rer. nat. (eq. Ph.D.) Biogeochemistry, University of Bremen, Bremen, DE (2003)
- Diplom (eq. MSc) Geology & Biology, University of Bremen, Bremen, DE, Major: geochemistry & hydrology (geology); microbiology, molecular biology (biology) (1999)
- Vordiplom (eq. Bsc) Geology & Biology, RWTH Aachen University, Aachen, DE, (1995)

Project Experience

Geochemist

Wood PLC (2021)

Environmental biogeochemistry of mine waters.

Research Associate

University of British Columbia, Vancouver, BC, CA (2020)

- Co-applicant on 5 successful grant applications ranging from CAD25,000 – 353,000 and project duration of 6 – 24 months including study design; developed project budgets.
- Project manager for 3 research projects studying chemistry, microbial diversity, and performance of a WWTP anaerobic digester, chemistry and microbiology of fracturing fluids, and the potential of Northern soils to degrade fracturing fluid constituents.
- Investigated the fate of fugitive gas in a northern aquifer.

Years of Experience

20+ (1 with Wood)

Office of Employment

Vancouver, BC

Languages

- English
- German
- French

Professional Associations

- In the process of applying for P.Geo with the Engineers and Geoscientists BC (EGBC)
- Member of International Society for Microbial Ecology (ISME)

Areas of Expertise

- Geochemistry and microbiology of frac fluids, degradation of frac fluid constituents by soil microbial communities, microbial degradation of fugitive gas, anaerobic WWTP digesters.
- Sampling: Surface water, groundwater, soil, water treatment plant, frac fluid, seafloor, and sea ice sampling for geochemical and biological analysis.
- Software: PhreeqC, R, ArcGIS, thermodynamic modelling.

- Studied redox chemistry and microbial diversity in various hydrological settings.
- Communication with other research groups, technicians, contractors, industry partners, regulators, and funding agencies.
- Reporting (including budgeting) and formulating deliverables to industry partners, regulators and funding agencies.
- Managed field teams during sampling in Northern BC, remotely and on-site.
- Co-supervision and mentoring of 3 BSc, 1 MSc, 2 Ph.D. students; trained postdocs, students, and lab, field and industry technicians.
- Developed, refined, or adapted methods for field sampling and analysis, defined SOPs for numerous field sampling and analytical methods.

Geochemical Consultant

On contract with Fugro GeoConsulting Inc., Bluebird Geoscience Inc., Right on Q Inc, University of Tromsø (2013 – 2017)

- Geochemical consultant on 4 offshore hydrocarbon exploration cruises.
- Field sampling and sample analysis are usually separate operations delaying results acquisition and potentially requiring pricy consecutive field trips. We introduced onboard hydrocarbon analysis to hydrocarbon exploration cruises for timely sample analysis allowing to guide survey cruises and reduce re-surveying.
- Excellent performance and service led to 4 consecutive contracts with Fugro GeoConsulting Inc. cruises plus 2 additional job offers.

Postdoctoral Research Associate

University of Georgia, Athens, GA, US (2011 – 2014)

- Head of radioisotope lab.
- Studied methane cycling in marine surface waters and sediments.
- Developed and implemented marine studies and lead research team on trips to the Gulf of Mexico, Laptev Sea, and Barrow, AK.

Postdoc

University of Southern Denmark (SDU), Odense, DK (2008 – 2011)

- Designed and implemented work program and organized field trip to sample hypersaline microbial mats in Eilat, Israel.
- Managed greenhouse with flume aquaria for time series project.
- Studied S-and C-cycle in hypersaline microbial mats.
- Supervision and mentoring, and co-supervision of MSc students.

NASA Ames Research Center, Moffett Field, CA, US (2005 – 2008)

- Secured funding through ORAU and EU to work at NASA in Moffett Field, CA and SDU in Odense, DK; CAD 450,000 over 5 years.
- Designed study to investigate S-and C-cycle in microbial mats.
- Field trips to Baja California, Yellowstone National Park, and Californian Sierras.

Max Planck Institute for Marine Sciences, Bremen, DE (2003 – 2005)

- Coordinator of the EU-project "TREAD – Transport, reactions, and dynamics of heavy metals in polluted marine sediments".
- Planning and organization of the "European workshop on heavy metal contaminated, marine sediments" to present the project results to stakeholders, governmental agencies and scientists 2005 in Bremen, DE.
- Managed international, inter-institutional sampling campaigns.
- Managed flume aquaria with heavy metal contaminated sediment.
- Managed field team as chief scientist on a research cruise to Svalbard, NO.
- Coordinated reporting, including budgeting, formulated deliverables.
- Co-supervised 3 PhD students, trained students, and lab technicians.

Field Technician

Hydro-Olzem, Aachen, DE (1993 – 1995)

- Soil sampling for contaminated site surveys.
- Soil profiling and development of sampling strategies.

Field Work

- Field trips: 40+ field trips to conduct surveys and sample water, soils, groundwater, frac fluids, microbial mats, WWTP digesters, sediments, and sea ice, including remote locations and contaminated sites (1999 – 2019).
- Marine surveys: 15+ research cruises to coastal and deep ocean sites from the tropics to the high Arctic, including coastal BC (1999 – 2017).
- Industry surveys: 4 industry hydrocarbon exploration surveys (2013 – 2017).

Niko Finke, PhD

Environmental Geochemist

Professional History

- Wood (2021 - Present)
- Urban Elements Sustainable Landscapes (2021)
- University of British Columbia, Vancouver, BC, CA (2015 - 2020)
- On contract with Fugro GeoConsulting Inc., Bluebird Geoscience Inc., Right on Q Inc, University of Tromsø (2013 - 2017)
- University of Georgia, Athens, GA, US (2011 - 2014)
- University of Southern Denmark (SDU), Odense, DK (2008 - 2011)
- NASA Ames Research Center, Moffett Field, CA, US (2005 - 2008)
- Max Planck Institute for Marine Sciences, Bremen, DE (2003 - 2005)
- Hydro-Olzem, Aachen, DE (1993 - 1995)

Additional Qualification

Publications / Presentations

- 15+ peer-reviewed publications
- 20+ oral presentations at international conferences and invited seminars
- 15+ poster presentations at international conferences
- 5+ presentations to the public at open house and demonstration events

Software / Skills

- Geochemical modelling with PhreeqC
- Statistical analysis using R-studio
- Thermodynamic modelling of biological processes
- Analysis of genetic data
- Map creation with ArcGIS
- Microsoft Office

Training

- Overview of the Impact Assessment Act (IAA), Government Canada (2020)
- Practical Project Management, UBC, Vancouver, BC, CA (2017)
- Basic Offshore Safety Induction & Emergency Training (Bosiet, including HUET and EBS), Falk, Houston, TX, USA (2017)
- H2S alive, Enform, Vancouver, BC, CA (2015)
- Standard First Aid CPR/AED level C (2015) Canadian Red Cross, Vancouver, BC, CA
- Transportation of dangerous goods (TDG 7) (2015) BCIT, Vancouver, BC, CA
- Class 5 driver's license, ICBC, Vancouver, BC, CA (2015)
- Course on speciation and bioavailability, University of Geneva, CH (2004)
- PhreeqC course, Dr. CAJ Appelo, Amsterdam, NL (2004)
- Radiation safety training, Vancouver, BC, CA (2015) Athens, GA, US (2011), Moffett Field, CA, US (2006), Kiel, DE (2001)

Bradley Markham, M.Sc., P.Geo. (Limited)

Senior Hydrogeologist

Professional Summary

Mr. Markham has experience in groundwater flow modeling pertaining to various hydrogeological problems including: simulating the impacts of various dewatering operations, seepage analysis, wellhead protection, as well as groundwater flow modeling in support of various remedial designs. He also has experience in the design and analysis of hydraulic testing programs such as constant/variable rate pumping tests, single/multiple well hydraulic testing (slug testing, packer testing) for the hydraulic characterization of both overburden and bedrock.

Qualifications

Education

- M.Sc., Hydrological Sciences, McMaster University, 2003
- B.Sc., Honours, Environmental Science (Biogeochemistry specialization, McMaster University, 2000

Project Experience

CONFIDENTIAL CLIENT Golden Valley GW Model and RA/IRM Work Plan, Golden Valley, MN, United States, $161,141, (02/28/2014 - 02/15/2016)

Wood prepared a groundwater model and remedial action/interim remedial measure (RA/IRM) Work Plan for this active industrial site.

CONFIDENTIAL CLIENT Golden Valley Offsite Remedial Investigation, Golden Valley, MN, United States, $344,080, (09/23/2015 - 06/30/2017)

Wood performed an offsite remedial investigation at this active industrial site.

Years of Experience

16 (16 with Wood)

Office of Employment

Eastern CA - Mississauga, ON.

Areas of Expertise

- Hydrogeologist

CONFIDENTIAL CLIENT Phase II & III Remedial Investigations, Remedial Designs, and Remedial Actions, $503,450, (07/17/2013 - 04/14/2015)

Wood performed a Phase II and III remedial investigation at this active industrial manufacturing facility where soil, groundwater and surface water have been impacted by chemicals of potential concern (COPCs) associated with wood preservation/treating and other plant operations. Site activities included environmental contamination delineation and monitoring and remediation of soil, groundwater, and surface water. The remedial investigation was performed under Resource, Conservation, and Recovery Act (RCRA) guidance in accordance with a consent decree issued by the Minnesota Pollution Control Agency (MPCA). Remedial activities that have been conducted include soil boring and monitoring well installation and sampling, regularly scheduled groundwater and surface water quality monitoring, recirculation line excavation and removal, installation and operation of a groundwater pump and treat system, drainage culvert removal, and drum and impacted soil removal and treatment.

LNG Canada Inc. Export Terminal Project, Kitimat, B.C.

Lead modeler in the development and implementation of groundwater flow model used to estimate influence of project build out on local surface water features and assess potential changes to contaminant migration pathways resulting from project build out.

FHELP OPTA EAST SMS System Design, Ft. Hills, AB.

Lead modeler in the development and implementation of a finite element (FEFLOW) 3D transient groundwater flow model used to design seepage management system for hydraulic containment of process impacted tailings. Conceptual model development involved analysis of slug testing data and multi-well aquifer performance testing data.

Northstar Aerospace (Canada) Inc., Cambridge, ON.

Development and implementation of a 3D groundwater flow model for the site which was used to evaluate groundwater flow patterns from contaminant source area to discharge zones and used to aid in the design of site pump-and-treat system. Conceptual model development involved analysis of slug testing data and multi-well aquifer performance testing data.

Upper Centennial Parkway, Hamilton ON.

Development and implementation of a numerical groundwater model to simulate dewatering, and an assessment of potential impacts arising from construction dewatering of 5km long sewer tunnel.

Windsor-Essex Parkway Project, Windsor, ON.

Lead modeler in the development and implementation of a 3D groundwater flow model for the site which was used to estimate groundwater inflows and resultant impacts to the nearby Ojibway Provincial Wetlands Complex arising from both construction dewatering activities and permanent dewatering features associated with sub-grade tunnels.

PhosCan Chemical Corp. Martisan Phosphate Deposit, Martison, ON.

Lead modeler in the development and implementation of a 3D transient groundwater flow model for the site which was used to estimate groundwater inflows, dewatering requirements and resultant impacts to the surface water features arising from potential mine dewatering operations.

Guyana Gold, Guyana

Assisted in the development and implementation of groundwater flow model used to estimate inflows into open pit mine sited next to a large river in saprolite rock.

VALE, Voisey's Bay Underground Mine Project, FEL3 Study, NL

Used developed groundwater flow model to provide estimates of groundwater seepage into proposed underground mine and potential seepage from nearby surface water body. Conceptual model development involved analysis of slug testing and packer testing data.

VALE, Dam Replacement Study at Frood-Stobie Tailings Area, Sudbury, ON

Assisted in development of groundwater flow model used to provide estimates of groundwater inflow and impacts to water table resulting from construction dewatering of proposed excavation.

VALE, Totten Mine, Sudbury, ON.

Assisted in the development of groundwater flow model used to provide estimates of groundwater inflow and impacts to water table resulting from mine dewatering and characterized potential interaction between mine and nearby flooded Worthington Cave Zone.

VALE, Nickel Refinery East Landfill Pump and Treat System Modeling Sudbury, ON.

Assisted with development and application of 3D groundwater flow model in support of groundwater extraction well system.

VALE Copper Cliff Copper Refinery Pump and Treat System Modeling Sudbury, ON.

Developed and used 3D groundwater flow model to support design of groundwater extraction well system.

VALE Sandy Pond Residue Handling and Storage Facility,Long Harbour, NL.

Assisted in development of groundwater flow and transport model to estimate impacts resulting from placement and operation of tailing storage facility. Used groundwater flow model to assist in development of mitigative measures.

Rainy River Gold Project, ON.

Assisted with the development and implementation of 3D groundwater flow model used in support of the baseline study and EA, Rainy River, Ontario. The developed groundwater flow model was used to estimate mine inflows and anticipated groundwater impacts.

Detour Gold Project, ON.

Assisted with the development and implementation of the 3D groundwater flow model for hydrogeological baseline study and EA, Detour Lake, Ontario. Study included model development, calibration, predictions of mine inflows and anticipated groundwater impacts. Conceptual model development involved analysis of slug testing data as well as single and double packer hydraulic testing.

Liberty McWatters Mine, ON.

Assisted with the development and implementation of 3D groundwater flow model for simulation of groundwater seepage into the proposed underground workings at the McWatters mine site and groundwater impact assessment associated with the mine dewatering operations.

Apollo Gold Pre-Feasibility Study, ON.

Assisted with the development and implementation of 3D groundwater flow model for the assessment of seepage rate into the existing underground mine workings and proposed open pit. The developed groundwater flow model was used to estimate the impact of groundwater extraction on the water level in the nearby lake.

Gold Eagle Mine, NL.

Assisted in the development of numerical groundwater model in support of the permit to take water application. The developed groundwater flow model was used to estimate the zone of influence and groundwater seepage rates into the underground workings associated with the proposed advanced exploration activities at the Gold Eagle Mine Property.

Phoenix Gold Eagle, NL.

Assisted in the development of numerical groundwater model in support of the permit to take water application. The model was used to predict groundwater seepage into the existing (McFinley drifts and shafts) and proposed underground mine workings and to estimate the zone-of-influence associated with the mine dewatering.

De Beers Victor Diamond Feasibility Study, ON.

Assisted with the Development of a series of two- and three-dimensional groundwater flow models utilized for the assessment of various dewatering operations at the proposed Victor Mine site.

Hydrogeological Study for Premier Ridge Mine Site, ON.

Assisted with development and application of 3D groundwater flow model for the assessment of the seepage rate into the proposed underground mine workings and zone-of-influence associated with the proposed dewatering.

Broken Hammer Pre-Feasibility Study, ON.

Assisted with development and application of 3D groundwater flow model for the assessment of the seepage rate into the proposed open pit and zone-of-influence associated with the proposed dewatering.

IKO Madoc, ON.

Assisted in development and application of 3D groundwater flow model for the assessment of seepage rate into the proposed expanded granite quarry and assessed the impact of its dewatering on the groundwater levels in the aquifer.

Environmental Baseline Studies for Hollinger Mine, ON.

Assisted with development and application of 3D groundwater flow model for the assessment of seepage rates into the existing underground mine workings and proposed open pit. Used developed model to estimate zone-of-influence (ZOI) associated with the proposed dewatering operations.

Advanced Exploration/Pre-Feasibility Study for Young-Davidson Mine, ON.

Assisted with development and application of 3D groundwater flow model for the assessment of seepage rates into the existing underground mine workings and proposed additional workings. Used developed model to estimate zone-of-influence (ZOI) associated with the proposed dewatering operations.

Shebandowan Eagle Mine Groundwater Study, ON.

Assisted with development of a 3D groundwater flow model for the proposed mine development in support of the PTTW application at the Sheband.

Wellhead Protection Area Study for Markstay-Warren, ON.

Designed and implemented three-dimensional groundwater flow modeling and pathline analysis for delineation of wellhead protection areas of municipal wells in the Municipality of Markstay-Warren, Ontario (2 well fields).

Wellhead Protection Area Study for Port Sydney, ON.

Designed and implemented three-dimensional groundwater flow modeling and pathline analysis for delineation of wellhead protection areas of municipal well in the Municipality of Port Sydney, Ontario (1 well field).

PJV Tailings Pond Relocation, Timmins, ON.

Developed a series of two-dimensional models to simulate the groundwater flow regime within a tailings impoundment under existing site conditions and after the addition of new tailings to the impoundment.

Misawa Wellhead Protection Study, Misawa AB, Japan

Assisted in development of three-dimensional groundwater flow modelling and pathline analysis for delineation of wellhead protection areas for the on-base water supply wells.

Potable Water Production Plan for Osan AB, South Korea

Assisted with the development of numerical groundwater flow model in support of the proposed water supply system.

Contaminant Transport Modeling

Mr. Markham has experience in contaminant/solute transport modeling pertaining to various groundwater contamination problems including: design of pump-and-treat systems, source removal scenarios and capping of landfills. Mr. Markham has provided technical assistance to several remedial programs for a variety of contaminants, including petroleum hydrocarbons, chlorinated solvents, metals and explosives. Responsibilities have included assistance during contaminant transport model development, assessment of dissolved plume volume/mass in the subsurface, model calibration, simulation of various scenarios, sensitivity analysis, report preparation and presentation.

Algoods, ON.

Assisted in the development and application of groundwater flow and contaminant transport model (dissolved phase chlorinated solvent plume) used to estimate plume containment by the capture zones of water-oil recovery wells.

Impact Area Groundwater Study Program, Camp Edwards, Massachusetts Military Reservation (MMR), MAS

Being a junior modeler for the Impact Area at MMR Mr. Markham assisted with the modification and development of the fate and transport model for the Impact Area. Mr. Markham provided assistance during the development and implementation of numerical models for contaminant fate and transport. These models are applied to remedial investigation/feasibility studies at sites impacted by testing and disposal of military munitions. The results of model simulations have been effectively conveyed to state federal and private stakeholders using advanced scientific visualization techniques including interactive 3-D graphics and animation.

Risk Assessment and Risk Management Plan, March Landfill, Ottawa, ON.

Junior Groundwater Flow and Contaminant Transport Modeler for this project associated a with a 1.5 kilometre long TCE plume migrating beneath a residential subdivision. His responsibilities included using particle tracking methods to assess the impact of pumping on plume migration and report preparation.

Additional Qualifications

Publications / Presentations

- "Simulating Seepage into Mine Shafts and Tunnels with MODFLOW". Zaidel, J., B. Markham, and D. Bleiker, Ground Water, vol. 48(3). 2010.

Software

- USGS-MODFLOW family of codes (using pre/post processors: VisualMODFLOW, Groundwater Vistas, GMS)
- Feflow
- Aqtesolv

Mario Bianchin, Ph.D, P.Geo. (BC), P.Geo. (AB)

Principal Hydrogeologist

Professional Summary

Dr. Bianchin is a Principal Hydrogeologist with over 26 years of environmental engineering experience. He has completed hydrogeological investigations from British Columbia, Ontario, and internationally; and is the Wood's Groundwater Practice Leader for British Columbia and the Yukon.

Dr. Bianchin has over 18 years of project management experience which includes a wide range of mine site assessments and environmental remediation, as well as large engineering support projects. He has management experience in coordinating resources from multiple Wood offices and overseeing financial schedule control to ensure the successful delivery of projects to clients. His understanding of client expectations and contractual requirements ensured the successful completion of complex projects, often with complicated geographic constraints. Most recently, Dr. Bianchin served as a Project Manager for a large environmental site assessment of a proposed LNG site and, of a former mine site in northern British Columbia. He has managed a number of mining hydrogeologic and contaminant assessment and remediation projects for Xstrata, Teck, Water Energy, New Gold, Centerra Gold and Seabridge.

Dr. Bianchin's current research focus areas include the use of stable and radiogenic isotopes in hydrogeologic assessments, in-situ immobilization and mobilization of selenium in relation to passive remedial strategies for the management of mine-contact water, natural attenuation of contaminants in groundwater, redox chemistry of estuarine hyporheic zones, and the development of a freeze shoe sampler for the simultaneous collection of redox-sensitive sediments and porewater from deep deltaic systems.

Qualifications

Education

- Ph.D, Hydrogeology, University of British Columbia, Vancouver, BC, Canada, 2010.
- M.Sc., Hydrogeology, University of British Columbia, Vancouver, BC, Canada, 2001.
- B.Sc., Physical Geography/Earth Sciences, Simon Fraser University, Burnaby, BC, Canada, 1998.
- Dipl. Technology, Chemical Engineering, Niagara College of Applied Arts and Technology, Welland, Ontario, 1988.

Years of Experience

26+ (7+ with Wood)

Office of Employment

Burnaby, BC

Languages

- English

Professional Associations

- Professional Geoscientist, BC, 39051.
- Professional Geoscientist, AB, 201901

Industries

- Mining
- Oil and Gas
- Infrastructure
- Government
- Transportation

Types of Facilities

- Mine Sites
- Liquid Natural Gas
- Water Treatment
- Military/Naval/Airforce
- Aviation

Areas of Expertise

- Project Management
- Contaminant Fate &Transport
- Groundwater Modelling
- Drainage Design
- Water Treatment Design
- Groundwater/Surface Water Interactions

Mario Bianchin, Ph.D, P.Geo. (BC), P.Geo. (AB)

Principal Hydrogeologist

Project Experience

Mining Closure/Reclamation Projects

Project Manager and Lead Hydrogeologist

Golden Predator Mining Corp. – Brewery Creek 2020 Permitting Support (2020 – Present)

Teck Project manager and lead hydrogeologist that led the design and completion of a preliminary site investigation of the mine site.

Project Manager and Lead Hydrogeologist

Teck Legacy Sites – Beaverdell Mine Site – Preliminary Site Investigation (March 2018 – Present)

Project manager and lead hydrogeologist that led the design and completion of a preliminary site investigation of the mine site.

Project Manager and Lead Hydrogeologist

SnipGold Corporation, Johnny Mountain Mine Closure and Reclamation – Phase 1 Landfill Design and Build (2018 – Present)

Project manager for the design of the new Johnny Mountain landfill. Wood was also responsible for construction oversight, sediment and erosion control management, preparation of record drawings and annual compliance report.

Project Manager and Lead Hydrogeologist

SnipGold Corporation, Johnny Mountain Mine Closure and Reclamation – Environmental Site Assessment (2016 – Present)

Led the environmental components for the development of the site reclamation project execution plan. Project Manager and technical lead hydrogeochemist that oversaw the design and implementation of the Johnny Mountain environmental site assessment that included a hydrogeological investigation, borrow source characterization study, geochemical investigation of waste rock material, closure site drainage plan development and technical assessment report of the proposed landfill expansion.

Project Manager and Lead Hydrogeologist

Mount Nansen Remediation Project, Mount Nansen Groundwater Quality Existing Conditions Report. Government of Yukon, Energy, Mines and Resources, Assessment and Abandoned Mines (2017)

Technical lead hydrogeologist that oversaw the compilation, assessment and interpretation of the groundwater quality data and, preparation of the groundwater quality existing conditions report in support of AAM's water use licence application as part of ongoing Care and Maintenance activities at the Mount Nansen site.

Project Manager and Lead Hydrogeologist

Mount Nansen Remediation Project, Update of Existing Conditions Reports – Surface Water, Hydrology, and Groundwater for Mount Nansen. Government of Yukon, Energy, Mines and Resources, Assessment and Abandoned Mines (2015 – 2016)

Technical lead hydrogeologist that oversaw the assessment and interpretation of the hydrogeological and groundwater quality components of the project baseline study. Work completed in support of Care and Maintenance Activities at the Mount Nansen Site.

Project Manager and Lead Hydrogeologist

Mount Nansen Remediation Project, Hydrogeological Baseline Study, Government of Yukon, Energy, Mines and Resources, Assessment and Abandoned Mines (2014 – 2015)

Technical lead hydrogeologist that oversaw the assessment and interpretation of the hydrogeological and groundwater quality components of the project baseline study. Key deliverables included the development of a conceptual groundwater flow model to support the design of the remedial phase involving the management of the orphan site's mine waste facilities.

Project Manager and Lead Hydrogeologist

Investigation of Non-point Source Metals and Acidity Levels in the Sudbury Smelter Wastewater Treatment System, 12-SS-009 Smelter Non-Point Source Study, Xstrata Nickel, Sudbury, ON (Lorax Environmental Services Ltd.) (2012 – 2013)

Project Manager and lead hydrogeologist. The project involved conducting an extensive hydrogeological investigation to determine non-point metal loadings from the smelter's various waste storage facilities draining into the site's Water Management Area; and extensive wetland system designed to ameliorate leachate discharged from the site to environmentally sensitive receptors. The project involved a detailed hydrogeological investigation involving the installation of drive-point (water table wells) and deep groundwater monitoring wells augmenting the existing monitoring network on site. Water quality results were integrated with a previously completed site water balance for the determination of loadings to the water conservation area (WMA). Key deliverables included a report summarizing findings and recommendations to reduce loadings, improvement of wetland function, as well as, for continued monitoring of groundwater quality.

Project Manager and Lead Hydrogeologist

Cyanide Plume Delineation and Containment, Attorney-Client Privilege Work, Lawson Lundell, LLP., Mexico (Lorax Environmental Services Ltd.) (2012 – 2014)

Project Manager and expert hydrogeologist for the detailed site investigation and containment of groundwater contamination associated with gold-leaching process at an active mine site. The engineered heap leach pad (similar in design to engineered landfills) lay across a very deep and complex groundwater system with preferential flow paths as result of bedrock faulting and fracturing. The field investigation involved rapid deployment/mobilization for the installation of six shallow monitoring wells, eight deep bedrock monitoring wells and one deep pumping well, totaling more than 1,200 metres in borehole advancement. The pumping well was installed to create a hydraulic trap to prevent offsite migration of mine contact water from the heap leach pad. Surface geophysical surveys were conducted in support of the investigation and the installation of an interim containment well and subsequent aquifer pumping tests. Project deliverables included a site wide cyanide audit report, an inter-laboratory evaluation report, and an investigation report which included results of CN plume delineation, hydrogeological, hydrogeochemical, stable- and radiogenic characterization of the bedrock system, a conceptual groundwater flow model, and preliminary assessment of CN fate and transport in deep bedrock groundwater.

Project Manager and Lead Hydrogeologist

Assessment of Natural Attenuation of Selenium in the Backfilled Dillon Pit, Brule Mine, Walter Energy, Chetwynd, BC (Lorax Environmental Services Ltd.) (2011 – 2013)

Project Manager and lead hydrogeologist that was responsible for the design and development of a field-based hydrogeologic study that assessed the nature of Se behaviour in the saturated zone of a relatively small pit backfilled with waste rock (in-pit waste rock storage facility). Field components involved the installation of a detailed monitoring network within saturated wasterock, the characterization of groundwater flow patterns within and around the pit and water quality monitoring including Se species analyses and characterization of redox conditions. Results of the work were summarized in a report and presented in at the 37th Symposium of Mine Reclamation (see publications section).

Project Manager and Lead Hydrogeologist

Kumtor Gold Mine – Tailings Management Facility Tailing Characterization, Kumtor Gold Company (Centerra Gold), Kumtor Gold Mine, Kyrgyz Republic (Lorax Environmental Services Ltd.) (2010)

Project Manager and lead hydrogeologist. Led a study characterizing the metal leaching and acid rock drainage (ML/ARD) characteristics of tailings deposited within the Mine Tailings Facility. The information was used to characterize pore-water source terms and for further evaluating metals loadings predictions associated with tailings seepage.

Professional History

Mining/Hydrogeological-Hydrogeochemical Baseline and Water Management Studies

Conuma Coal Resources, Hermann Disturbance Area, Joint Environmental Assessment Certificate and Mines Act Permit Application. Northeast British Columbia Coal Region, Water Management System Design. Tumbler Ridge, BC (2019 – Present)

Project manager and technical lead hydrogeochemist responsible for leading a multidisciplinary team towards the completion of Issued-for-Permit (IFP) – Level Design for the project's Water Management Plan which included design of the Water Treatment System consisting of settling ponds, biochemical reactors, polishing and aeration ponds. This work was completed in support of the project's BC Environmental Assessment and Mines Act Permit Applications.

Teck Coal Fording River Operations (FRO) Saturated Rock Fill (SRF) – Eagle 4 – Well Field Design/Construction (2019 – Present)

Senior technical reviewer of SRF full scale trial well field design which included the design and installation of injection, extraction and monitoring wells.

Teck Coal Elkview Operations (EVO) Saturated Rock Fill (SRF) – Full Scale Trial (FST 2) – Well Design/Construction (2019 – Present)

Senior technical reviewer of SRF full scale trial (FST 2) well field design which included the design and installation of injection, extraction and monitoring wells. This scope includes expansion of the EVO SRF FST 1 well field.

Conuma Coal Resources, Brule Mine, Biochemical Reactor #1 (BCR) Dam Safety Review, Tumbler Ridge, BC (2018 – Present)

Project manager for the Dam Safety Review of Brule Mine's BCR #1.

Conuma Coal Resources, Brule Mine, Biochemical Reactor #2 (BCR#2) Design, Tumbler Ridge BC (2019 – Present)

Project manager and technical lead hydrogeochemist responsible for leading a multidisciplinary team towards the completion of Issued-for-Construction (IFC) – Level Design of Brule Mine's BCR#2.

Conuma Coal Resources, Brule Mine, Biochemical Reactor #1 (BCR#1) Operations, Maintenance and Surveillance (OMS) Manual. Tumbler Ridge, BC (2019 – Present)

Project manager and technical lead hydrogeochemist responsible for leading a multidisciplinary team towards the completion of the OMS Manual for the Brule Mine BCR#1.

Capstone Mining Corp. 2018 Technical Report, Santo Domingo, Chile (2018)

Qualified Professional for environmental sections of the Technical Report. Responsibilities included reviewing and summarizing pertinent environmental information from existing reports and preparing relevant sections of the prefeasibility study report.

Teck Coal Fording River Operations SWIFT Water Management Plan South Lower System Seepage Study (2017 – Present)

Project manager and technical lead hydrogeologist that oversaw the estimation of seepage from the proposed FRO South lower collection system. The assessment included an evaluation of available geologic and hydrogeologic information to generate a preliminary conceptual model of the local groundwater flow system to support the construction of a numerical groundwater flow model. SEEP/W was used to generate estimates of seepage from the collection channels, the two rock drain ponds, the primary and secondary ponds. Sensitivity analyses were completed on variables of greatest uncertainty particularly groundwater gradient and hydraulic conductivity to constrain seepage predictions.

Teck Coal Elkview Operations (EVO) Saturated Rock Fill (SRF) – Full Scale Trial – Well Design. (2016 – 2018)

Senior technical reviewer of SRF full scale trial well field design which included the design and installation of injection, extraction and monitoring wells. The full-scale trial project focuses on the evaluation of using SRF to immobilize redox-sensitive metalloid species and other contaminants (nitrate) as an option for treatment of mine-contact water to meet Elk Valley Water Quality Plan objectives.

Teck Coal Fording River Operations Water Management Plan SWIFT North Greenhill Line Creek Operations Catch Basin Primary and Secondary Pond Seepage (2015 – Present)

Technical lead hydrogeologist that oversaw the estimation of seepage from the proposed North Greenhills Catch Basin Primary and Secondary Ponds. The assessment included an evaluation of available geologic and hydrogeologic information to generate a preliminary conceptual model of the local groundwater flow system to support the construction of a numerical groundwater flow model. SEEP/W was used to generate estimates of seepage from the proposed ponds. Sensitivity analyses were completed on variables of greatest uncertainty particularly groundwater gradient and hydraulic conductivity.

Teck Coal Line Creek Operations, Se AWTP Buffer Pond Design – Shallow Groundwater Seepage Estimates and Underdrain System Evaluation (2015)

Technical lead hydrogeologist responsible for estimating seepage rates to support the design of the underdrain system for the engineered and lined water retention pond. Wood has been requested by Teck Resources Limited to design and build the water retention pond associated with the West Line Creek Active Water Treatment Facility. The hydrogeological assessment included an evaluation of available geologic and hydrogeologic information to generate a preliminary conceptual model of the local groundwater flow system that supported the estimates of seepage through use of applicable analytical solutions.

Teck Coal Line Creek Operations, Dry Creek Water Management System – Capture Efficiency Assessment (2015)

Technical lead hydrogeologist responsible for providing a preliminary conceptual assessment of capture efficiency of the Dry Creek Water Management System (DCWMS) at their Line Creek Operations (LCO). This assessment involved an evaluation of available hydrogeologic information to generate a preliminary conceptual model of local groundwater flow of the Dry Creek watershed. Deliverables of this work included recommendations to improve the understanding of groundwater flow, including a discussion on data requirements and rationale for the development of a groundwater flow model in line with conditions of the Dry Creek Water Management Plan (DCWMP) British Columbia Ministry of Environment (BC MOE) approval, stipulating the requirement for an options analyses for determining site performance objectives (SPOs) and in-stream flow requirements (IFRs).

CanAus Coal Limited, Prefeasibility Study (2014 – 2015)

Technical lead on hydrological and hydrogeological components of the prefeasibility study. Responsibilities included reviewing and summarizing pertinent environmental information from existing reports and preparing relevant sections of the prefeasibility study report.

Brule Mine 5- year Plan – Updated Hydrogeological Baseline Study, Walter Energy, Chetwynd, BC (Lorax Environmental Services Ltd.) (2012 – 2014)

Project Manager and lead hydrogeologist that oversaw the design and implementation of the Brule Mine groundwater monitoring system to update the mine's baseline study. Field components included aquifer hydraulic testing and groundwater quality monitoring including stable- and radiogenic isotopic characterization. Key deliverables of the project included the development of a conceptual groundwater flow model, assessment of potential impacts to groundwater from the mine's waste storage facilities, and the development of a groundwater mitigation and monitoring plan. Results of the baseline study were integrated into the Brule Mine 5 Year Plan as part of their Mines Act permit application (MAPA). Reporting deliverables included the preparation of updated hydrogeological baseline report, sections of the water management plan and selenium management plan.

Kemess Underground (KUG)-Hydrogeology Baseline Study, AuRico Gold, Kemess, BC (Lorax Environmental Services Ltd.) (2011 – 2014)

Project Manager and lead hydrogeologist that was responsible for the design and implementation of the KUG hydrogeological baseline characterization of the project site. Field components included approximately 8,000 m of diamond drilling in granitoid fractured bedrock, aquifer hydraulic testing, monitoring well installation, instrumentation and groundwater quality monitoring. The program also included a stable- and radiogenic isotopic study of the project site to characterize groundwater recharge, flow paths and travel times to environmental receptors. Key deliverables of the project included the development of a conceptual groundwater flow model, assessment of potential impacts to groundwater and contribution to the groundwater mitigation and monitoring plan. Report deliverables a hydrogeological baseline report, as well as, contributing to the environmental assessment process including project description and the three-dimensional finite element numerical model.

Kemess Underground (KUG) Seepage Predictions Study in support of the Block Cave Full Feasibility Study, AuRico Gold, Kemess, BC (Lorax Environmental Services Ltd.)

(2011 – 2013)

Project Manager and hydrogeological lead on predicting groundwater seepage estimates for developmental, operational and closure phases of the proposed underground operation. Groundwater estimates were derived using analytical solutions.

Environmental Impact Assessment, ECHO HILL Project Site, Hillsborough Resources Limited, ECHO HILL, Tumbler Ridge, BC (Lorax Environmental Services Ltd.) (2010 – 2012)

Project manager and lead hydrogeologist that was responsible for the design and implementation of the hydrogeological baseline characterization of the project site. Field components included borehole drilling, monitoring well installations, instrumentation, aquifer hydraulic testing and groundwater quality monitoring. Project deliverables included the preparation of a hydrogeological baseline report.

Mario Bianchin, Ph.D, P.Geo. (BC), P.Geo. (AB)

Principal Hydrogeologist

Mining/Permitting/Regulatory Review

Nuclear Waste Management Organization (NWMO), North of Superior Ph2 BH4, Ignace, Ontario (2019 – Present)

Technical hydrogeochemical lead for two work-packages involving detailed porewater geochemical evaluation.

Conuma Coal Resources Ltd., Brule Mine 2018 Selenium Management Plan (SeMP) – QEP Review (2018)

Project manager and lead Qualified Environmental Professional (QEP) for the review of the 2018 SeMP.

SnipGold Corporation, Johnny Mountain Mine Closure and Reclamation – Landfill Expansion Permitting (2018 – Present)

Project manager for providing permitting support for an amendment of their Waste Discharge Authorization (Permit) under the British Columbia Environmental Management Act.

Baseline Hydrogeological Studies in Support of Special Waste Permitting/Environmental Assessment for Northern Enviro Services, Land Treatment Facility Expansion. Watson Lake, Yukon (2017 – Present)

Project Manager and technical lead hydrogeochemist that oversaw the conceptualization of the facilities expansion plans to handle greater volumes and varying special waste types. This project also involved identifying the regulatory environmental assessment and permitting pathway under the Yukon Socio-economic Assessment Act (YESAA) and the Yukon Department of Environment. Wood provided the necessary technical support and dialogue with regulators to achieve the approvals and permitting objectives.

Teck Legacy Sites – Beaverdell Mine Site – Permit Compliance Support (2018 – Present)

Project manager and lead hydrogeologist that lead the development of groundwater monitoring program to achieve permit compliance.

Yukon Water Board Technical Advisory Services, Elsa Reclamation and Development Company Ltd. Keno Hill Silver District Operation – Renewal of Water Licence QZ12-057. Whitehorse, Yukon (2017 – 2018)

Technical Lead Hydrogeologist. Completing a detailed review of Water Licence Renewal Application.

North Shore Wastewater Treatment Plant Conveyance Project Predesign, Greater Vancouver Sewerage and Drainage District, Metro Vancouver (2017 – 2018)

Environment Lead for North Shore Conveyance Partners P3 pursuit of project. Responsible for the development of project permitting plan, assessment and scoping of the soil and groundwater investigation plan, support the Contaminated Sites Approved Professional in developing scope for soil and groundwater management plan (the Remedial Plan).

Mario Bianchin, Ph.D, P.Geo. (BC), P.Geo. (AB)

Principal Hydrogeologist

Oil & Gas Contaminated Sites Investigation

LNG Canada Project. Early-Works Soil and Groundwater Management. LNG Canada, Kitimat, British Columbia (2015 – Present)

Project Manager and Senior Technical Lead (Hydrogeologist) leading a team of approximately 20 people to support the management of soil and groundwater during the construction of the Early Works phase of the Project. The project also involved supporting the Engineering team in securing Fisheries Act Authorizations and understanding overall risk to Project at full buildout through changes in groundwater flow conditions. A three-dimensional groundwater flow developed and calibrated to baseline conditions was used to simulate project effects on groundwater flow at full buildout. Additional engineering support was provided in evaluating plant design elevation and mitigating against seasonal variations in water levels.

Enbridge Line 3 Replacement Program, Topographic High Assessment, Enbridge Pipelines Inc. Edmonton, Alberta (Ongoing)

Senior hydrogeologist providing numerical modelling support to evaluate the viability of the Topographic High Segmentation proposal for the decommissioning of their Line 3 pipeline. Modeling was completed to evaluate the consequence of pipeline decommissioning on groundwater flow and potential implications for adjacent land uses including agricultural practices.

Domestic Water and Waste-Water Treatment Research/Field Services/Operations Optimization and Operator Training (Gore & Storrie now CH2MHill)

Gore & Storrie Ltd now CH2M Hill, Greater Toronto Area) (1988 – 1993)

Over a five-year span worked with the Water and Waste-Water Treatment Divisions in completing the following:

- Bench- and pilot scale treatability studies.
- Field services including sampling of storm and sanitary sewers using flow-controlled automatic sampling apparatus.
- Waste-water treatment plant optimization and operator training.
- Analytical lab analyses to support water and waste-water treatment research and monitoring programs.

Professional History

- Wood (2014 - Present)
- Lorax Environmental Services Ltd. (2010 - 2014)
- University of Malta (2009 - 2010)
- University of British Columbia (1998 - 2001, 2003 - 2010)
- Keystone Environmental Limited (2000 - 2003)
- Gore & Storrie Ltd. (1988 - 1989, 1991 - 1994)
- Canadian Armed Forces (1990 - 1991)

Mario Bianchin, Ph.D, P.Geo. (BC), P.Geo. (AB)

Principal Hydrogeologist

Additional Qualification

Publications / Presentations

- Gladu, J.G., Hollenberg, R. Miller, EF. Hidber, K. and M. Bianchin. 2020. High Elevation and Latitude Bioremediation of Petroleum Hydrocarbons in Soil at a Remote Mine Site. 43rd Annual Mine Reclamation Symposium, British Columbia, Technical and Research Committee on Reclamation, Kimberly, BC. 21-24 September 2020.
- Bianchin, M., E. Miller, J. Gladu and D. Wall. 2019. Challenges and Solutions to Meeting Indigenous and Stakeholder Mine Closure Objectives in a Remote, High Alpine Environment. 42nd Annual Mine Reclamation Symposium, British Columbia, Technical and Research Committee on Reclamation, Kimberly, BC. 17-19 September 2019.
- Gladu, J.G., and M. Bianchin. 2020. Managing Soil and Groundwater Risks at Mine Sites: A British Columbia Regulatory Overview. 42nd Annual Mine Reclamation Symposium, British Columbia, Technical and Research Committee on Reclamation, Kimberly, BC. 17-19 September 2019.
- Bianchin, M. and B. Malyk. 2019. Coal Mine Water Treatment and Proposed CMER. Invite presenter and discussion panel. Western Canadian Coal Society. Vancouver, BC. April 29, 2019.
- Bianchin, M. and A. Mayo. In progress. Use of stable and radiogenic isotopes to evaluate the hydraulic connectivity in fractured granitoid rocks.
- Volden, L., Kirste, D., Gordon, R. and M. Bianchin. Investigating the Geochemistry of Selenium in the Residual from Biologically Treated Mine-Impacted Waters. Conference Paper. Resources for Future Generations 2018. Vancouver 16-21, 2018.
- Bianchin, M. Bent, H., and A. Mayo. 2014. Use of stable and radioisotopes in an integrative approach for characterizing groundwater flow in a moderately fractured bedrock aquifer. Geological Society of America Annual Meeting, Vancouver, British Columbia, 19-22 October 2014.
- Bianchin, M., Smith, L., R. Beckie. 2014. Freeze Shoe Sampler for the Collection of Hyporheic Zone Sediments and Porewater. Groundwater, Doi:10.111/gwat.12195.
- Bianchin, M., Martin, A., J. Adams. 2013. In-Situ Immobilization of Selenium within the Saturated Zones of Backfilled Pits at Coal-Mine Operations. 37th Annual Mine Reclamation Symposium, British Columbia, Technical and Research Committee on Reclamation. (http://dhl.handle.net/2329/45284).
- Martin, A., M. Bianchin, D.J. Adams. 2013. Assessment of Selenium Attenuation in Saturated Pit Backfill. North American Metals Council - Selenium Working Group, Vancouver, BC CA. 6/2013.
- Bianchin, M. Smith, L., R. Beckie. 2011. Defining the hyporheic zone in a large tidally influenced river. Journal of Hydrology 406, 16-29.
- van Geen, A. 2011. International Drilling to Recover Aquifer Sands (IDRAs) and Arsenic Contaminated Groundwater in Asia. Workshop participant. Doi:10.2204/iodp.sd.12.06.2011.
- Bianchin, M. Smith, L., R. Beckie. 2010. Quantifying hyporheic exchange in a tidal river using temperature time series. Water Resources Research, 46, W07507.
- Bianchin, M. 2010. A field investigation characterizing the hyporheic zone of a tidally-influenced river. Ph.D. Thesis. University of British Columbia. (http://hdl.handle.net/2429/23484).
- Bianchin, M., Smith, L., J.F. Barker and R. Beckie. 2006. Anaerobic degradation of naphthalene in a fluvial aquifer: A radiotracer study. Journal of Contaminant Hydrology 84, 178-196.
- Bianchin, M., Roschinski, T., Ross, K., Smith, L., Mohn, W., and R. Beckie*. 2006. The physical, geochemical and microbial conditions and processes in the hyporheic zone of a large tidally influenced river: the Fraser River, British Columbia, Canada. Eos Transactions. AGU, 87(52), Fall Meeting Supplement, Abstract B22C-07.

Attachment 2

Third-party Review Response Table for Groundwater, Surface Water and Geochemistry

NSECC – Scope of Work	Groundwater Review Comments	Surface Water Review Component	Geochemistry Review Component
a) Assess the general applicability of the water modelling used for the EA submission from AMNS "Touquoy Gold Mine Modifications, July 2021" (primarily Appendix D and Appendix A). This assessment should include answering key questions provided in the BCMOE Guidelines for Groundwater Modelling (BCMOE 2012, page 218, Section 11.2.4 Content of Model Appraisal), as well as other similar questions that could be applied to the surface water modelling included in the submission.	Refer to Attachment 3 for a detailed response, however, in general the documentation lacks the required level of detail to permit a complete assessment of the general applicability of the groundwater models. It is likely that the groundwater models are adequate for regional modelling and assessing drawdown effects. They may also be suitable for assessing groundwater transport where the risk of an impact is low (i.e. sources are low concentration or attenuation is significant) or where they are used to assess small changes in the project footprint (i.e. the WRSF). They are appropriate for high-level type estimates of flow system behavior but not a detailed assessment of mitigation measures around individual site features (i.e. the seepage ditches).	No specific models have been used for surface water modeling. Regression analysis of flow from regional hydrometric stations has been carried out. This is used for the estimation of flows at ungagged locations. Additionally, seasonal streamflow measurements have been initiated since 2017, and stage-flow relationships have been developed using available data. The regional regression models and pro-rated data sets have been used to assess mean monthly flows and changes in flow regime. The approaches used are generic, and acceptable for standard hydrologic analysis.	Several different models have been used to address different aspects of the proposed expansion. Several water balance models, a geochemical source term model and water quality models. The primary question addressed with the models is the effect of the mine expansion on the water flow, water quality, and environmental impact. Chemical leaching from the waste rock, reactions during transport, and toxicology of the different species should be included in the geochemical part of the model. The presented source term model addresses the leaching, the water quality limits the toxicology and limitations, and uncertainties are addressed. Reactions during transport, chemical or microbial, are not explicitly considered in the models. Reactions generally lead to reduced loading of species, which makes the model more conservative by not including them. Conversely, if a reactive species is used as indicator for transport of other species (e.g., sulfate as indicator for mining impact), then loading maybe more rapid than simulated. The water balance model and the source term model are essential parameters used to model the transport of the Parameters of Potential Concern (POPC_. For most of the aspects of the water quality models the necessary data are available and used. Concerning the sulfate anomaly in Watercourse 4 (WC4) however, more information is necessary (see below for details). Evaluation of the modeling practices is hindered by a lack of detailed documentation of the input parameters and assumptions. The most important implication of the limitations in the modeling address existing conditions with only minor effects on the expansion plans.
b) Review the models and combinations of models used and discuss their suitability in their uses within the submission (e.g., characterizing and making predictions for the AMNS Touquoy Gold site environmental conditions through the described project phases, for all risk areas, and the overall site from a water quantity and quality perspective).	See response to a) above.	A previous report "Water Balance Report, Revision 2.0, Atlantic Gold Tailings Management Facility; by Stantec, 2016" has been reviewed. Also, an in-depth review of information provided in Appendix A1 has been carried out. Provided that the "operational water management plan" provided in Appendix A1 is fully implemented, the Project will not face any environmental consequences in terms of surface water quantity. This re-assures the Justification provided in sections 7.5.1 through 7.5.4 for surface water quantity.	The appendices D.2 WASTE ROCK STORAGE AREA GROUNDWATER MODELLING UPDATE, TOUQUOY GOLD MINE, D.3 WATER QUALITY PREDICTIONS FOR SCRAGGY LAKE AND WATERCOURSE NO.4, TOUQUOY GOLD MINE, D.5 TOUQUOY GOLD PROJECT, ASSIMILATIVE CAPACITY STUDY OF MOOSE RIVER – TOUQUOY PIT DISCHARGE as well as the SD 19 2020 Annual Report were reviewed to determine the combination and suitability of the models used • With respect to Appendix D.2 and the 2020 Annual report it is noted that the particle track model shows an increased inflow of WRSA seepage into watercourse 4 (WC4). Remedial measures for this condition are not discussed in the application. Remedial measures will be needed for the current as well as for the extended state,

NSECC – Scope of Work	Groundwater Review Comments	Surface Water Review Component	Geochemistry Review Component
			however, this aspect has no major influence on the extension of the operations. • With respect to appendix D.3 it is noted that WC4 is included in the water quality model, but results for the time series data and especially for sulfate are only presented for Scraggy Lake. WC4 data would be needed to verify the accuracy and usefulness of the model. This is more related to mitigation measures required for the current state, and not essential for the planned extension according to the application. • With respect to appendix D.5 it is noted that the prediction of the water quality parameters is not well described. • Reactions (e.g. microbial and adsorption) and differences in diffusion coefficients are not included, however, considering the low flow rate, this should not affect the Moose River water quality.
c) Describe how the model limitations, uncertainties, and interdependencies are reflected in the model results	The groundwater model reports do not include sufficient detail in key areas around the WRSF and the downgradient side of the open pit to assess the proposal adequately where risks of environment impacts are high, particularly downgradient of the open pit lake. The models do not evaluate needed remedial measures around the WRSF, although these may not be relevant to the proposed expansion of the WRSF. • There appears to be inconsistent use of groundwater discharge rates from the open pit to the Moose River in between Appendix D.1 and D.5, and within Appendix D.5. • The source terms for the open pit lake and tailings within the open pit require additional explanation to be supported. • The concentrations of parameters of concern downgradient of the open pit lake in Appendix D.5 appear to be far too low to be realistic, however, there is insufficient information to assess them. • It would be useful for the relative elevations of Square Lake and the ditches on the north side of the WRSF to have been provided. • The TMF is not included in the WRSF model, which may affect groundwater flows to Watercourse #4.	All surface water-related calculations have been performed monthly. This is acceptable for the environmental and operational water balance analysis. Runoff coefficients, evaporation factors, and seepage rates used are within norms. Runoff data from additionally established stream gauging stations has been further enhanced based on regional runoff regression relationships. This is acceptable when recorded streamflow data is not available. However, no uncertainty/sensitivity analysis has been provided.	Water quality predictions are presented in appendix D.3 to determine the effect of expanding of operations on the water quality. The model does not include results for sulfate on WC4, a POPC addressed previously in the annual report. Appendix D.3 discusses groundwater seepage as source for anomaly, while previously surface runoff was discussed. This discrepancy needs to be addressed independent of the expansion and should therefore not influence the assessment of the proposal

NSECC – Scope of Work	Groundwater Review Comments	Surface Water Review Component	Geochemistry Review Component
d) Describe any additional areas where some form of water modelling could help to comprehensively understand potential environmental adverse effects - either at specific locations, or for the site overall.	More detailed information in critical areas downgradient of the WRSF and Open pit would be useful.	No comments.	Groundwater and surface water quality is modeled in appendices D3, D.5 using geochemical source terms from appendix D.4. Scaling factors were derived in D.4 for the different species. For the groundwater transport not additional factors such as adsorption and microbial conversion are considered. Both factors will reduce the transport speed and at first sight are conservative. When basing the transport of other POPCs on the measurements of sulfate e.g., in WC4, however, it is important to understand if sulfate transport has been affected by additional reactions, which could decrease its transport rate in relation to other species.
e) Describe what aspects of the water models are being used in the context of supporting site decision making.	The groundwater models provide the rates of water movement and solute loading from areas of potential contamination to environmental receivers (i.e. primarily Watercourse #4 and the Moose River).	Please refer to 1(a) for surface water.	The appendices D.2 WASTE ROCK STORAGE AREA GROUNDWATER MODELLING UPDATE, TOUQUOY GOLD MINE, D.3 WATER QUALITY PREDICTIONS FOR SCRAGGY LAKE AND WATERCOURSE NO.4, TOUQUOY GOLD MINE, D.5 TOUQUOY GOLD PROJECT, ASSIMILATIVE CAPACITY STUDY OF MOOSE RIVER – TOUQUOY PIT DISCHARGE were reviewed to determine site decision making process • The source term model is used as input for all the water quality models, so are the water balance and flow models. The water quality models and the particle track model are used to understand the change in environmental impact e.g., between the current and expanded footprint of the WRSA. Together these are used to infer mitigation practices needed.
a) The technical evaluation is expected to include assessing the computer models MODFLOW-NWT, MT3D- USGS, FLOWPATH, and GOLDSIM. In addition, assess the WRSA/TMF Geochemical Source Term Modelling by Lorax Environmental (2020) that in part uses the numerical geochemical model PHREEQC.	See Attachment 3 for comments on the groundwater models.	No models used for surface water component.	The Appendices D.3 WATER QUALITY PREDICTIONS FOR SCRAGGY LAKE AND WATERCOURSE NO.4, TOUQUOY GOLD MINE, D.4 TOUQUOY GOLD MINE – WRSA GEOCHEMICAL SOURCE TERMS, D.5 TOUQUOY GOLD PROJECT, ASSIMILATIVE CAPACITY STUDY OF MOOSE RIVER – TOUQUOY PIT were reviewed in terms of methodology. • With respect to appendix D.3 it is noted that results are only presented for Scraggy Lake, not for the other sampling stations, limiting its usefulness of the model. • With respect to appendix D.4 it is noted that solubility constraints for WRSA source term partly are modeled (PHREEQC) and partly measured. It is unclear if the two are compared (i.e., use chemistry data to check modeled species) to verify findings. • With respect to appendix D.4 it is noted that source-terms were derived from humidity cells, column experiments, and leakage data, scaling factor for source term derived from field data and column experiments. No objections found to the methodology used.

NSECC – Scope of Work	Groundwater Review Comments	Surface Water Review Component	Geochemistry Review Component
			• With respect to appendix D.5 it is noted that details on Moose River/Pit Lake water quality model not well presented complicating the evaluation of the model. Source terms are not as derived from a different mine site, which may be acceptable with an explanation. Concentrations of POPC's in groundwater downgradient of the pit lake (given in Table 5.4 of Appendix D.5) appear to be far too low, or at least lack sufficient detail to be supported.
b) Evaluate using standard industry technical guidance for groundwater modelling and surface water modelling, including the BCMOE Guidelines for Groundwater Modelling key questions for peer reviews (BCMOE 2012, page 222, Section 11.3.4 Content of Peer Review) and others as necessary.	See Attachment 3 for comments on the groundwater models.	No models used for surface water component.	Not applicable.
c) Provide a detailed evaluation document that comprehensively assesses the water models, their design, their use at the site and an assessment of the validity of model development against the standard technical guidance methodology referenced.	Addressed elsewhere within this table and other parts of this review document.	No models used for surface water component.	Addressed elsewhere within this table and other parts of this review document.
d) What are the key water modelling data and analysis gaps and how significant are they in terms of their potential impacts on the conclusions stated in the submission?	There is a lack of detailed information in the areas downgradient of the open pit and WRSF, which makes an assessment of the accuracy of the models difficult.	The analysis has been carried out using monthly data for the climate-normal, 100 year wet and 100 year dry conditions. The dataset has been created from observed climate data and measured/prorated stream flow data. No data gaps have been reported. The effects due to the Project, in terms of surface water components, are not significant. Therefore, impacts due to any data gaps, although not analyzed/reported, would be within limits	The appendices D.2 WASTE ROCK STORAGE AREA GROUNDWATER MODELLING UPDATE, TOUQUOY GOLD MINE, D.3 WATER QUALITY PREDICTIONS FOR SCRAGGY LAKE AND WATERCOURSE NO.4, TOUQUOY GOLD MINE, D.5 TOUQUOY GOLD PROJECT, ASSIMILATIVE CAPACITY STUDY OF MOOSE RIVER – TOUQUOY PIT DISCHARGE were reviewed to determine key data and analysis gaps. • With respect to appendix D.3 it is noted that the WC4 data is not presented • With respect to appendix D.5 it is noted that reactions during groundwater flow are not considered. • With respect to the sulfate anomaly in WC4 it is noted that flow data for SW23 and SW19, water quality data for WRSP1 and MW15 are not presented but needed to inform mitigation measures • As mentioned before, these gaps mostly impact current conditions with little impact on the WRSF expansion.

NSECC – Scope of Work	Groundwater Review Comments	Surface Water Review Component	Geochemistry Review Component
Given several interacting groundwater and surface water models (computer numerical models) used for both water quantity (flow/levels) and water quality predictions at this site, evaluate and describe how the proponent has put together/summarized and made conclusions from the water data. Are the conclusions made complete, justifiable and reliable? What, if any, additional water modelling work or evaluation could be done to improve conclusions?	The conclusion that the expansion of the WRSF will not result in a significant change in environmental impacts is reasonable (noting that remedial measures are already in progress to address recent concerns and will presumably be effective). The conclusion that the use of the open pit for tailings disposal will not result in a significant impact may be reasonable, but supporting document is insufficient to evaluate this conclusion independently. The proponent should provide additional documentation to support the use of assumptions and in particular to clearly identify sources of information and their relevance.	Surface water-related conclusions have been drawn using long hydrometric data, locally measured streamflow data, and changes in watershed areas in view of the proposed modifications to facilities/operation. Net-change due to such modifications have been justified minimum. However, potential adverse effects are assured to be less following regulatory compliance, adhering to existing management plans, implementation of best management practices and implementation of site-specific design features.	The appendices D.2 WASTE ROCK STORAGE AREA GROUNDWATER MODELLING UPDATE, TOUQUOY GOLD MINE, D.3 WATER QUALITY PREDICTIONS FOR SCRAGGY LAKE AND WATERCOURSE NO.4, TOUQUOY GOLD MINE, D.5 TOUQUOY GOLD PROJECT, ASSIMILATIVE CAPACITY STUDY OF MOOSE RIVER – TOUQUOY PIT DISCHARGE as well as the SD 19 2020 Annual Report were reviewed to determine the summary and conclusions. • With respect to the annual report, it is noted that source predictions for the sulfate anomaly are not supported by the geochemical data as WC 4 sulfate concentrations are about 80% of ditch concentrations. MW15, WRSP1 chemistry and SW23 and SW19 flow data could help resolve the issue. • With respect to appendix D.2 it is noted that the increased seepage from WRSA into WC4 from the extended footprint shown by the particle track model and corresponding mitigation measures are not discussed. • With respect to appendix D.3 it is noted that model results for SW3/WC4 could aid in addressing the sulfate anomaly and would also ease the evaluation as well as usefulness of the model for the impact of the mine activity on the local environment. • The sulfate anomaly impacts the local environment, but the effect of the WRSF expansion are limited and require similar mitigation measures.
Is the availability of field data adequate for determining model predictions in risk areas (Moose River, surface water discharge points, off site groundwater flows). If not, what additional data should be obtained?	Very little field data from borehole logs and elevation surveys is provided to assess the adequacy of characterization work to support the modelling.	The conclusions made are complete and justifiable. No additional modeling is required for the surface water component.	• With respect to the sulfate anomaly MW15, WRSP1, and WRSA saturated zone chemistry and SW23 and SW19 flow data could help resolve the source term and increase the accuracy of the water quality model (Appendix D.3).
How well does MODFLOW-NWT flow modelling describe current conditions and predict potential future flow and quality conditions for the major risk areas of the site (Moose River leakage/discharge, other groundwater- surface water discharges, groundwater flows from the TMF, Open Pit dewatering/ filling conditions). What are the uncertainties relevant to these predictions?	See a. For the pit lake seepage scenario, there is insufficient information to understand whether groundwater will flow from the pit lake to the Moose River through a rapid overburden pathway. Characterization of the bedrock and overburden in this area appears to be lacking, and sensitivity analysis of different bedrock overburden contact elevations is recommended to understand if additional field work is required or if the pit lake should be maintained at a different level.	Not applicable.	• To determine mitigation measures needed to reduce impact on WC4 the source of sulfate to WC4 needs to be determined. • 2016 surface and groundwater model is not representative of existing in situ conditions and only limited results are presented from new models for surface water and none for ground water. Evaluation and interpretation are thus difficult

NSECC – Scope of Work	Groundwater Review Comments	Surface Water Review Component	Geochemistry Review Component
How do the groundwater water quality modelling results (MT3D-USGS and particle tracking from FLOWPATH) and surface water quality modelling results (GOLDSIM and any others) compare with each other and are there areas (such as areas of groundwater discharge to surface water) where the model results intersect?	See comments in Attachment 3.	Not applicable.	The MT3D groundwater model (appendix D.1, D.5) shows only little seepage of chloride into the Moose River. The presented influx has only little impact on the Moose River water quality. Only minor concerns could be found: • Chloride gradient from the pit lake to the subsurface seems to be steep to not change between 5 and 500 years after filling up the pit. The reduction in concentration from 1 to approximately 10-5 mg/L also seems to be unrealistic within a 5-year time frame given the potential passage of groundwater through permeable overburden. • Groundwater flow information in graphs would help evaluate the concentration predictions. • Scaling for other species, microbial and chemical reactions, difference in diffusion coefficients not discussed. Concentrations leaking into Moose River based on source term concentrations and mass loading **(Appendix D5)**. • Scaling due to adsorption, and differences in diffusion coefficient do not seem to be considered for seepage into Moose River, nor are interactions between species and particle surfaces resulting in a "chromatographic" influence on diffusion rate.
How are the water models being used to determine and design the potential for site mitigation measures?	The groundwater models lack sufficient detail to model mitigation measures such as seepage collection ditches around the WRSF in detail, however, this may not be relevant to the evaluation of the proposed expansion of this facility which is a small expansion. Mitigation of open pit lake water quality is treatment, which is not part of groundwater modelling. It is recommended that a mitigation scenario where the pit lake is lowered to prevent groundwater migration from the pit lake to the Moose River is prepared as well as trigger thresholds for water treatment.	No comment	• Mitigation measures to reduce the leakage are not discussed.

Attachment 3

Attachment 3a
Review Comments on Appendix D.1 and D.2 of the Touquoy Gold Project Modifications – EARD Final

Attachment 3b
Table 1
Detailed Comments on Appendix D.1 and D.2

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Memorandum

To	**Bruce Fraser**	File no	**TE211058**
From	**Simon Gautrey** **Brad Markham**	cc	
Date	**7 January 2022**		

Subject: Peer Review of Appendix D.1 and D2. of the Touquoy Gold Project Site Modifications – Environmental Assessment Registration Document

1.0 Introduction

Wood Environmental & Infrastructure Solutions, a Division of Wood Canada Limited (Wood) is pleased to provide St Barbara Limited (the Client) with a 3rd Party peer review of the groundwater modelling presented and referenced in the Touquoy Gold Project Site Modifications Environmental Assessment Registration documents.

As Wood understands, the purpose of the Touquoy Gold Project Site Modifications – Environmental Assessment Registration Document is to support modifications to the existing project to allow for: 1) disposal of tailings into the open pit, and 2) allow for a slight expansion of the Waste Rock Storage Facility (WRSF). To this end, the following Appendices of the *Touquoy Gold Project Site Modifications – Environmental Assessment Registration Document* have been reviewed:

- Appendix D.1 Groundwater Flow and Solute Transport Modelling to Evaluate Disposal of Tailings in Touquoy Open Pit, and;
- Appendix D.2 Waste Rock Storage Area Groundwater Modelling Update, Touquoy Gold Mine.

The peer review has been made in the context above using what are considered by the reviewers to be standard industry technical practices for groundwater modelling studies of this type. This peer review largely follows the British Columbia Ministry Of Environment (BCMOE) Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities recommendations for conducting peer reviews.

This peer review includes the applicability of the groundwater flow model and evaluates the appropriate technical model methodologies, assumptions, design, and verification of for all significant water models employed at the site for supporting the EA submission.

The comments below are to be read in conjunction with the detailed comments that are presented in Table 1 at the end of this memo.

2.0 Peer Review Comments

The subsections below generally follow the recommended format of the peer review checklist outlined in Table D3 of Appendix D – Modelling & Model Review Checklists.

2.1 Conceptual Model

Description of conceptual model is limited and does not permit a full assessment of the suitability of the modelling approach to achieving the stated objectives as reported. As an example, there are no figures, data or discussion related to the following:

- groundwater occurrence, movement and potential interaction within the major hydrostratigraphic units at site;
- areas of potential groundwater recharge and discharge;
- estimates of potential groundwater recharge based on available stream flow data;
- thickness of overburden units at site;
- available borehole and test pit logs;
- distribution of hydraulic conductivity test locations and inferred values; and
- inferred groundwater flow directions for the pre-mining or current site conditions are not provided.

While references from previous studies which may contain much of the information noted above are provided, there are no summary figures or tabulated data provided in the reviewed modelling report.

2.2 Model Design

The groundwater modeling has been undertaken using USGS MODFLOW-NWT (groundwater flow) and MT3D-USGS (mass transport) codes. The pre- and post-processor used to assemble the MODFLOW/MT3D input files and process the simulation results is Groundwater Vistas (v7). The MODFLOW/MT3D family of numerical codes are widely accepted by regulators for use in simulating groundwater flow and transport at mine sites, while Groundwater Vistas is an accepted off-the-shelf GUI.

Both the horizontal and vertical spatial extents of the modelling domain are deemed appropriate for the stated purposes of the model with horizontal model boundaries extending out to the logical watershed boundaries and are not artificially close to site features. Horizontal model grid refinement in the areas of interest (5x5m cells) is considered appropriate for flow and transport considering the scale of the model. Vertical grid discretization is considered appropriate (model layers corresponding to overburden, weathered bedrock and then coincident with open pit bench elevations). Groundwater flow simulations are conducted in steady-state which is considered acceptable given the anticipated low storage properties of the bedrock units which make up the bulk of the model domain.

Model boundaries coincide with the major surface water features within the model domain (rivers/lakes) although it is not possible to comment on the appropriateness of the values of the boundary conductance terms, which control the exchange of water between the aquifer and boundary, as they are not provided in the model report. Implementation of the open pit within the numerical model was accomplished by assigning modflow drain cells to the potential pit seepage faces which is a standard and accepted methodology however it is not possible to comment on the appropriateness of the drain conductance terms that have been applied to the drain boundary as they are not provided in the model report.

It is not possible to comment on the accuracy of the numerical solution as model convergence criteria or overall mass balance/flow budgets were not disclosed in the report. It should be noted however, that exclusion of convergence criteria or other solver settings from modelling reports is not unusual although it is common practice to provide commentary on the model mass balance (which has not been done in the provided report).

With respect to the transport model set-up there is only a limited description provided regarding its implementation. Transport boundary conditions (source/sink terms) used to simulate release of solute (i.e., constant concentration cells) are not described and no figures are provided showing where transport boundaries have been placed within the model. Given this, it is not possible to comment on these aspects of the transport model.

2.3 Model Calibration

The groundwater flow model was calibrated to the current, as of 2019, site conditions, for two sets of observational data: groundwater levels and baseflow in the Moose River representing average annual condition and, groundwater levels and baseflow in the Moose River during summer (low flow) conditions and to observed pit inflows during 2019. PEST was used to aid in the model calibration process. The model calibration process was semi-automated and followed accepted methodology. Overall model calibration statistics appear reasonable and are within industry accepted ranges. Observational data from the TMA/WRSA, such as stream flow gauging in tributaries near these features or seepage collection volumes from perimeter ditches, was not used in model the calibration for the site-wide groundwater flow model. This is considered acceptable practice for the site wide model as at the scale of predicting the inflows/impacts from the dewatered open pit they are likely not important at that scale. This may not be the case, however, for the modified model described Appendix D.1 and AppednicD.2 which considers smaller scale flow processes (i.e., at the scale of the individual tributaries and collection ditches around the WRSA). This is discussed further in Section 2.7 below.

Initial model input hydraulic conductivities for each of the bedrock units and their selection rationale are not provided while final calibrated hydraulic conductivity and anisotropy values for bedrock units are quite variable between weathered and competent members of the same bedrock type (i.e., vary from 2x to more than 50x). While the selected hydraulic properties fall within realistic ranges, rationale for the differences in hydraulic properties between bedrock units is not provided in the report as reviewed and it is unclear whether they are supported by the available data or have been introduced solely to satisfy the model calibration. The modelling description would benefit with some discussion of the initial model input parameters.

Groundwater flow model sensitivity runs were conducted and show that the model is most sensitive to the overburden K and K of the weathered bedrock.

With respect to model calibration as it relates the modelling described in Appendix D.2, using a site-wide model that has been developed and calibrated at a site-wide scale can be problematic when it is used for more detailed analysis on individual site features such as the WRSA. This is because at the smaller scale, local features may play an important in controlling the hydraulic regime around these features. Appendix D.2 does not mention the potential limitations in adopting a 'site-wide' model for use at the scale of the WRSA.

The transport model was not calibrated to site specific data and used literature values representing a conservative solute for transport specific model inputs. Predictions of solute transport therefore carry a higher degree of uncertainty because site-specific transport parameters were not available and the transport model is not calibrated. The limitations in using this approach are not discussed in the modelling report and should be mentioned.

2.4 Model Verification

The groundwater flow and transport model was not verified against additional datasets after it was calibrated. The model was ran for the 'pre-development' site conditions (no open pit) but model results were not compared against the pre-development observed data. If sufficient pre-mining baseline data are available for comparison this could be used as a model verification dataset.

2.5 Model Predictions

After calibration, the model was used in predictive mode to simulate several different cases. The pre-mining conditions, fully developed mine case, operational mine case (as the mine is backfilled with tailings), and post closure case were simulated. All simulations were made in steady-state mode and transport simulations were undertaken with the post closure model.

Pre-mining model results, while plausible, have not been compared against the observed baseline data and model computed drawdown for the current conditions have not compared against the inferred drawdown data which would be beneficial. For the fully developed and operational mine cases model predictions have been made using the calibrated model input parameters only. Predictive uncertainty analysis has not been completed for the flow predictions for these model cases.

Application of the transport specific model boundaries is not well described and should be made clearer. Additional figures, including a model cross-section showing the model set-up and applied flow and transport boundaries would be beneficial. The report should point out that transport runs have been conducted using the properties of a conservative solute (i.e. chloride) which is being used as an analogue for each of the chemical species listed in Table 5.3 and that only advection and dispersion are being simulated. While this is an acceptable practice, the report should draw attention to the limitations of this approach. Uncertainty with respect to the role of bedrock faulting and porosity in solute transport has been addressed in the transport modelling.

2.6 Model Uncertainty

Model sensitivity with respect to input hydraulic conductivity values has been addressed during the calibration phase of model development. Model results were found to be most sensitive to the hydraulic conductivity values of stony till and the hydraulic conductivity of the weathered Tangier & Moose River Members fractured bedrock units. Tabulated hydraulic conductivity data for the stony till is not provided in the report but bedrock hydraulic conductivity data shown on Figure 3.1 indicate that the bulk of the hydraulic conductivity estimates for shallow bedrock are above the calibrated value of 2.4E-07 m/s.

Predictive simulations for all modeled flow and transport do not account for the uncertainty with respect to the input hydraulic conductivities of the above-mentioned units. Additionally, Appendix D.1 and D.2 do not contain sufficient detail to confirm key hydrostratigraphic contacts, i.e., whether or not the flooded open pit is entirely within bedrock at its flooded elevation of 108 m.

2.7 Additional Comments Related Specifically to Appendix D.2

The groundwater flow model on which the WRSA model update is based on was developed as a regional scale numerical model designed to predict the impacts to groundwater from the dewatering of the Touquoy open pit mine. The model was calibrated to water levels across the entire site, without particular attention to any one area, such as the WRSA. The level of detail used in the construction of these types of large scale (i.e., watershed based) models is often reflective of this and often ignores smaller scale features which may be of little importance with respect to the overall site-wide groundwater flow system.

While it is common practice to adapt these larger scale models for use in examining smaller scale site features, such as the WRSA. Where this is done more detailed discussion should be included to address any of the potential bias in model results that may arise because of this., Additional discussion should be included regarding the appropriateness of the model calibration when looking at the scale of the WRSA and if changes in the model set-up or inclusion of additional calibration (if available) is required to satisfy the required level of confidence in the results.

With respect to the boundary condition selected to represent seepage from the WRSA there is no justification provided for the initial input value for the recharge to the WRSA. As this value directly represents the amount of seepage discharging from the base of the WRSA, there should be discussion of the appropriateness of the input value and how it was derived.

For the modified model described in Appendix D.2, additional model layers have been added to accommodate the WRSA and drain boundaries added to simulate the seepage control ditches at the perimeter of the structure. The elevations of the drain boundaries have been set to 1m below the ground surface elevation rather than to the ditch invert of an engineered structure. While this is considered acceptable practice for 'high level' type estimates of the potential seepage collection of the ditch the potential limitations of this approach should be pointed out in the discussion. As model simulations show that the collection ditches intercept about half of the groundwater seepage from the WRSA this can be important consideration. The Tailings Management Facility (TMF) which is located directly south of the WRSA has not been included in the modified model. The TMF will likely influence the groundwater elevations and flow directions within the footprint of this structure. As particle tracking results show that there is the potential for WRSA seepage to travel beneath the TMF, the potential model error introduced

by omission of this feature should be included. Had the TMF been included in the model, some of the seepage from the WRSA that is presently modelled as being captured by the TMF seepage collection system may have been simulated as being deflected to a natural water feature instead.

Comments made above in Section 2.6 with respect to the treatment of uncertainty in input parameter values (i.e., hydraulic conductivity) in the model predictions are also applicable here. While the total amount of seepage from the WRSA will not be impacted, the apportionment of groundwater seepage to the various surface water features can be affected.

Changes to the groundwater flow system due to the presence of the TMF will likely alter the groundwater flow system within the footprint of the TMF. While this will not change the amount of seepage discharging from the TMA it does have the potential to alter the flow paths and therefore final discharge locations of particle tracks and thus change the proportion of discharge reaching surface water body receptors (i.e., the distribution of discharges shown in Table 1 and 2 will change, but not the overall totals). The TMF should be included in model simulations.

3.0 Conclusions

In general, Appendix D.1 and D.2 of the Touquoy Gold Project Site Modifications – Environmental Assessment Registration Document lack the required level of detail, in certain areas, to be able to provide comment on all of the recommended aspects of model development outlined above. While some of these may be considered of secondary importance, others such as discussion of the transport model set-up and implementation are of greater importance. Additional detail should be provided which would allow a more complete review.

Additionally, the treatment of uncertainty within model input parameters for both Appendix D.1 and D.2, was also not addressed during the predictive simulations and represents a deficiency which should also be addressed.

Should you have any questions, or concerns, please do not hesitate to contact the undersigned.

Respectfully submitted,

Wood Environment & Infrastructure Solutions,
a Division of Wood Canada Limited

Prepared by:	**Reviewed by:**
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Table 1 Detailed Review Comments and Recommendations Regarding Appendix D.1 and D.2

ID	Summary of Comments and Recommendations with Respect to the Groundwater Model
D1.app_gw_model_pit.pdf	
1	General Comments Sections 1 and 3: The sections describing the project site and conceptual hydrogeological model are described only in limited detail. For example, typically maps are provided showing inferred groundwater equipotential lines and flow directions based on baseline data, potential groundwater recharge and discharge locations, the distribution of data used in generating overburden thickness maps etc. There is also limited discussion of groundwater and surface water interactions.
2	Section 2.2, - Climate pg 2.3 (12): Table 2.1 – Lake Evaporation is presented as mm/day – should be mm/yr
3	Section 3.3.1, - Overburden Hydrostratigraphic Units pg 3.1 (19): Slug test values should be tabulated and provided.
4	Section 4.2, - Distribution of Hydrogeological Parameters pg 4.4 (25): There are no figures provided to show how the material properties (K, recharge, etc.) are distributed within the numerical model. Figures should be provided showing the distributions of hydraulic properties as they have been implemented within the numerical model.

ID	Summary of Comments and Recommendations with Respect to the Groundwater Model
5	Section 4.2, - Distribution of Hydrogeological Parameters pg 4.4 (25): It would be beneficial to include Figures showing the locations and inferred values from hydraulic testing. A histogram of hydraulic test results would also be useful in demonstrating that using the geometric mean value for input hydraulic conductivity is appropriate.
6	Section 4.3.1, - Model Boundary pg 4.4 (25): There should be figures included showing the distribution of data points used in making the bedrock surface. Additionally, contour maps of bedrock elevation and overburden thickness should be provided. These may be of particular importance when considering groundwater movement at the scale of the WRSA i.e., demonstrating confidence in the distribution of hydraulic properties of the shallow soils that underlay the WRSA.
7	Section 4.3.2, - Recharge and Evapotranspiration pg 4.4 (25): Was available surface flow gauging (i.e., estimated baseflow values) used to help in establishing recharge rates? The bulk of the model domain (Figure 2.3) indicates that bedrock is the predominant surficial material, would it be expected to have the same recharge and evapotranspiration rates as the till soils located in the southern portion of the model domain. No description is provided about how the initial transpiration parameters were selected or how these were adjusted during the model calibration process.

ID	Summary of Comments and Recommendations with Respect to the Groundwater Model
8	Section 4.3.3, - Lakes pg 4.4-4.5 (25-27): Individual lakes that had bathymetric data available should be listed. For other lakes assumptions used regarding lake depth should be stated. Since the conductance term is related to the conductivity/thickness of the lakebed sediments the final selected values should be discussed - are they plausible given what is known, or can be reasonably assumed, about the properties and thickness of the lakebed sediments. For the GHB cells used to represent lakes, was a single set of conductance terms used for both summer and average annual condition model calibrations?
9	Section 4.3.4, - Watercourses pg 4.6 (27): Similar comment as with the GHB's used to represent lakes, i.e., since the conductance term is related to the conductivity/thickness of the riverbed sediments the final values should be discussed - are they plausible given what is known, or can be reasonably assumed, about the properties of the riverbed sediments. For the river cells used to represent watercourses, was a single set of conductance terms used for both summer and average annual condition model calibrations?
10	Section 4.3.5, - Touquoy Open Pit pg 4.6 (27): As the final conductance term applied to the drain cells representing the potential seepage faces of the open pit are based on the thickness and hydraulic properties of the blast affected bedrock they should be discussed with respect to those terms. Initial input and final calibrated conductance terms should be provided. Was a single set of conductance terms used to estimate the pit inflow rates for both summer and average annual condition model calibrations?
11	Section 4.4.1, - Calibration Methodology pg 4.7 (28): Conductance of drain cells representing dewatered open pit faces were also varied as part of the model calibration, this should be included in the list of calibration parameters.

ID	Summary of Comments and Recommendations with Respect to the Groundwater Model
12	Section 4.4.2, - Calibration to Water Levels pg 4.7 (28): When assessing impacts to groundwater levels/flows resulting from mine operations groundwater flow models are often initially calibrated to the pre-mining conditions. Once calibrated the model can then be verified against the operational data. Is there a reason that was not done here?
13	Section 4.4.2, - Calibration to Water Levels pg 4.8 (29): Figure 4.5 – wells 6749 and 6719 are shown on figure but not included in the data tables, if they have not been used in model calibration they should be removed from the figure.
14	Section 4.4.2, - Calibration to Water Levels pg 4.14-4.15 (35-36): Although the overall model calibration statistics appear reasonable, a residual distribution map should be included to see, even if only qualitatively, if there are any areas where there could be bias in the model predictions. From Figure 4.6 it looks as if model calibration may not be as good in those areas with observed groundwater elevations above about 125m. From Figure 3.7-3.8 of Stantec (2021) it looks as if areas of >125m gw elevation are located around the WRSA and Plant site which are areas of primary importance in Appendix D2 – Waste Rock Storage Area Groundwater Modelling Update.
15	Section 4.4.3, - Calibration to Groundwater Flow Rates pg 4.15 (36): Determination of baseflow would benefit from more discussion of surface water flows in Section 2 and a plot of the regression fitting. Not enough information is presented to make a determination on the suitability of the baseflow estimation.
16	Section 4.4.3, - Calibration to Groundwater Flow Rates pg 4.15 (36): Have the pit inflow numbers been processed to account for process water pumped into the open pit for operational purposes? Has precipitation been removed from the pit inflow rates?

ID	Summary of Comments and Recommendations with Respect to the Groundwater Model
17	Section 4.4.4, - Calibrated Model Parameters pg 4.16 (37): Differences in hydraulic conductivities between weathered and competent members of the same bedrock type vary from 2x to more than 50x. Does the available data support this spatial variability? Section 3.3.2 states that there appears to be no significant differences in hydraulic properties between the greywacke and argillite bedrock types at the Touquoy site, however the weathered units of these rock types vary by almost 20x between the Tangier and Moose River greywacke and Moose River argilite. What is the rationale behind the difference? Also, the ratio between the weathered/competent bedrock hydraulic conductivity of these two units varies between 49x for the Tangier and Moose River greywacke vs 2x for the Moose River argilite. Is this supported by the available data or is it a result of the PEST calibration procedure? A similar comment can be made regarding the vertical anisotropy values for bedrock units presented in Table 4.6.
18	Section 4.4.4, - Calibration to Groundwater Flow Rates pg 4.16 (37): Since conductance terms representing streambed sediments, lakebed sediments and blast affected bedrock were used in model calibration the initial input and final calibrated values should be discussed here. Do the calibrated values represent realistic properties for these units?
19	Section 4.4.5, - Calibration Uncertainty pg 4.16 (37): The calibration measure to which the model is sensitive is not defined here. Is this related to the RMS error?, M.A.E?, Pit inflow estimate...etc?.
20	Section 4.4.6, - Sensitivity of Streambed and Pit Wall Conductance pg 4.18 (39): Since the conductance terms influence water level predictions as well as inflow predictions is there a reason they were not included in the PEST calibration routine?
21	Section 4.4.6, - Sensitivity of Streambed and Pit Wall Conductance pg 4.18 (39): Were the conductance terms of the GHB/river cells and pit seepage faces varied together? If so, what is the basis for varying these together as they are physically separate and unrelated.

ID	Summary of Comments and Recommendations with Respect to the Groundwater Model
22	Section 5.1.2, - Results pg 5.1 (41): Figure 5.1 should also show the inferred groundwater contours from the premine baseline data and comment on the model match. As it is, no comments can be made regarding the model match to the premining heads/hydraulic gradients. How do the simulated premining baseflows compare to the observed premine baseline baseflow data? Model computed drawdown for the current 2019 conditions should be compared to the actual drawdown that has been inferred from the baseline (premine) site data.
23	Section 5.2.1, - Model Setup pg 5.3 (43): A figure showing model cross section through the simulated pit illustrating the model changes would be useful here.
24	Section 5.2.2, - Results pg 5.3 (43): Table 5.1 should state that the presented groundwater flows are model simulation results.
25	Section 5.2.2, - Results pg 5.4 (44): Figure 5.2 - the 10m drawdown contour appears to fall within a portion of the dewatered pit that has been excavated deeper than 10m. The inferred drawdown from site monitoring data should be shown on this figure. It would also be beneficial to show a model cross section through the open pit illustrating the drawdown.

ID	Summary of Comments and Recommendations with Respect to the Groundwater Model
26	Section 5.3.1, - Model Setup pg 5.5 (45): The description of the modifications made to the model to simulate the partially flooded conditions is not clear, from the description is not clear if drain cells below the stage elevation, i.e., in the flooded portion of the pit, are removed. Have the drain cells in the flooded portions of the open pit where tailings have been placed been removed from the model for each of the stages? What type of boundary has been applied to the surface of the tailings placed in the open pit to simulate the pit lake?
27	Section 5.3.2, - Results pg 5.8 (48): Figure 5.5 - The footprint of the end pit lake should be shown on the figure.
28	Section 5.4, - Model Setup pg 5.9 (49): References should be provided for literature values used in model set up.
29	Section 5.4, - Model Setup pg 5.9 (49): A description of the transport model assumption and limitations should be included, i.e., pointing out that the transport model is not calibrated, only advection/dispersion (no sorption/reactions etc) is simulated.
30	Section 5.4, - Model Setup pg 5.9 (49): Transport specific model boundaries, i.e. constant concentration cells applied within tailings, recharge concentration applied to top of tailings, are not described. More description of the implementation of the transport model should be included here. Transport model time step-size should also be discussed.
31	Section 5.4.2, - Model Results pg 5.10 (50): Are relative concentration plots shown on Figures 5.6 to 5.8 shown as maximum concentration with depth?

ID	Summary of Comments and Recommendations with Respect to the Groundwater Model
32	Section 5.5, - Prediction Confidence pg 5.21 (61): Are relative concentration plots shown on Figures 5.6 to 5.8 shown as maximum concentration with depth?
D1.app_gw_model_wrsa.pdf	
1	Methodology pg 2 The model on which the WRSA model update is based on was developed as a regional scale numerical model designed to predict the impacts to groundwater from the dewatering of the Touquoy open pit mine. It was calibrated to water levels across the entire site, without particular attention to any one area, such as the WRSA. Some discussion of this should be made here along with discussion in potential bias in model results when looking at the scale of the WRSA and if changes in the model calibration for simulating seepage from the WRSA is warranted.
2	Methodology pg 2 As the stage of the drains is set at 1m below the local ground surface elevation rather than based on an actual engineered ditch invert elevation some mention of the potential errors and how they may affect the accuracy of the model predictions should be made as it illustrates the level of detail incorporated into the modelling and the level of confidence in the model results that can be expected.
3	Methodology pg 2 Estimated lake evaporation value of 515 mm/yr has been used in calculating the net precipitation on the WRSA. Given that the waste rock is coarse material and not vegetated it may be expected that evaporative loses will be lower than the 515 mm/yr. This would result in a higher recharge to the WRSA. Additionally, no justification is provided for the assumed runoff coefficient of 30%. As specified recharge input to the footprint of the WRSA represents the seepage from the WRSA there should be more description of the assumptions used in generating the recharge value.

ID	Summary of Comments and Recommendations with Respect to the Groundwater Model
4	Methodology pg 2 Should mention/reference what software code was used to calculate particle tracks.
5	Methodology pg 3 A plot of model computed and inferred hydraulic head values over the WRSA/TMF footprints and nearby surface water receptors should be included along discussion of the model match to the observed heads.
6	Results, pg 7 Changes to the groundwater flow system due to the presence of the TMF will likely alter the groundwater flow system within the footprint of the TMF. While this will not change the amount of seepage discharging from the TMA it does have the potential to alter the flow paths and therefore final discharge locations of particle tracks and thus change the proportion of discharge reaching surface water body receptors (i.e., the distribution of discharges shown in Table 1 and 2 will change, but not the overall totals). The TMF should be included in model simulations.
7	Results, pg 7 Sensitivity analysis was carried out on the recharge rates only.

APPENDIX C.2

Waste Rock Storage Area, West Ditch Reconstruction, Touquoy Gold Mine Industrial - Approval 2012-084244-11

Stantec

Memo

To:	Craig Hudson, AMNS	From:	Dan McQuinn
Cc:	Paul Cobham Barb Bryden Jeff Gilchrist Paul Deering		
File:	Stantec Project No. 121619250 AMNS PO 00024496	Date:	January 17, 2022
Doc No.	**MEM-211-900.6000-A-14JAN22**		

References: Waste Rock Storage Area, West Ditch Reconstruction, Touquoy Gold Mine Industrial Approval 2012-084244-11

At your request this letter and the attachments provide design drawings and the basis for the design of improvements to the existing west section of the Waste Rock Storage Area (WRSA) drainage ditch. The purpose of the project is to mitigate the risk of possible runoff and/or shallow groundwater seepage from the WRSA to Water Course No.4. in accordance with the following request by Nova Scotia Environment and Climate Change (NSECC):

> *By no later than January 17, 2022, the Approval Holder shall submit to the Department the results of an investigation of whether or not the seepage collection ditch for the Waste Rock Storage Area is capable of collecting all toe seepage and runoff from the WRSA as per Phase 1 design; and an engineering design and timeline for improvements to the current WRSA seepage and runoff collection system.*

Test pit investigations and survey data indicate that a portion of the west side of the existing WRSA drainage ditch was constructed above the original ground surface with a clay liner placed over a rockfill base. The ditch invert gradient is relatively flat and somewhat uneven resulting in areas of ponding which could result in possible leakage from the ditch. The water quality results downstream of the ditch indicate that this configuration may allow some of the runoff and shallow groundwater below the stockpile to flow under the ditch through the rockfill and into the receiving environment.

Updates to the ditch include:

- Increasing the minimum invert slope gradient to at least 0.6%.
- Replacing the existing rockfill below the ditch with clay till borrow to form a cutoff of westward subsurface flow, directing it into the ditch and ultimately to the WRSA West Pond.
- Replacing the existing rockfill berm with a clay till borrow berm protected by rockfill.

Based on our observations and discussions with AMNS staff, the Phase I design is functioning adequately as it relates to conveying collected water flows through the ditch with no evidence of overtopping. The design flow calculations presented in the Phase 1 Design Basis Memo have been reviewed and we confirm that the ditch is capable of conveying surface runoff and shallow seepage from the WRSA for a design event of the 1 in 25 year, 24-hour return period storm. Therefore, the same general design criteria, concepts and methodology used for the Phase I design have been used or made more stringent for the west ditch updated design. The Phase I Design Basis memo (MEM059-900-.400-B-23Mar18) can be referenced for additional details related to the design of the Phase I.

References: Waste Rock Storage Area, West Ditch Reconstruction, Touquoy Gold Mine Industrial Approval 2012-084244-11

The attached IFC drawings illustrate the design concept. It is intended that the existing fill material will be replaced with clay till borrow down to bedrock or at least 0.3 metres below the original glacial till surface in the configuration shown on the profile and sections. The finished ditch invert subgrade (clay surface) will be constructed at a gradient of 0.6%.

We trust that this information is adequate for your present purposes. If you have any questions, please do not hesitate to contact us at your convenience.

Stantec Consulting Ltd.

Dan R. McQuinn, P.Eng.
Senior Principal, Geotechnical Engineering

Attachment: SK 114 WASTE ROCK STORAGE AREA WEST DITCH RECONSTRUCTION

NOTE:
DITCH RECONSTRUCTION BASELINE STATIONING BASED ON AS-BUILT SURVEY DATA PROVIDED BY ATLANTIC MINING NS INC.

MATERIALS

1. TYPE 1 CLAY TILL BORROW
   A. THE SPECIFIED CLAY TILL BORROW SHALL BE SOURCED FROM THE DRUMLINS LOCATED AT APPROVED LOCATIONS WITHIN THE SITE BOUNDARIES, OR AN APPROVED OFFSITE BORROW PIT. CLAY TILL BORROW SHALL CONTAIN A MINIMUM OF 45% PERCENT BY WEIGHT OF SILT AND CLAY SIZE PARTICLES (THE MATERIALS PASSING THE 0.075 mm SIEVE SIZE). THE MAXIMUM PARTICLE SIZE SHALL BE 100 mm, AND SUCH PARTICLES SHALL NOT CONSTITUTE MORE THAN 20 PERCENT OF THE MATERIAL USED. OVERSIZE PARTICLES SHALL BE REMOVED IN THE BORROW AREA. THE CLAY TILL BORROW SHALL HAVE A PLASTICITY INDEX GREATER THAN 4, AND A PLACED PERMEABILITY AS PER THE DETAILS PROVIDED BELOW.

2. TYPE 10 ROCKFILL
   A. SHALL CONSIST OF COARSE, NON-MINERALIZED, NON-ACID GENERATING, NON-METAL LEACHING WASTE ROCK FROM THE OPEN PIT MINE AND DELIVERED TO THE HAUL ROAD VIA MINE FLEET.
   B. ROCKFILL SHOULD BE PRODUCED FROM A HARD DURABLE ROCK SOURCE, SUCH AS THE GREYWACKE AND/OR THE DURABLE ARGILLITE AND BE FREE OF DELETERIOUS MATERIALS SUCH AS ORGANIC MATTER, AND WEAK ROCK.
   C. GRADATION LIMITS FOR THE TYPE 10 ROCKFILL ARE SHOWN IN TABLE 1 BELOW.

TABLE 1: TYPE 10 ROCKFILL GRADATION LIMITS

PARTICLE SIZE (mm)	PERCENT PASSING BY WEIGHT
300 mm	100*
150 mm	45 - 100
60 mm	10 - 45
19 mm	0 - 30
1.18 mm	0 - 15
0.075 mm	0 - 5

* MAXIMUM 5 % OVERSIZE UP TO 450 mm MAXIMUM DIMENSION.

EXECUTION

1. BEFORE CONSTRUCTION BEGINS INSTALL EROSION AND SEDIMENTATION CONTROL MEASURES AROUND THE SITE AS FOLLOWS:
   A. SILT FENCING TO BE PLACED ALONG THE BASE OF THE EXISTING ROCKFILL SLOPE TO PROTECT WOODED NATURAL AREAS AS SHOWN ON DRAWING. THE SILT FENCE SKIRT IS TO BE BURIED BELOW THE ROOTMAT WITH MINIMAL DISTURBANCE TO THE VEGITATION TO ACHIEVE NECESSARY PROTECTION.
   B. DO NOT ALLOW STORM WATER TO ESCAPE THE CONSTRUCTION AREA EXCEPT THROUGH THE EXISTING DOWNSTREAM DITCH OUTLET.
   C. PLACE SUMP PITS AND OR DAMS STRATEGICALLY NEAR THE WORK SITE TO COLLECT STORM AND EXCESS SURFACE WATER. PUMP OR DRAIN BY GRAVITY ALL COLLECTED WATER TO THE DOWNSTREAM DITCH OUTLET. MODIFY THE PITS/DAMS AS THE WORK PROCEEDS TO SUIT DEWATERING AND WATER CONTROL REQUIREMENTS.
2. BEFORE CONSTRUCTION BEGINS LOCATE ALL BURIED AND ABOVE GROUND SERVICES AND ENSURE THAT NO SERVICES (WATERLINES, CULVERTS, TAILINGS LINES, FORCE MAINS, ELECTRICAL INFRASTRUCTURE OR MONITORING WELLS) ARE IN CONFLICT WITH THE PROPOSED WORK. INFORM THE ENGINEER OF ANY SUCH CONFLICTS.
3. NOTIFY MINE OPERATIONS WHEN PERFORMING WORK WITHIN 20 METRES OF THE MONITORING WELLS. THE OWNER WILL PROVIDE ANY SPECIAL PROTOCOLS IN THIS REGARD.
4. REPAIR ANY DAMAGED INFRASTRUCTURE AT NO COST TO THE OWNER.
5. EXCAVATE THE EXISTING DITCH TO THE LINES AND GRADES SHOWN ON THE DRAWING IN SECTIONS. THE SECTIONS MUST BE LIMITED IN LENGTH TO A SIZE THAT CAN BE EXCAVATED AND FULLY REPLACED WITH CLAY AND TYPE 10 ROCKFILL TO THE REQUIRED GRADES DURING DRY WEATHER.

EXECUTION CONTINUED

6. MONITOR THE WEATHER FORECASTS AND ENSURE THAT NO EXCAVATED AREAS ARE EXPOSED TO RUNOFF AND THAT SEDIMENT LADEN WATER DOES NOT ESCAPE THE SITE EITHER OVERLAND OR THROUGH THE ROCKFILL SUBGRADE.
7. PLACE TYPE 1 CLAY MATERIAL IN HORIZONTAL LAYERS WITH A MAXIMUM LOOSE LIFT THICKNESS OF 300 mm AND COMPACT EACH TO THE SPECIFIED DENSITY USING A MINIMUM 10 TONNE SHEEP'S FOOT ROLLER.
   A. TYPE 1 MATERIALS SHALL NOT BE PLACED UNDER WATER, NOR SHALL ANY MATERIALS BE PLACED UNTIL THE SUBGRADE IS APPROVED BY THE ENGINEER.
   B. THE GRADATION AND DISTRIBUTION OF THE MATERIALS SHALL BE SUCH THAT THE FILL DOES NOT CONTAIN LENSES, POCKETS, STREAKS, AND LAYERS OF MATERIALS DIFFERING SUBSTANTIALLY IN TEXTURE OR GRADATION FROM THE SURROUNDING MATERIAL.
   C. IF, AS DETERMINED BY THE ENGINEER OR HIS REPRESENTATIVE, SEGREGATION HAS OCCURRED, THE SEGREGATED MATERIAL SHALL BE REMOVED AND REPLACED WITH SUITABLE MATERIAL BY AND AT THE EXPENSE OF THE CONTRACTOR.
   D. UNLESS APPROVED BY THE ENGINEER, PLACEMENT OF TYPE 1 CLAY BORROW SHALL BE SUSPENDED WHEN SNOW IS FALLING OR WHEN THE AMBIENT TEMPERATURE IS CAUSING FILL TO FREEZE BEFORE IT IS COMPACTED.
   E. THE FILL SURFACE SHALL BE SLOPED OR CROWNED AT ALL TIMES DURING CONSTRUCTION SO THAT WATER WILL READILY DRAIN OFF. UNLESS OTHERWISE SHOWN OR APPROVED, THE FILL SHALL BE PLACED WITH EQUIPMENT TRAVELLING PARALLEL TO THE CENTERLINE OF THE DITCH.
   F. REMOVE ANY SOFT AND/OR YIELDING SPOTS IDENTIFIED DURING THE COMPACTION PROCESS AND REPLACE WITH APPROVED TYPE 1 CLAY BORROW.
   G. THE MOISTURE CONTENT SHALL BE UNIFORM AS PRACTICABLE THROUGHOUT ANY ONE LAYER OF MATERIAL AND SHALL BE AT OR NOT MORE THAN TWO PERCENT ABOVE OR BELOW THE OPTIMUM MOISTURE CONTENT FOR THE TYPE 1 CLAY BORROW MATERIAL DETERMINED BY THE ENGINEER OR HIS REPRESENTATIVE.
   H. COMPACT TYPE 1 CLAY BORROW TO AT LEAST 98 PERCENT OF THE STANDARD PROCTOR MAXIMUM DRY DENSITY AS DETERMINED IN ACCORDANCE WITH ASTM D698. COMPACT IN A SYSTEMATIC FASHION TO ENSURE THAT A CONSISTENT NUMBER OF PASSES ARE MADE COMPLETELY OVER EACH LIFT.
   I. THE TYPE 1 MATERIAL SHALL ACHIEVE A PERMEABILITY OF 1×10^{-8} m/s OR LOWER TO BE VERIFIED DURING CONSTRUCTION BY THE ENGINEER OR HIS REPRESENTATIVE.
   J. PROOF ROLL THE TOP OF THE CLAY CORE USING A SHEEP'S FOOT ROLLER AND REMOVE ANY SOFT AND/OR YIELDING SPOTS AND REPLACED WITH APPROVED TYPE 1 CLAY BORROW MATERIAL.
8. PLACE AND COMPACT TYPE 10 ROCKFILL TO THE LINES AND GRADES SHOWN ON THE DRAWING. TYPE 10 MATERIAL SHALL BE SPREAD IN HORIZONTAL LAYERS WITH A MAXIMUM LOOSE LIFT THICKNESS OF 500 mm.
9. REMOVE BEDROCK WHERE REQUIRED TO THE LINES AND GRADES SHOWN ON THE DRAWING BY MECHANICAL MEANS (i.e. EXCAVATOR OR ROCK BREAKER).
10. REMOVE SILT BARRIERS AND DISPOSE OFFSITE. REPAIR ANY DISTURBED SURFACE LAYERS TO ORIGINAL CONDITION.

WINTER CONSTRUCTION

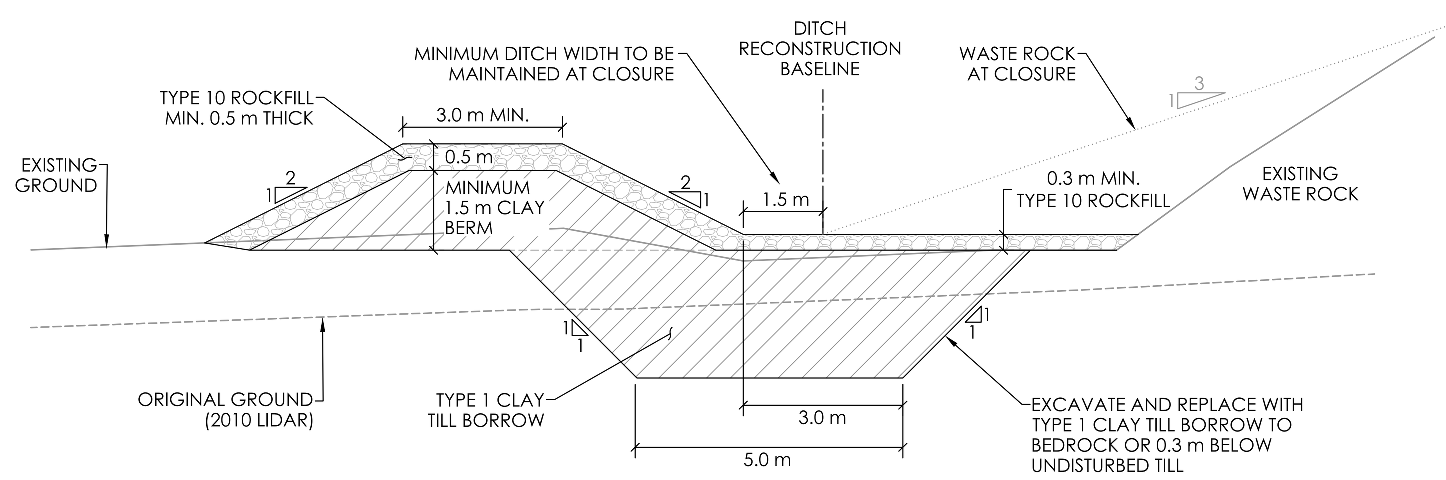
1. THE PLACEMENT OF ENGINEERED FILL DURING COLD WEATHER CONDITIONS REQUIRES ADDITIONAL CARE AND EFFORT. SPECIAL PROCEDURES AND PRECAUTIONS MUST BE EXERCISED TO MINIMIZE THE RISK OF FUTURE PROBLEMS.
2. A SITE MEETING SHALL BE HELD AT PROJECT START-UP TO DISCUSS THE SCHEDULE OF FILL PLACEMENT FOR THE DITCH CONSTRUCTION AND TO DETERMINE IF FILL PLACEMENT WILL OCCUR DURING THE WINTER MONTHS.

WINTER CONSTRUCTION CONTINUED

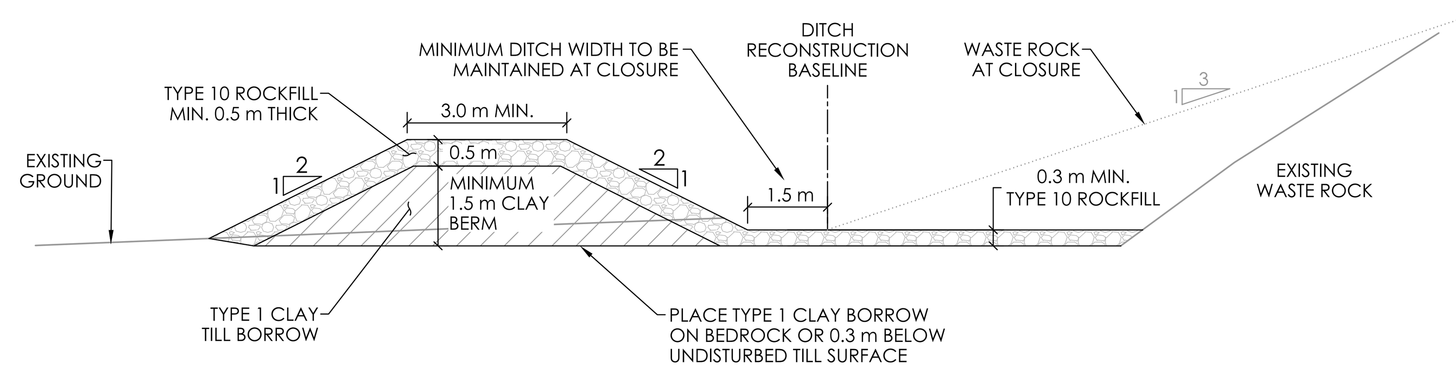
3. FILL PLACEMENT DURING THE WINTER MONTHS SHALL ADHERE TO THE FOLLOWING RECOMMENDATIONS:
   A. THE ROOTMAT/TOPSOIL LAYER AND ANY OVERLYING SNOW WILL REDUCE THE FROST PENETRATION. CONDUCT ONLY THE EXCAVATION WORK REQUIRED FOR EACH DAY OF WORK TO MINIMIZE FREEZING OF THE UNDERLYING SOIL. THIS APPLIES FOR FILL AREAS AND THE BORROW SOURCE.
   B. EXCAVATED MATERIAL TO BE USED AS FILL SHOULD NOT BE STOCKPILED, BUT SHOULD BE PLACED AND COMPACTED IMMEDIATELY AFTER EXCAVATION.
   C. PLACEMENT OF TYPE 1 CLAY BORROW SHALL NOT BE CARRIED OUT AT TEMPERATURES BELOW 0°C. DURING STRONG WIND CONDITIONS, THIS ALLOWABLE TEMPERATURE SHOULD BE INCREASED TO SUIT THE SITE-SPECIFIC CONDITIONS. PLACEMENT OF ROCKFILL MAY BE PLACED BELOW -5°C UNDER THE DIRECTION OF THE ENGINEER.
   D. FILL MATERIALS SHOULD BE COMPACTED TO THE SPECIFIED DRY DENSITY BEFORE THE TEMPERATURE OF THE FILL DROPS BELOW 2°C. TO MAINTAIN IMPORTED FILL ABOVE 2°C, IT MAY BE NECESSARY TO HAUL THE FILL IN DUMP TRUCKS HAVING HEATED BOXES WITH INSULATED TARPAULINS OVER THE BOX. REGULAR CHECKS OF THE SOIL TEMPERATURE SHOULD BE MADE AT THE PIT, IN THE TRUCKS AT THE SITE PRIOR TO DUMPING, AND FREQUENTLY DURING COMPACTION.
   E. FILL PLACEMENT SHALL BE CONDUCTED IN SMALL AREAS. THIS MAY ALLOW FOR CONTINUOUS PLACEMENT OF FILL LIFTS DURING THE WORKDAY WITHOUT THE REQUIREMENT FOR EXCAVATION/SCRAPING OF FROZEN MATERIAL PRIOR TO PLACEMENT OF THE NEXT LIFT.
   F. FOR INTERMEDIATE FILL LIFTS, FROST PROTECTION (E.G., STRAW, INSULATED TARP, ETC.) SHALL BE PROVIDED AT THE END OF THE WORKDAY OR FILL THAT FREEZES OVERNIGHT SHALL BE SCRAPED OFF AND DISPOSED OF PRIOR TO PLACING SUBSEQUENT LIFTS OF FILL IN THE MORNING. ANY SNOW OR ICE SHALL ALSO BE REMOVED. FILL SURFACES SHALL BE SLOPED TO PREVENT PONDING OF WATER DURING MILDER WEATHER.
   G. EDGES OF FILL LIFTS SHOULD BE TAPERED AND COMPACTED.
   H. FROZEN MATERIAL FROM THE BORROW PIT SHALL BE REMOVED FROM THE FACE OF THE EXCAVATED AREA AND DISPOSED OF AT AN APPROVED LOCATION.
   I. MATERIAL CONTAINING SNOW OR ICE SHALL NOT BE INCORPORATED IN THE WORK. DURING SNOW EVENTS, FILL PLACEMENT SHALL BE STOPPED. WHEN THE EARTHWORKS RESTART, ALL SNOW AND ICE SHALL BE REMOVED FROM THE FILL SURFACE PRIOR TO SUBSEQUENT FILL PLACEMENT. TO REMOVE ALL SNOW AND/OR ICE AFTER A SNOW EVENT, SOME OF THE UNDERLYING FILL MAY HAVE TO BE REMOVED AND WASTED.

NOTE

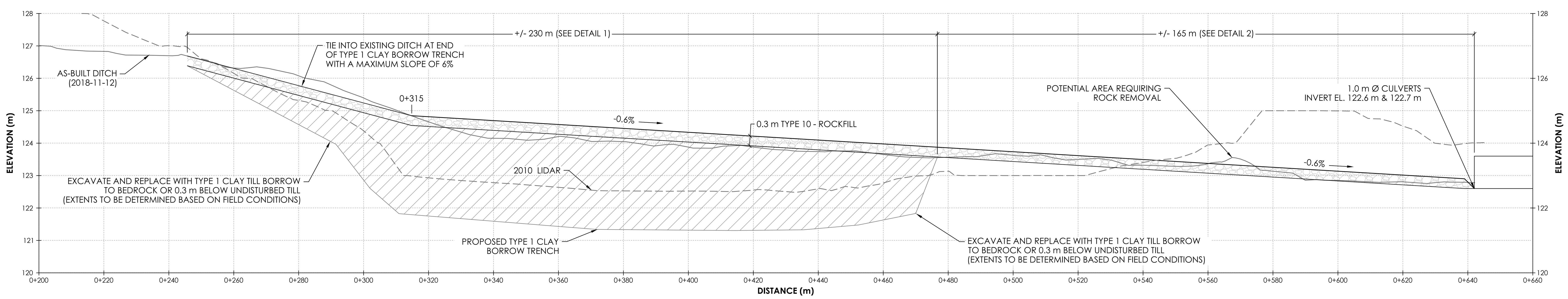
STOP WORK IMMEDIATELY FOLLOWING ANY OBSERVATIONS OF SEDIMENT IN WATERCOURSE 4 AND NOTIFY THE ENGINEER AND OWNER. DETERMINE IF WRSA WEST DITCH CONSTRUCTION ACTIVITIES ARE CONTRIBUTING TO THE SEDIMENT RELEASE. IF CONSTRUCTION IS A CONTRIBUTING FACTOR, TAKE ACTION TO REDUCE CONSTRUCTION IMPACTS ON WATER QUALITY IN WATERCOURSE 4 PRIOR TO RESUMING CONSTRUCTION. REFER TO EROSION AND SEDIMENT CONTROL PLAN FOR ADDITIONAL DETAILS ON EROSION AND SEDIMENT CONTROL.



TYPICAL WEST DITCH WITH BERM AND TRENCH 1 SK-114
SCALE 1 : 100



TYPICAL WEST DITCH WITH BERM 2 SK-114
SCALE 1 : 100



LONGITUDINAL PROFILE 3 SK-114
HORIZONTAL SCALE 1 : 750
VERTICAL SCALE 1 : 75

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Legend
- DITCH RECONSTRUCTION BASELINE / AS-BUILT CENTERLINE
- SEDIMENT FENCE
- EXISTING WRSA IA LIMITS
- TYPE 1 CLAY TILL BORROW TRENCH (PLAN VIEW)

Notes
1. DRONE IMAGES (2019/2020) AND WRSA DITCH AS-BUILT SURVEY DATA PROVIDED BY ATLANTIC MINING NS INC.
2. PLEASE REFER TO THE EROSION AND SEDIMENT CONTROL PLAN (STANTEC 2010) DEVELOPED FOR THE TOUQUOY SITE FOR BEST MANAGEMENT PRACTICES FOR CONSTRUCTION WORKS RELATED TO EROSION AND SEDIMENT CONTROL AT THE SITE. TO ALIGN WITH THE KEY PRINCIPLES OF THE PLAN THE CONSTRUCTION WORK SHALL MINIMIZE THE AMOUNT OF EXPOSED SOIL AS WELL AS THE TIME OF THE EXPOSURE TO MINIMIZE EROSION AND SEDIMENT TRANSPORT. IF REQUIRED, EXPOSED SOILS SHALL BE COVERED WITH NON-ERODIBLE MATERIALS, SEALED WITH A ROLLER OR TARPED BEFORE END OF DAY EACH CONSTRUCTION DAY.
3. ADDITIONAL BEST MANAGEMENT PRACTICES MAY NEED TO BE IMPLEMENTED TO MINIMIZE EROSION AND SEDIMENT TRANSPORT FROM THE SITE. THESE SHALL BE IMPLEMENTED AS REQUESTED BY ATLANTIC MINING NS INC. OR DESIGNATE DURING CONSTRUCTION.
4. ROUTINE CLEAN OUT OF DITCH MAY BE REQUIRED TO REMOVE SEDIMENT.
5. TEMPORARY STABILITY OF EXCAVATION IS THE RESPONSIBILITY OF THE CONTRACTOR.

ISSUED FOR CONSTRUCTION

STAMP — 2022-01-14

No.	DETAILS	BY	APPD.	DATE
-	-	-	-	-

REVISIONS

CLIENT: **ATLANTIC MINING NS INC.**

PROJECT: **TOUQUOY GOLD PROJECT**

PROJECT LOCATION: **HALIFAX COUNTY, NOVA SCOTIA**

JOB No.:	SCALE:	DATE:
121619250	AS SHOWN	2022-01-14

DRAWN BY:	DESIGNED BY:	APPROVED BY:
JL	DM	JG

DRAWING TITLE: **WASTE ROCK STORAGE AREA WEST DITCH RECONSTRUCTION**

DRAWING No.: **SK-114** REVISION No.: **0**

APPENDIX C.3

Waste Rock Storage Area, West Ditch Reconstruction – Construction Schedule - Touquoy Gold Project, Halifax County, NS

Memo

To:	Paul Cobham, AMNS	From:	Dan McQuinn, P.Eng. Stantec Consulting Ltd.
cc	Craig Hudson Barb Brydon Andrew Taylor Paul Deering Jeff Gilchrist		
File:	121619250	Date:	February 2, 2022
Doc No.	**MEM-212-900.4500-A-02FEB22**		

Reference: **Waste Rock Storage Area, West Ditch Reconstruction – Construction Schedule Touquoy Gold Project, Halifax County, NS**

In preparation for reconstruction of the Waste Rock Storage Area west ditch an initial site meeting was held on January 24 with the contractor, Alva Construction Ltd. (Alva), and Stantec Consulting Ltd. (Stantec), to discuss environmental controls and site conditions. Several concerns were raised during the meeting that were primarily related to weather conditions and consequences of proceeding with the project during the winter season. Items noted are as follows:

1. A series of test pits were attempted with a Komatsu PC490 excavator to assess frost conditions in the proposed excavation areas. Although an area where water was flowing showed limited frost penetration the large majority encountered hard frost (frozen materials i.e. soil, rockfill etc.) not practical for excavation by mechanical means to meet the project requirements.

The shallow excavation shown in this photograph was a result of several minutes of effort with a large excavator without penetrating the frozen ground.

Reference: Waste Rock Storage Area, West Ditch Reconstruction – Construction Schedule Touquoy Gold Project, Halifax County, NS

An important requirement for this project is to be able to excavate and restore discrete sections of the ditch with backfill each day to ensure that ditch water cannot escape over night with a risk of sediment release. This requirement cannot be ensured considering the very slow rate of excavation that would be caused by the hard frost.

2. A further concern is clay till borrow compaction. It will be necessary to place and adequately compact the clay till borrow for the ditch liner in a non-frozen state to ensure a sufficiently low permeability. By necessity, the clay must be hauled from a remote source approximately 4 km from the construction site. The time to transport the clay in the predicted cold weather allows it to cool; this circumstance along with delays anticipated with frost excavation increase the likelihood that the clay will freeze before it can be compacted and covered.

3. Installation of sediment control measures are not as effective during frozen conditions and will be difficult to install, seal and maintain. Installation of silt fences along the perimeter of the project between the work site and Water Course 4 are an important line of defense. It is necessary to partially bury the fences for a proper seal. However, it is difficult to discretely excavate in the rough vegetated terrain when the ground is frozen without causing significant disturbance and not creating an effective water seal.

4. Although usually manageable with some difficulty there are several other impediments associated with winter earthwork construction such as ice and snow contamination, freezing pumps, and short daylight hours that combined with items 1, 2 and 3 could jeopardize the quality of the work and possibly risk a sediment release in flash thaw and/or heavy rain conditions.

Considering the conditions outlined above it is our opinion that the risk of a sediment release and/or poor-quality clay construction associated with winter conditions favors commencing the project when the ground is sufficiently thawed and weather conditions are more beneficial. It would be helpful to monitor conditions and when appropriate, notify NSECC of upcoming work, thus reducing the risk of sediment releases.

Regards

STANTEC CONSULTING LTD.

Dan McQuinn P.Eng.
Geotechnical Engineer

APPENDIX D

Touquoy Gold Project Assimilative Capacity Study of Moose River Touquoy Pit Discharge (Updated)

Touquoy Gold Project Assimilative Capacity Study of Moose River – Touquoy Pit Discharge (Updated)

FINAL REPORT

March 11, 2022

Prepared for:

Atlantic Mining NS Inc.
409 Billybell Way, Mooseland
Middle Musquodoboit, NB B0X 1N0

Prepared by:

Stantec Consulting Ltd.
300W-675 Cochrane Drive
Markham, ON L3R 0B8

Project Number: 121619250

Revision: 1

Limitations and Sign-off

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1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by Atlantic Mining NS Inc. (AMNS) to conduct an assimilative capacity study of Moose River for effluent discharge and seepage from the in-pit disposal of tailings as part of the Touquoy Gold Project. The Touquoy Gold Mine is located in Halifax County, Nova Scotia, approximately 60 kilometres northeast of Halifax. The study is focused on the water surplus in the exhausted Touquoy pit (Open Pit) during reclamation/closure phase discharged via a proposed spillway to Moose River at the final discharge point.

The objective of the assimilative capacity study is to define parameters of potential concern for the effluent, characterize the mixing zone for the Touquoy pit effluent and propose the maximum effluent limits for the parameters of potential concern.

This report is an update of the Stantec 2019 Assimilative Capacity Report and addresses NSE comments and third party review comments as well as further field groundwater investigations and modelling.

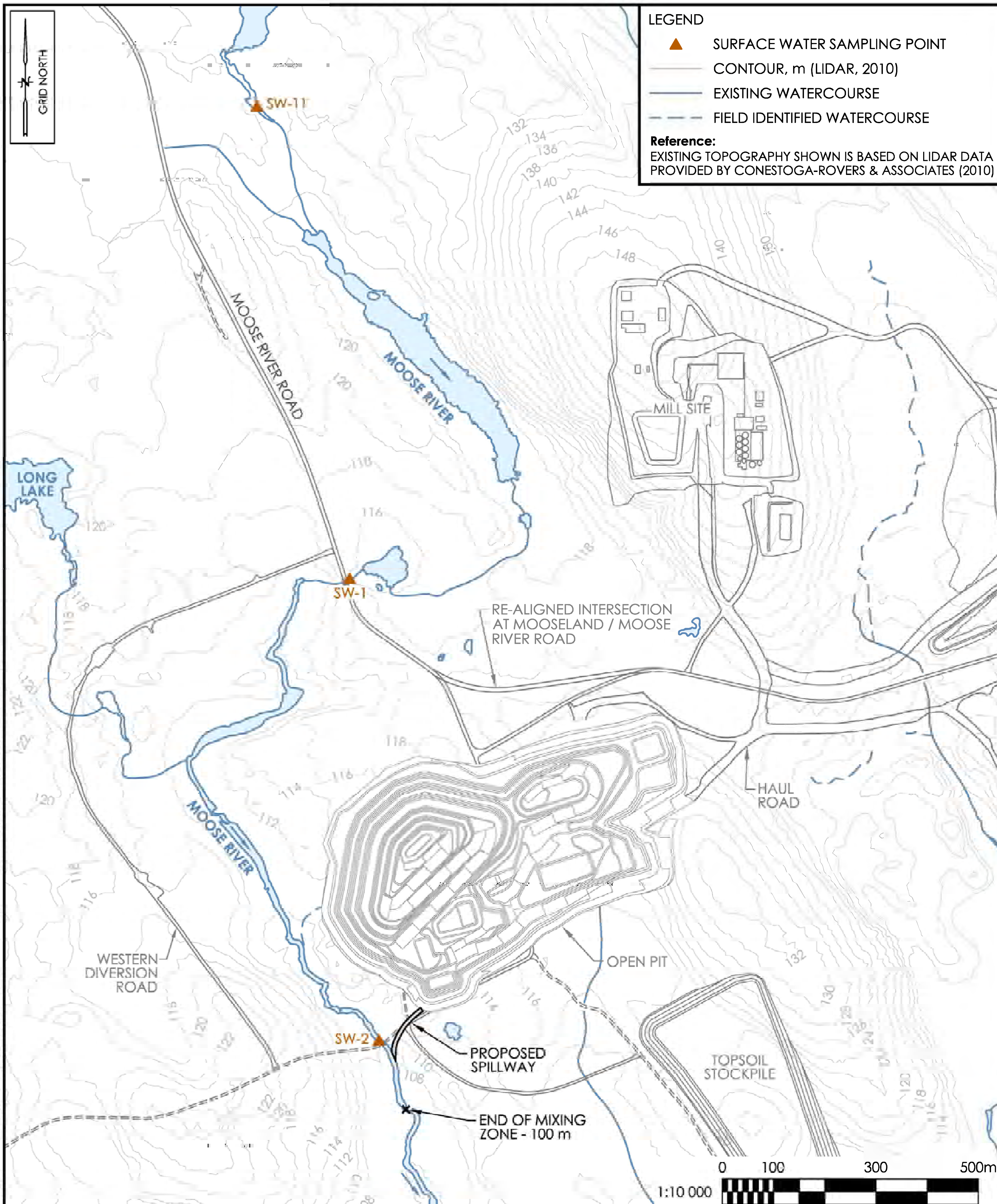
2.0 BACKGROUND

The Touquoy Mine Site in Halifax County, Nova Scotia comprises an area approximately 271 hectares (ha). Site areas associated with major project components include the Mill Facility, Open Pit, Tailings Management Facility (TMF), Waste Rock Storage Area (WRSA), Clay Borrow Area, and ancillary facilities. The Open Pit is located between Moose River on the west and Watercourse # 4 on the east that each flow north to south adjacent to the limits of the Open Pit.

The existing Open Pit is actively dewatered and pumped to the TMF. Water in the TMF is decanted to the effluent treatment plant for treatment.

Over several years, the Open Pit will be allowed to fill through natural runoff, direct precipitation, and groundwater inflow, as well as flows from the deposition of the tailings slurry from the mill, supplemental flows from the WRSA ponds, and periodic flows from the polishing pond downstream of the existing TMF. This will result in a water cover over the tailings surface. Once water quality in the pit lake meets the MDMER discharge criteria, water surplus from natural processing (e.g., snowmelt or rainfall events) will be released to Moose River via an engineered spillway.

Figure 1 presents the study area including the Open Pit, surface water monitoring station SW-2 and proposed spillway to convey overflow from the pit to Moose River. The engineered spillway is 110 m long with an invert elevation of 108.0 metres (m) at the Open Pit and elevation of 107.5 m at the outlet to Moose River at the bank. The channel will have an approximate slope of 0.45% (Figure 2).



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SITE MAP TOUQUOY GOLD PROJECT NOVA SCOTIA	Job No.:	121619250	Fig. No.: 1
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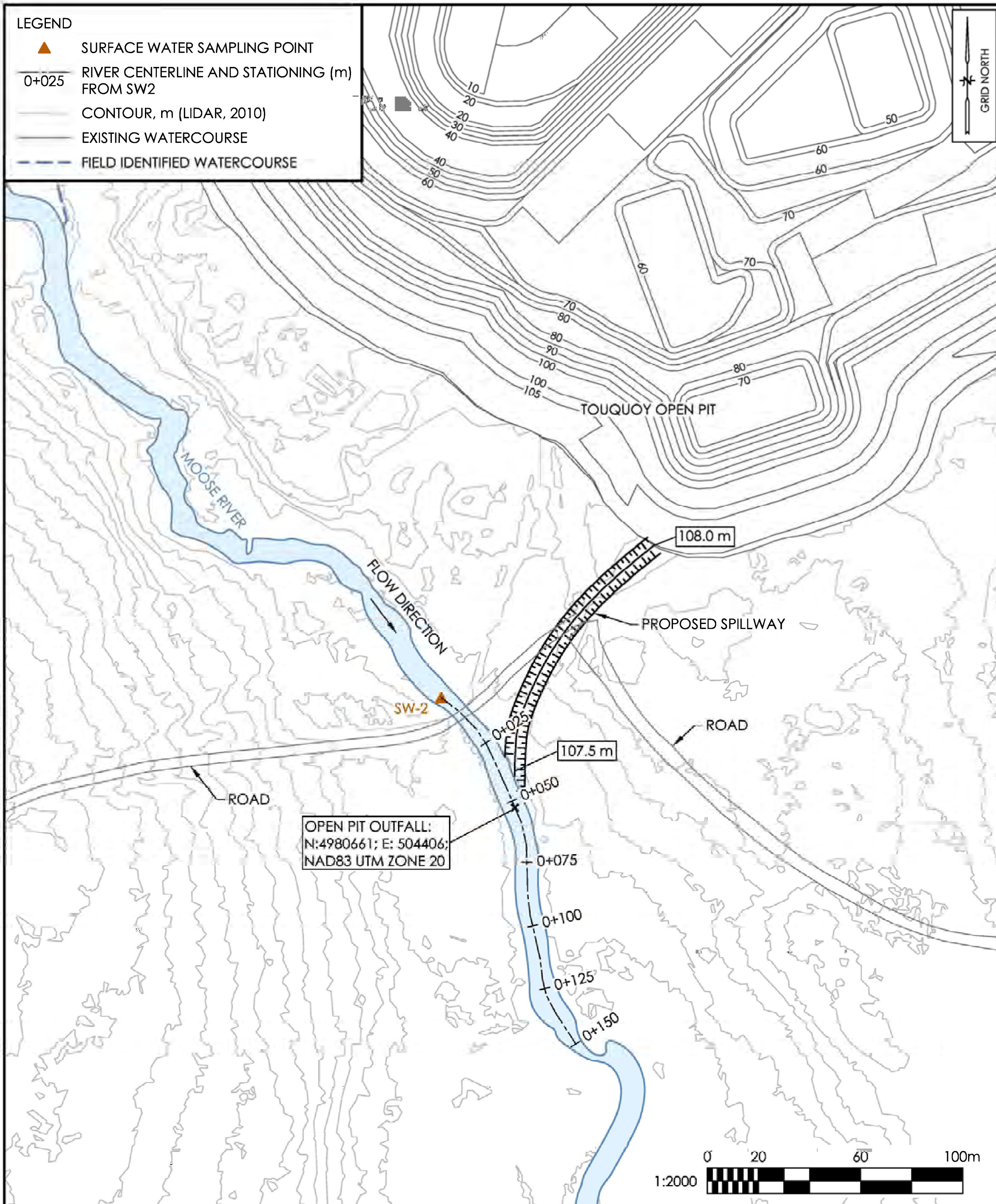

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LOCATION OF OPEN PIT OUTFALL

TOUQUOY GOLD PROJECT
NOVA SCOTIA

Client: ATLANTIC MINING NS INC

Job No.:	121619250
Scale:	1 : 2000
Date:	11-JUN-2021
Dwn. By:	JL
App'd By:	RJ

Fig. No.: 2

Stantec

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3.0 REGULATORY FRAMEWORK

Effluent discharge from the Open Pit is regulated by the *Metal and Diamond Mining Effluent Regulation* (MDMER). The maximum authorized monthly mean concentrations for effluent water quality for existing mines effective June 1, 2021 are presented in Table 3.1, and are based on those presented in Schedule 4 - Table 2 of the MDMER regulation. Wastewater treatment will be required for parameters that are predicted to exceed the MDMER limits in the effluent.

Table 3.1 MDMER Limits for Mine Effluent after June 1, 2021

Parameter	MDMER, Table 2, Schedule 4
Arsenic	0.3 mg/L
Copper	0.3 mg/L
Cyanide	0.5 mg/L
Lead	0.1 mg/L
Nickel	0.5 mg/L
Zinc	0.5 mg/L
Suspended Solids	15.00 mg/L
Radium 226	0.37 Bq/L
Un-ionized ammonia (as N)	0.5 mg/L

Note: The concentrations for metals and cyanide are total values.

The Canadian Council Ministers of the Environment (CCME) framework for assessing assimilative capacity of the receiver (CCME 2003) was used in this study. The key steps outlined in the CCME guidance are as follows:

1. Identifying physical/chemical and/or biological parameters of potential concern (PoPC) for the proposed discharge. Parameters of potential concern are defined as those which exceed the applicable regulatory limits in the Open Pit overflow effluent.
2. Establishing appropriate (i.e., freshwater) ambient Water Quality Objectives (WQOs) for receiving waters. The WQOs for this study were based on the Nova Scotia Environment and Climate Change (NSECC) criteria provided in Table 6 of Appendix K of the Industrial Approval for the site (Approval 2012-084244-08), which are largely derived from the Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (CCME 2021).
3. If the background concentration of a POPC in the receiving environment is higher than the WQO on which the discharge limit is established, the discharge limit should not be more stringent than the natural background concentration.
4. Determining the areal extent of the initial mixing zone (IMZ) in the area of the outfall in the receiving water. CCME (2003) defines the mixing zone as, “an area contiguous with a point source (effluent) where the effluent mixes with ambient water and where concentrations of some substances may not comply with water quality guidelines or objectives”.

5. Developing use-protection-based effluent discharge limits at the end-of-pipe which will meet ambient WQOs at the edge of the mixing zone (through modelling and other methods).

As per Chapter 6 of CCME (2003) the conditions within a mixing zone should not result in the bioaccumulation of chemicals (e.g., metals) to levels that are harmful or toxic.

4.0 RECEIVING WATER HYDROLOGY

The Open Pit effluent will reach Moose River in close proximity to SW-2. The upstream Moose River catchment area at SW-2 is 39.03 square kilometres (km^2). No long-term hydrometric stations exist on Moose River around the Touquoy Mine Site.

In the absence of long-term local hydrologic records, regional relationships were developed using selected Water Survey of Canada (WSC) stations to transpose flow data to the Touquoy Mine Site. The WSC stations were selected based on criteria including catchment area, station location, and period of record. Transpositional scaling is based on the assumption of homogeneity (due to their proximity and similar climate and land use conditions) between the selected regional WSC stations.

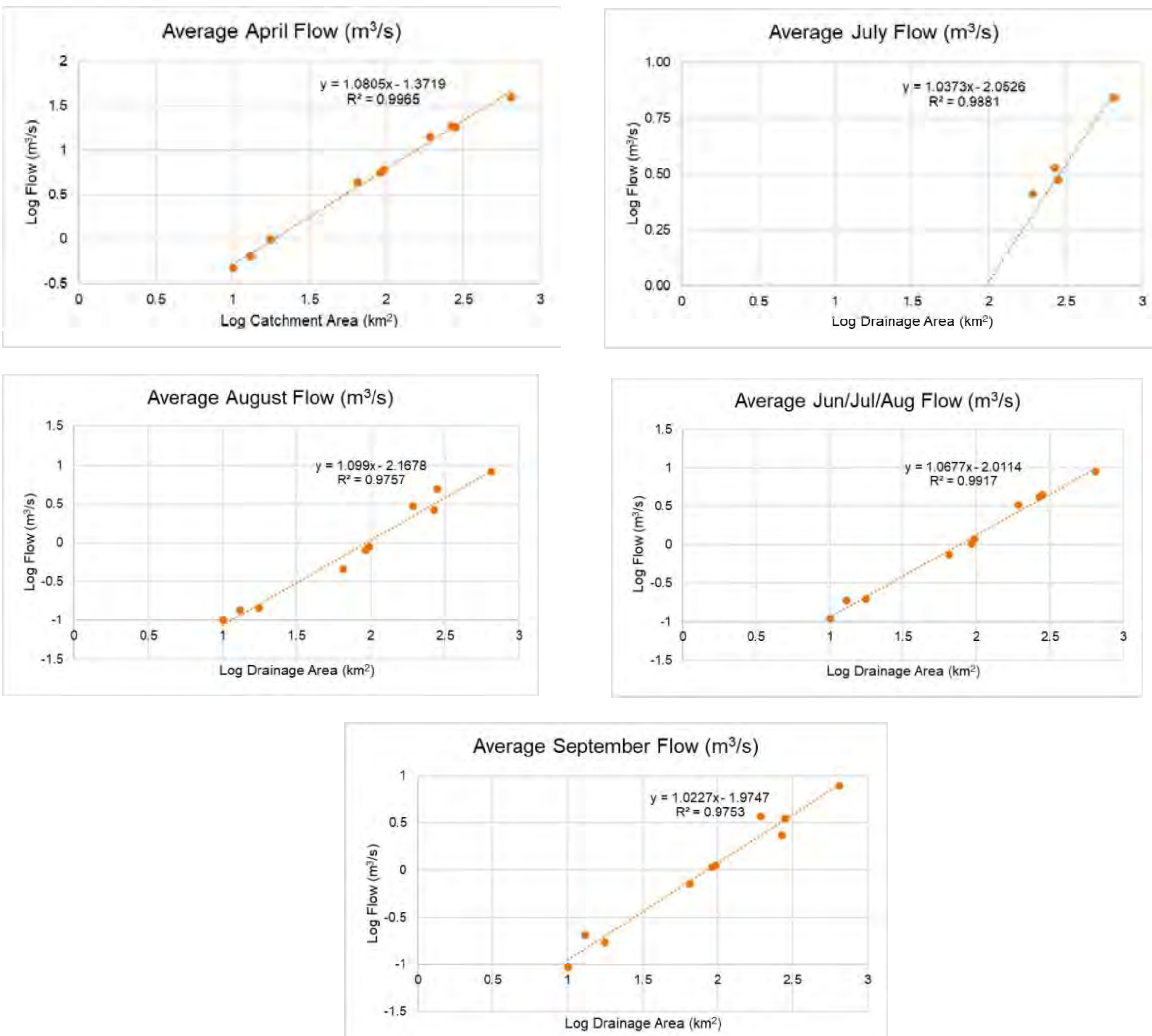
There are limited gauging station datasets available in Nova Scotia near the site that meet the primary selection criteria (e.g., catchment area, distance to Touquoy Mine Site). The WSC stations selected for the regional hydrology assessment are summarized in Table 4.1.

Table 4.1 WSC Regional Hydrology Stations

Station ID	Station Name	Drainage Area (km^2)	Years of Record	Record Period	Distance to Mine Site (km)
01DH003	Fraser Brook Near Archibald	10.1	26	1965-1990	45
01EJ004	Little Sackville River at Middle Sackville	13.1	39	1980-2018	65
01EE005	Moose Pit Brook at Tupper Lake	17.7	39	1981-2019	192
01EH006	Canaan River at Outlet of Connaught Lake	65.4	11	1986-1996	107
01DP004	Middle River of Pictou at Rocklin	92.2	54	1965-2018	58
01DG003	Beaverbank River Near Kinsac	96.9	98	1921-2018	60
01FA001	River Inhabitants at Glenora	193	55	1965-2019	150
01ED013	Shelburne River at Pollard's Falls Bridge	268	21	1999-2019	202
01EO003	East River St. Marys at Newtown	282	15	1965-1979	75
01EK001	Musquodoboit River at Crawford Falls	650	82	1915-1996	27

Average monthly flows for Moose River at SW-2 were derived using the regional relationships. Figure 3 presents the regression analysis completed to determine the relationship between catchment areas and average flow in April, August, September, and June-July-August for the selected WSC stations. April corresponds to the highest flows in the region and summer months typically correspond to the lowest flows.

Figure 3 Regional Regression Analysis



As presented on Figure 3, strong linear trends exist between the average monthly flow rates of the selected monitoring stations and drainage area for April, August, September and June to August with correlation coefficients (R^2) of 0.997, 0.976, 0.975 and 0.972, respectively. From these regional relationships, the average April and August flows for SW-2 in Moose River are estimated to be 2.23 cubic metres per second (m^3/s) and 0.38 m^3/s, respectively. Results of the statistical analysis on the regional flow records indicated that generally the peak and low flow events occur in April and August, respectively.

5.0 RECEIVING WATER QUALITY

The effluent will be discharged to Moose River via an engineered spillway as presented on Figure 2. A monitoring program has been ongoing since 2016 to monitor background water quality in Moose River at three monitoring stations SW-1, SW-2, and SW-11. Table 5.1 summarizes the location of each monitoring station.

Table 5.1 Water Quality Monitoring Stations on Moose River

Site	Location	Rationale	Location Description
SW-1	504325E, 4981604N	Background	Moose River – adjacent to site and upstream of Moose River road culvert and Open Pit
SW-2	504378E, 4980703N	Downstream – Near-field	Moose River – downstream of Facility and upstream of Bridge, just below the Open Pit
SW-11	504140E, 4982529N	Background	Moose River – upstream of the Site to represent relatively un-impacted conditions upstream of the facility

Surface water monitoring station SW-2 is located immediately upstream of the proposed effluent location (Figure 1) and therefore was used to characterize ambient water quality.

Table 5.2 summarizes the 2016 and 2017 water quality data at SW-2 for total metals, cyanides. The table also presents the Water Quality Objectives provided in Appendix K, Table 6 of the Industrial Approval (Approval 2012-084244-08). The background water quality for Moose River at SW-2 has four parameters which exceed the WQOs: aluminum, arsenic, cadmium and iron. Tables A-1 to A-3 in Appendix A present a complete list of monitored water quality parameters and statistics.

Table 5.2 Background Water Quality at SW-2

Water Quality Parameter	Average Concentration mg/L	75^{th} Percentile Concentration mg/L	Water Quality Objective mg/L
Aluminum	**0.169**	**0.187**	0.005 [1]
Arsenic	**0.012**	**0.018**	0.005
Calcium	1.2	1.3	-
Cadmium	**0.000014**	**0.000019**	0.00004 [1]
Cobalt	<0.0004	<0.0004	0.010
Chromium	<0.001	<0.001	-
Copper	<0.002	<0.002	0.002 [1]
Iron	**0.48**	**0.62**	0.3
Lead	<0.0005	<0.0005	0.001 [1]
Mercury	<0.000013	<0.000013	0.000026

Water Quality Parameter	Average Concentration mg/L	75th Percentile Concentration mg/L	Water Quality Objective mg/L
Magnesium	0.488	0.52	-
Manganese	0.06	0.07	0.82
Molybdenum	<0.002	<0.002	0.073
Nickel	<0.002	<0.002	0.025 [1]
Tin	<0.001	<0.001	-
Selenium	<0.001	<0.001	0.001
Silver	<0.0001	<0.0001	0.0001
Sulphate	<2	<2	-
Thallium	<0.0001	<0.0001	0.0008
Uranium	<0.0001	<0.0001	0.015
Zinc	<0.005	<0.005	$e^{\{0.947(\ln[hardness])-0.815(pH)+0.398(\ln[DOC]+1.625\}}$ (if Hardness is 23.4 to 399 mg/L, pH is 6.5 to 8.13, and DOC is 0.3 to 22.9 mg/L)[1]
WAD Cyanide	<0.003	<0.003	0.005[2]
Total Cyanide	<0.005	<0.005	-
Nitrate (as N)	<0.05	0.054	13
Nitrite (as N)	<0.01	<0.01	0.06
Ammonia (as N)	<0.05	0.062	-

Note: Bold values indicate exceedance of water quality objectives, empty field indicates no water quality value.

[1] pH< 6.5 and hardness < 17 mg/L, baseline water quality data at SW-2

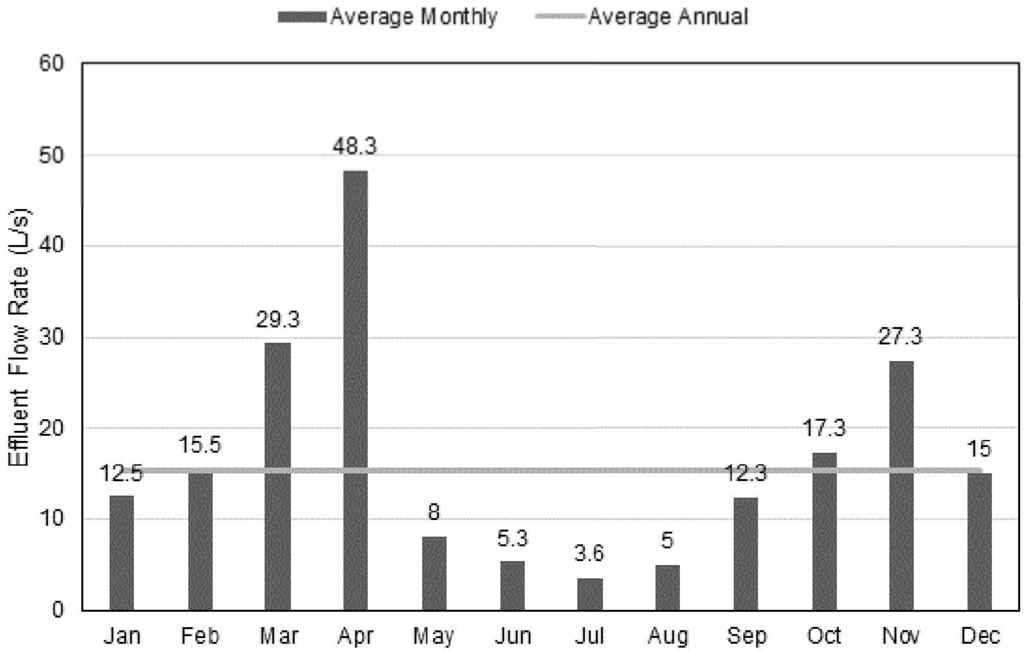
[2] Free form cyanide

6.0 EFFLUENT WATER QUANTITY AND QUALITY

An environmental water balance was used to predict the Open Pit effluent overflow to Moose River at mine closure (Stantec 2021b). Figure 4 shows the average predicted monthly Open Pit overflow under climate normal conditions. As shown in the figure, average monthly effluent flow will vary seasonally from 3.6 litres per second (L/s) in July to 48.3 L/s in April. The average monthly effluent flow rate to Moose River will be 16.9 L/s.

The Open Pit seepage rate to the river was simulated using a groundwater flow model (Stantec 2021a). Average daily seepage rate to Moose River was estimated at 258 cubic metres per day, or 3.0 L/s.

Figure 4 Monthly Effluent Flow Rates



Effluent water quality was predicted using the water quality and quantity model and groundwater flow model (Stantec 2021a and Stantec 2021b). Water quality modelling considered the pore water quality in the tailings and the groundwater inflow quality in the pit floor and walls, dilution from surface runoff, direct precipitation, and process water surplus, and the geochemistry of the individual water quality parameters. Table 6.1 presents a list of predictions of the average and maximum concentrations in the effluent for metal parameters and nitrogen species. Concentrations of aluminum, arsenic, cobalt, copper, WAD cyanide, and nitrite in the effluent water quality have exceedance of the WQOs. In addition, the effluent concentrations of arsenic and ammonia are predicted to slightly exceed the 2021 MDMER discharge limit, therefore, arsenic and ammonia treatment will be required prior to release of the effluent to environment.

Total cyanide and weak acid-dissociable (WAD) cyanide concentrations in the effluent are below the MDMER discharge limit for cyanide (i.e., 0.5 milligrams per litre (mg/L) for total cyanide). There are no WQOs guidelines for these forms of cyanide. Further discussion about cyanide is presented in Section 10.0.

Predicted maximum concentration of arsenic in the effluent is 0.616 mg/L. The MDMER limit is 0.3 mg/L, therefore, arsenic will require treatment prior to discharge. The regulatory effluent limit of 0.3 mg/L was assumed in modeling of the mixing zone.

Table 6.1 Predicted Effluent Water Quality Parameters and Limits

Water Quality Parameter	Average Monthly Concentration in Touquoy Pit Discharge mg/L	Maximum Concentration in Touquoy Pit Discharge mg/L	MDMER Maximum Monthly Discharge Limit mg/L	Water Quality Objective mg/L
Aluminum	**0.015**	**0.033**	**-**	0.005 [1]
Arsenic	**0.178**	**0.616**	**0.3**	0.005
Calcium	24.5	49.4	-	-
Cadmium	0.000005	0.000008	-	0.00004 [1]
Cobalt	0.009	**0.046**	**-**	0.01
Chromium	0.00015	0.00031	-	-
Copper	**0.005**	**0.026**	0.3	0.002 [1]
Iron	0.012	0.029	-	0.3
Lead	0.00008	0.00020	0.1	0.001 [1]
Mercury	0.000012	0.000016	-	0.000026
Magnesium	3.24	4.89	-	-
Manganese	0.062	0.102	-	0.82
Molybdenum	0.003	0.007	-	0.073
Nickel	0.006	0.013	0.5	0.025 [1]
Tin	0.001	0.003	-	-
Selenium	0.00020	0.00056	-	0.001
Silver	0.00001	0.00003	-	0.0001
Sulphate	69.0	166	-	-
Thallium	0.00001	0.00003	-	0.0008
Uranium	0.0028	0.0032	-	0.015
Zinc	0.0009	0.0019	0.5	$e^{\{0.947(\ln[hardness]) - 0.815(pH) + 0.398(\ln[DOC] + 1.625\}}$ (if Hardness is 23.4 to 399 mg/L, pH is 6.5 to 8.13, and DOC is 0.3 to 22.9 mg/L)
WAD Cyanide	**0.016**	**0.087**	-	0.005[2]
Total Cyanide	0.048	0.249	0.5	-
Nitrate (as N)	1.36	3.98	-	13
Nitrite (as N)	**0.144**	**0.693**	**-**	0.06
Ammonia (as N)	0.070	0.721	**-**	-
Unionized Ammonia (as N)	0.002	0.011	0.5	0.019[3]

Note: Bold values indicate exceedance of water quality objectives, empty field indicates no water quality value.
[1] pH< 6.5 and hardness < 17 mg/L, baseline water quality data at SW-2

[2] Free form of cyanide

[3] Unionized ammonia estimated using maximum summer temperature and pH observed at SW-2

7.0 GROUNDWATER SEEPAGE FROM TOUQUOY PIT TO MOOSE RIVER

Groundwater seepage from the Open Pit discharging directly to Moose River was predicted using a groundwater model (Stantec 2021a). The groundwater seepage from the Open Pit to Moose River is estimated to be 3.0 L/s, based on climate normal conditions. Particle tracking was done using the groundwater model, but no transport modeling was conducted. Adsorption and chemical reactions were not evaluated in the groundwater model, therefore the groundwater quality predictions are considered conservative. Table 7.1 presents a list of average water quality concentrations in the groundwater seepage based on the water quality source terms predicted for the tailings. As shown on Table 7.1, no parameters in the seepage are predicted to exceed the MDMER or WQOs.

Table 7.1 Predicted Water Quality of Seepage from Touquoy Pit

Water Quality Parameter	Average Concentration in Seepage mg/L
Aluminum	< DL
Arsenic	0.002
Calcium	0.06
Cadmium	< DL
Cobalt	< DL
Chromium	< DL
Copper	0.000007
Iron	< DL
Lead	< DL
Mercury	< DL
Magnesium	0.01
Manganese	0.0002
Molybdenum	< DL
Nickel	< DL
Tin	< DL
Selenium	< DL
Silver	< DL
Sulphate	0.62
Thallium	< DL
Uranium	< DL
Zinc	< DL
WAD Cyanide	< DL
Total Cyanide	< DL
Nitrate (as N)	< DL

Water Quality Parameter	Average Concentration in Seepage mg/L
Nitrite (as N)	< DL
Total Ammonia (as N)	0.023

* Free form of cyanide

8.0 ASSIMILATION RATIOS

Assimilation or dilution ratio analysis was conducted to find the worst-case month for dilution and mixing, i.e., the month with the lowest assimilative capacity. The Open Pit effluent post-mine closure will be driven by the same metrological factors (precipitation, evaporation, snowmelt) as the whole Moose River catchment. A very low flow in the river will correspond to a very low effluent flow from the Open Pit. The same relationship will exist with high flows.

Table 8.1 presents the dilution ratios of the effluent with the receiver water assuming full mixing. The dilution ratios were calculated as a ratio of flow in the receiver to the effluent flow for the same month. A ratio between the catchment area of Moose River at SW-2 (39.03 km^2) and catchment area of the Open Pit (0.41 km^2) is 95 to 1. The minimum dilution ratio of 36 is observed in September. Groundwater seepage was conservatively excluded from dilution calculations as its water quality is predicted to be similar to background concentrations in Moose River.

Table 8.1 Dilution Ratio in the Receiver at Full Mixing

Month	Receiver Flow (L/s)	Effluent Flow (L/s)	Seepage (L/s)	Dilution Ratio Of Effluent to Receiver Flow
June/July/August	487	4.6	3.0	106
July	396	3.6	3.0	110
August	381	5.0	3.0	76
April	2,226	48.3	3.0	46
September	450	12.3	3.0	36

9.0 MIXING ZONE STUDY

The approach to modelling the areal extent of the initial mixing zone involved the application of an effluent plume model. The Cornell Mixing Zone Expert System (CORMIX), version 12.0 (Doneker and Jirka 2017) was used in this study. CORMIX is a software system for the analysis, prediction, and design of aqueous toxic or conventional pollutant discharges into diverse water bodies. The major emphasis is on the geometry and dilution characteristics of the initial mixing zone, but the system also predicts the behaviour of the discharge plume at larger distances. The basic CORMIX methodology relies on the assumption of steady ambient conditions. Background information regarding the physical characteristics of the receiving waters was used as input to the model, which is provided below.

9.1 CORMIX MODEL INPUTS

The required model inputs for the ambient conditions include flows, water density, wind, and depth of water in Moose River. Ambient flow affects the near-field transport and shape of the resulting plume from the effluent. Boundary ambient conditions are defined by average river depth at the outfall and in the mixing zone. Model inputs are summarized below:

- The average flow in Moose River in September is 450 L/s and the climate normal effluent flow 12.3 L/s in September.
- The Moose River channel geometry at the outfall was estimated based on river bathymetry data measured at SW-2 as part of the on-going hydrometric monitoring program for Touquoy operation. Channel width with active flow at the discharge point is 8 m. The average water depth used in the model is 1.5 m for high water conditions.
- The horizontal angle (sigma) of spillway channel to the bank was assumed 45˚ based on proposed spillway design. The spillway was assumed to have a trapezoidal shape with a bottom width of 3 m and side slopes of 2:1. Longitudinal slope of the spillway is 0.45%.
- Both the effluent and receiver were assumed to have the same temperature of 10°C and same density of 1,000.5 kg/m^3.
- The Manning's roughness coefficient used in the model, which represents the roughness or friction applied to the flow by the channel and based on the bottom substrate, was assumed to be 0.035 for low flow conditions and 0.04 for high flow conditions.
- Winds in CORMIX can affect the circulation, mixing, and plume movement in the river channel. The mean wind speed of 4.2 m/s from at the Halifax Stanfield International Airport was used in the model.

9.2 ASSUMPTIONS

The following assumptions of the modelling investigation were made in the assimilative capacity study:

- Steady ambient and effluent conditions were assumed in CORMIX
- Outfall configuration (spillway size and slope) was based on available preliminary design
- CORMIX parameters were derived based on available field data and literature
- Bathymetry information in the mixing zone was based on cross-section information at SW-2
- Modelling was conservatively focused on dilution and mixing ratios and decay and bioaccumulation were not simulated.

10.0 RESULTS AND DILUTION RATIOS

The distance from the effluent discharge location to the boundary of the mixing zone applied in this study is limited to 100 m as per guidance from NSECC (Environment Canada 2006).

The CORMIX model showed that a full-mixing dilution ratio of 36 is achieved within 92 m from the outfall.

Concentrations of the parameters of potential concern at the end of the mixing zone were calculated conservatively. The maximum Open Pit concentrations were used to define the effluent and the 75th percentile was used to define the receiving water ambient water quality conditions. Treatment of arsenic to the regulatory limit of 0.3 mg/L will be required. The seepage load (concentration times seepage rate) is very low as groundwater is of similar or better quality than background water quality in Moose River (Table 7.1).

The focus of assessment was on six parameters of potential concern with concentrations in the effluent predicted to exceed the WQOs presented by NSECC: aluminum, arsenic, cobalt, copper, nitrite, and cyanide. At the end of the mixing zone four out of six parameters (cyanide, cobalt, copper, and nitrate) are below the WQO. Aluminum and arsenic are above the WQO at the end of the mixing zone due to the elevated natural background concentrations.

Concentrations of the parameters of potential concern at the end of the mixing zone are presented inTable 10.1.

Table 10.1 Water Quality Modelling Results, mg/L

WQ Parameter	Effluent Max, mg/L	Receiver, 75th Percentile	Water Quality Objectives	MDMER	Concentration at 92 m. Fully Mixed
Aluminum	0.033	0.187	0.005[1]	-	0.183
Arsenic	0.3	0.018	0.005	0.3	0.026
WAD Cyanide	0.087	<0.003	0.005[2]	-	0.004
Total Cyanide	0.249	<0.003	-	0.5	0.008
Cobalt	0.046	<0.0004	0.010	-	0.0015
Copper	0.026	<0.002	0.002[1]	0.3	0.0017
Nitrite (as N)	0.693	<0.01	0.06	-	0.024

[1] pH< 6.5 and hardness < 17 mg/L, baseline water quality data at SW-2

[2] Free form of cyanide

Aluminum is predicted to have lower concentration in the effluent in comparison with the ambient background. Therefore, the predicted aluminum concentration at the end of the mixing zone will be slightly lower than background, but still above the WQOs (when ambient pH above 6.5) , resulting in a slight improvement in ambient aluminum concentrations.

Predicted maximum concentration of arsenic in the effluent is 0.616 mg/L. The MDMER limit is 0.3 mg/L, therefore, arsenic will require treatment prior to discharge. After arsenic treatment to the MDMER limit of 0.3 mg/L, its concentration at the end of the mixing zone is predicted at 0.026 mg/L. High arsenic background concentration limits mixing potential of this parameter. The arsenic concentration at the 92 m mixing zone boundary is above the WQOs. A site-specific water quality objective of 0.03 mg/L was developed for the Touquoy Mine Site (Intrinsik 2019) based on the CCME guideline (2001). The predicted arsenic concentrations are below the reported lowest toxic levels for fish, algae and aquatic plants.

11.0 CONCLUSIONS

It was determined that a 100-m mixing zone would be appropriate for the Touquoy pit effluent on the basis of requirements of NSECC.

Ambient water quality was characterized using the 2016 and 2017 water quality data at SW-2. Background water quality in Moose River at SW-2 has four parameters which exceed the WQOs specified in the existing Industrial Approval: total aluminum, arsenic, cadmium and iron.

The concentrations of total aluminum, arsenic, cobalt, copper, and nitrite were identified to potentially exceed the WQOs in the Open Pit effluent. Arsenic concentrations in the effluent exceed the MDMER limits. Therefore, arsenic treatment will be required prior to release of the effluent to environment.

The CORMIX (version 12.0) three-dimensional model was used to derive the effluent criteria for the Touquoy pit effluent discharge to Moose River. The outfall configuration, bathymetry and flows were modeled conservatively based on available information. The extent of the downstream mixing zone is 92 m.

Concentrations of the parameters of potential concern at the end of the mixing zone are presented in Table 10.1. The predicted aluminum concentration at the end of the mixing zone will be slightly lower than background, but above the WQOs. The predicted arsenic concentration is above the WQOs but below the site specific water quality objective (Intrinsik 2019).

12.0 CLOSURE

This report has been prepared for the sole benefit of the Atlantic Mining NS Inc. (AMNS). This report may not be used by any other person or entity without the express written consent of Stantec Consulting Ltd. and AMNS.

Any use that a third party makes of this report, or any reliance on decisions made based on it, are the responsibility of such third parties. Stantec Consulting Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made, or actions taken, based on this report.

The information and conclusions contained in this report are based upon 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 and recommendations presented in this report should not be construed as legal advice.

The conclusions presented in this report represent the best technical judgment of Stantec Consulting Ltd. based on the data obtained from the work. If any conditions become apparent that differ from our understanding of conditions as presented in this report, we request that we be notified immediately to reassess the conclusions provided herein.

13.0 REFERENCES

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APPENDIX A
Water Quality Parameters and Statistics

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Table A.1 Surface Water Analytical Data - SW-2

Parameter	Units	2016-2017 Statistics						2016 Statistics			2017 Statistics			NSE Tier 1 EQS Freshwater
	Units	Minimum	Mean	Maximum	Median	75th	Count	Minimum	Mean	Maximum	Minimum	Mean	Maximum	
Anion Sum	me/L	0.10	0.14	0.21	0.14	0.165	22	0.12	0.149	0.21	0.1	0.14	0.17	-
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	-
Calculated TDS	mg/L	8.00	11.25	14.00	11.00	13	12	-	-	-	8	11.3	14	-
Carb. Alkalinity (calc. as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	-
Cation Sum	me/L	0.18	0.25	0.31	0.26	0.28	22	0.18	0.256	0.31	0.18	0.239	0.3	-
Colour	TCU	23.00	66.27	140.00	60.00	74	22	23	62.6	140	44	69.3	110	-
Conductivity	µS/cm	21.00	26.00	35.00	24.50	28	22	22	26.2	35	21	25.8	33	-
Dissolved Chloride (Cl)	mg/L	3.60	4.80	5.90	4.75	5.275	22	4.2	4.84	5.3	3.6	4.77	5.9	-
Dissolved Fluoride (F-)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
Dissolved Sulphate (SO4)	mg/L	<2.0	<2.0	2.6	<2.0	<2.0	22	<2	<2	2.6	<2	<2	2	-
Hardness (CaCO3)	mg/L	3.50	5.00	7.30	4.85	5.25	22	3.5	5.14	7.3	3.8	4.89	6.7	-
Ion Balance (% Difference)	%	10.50	26.35	40.90	27.55	30.15	22	14.3	26.4	40.9	10.5	26.3	40.5	-
Langelier Index (@ 20C)	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
Langelier Index (@ 4C)	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (N)	mg/L	<0.050	<0.050	0.18	<0.050	0.054	22	<0.05	0.0507	0.18	<0.05	<0.05	0.12	-
Nitrate + Nitrite (N)	mg/L	<0.050	<0.050	0.18	<0.050	0.054	22	<0.05	0.0507	0.18	<0.05	<0.05	0.12	-
Nitrite (N)	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	22	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-
Nitrogen (Ammonia Nitrogen)	mg/L	<0.050	<0.050	0.14	<0.050	0.062	21	<0.05	<0.05	0.095	<0.05	<0.05	0.14	-
Orthophosphate (P)	mg/L	<0.010	<0.010	0.011	<0.010	<0.010	22	<0.01	<0.01	0.011	<0.01	<0.01	0.011	-
pH	pH	4.90	6.05	6.89	6.05	6.2375	22	4.9	6.03	6.89	5.63	6.07	6.47	-
Reactive Silica (SiO2)	mg/L	<0.50	1.16	2.50	1.090	1.875	22	<0.5	1.02	2.5	<0.5	1.27	2.2	-
Saturation pH (@ 20C)	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
Saturation pH (@ 4C)	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Alkalinity (Total as CaCO3)	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	22	<5	<5	<5	<5	<5	<5	-
Total Chemical Oxygen Demand	mg/L	14.00	27.36	67.00	24.50	27.75	22	14	27.8	67	20	27	43	-
Total Mercury (Hg)	µg/L	<0.013	<0.013	0.02	<0.013	<0.013	22	<0.013	<0.013	<0.013	<0.013	<0.013	0.02	0.026
Total Organic Carbon (C)	mg/L	3.90	7.90	19.00	6.95	9.375	22	3.9	7.49	19	4.4	8.25	13	-
Total Suspended Solids	mg/L	<1.0	2.68	32	<1.0	1.2	22	<1	4.86	32	<1	<1	<2	-
Total Dissolved Solids	mg/L	9.00	11.90	15.00	11.00	13.5	10	9	11.9	15	-	-	-	-
Turbidity	NTU	0.43	1.17	3.30	1.10	1.375	22	0.58	1.34	3.3	0.43	1.02	1.8	-
Dissolved Aluminum (Al)	mg/L	70.00	176.00	270.00	170.00	220	5	-	-	-	70	176	270	10
Dissolved Antimony (Sb)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	5	-	-	-	<1	<1	<1	20
Dissolved Arsenic (As)	mg/L	5.10	8.64	13.00	6.90	13	5	-	-	-	5.1	8.64	13	5
Dissolved Barium (Ba)	mg/L	2.80	4.58	6.50	4.70	5.2	5	-	-	-	2.8	4.58	6.5	1000
Dissolved Beryllium (Be)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	5	-	-	-	<1	<1	<1	5.3
Dissolved Bismuth (Bi)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	-
Dissolved Boron (B)	mg/L	<50	<50	<50	<50	<50	5	-	-	-	<50	<50	<50	1200
Dissolved Cadmium (Cd)	mg/L	<0.010	0.014	0.027	0.017	0.018	5	-	-	-	<0.01	0.0144	0.027	0.01
Dissolved Calcium (Ca)	mg/L	1100.00	1340.00	1700.00	1300.00	1500	5	-	-	-	1100	1340	1700	-
Dissolved Chromium (Cr)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	5	-	-	-	<1	<1	<1	-
Dissolved Cobalt (Co)	mg/L	<0.40	<0.40	<0.40	<0.40	<0.40	5	-	-	-	<0.4	<0.4	<0.4	10
Dissolved Copper (Cu)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	2
Dissolved Iron (Fe)	mg/L	310.00	438.00	660.00	450.00	450	5	-	-	-	310	438	660	300
Dissolved Lead (Pb)	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	5	-	-	-	<0.5	<0.5	<0.5	1
Dissolved Magnesium (Mg)	mg/L	450.00	538.00	620.00	510.00	620	5	-	-	-	450	538	620	-
Dissolved Manganese (Mn)	mg/L	20.00	51.60	84.00	57.00	66	5	-	-	-	20	51.6	84	820
Dissolved Molybdenum (Mo)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	73
Dissolved Nickel (Ni)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	25
Dissolved Phosphorus (P)	mg/L	<100	<100	<100	<100	<100	5	-	-	-	<100	<100	<100	-

Parameter	Units	2016-2017 Statistics						2016 Baseline Statistics			2017 Statistics			NSE Tier 1 EQS Freshwater
	Units	Minimum	Mean	Maximum	Median	75th	Count	Minimum	Mean	Maximum	Minimum	Mean	Maximum	
Dissolved Potassium (K)	mg/L	180.00	220.00	320.00	210.00	210	5	-	-	-	180	220	320	-
Dissolved Selenium (Se)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	5	-	-	-	<1	<1	<1	1
Dissolved Silver (Ag)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	5	-	-	-	<0.1	<0.1	<0.1	0.1
Dissolved Sodium (Na)	mg/L	2600.00	2860.00	3100.00	3000.00	3000	5	-	-	-	2600	2860	3100	-
Dissolved Strontium (Sr)	mg/L	5.40	6.88	8.80	6.40	7.9	5	-	-	-	5.4	6.88	8.8	21000
Dissolved Thallium (Tl)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	5	-	-	-	<0.1	<0.1	<0.1	0.8
Dissolved Tin (Sn)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	-
Dissolved Titanium (Ti)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	-
Dissolved Uranium (U)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	5	-	-	-	<0.1	<0.1	<0.1	300
Dissolved Vanadium (V)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	6
Dissolved Zinc (Zn)	mg/L	<5.0	<5.0	5.60	<5.0	<5.0	5	-	-	-	<5	<5	5.6	30
Cyanate	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	22	<0.005	<0.005	<0.005	<0.05	<0.05	<0.05	-
Strong Acid Dissoc. Cyanide (CN)	mg/L	<0.0010	<0.0010	0.002	<0.0010	<0.0010	22	<0.001	<0.001	0.0012	<0.001	<0.001	0.0018	0.005
Thiocyanate	mg/L	<0.17	<0.17	<0.17	<0.17	<0.17	22	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	-
Weak Acid Dissociable Cyanide (CN-)	mg/L	<0.003	<0.003	0.004	<0.003	<0.003	22	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	-
Benzene	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	22	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0013	2100
Toluene	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	22	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0013	700
Ethylbenzene	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	22	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0013	320
Total Xylenes	mg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	22	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0026	330
>C10-C16 Hydrocarbons	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	22	<0.05	<0.05	<0.05	<0.01	<0.01	<0.013	-
C6 - C10 (less BTEX)	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	22	<0.01	<0.01	<0.01	<0.05	<0.05	<0.05	-
>C16-C21 Hydrocarbons	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	22	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-
>C21-<C32 Hydrocarbons	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
Modified TPH (Tier1)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.15
Hydrocarbon Resemblance	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Radium-226		<0.050	<0.050	<0.050	<0.050	<0.050	2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0
Total Aluminum (Al)	µg/L	73.00	169.23	350.00	165.00	187.5	22	73	171	350	100	168	260	10
Total Antimony (Sb)	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	20
Total Arsenic (As)	µg/L	4.00	12.25	30.00	7.85	17.75	22	4	14.7	30	4.6	10.2	19	5
Total Barium (Ba)	µg/L	2.50	4.11	8.60	3.80	4.375	22	2.5	4.3	8.6	3	3.96	5.8	1000
Total Beryllium (Be)	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	5.3
Total Bismuth (Bi)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	-
Total Boron (B)	µg/L	<50	<50	<50	<50	<50	22	<50	<50	<50	<50	<50	<50	1200
Total Cadmium (Cd)	µg/L	<0.010	0.014	0.04	0.014	0.019	22	<0.01	0.0162	0.04	0.01	0.0128	0.022	0.01
Total Calcium (Ca)	µg/L	840.00	1198.18	1700.00	1200.00	1300	22	840	1230	1700	920	1170	1600	-
Total Chromium (Cr)	µg/L	<1.0	<1.0	1.7	<1.0	<1.0	22	<1	<1	1.7	<1	<1	<1	-
Total Cobalt (Co)	µg/L	<0.40	<0.40	0.71	<0.40	<0.40	22	<0.4	<0.4	0.71	<0.4	<0.4	<0.4	10
Total Copper (Cu)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	2
Total Iron (Fe)	µg/L	190.00	483.18	850.00	485.00	617.5	22	190	481	810	200	485	850	300
Total Lead (Pb)	µg/L	<0.50	<0.50	0.86	<0.50	<0.50	22	<0.5	<0.5	0.86	<0.5	<0.5	<0.5	1
Total Magnesium (Mg)	µg/L	350.00	488.18	750.00	460.00	520	22	350	503	750	370	476	630	-
Total Manganese (Mn)	µg/L	29.00	60.00	180.00	54.00	68.5	22	35	70.1	180	29	51.6	88	820
Total Molybdenum (Mo)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	73
Total Nickel (Ni)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	25
Total Phosphorus (P)	µg/L	<100	<100	<100	<100	<100	22	<100	<100	<100	<100	<100	<100	-
Total Potassium (K)	µg/L	130.00	215.91	530.00	190.00	240	22	150	256	530	130	183	310	-
Total Selenium (Se)	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	1
Total Silver (Ag)	µg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total Sodium (Na)	µg/L	2100.00	2772.73	3500.00	2800.00	3000	22	2200	2850	3500	2100	2710	3400	-
Total Strontium (Sr)	µg/L	4.50	6.30	11.00	5.85	6.65	22	4.5	6.39	11	4.6	6.22	8.8	21000

Parameter	Units	2016-2017 Statistics						2016 Baseline Statistics			2017 Statistics			NSE Tier 1
	Units	Minimum	Mean	Maximum	Median	75th	Count	Minimum	Mean	Maximum	Minimum	Mean	Maximum	
Total Thallium (Tl)	µg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.8
Total Tin (Sn)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	-
Total Titanium (Ti)	µg/L	<2.0	<2.0	3.70	2.15	2.5	22	2	<2	3.5	<2	2.07	3.7	-
Total Uranium (U)	µg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	300
Total Vanadium (V)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	6
Total Zinc (Zn)	µg/L	<5.0	<5.0	6.1	<5.0	<5.0	22	<5	<5	6.1	<5	<5	6	30

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Table A.2 2016 Surface Water Monitoring - SW-2

Parameter	March	April	May	June	July	August	September	October	November	December
Anion Sum	0.15	0.12	0.14	0.14	0.13	0.15	0.21	0.13	0.19	0.13
Bicarb. Alkalinity (calc. as CaCO3)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Calculated TDS	-	-	-	-	-	-	-	-	-	-
Carb. Alkalinity (calc. as CaCO3)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cation Sum	0.21	0.18	0.26	0.25	0.28	0.28	0.28	0.31	0.28	0.23
Colour	49	57	52	68	53	33	23	140	74	77
Conductivity	22	22	23	23	24	28	31	35	27	27
Dissolved Chloride (Cl)	5.3	4.2	5	4.8	4.5	5.3	5.1	4.7	5	4.5
Dissolved Fluoride (F-)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Sulphate (SO4)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.6	<2.0	2.2	<2.0
Hardness (CaCO3)	4.4	3.5	4.6	5	5.5	5.1	4.9	7.3	6	5.1
Ion Balance (% Difference)	16.7	20	30	28.2	36.6	30.2	14.3	40.9	19.2	27.8
Langelier Index (@ 20C)	-	-	-	-	-	-	-	-	-	-
Langelier Index (@ 4C)	-	-	-	-	-	-	-	-	-	-
Nitrate (N)	<0.050	<0.050	<0.050	<0.050	0.055	0.052	0.18	<0.050	<0.050	0.07
Nitrate + Nitrite (N)	<0.050	<0.050	<0.050	<0.050	0.055	0.052	0.18	<0.050	<0.050	0.07
Nitrite (N)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Nitrogen (Ammonia Nitrogen)	<0.050	<0.050	0.062	<0.050	0.095	<0.050	0.062	<0.050	0.091	<0.050
Orthophosphate (P)	0.01	<0.010	<0.010	0.011	0.01	0.011	<0.010	<0.010	<0.010	0.011
pH	6.17	5.62	6.24	5.93	6.66	6.16	6.89	4.9	5.86	5.82
Reactive Silica (SiO2)	1.3	0.88	<0.50	<0.50	0.52	<0.50	<0.50	2.5	1.8	2.2
Saturation pH (@ 20C)	-	-	-	-	-	-	-	-	-	-
Saturation pH (@ 4C)	-	-	-	-	-	-	-	-	-	-
Total Alkalinity (Total as CaCO3)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Total Chemical Oxygen Demand	21	17	22	23	24	27	14	67	38	25
Total Mercury (Hg)	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013
Total Organic Carbon (C)	5	4.9	5.5	6.2	7.1	4.6	3.9	19	9.4	9.3
Total Suspended Solids	<1.0	<1.0	<1.0	2.4	<1.0	<1.0	32	1.2	<1.0	10
Total Dissolved Solids	11	9	11	10	11	11	15	14	15	12
Turbidity	1.4	1.3	1.1	1	1.4	1	0.58	3.3	1.4	0.91
Dissolved Aluminum (Al)	-	-	-	-	-	-	-	-	-	-
Dissolved Antimony (Sb)	-	-	-	-	-	-	-	-	-	-
Dissolved Arsenic (As)	-	-	-	-	-	-	-	-	-	-
Dissolved Barium (Ba)	-	-	-	-	-	-	-	-	-	-
Dissolved Beryllium (Be)	-	-	-	-	-	-	-	-	-	-
Dissolved Bismuth (Bi)	-	-	-	-	-	-	-	-	-	-
Dissolved Boron (B)	-	-	-	-	-	-	-	-	-	-
Dissolved Cadmium (Cd)	-	-	-	-	-	-	-	-	-	-
Dissolved Calcium (Ca)	-	-	-	-	-	-	-	-	-	-
Dissolved Chromium (Cr)	-	-	-	-	-	-	-	-	-	-
Dissolved Cobalt (Co)	-	-	-	-	-	-	-	-	-	-
Dissolved Copper (Cu)	-	-	-	-	-	-	-	-	-	-
Dissolved Iron (Fe)	-	-	-	-	-	-	-	-	-	-
Dissolved Lead (Pb)	-	-	-	-	-	-	-	-	-	-
Dissolved Magnesium (Mg)	-	-	-	-	-	-	-	-	-	-

Parameter	March	April	May	June	July	August	September	October	November	December
Dissolved Manganese (Mn)	-	-	-	-	-	-	-	-	-	-
Dissolved Molybdenum (Mo)	-	-	-	-	-	-	-	-	-	-
Dissolved Nickel (Ni)	-	-	-	-	-	-	-	-	-	-
Dissolved Phosphorus (P)	-	-	-	-	-	-	-	-	-	-
Dissolved Potassium (K)	-	-	-	-	-	-	-	-	-	-
Dissolved Selenium (Se)	-	-	-	-	-	-	-	-	-	-
Dissolved Silver (Ag)	-	-	-	-	-	-	-	-	-	-
Dissolved Sodium (Na)	-	-	-	-	-	-	-	-	-	-
Dissolved Strontium (Sr)	-	-	-	-	-	-	-	-	-	-
Dissolved Thallium (Tl)	-	-	-	-	-	-	-	-	-	-
Dissolved Tin (Sn)	-	-	-	-	-	-	-	-	-	-
Dissolved Titanium (Ti)	-	-	-	-	-	-	-	-	-	-
Dissolved Uranium (U)	-	-	-	-	-	-	-	-	-	-
Dissolved Vanadium (V)	-	-	-	-	-	-	-	-	-	-
Dissolved Zinc (Zn)	-	-	-	-	-	-	-	-	-	-
Cyanate	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Strong Acid Dissoc. Cyanide (CN)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0012	<0.0010	<0.0010
Thiocyanate	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Weak Acid Dissociable Cyanide (CN-)	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	<0.003
Benzene	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Toluene	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ethylbenzene	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Xylenes	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
>C10-C16 Hydrocarbons	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
C6 - C10 (less BTEX)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
>C16-C21 Hydrocarbons	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
>C21-<C32 Hydrocarbons	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Modified TPH (Tier1)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Hydrocarbon Resemblance	-	-	-	-	-	-	-	-	-	-
Radium-226	-	-	-	-	-	<0.050	-	-	-	-
Total Aluminum (Al)	150	140	170	140	170	100	73	350	210	210
Total Antimony (Sb)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Arsenic (As)	5.2	4	30	23	29	20	17	8	5.7	4.9
Total Barium (Ba)	3.6	3.9	3.9	3.6	3.2	3	2.5	8.6	5.8	4.9
Total Beryllium (Be)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Bismuth (Bi)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Boron (B)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Total Cadmium (Cd)	0.015	0.016	0.025	<0.010	<0.010	<0.010	<0.010	0.04	0.024	0.022
Total Calcium (Ca)	1000	840	1200	1200	1400	1200	1200	1700	1400	1200
Total Chromium (Cr)	<1.0	<1.0	1.6	<1.0	<1.0	<1.0	1.7	<1.0	<1.0	<1.0
Total Cobalt (Co)	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	0.71	<0.40	<0.40
Total Copper (Cu)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Iron (Fe)	240	190	580	530	810	480	490	690	430	370
Total Lead (Pb)	<0.50	<0.50	0.86	<0.50	<0.50	<0.50	<0.50	0.52	<0.50	<0.50
Total Magnesium (Mg)	430	350	420	470	520	500	450	750	590	550
Total Manganese (Mn)	43.00	35.00	89.00	55.00	64.00	37.00	53.00	180.00	75.00	70.00

Parameter	March	April	May	June	July	August	September	October	November	December
Total Molybdenum (Mo)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Nickel (Ni)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Phosphorus (P)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Total Potassium (K)	240	210	300	180	150	160	240	530	310	240
Total Selenium (Se)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Silver (Ag)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Sodium (Na)	2400	2200	3100	2800	3000	3500	3500	2700	2900	2400
Total Strontium (Sr)	5.1	4.5	5.2	5.6	6.7	5.9	5.4	11	7.8	6.7
Total Thallium (Tl)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Tin (Sn)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Titanium (Ti)	2.1	<2.0	2.8	<2.0	2.5	<2.0	<2.0	3.5	<2.0	2
Total Uranium (U)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Vanadium (V)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Zinc (Zn)	<5.0	<5.0	6.1	<5.0	<5.0	<5.0	<5.0	6.1	<5.0	<5.0

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Table A.3 2017 Surface Water Monitoring - SW-2

Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Anion Sum	0.17	0.12	0.17	0.1	0.12	0.12	0.11	0.13	0.15	0.15	0.17	0.17
Bicarb. Alkalinity (calc. as CaCO3)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Calculated TDS	13	10	12	8	10	9	10	10	14	12	14	13
Carb. Alkalinity (calc. as CaCO3)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cation Sum	0.26	0.21	0.21	0.18	0.21	0.24	0.26	0.23	0.3	0.26	0.28	0.23
Colour	61	55	44	52	74	63	59	48	110	72	110	84
Conductivity	29	24	25	21	22	24	24	24	29	27	33	28
Dissolved Chloride (Cl)	5.8	4.3	4.6	3.6	4	4.3	3.9	4.3	5.4	5.2	5.9	5.9
Dissolved Fluoride (F-)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Sulphate (SO4)	<2.0	<2.0	2	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Hardness (CaCO3)	4.7	4.5	4.3	3.8	4.3	4.4	5	4.7	6.7	5.3	6.2	4.8
Ion Balance (% Difference)	20.9	27.3	10.5	28.6	27.3	33.3	40.5	27.8	33.3	26.8	24.4	15
Langelier Index (@ 20C)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Langelier Index (@ 4C)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Nitrate (N)	0.073	<0.050	<0.050	<0.050	0.12	<0.050	<0.050	0.092	<0.050	<0.050	<0.050	<0.050
Nitrate + Nitrite (N)	0.073	<0.050	<0.050	<0.050	0.12	<0.050	<0.050	0.092	<0.050	<0.050	<0.050	<0.050
Nitrite (N)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Nitrogen (Ammonia Nitrogen)	0.082	<0.050	<0.050	-	0.14	0.05	<0.050	0.062	<0.050	<0.050	<0.050	<0.050
Orthophosphate (P)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.011	<0.010	<0.010	<0.010	<0.010	<0.010
pH	5.63	6.03	5.96	5.92	6.28	6.33	6.47	6.23	6.18	6.06	5.84	5.97
Reactive Silica (SiO2)	1.9	1.8	1.3	0.74	0.71	<0.50	0.51	0.52	2.1	1.3	2.2	1.9
Saturation pH (@ 20C)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Saturation pH (@ 4C)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Total Alkalinity (Total as CaCO3)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Total Chemical Oxygen Demand	27	23	21	24	20	27	22	26	35	28	43	28
Total Mercury (Hg)	<0.013	<0.013	<0.013	<0.013	<0.013	0.02	<0.013	<0.013	0.013	<0.013	<0.013	<0.013
Total Organic Carbon (C)	6.5	5.7	4.4	4.7	6.9	7.2	7.6	7	13	10	13	13
Total Suspended Solids	<1.0	<1.0	<1.0	1.6	<2.0	1.4	<2.0	<1.0	1.2	<1.0	1.2	<1.0
Total Dissolved Solids	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	1.2	1.1	0.96	1.2	1.4	1.1	0.66	0.43	0.7	0.71	1.8	1
Dissolved Aluminum (Al)	-	-	-	-	-	-	-	70	220	150	270	170
Dissolved Antimony (Sb)	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Arsenic (As)	-	-	-	-	-	-	-	13	13	6.9	5.2	5.1
Dissolved Barium (Ba)	-	-	-	-	-	-	-	2.8	5.2	3.7	6.5	4.7
Dissolved Beryllium (Be)	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Bismuth (Bi)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Boron (B)	-	-	-	-	-	-	-	<50	<50	<50	<50	<50
Dissolved Cadmium (Cd)	-	-	-	-	-	-	-	<0.010	0.018	<0.010	0.027	**0.017**
Dissolved Calcium (Ca)	-	-	-	-	-	-	-	1100	1700	1300	1500	1100
Dissolved Chromium (Cr)	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Cobalt (Co)	-	-	-	-	-	-	-	<0.40	<0.40	<0.40	<0.40	<0.40
Dissolved Copper (Cu)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Iron (Fe)	-	-	-	-	-	-	-	320	660	450	450	310
Dissolved Lead (Pb)	-	-	-	-	-	-	-	<0.50	<0.50	<0.50	<0.50	<0.50
Dissolved Magnesium (Mg)	-	-	-	-	-	-	-	450	620	490	620	510

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Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Dissolved Manganese (Mn)	-	-	-	-	-	-	-	20	66	31	84	57
Dissolved Molybdenum (Mo)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Nickel (Ni)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Phosphorus (P)	-	-	-	-	-	-	-	<100	<100	<100	<100	<100
Dissolved Potassium (K)	-	-	-	-	-	-	-	180	210	180	320	210
Dissolved Selenium (Se)	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Silver (Ag)	-	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Sodium (Na)	-	-	-	-	-	-	-	2600	3100	3000	3000	2600
Dissolved Strontium (Sr)	-	-	-	-	-	-	-	5.4	8.8	6.4	7.9	5.9
Dissolved Thallium (Tl)	-	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Tin (Sn)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Titanium (Ti)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Uranium (U)	-	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Vanadium (V)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Zinc (Zn)	-	-	-	-	-	-	-	<5.0	<5.0	<5.0	5.6	<5.0
Cyanate	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Strong Acid Dissoc. Cyanide (CN)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0018	<0.0010	0.001	0.0013	<0.0010	<0.0010	<0.0010
Thiocyanate	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Weak Acid Dissociable Cyanide (CN-)	<0.003	<0.003	<0.003	<0.003	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Benzene	<0.0010	<0.0010	<0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Toluene	<0.0010	<0.0010	<0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ethylbenzene	<0.0010	<0.0010	<0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Xylenes	<0.0020	<0.0020	<0.0026	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
>C10-C16 Hydrocarbons	<0.010	<0.010	<0.013	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
C6 - C10 (less BTEX)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
>C16-C21 Hydrocarbons	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
>C21-<C32 Hydrocarbons	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Modified TPH (Tier1)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Hydrocarbon Resemblance	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	-	-	-	<0.050	-	-	-	-	-	-	-	-
Total Aluminum (Al)	190	150	140	130	170	160	140	100	220	170	260	180
Total Antimony (Sb)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Arsenic (As)	4.6	4.7	6.9	6.2	11	18	19	17	16	7.7	6.1	5.5
Total Barium (Ba)	4.3	3.9	3.7	3.2	3.9	3.4	3.4	3	5.1	3.4	5.8	4.4
Total Beryllium (Be)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Bismuth (Bi)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Boron (B)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Total Cadmium (Cd)	0.018	0.012	0.016	0.018	0.013	<0.010	<0.010	<0.010	0.01	**0.011**	**0.022**	**0.019**
Total Calcium (Ca)	1100	1100	1000	920	1000	1100	1300	1200	1600	1300	1400	1000
Total Chromium (Cr)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Cobalt (Co)	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40
Total Copper (Cu)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Iron (Fe)	320	290	250	200	340	630	750	610	850	590	620	370
Total Lead (Pb)	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Total Magnesium (Mg)	490	460	420	370	430	420	460	460	600	520	630	450
Total Manganese (Mn)	61	51	42	35	58	52	41	29	71	35	88	56

Stantec

Parameter	61	51	42	35	58	52	41	29	71	35	88	56
Total Molybdenum (Mo)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Nickel (Ni)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Phosphorus (P)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Total Potassium (K)	150	150	170	200	170	170	130	150	220	160	310	210
Total Selenium (Se)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Silver (Ag)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Sodium (Na)	3200	2400	2500	2100	2300	2800	2900	2600	3400	3000	3000	2300
Total Strontium (Sr)	6.1	5.8	5.6	4.6	5.6	5.6	6.5	5.7	8.8	6.4	7.5	6.4
Total Thallium (Tl)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Tin (Sn)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Titanium (Ti)	<2.0	<2.0	<2.0	<2.0	2.2	2.4	2.7	2.2	3.7	3	2.2	2.5
Total Uranium (U)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Vanadium (V)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Zinc (Zn)	<5.0	<5.0	<5.0	<5.0	6	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0

Stantec

Hydrometric Station Summary

Hydrometric Station ID	SW-23	**Flow meter used**	OTT MF Pro
Location	Upstream, relatively unimpacted conditions	**Time Averaging**	40 seconds
Installation Date	12-Mar-2021	**Data Collected at site**	Water temperature, water level, atm. pressure
Coordinates	20T 505367E, 4982104N	**Main channel**	Rocky, narrow, runs through alder swamp
Access	Billybell Way (Admin Road)	**Channel Bottom**	Boulder 30%, Fines 30%, Rubble 20%, Sand 20%
Drainage Area	0.371 km²	**Flood Plain**	Alder swamp, grasses, sedges
Period of Record	11 March, 2021 to present	**Comments**	Culvert under Billybell Way located approximately 3 m upstream.

Water Level

Date: October 15, 2021

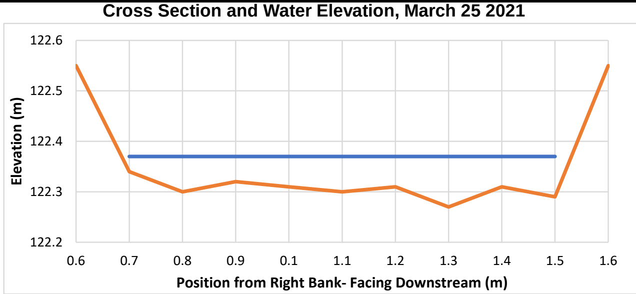
Map: SW-23 Watercourse No. 4

SW-23 facing Upstream, Oct 15 2021

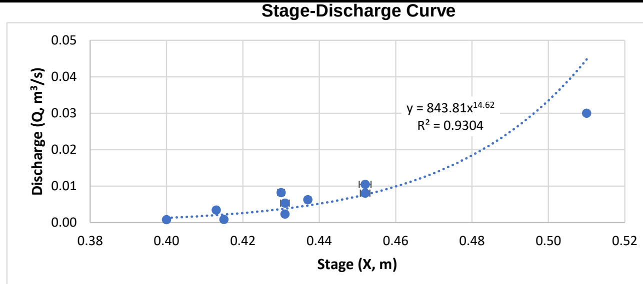
SW-23 facing Downstream, Oct 15 2021

Date	Stage (m)	Discharge (m^3/s)	Discharge Accuracy (%)
3/11/2021 10:40	0.430	0.008	10.4
3/25/2021 14:40	0.452	0.010	14.8
3/31/2021 0:00	---	---	---
4/6/2021 14:38	0.510	0.030	1.5
4/9/2021 13:50	0.437	0.006	11.8
5/18/2021 10:25	0.400	0.001	0.9
7/8/2021 13:45	0.413	0.003	1.1
7/23/2021 14:20	0.452	0.008	15.3
8/24/2021 13:30	0.415	0.001	30.6
9/13/2021 13:05	0.431	0.005	20.9
10/15/2021 13:15	0.431	0.002	13.2

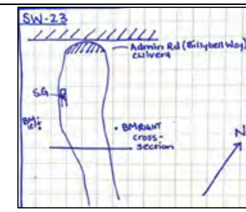
Cross Section and Water Elevation, March 25 2021



Stage-Discharge Curve

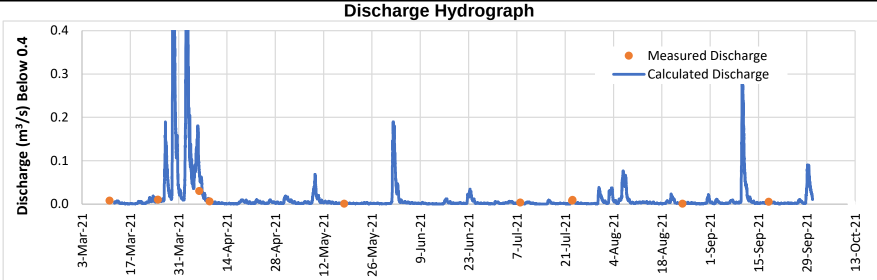


Benchmark Elevation Surveys

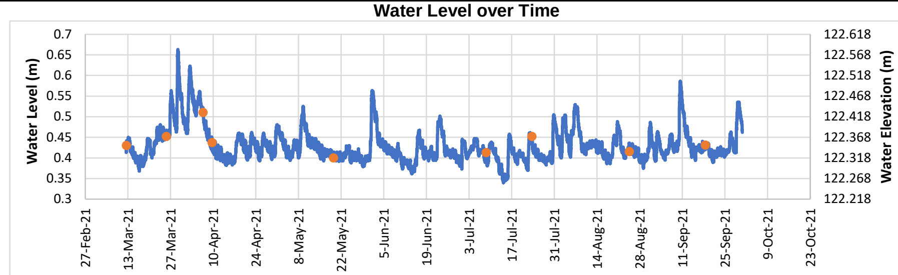


Top of 1m Staff Gauge	West Benchmark	East Benchmark	Date
122.918	123.164	122.859	6-Aug-21

Discharge Hydrograph



Water Level over Time



Stantec

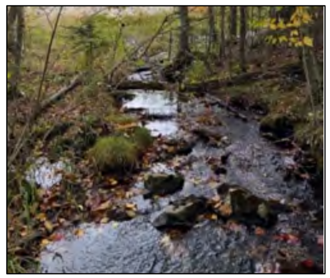
Hydrometric Station Summary

Hydrometric Station ID	SW-19 Downstream	**Flow meter used**	OTT MF Pro
Location	Downstream, adjacent to the WRSA	**Time Averaging**	40 seconds
Installation Date	12-Mar-2021	**Data Collected at site**	Water temperature, water level, atm. pressure
Coordinates	20T 505317E, 4981589N	**Main channel**	Rocky, shallow, channel between 2 culverts
Access	North of Mooseland Road	**Channel Bottom**	Rubble 70%, Cobble, Silt, Gravel
Drainage Area	0.613 km²	**Flood Plain**	Mixed wood forest, mosses
Period of Record	2021 - present	**Comments**	Section runs between culvert under WRSA and double culvert under Mooseland Road

Water Level

Date: October 15 2021

Map: SW-19 Watercourse No. 4

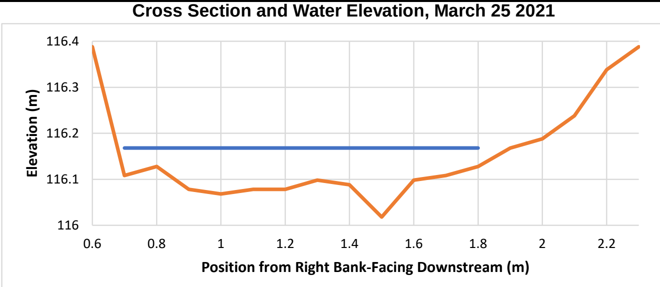


SW19D facing Upstream, Oct 15 2021

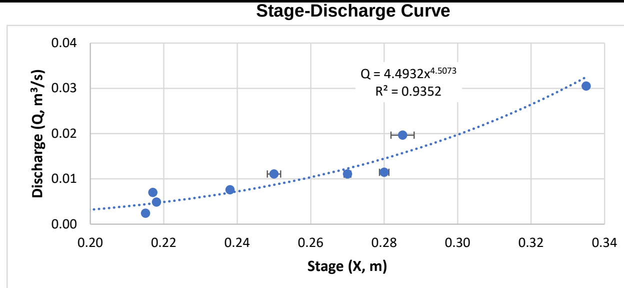
SW19DS facing Downstream, Oct 15 2021

Date	Stage (m)	Discharge (m^3/s)	Discharge Accuracy (%)
3/11/2021 11:10	0.280	0.011	11.1
3/25/2021 13:35	0.285	0.020	16.0
3/31/2021 0:00	---	---	---
4/6/2021 14:00	0.335	0.031	5.9
4/9/2021 13:15	0.250	0.011	0.4
5/18/2021 11:15	0.215	0.002	7.1
7/8/2021 12:20	0.238	0.008	12.2
7/23/2021 12:40	0.270	0.011	1.6
8/24/2021 12:05	0.190	0.003	23.6
9/13/2021 11:45	0.217	0.007	2.1
10/15/2021 11:40	0.218	0.005	11.0

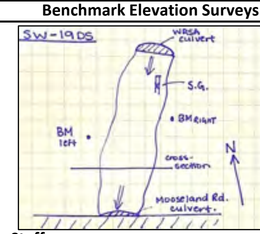
Cross Section and Water Elevation, March 25 2021



Stage-Discharge Curve

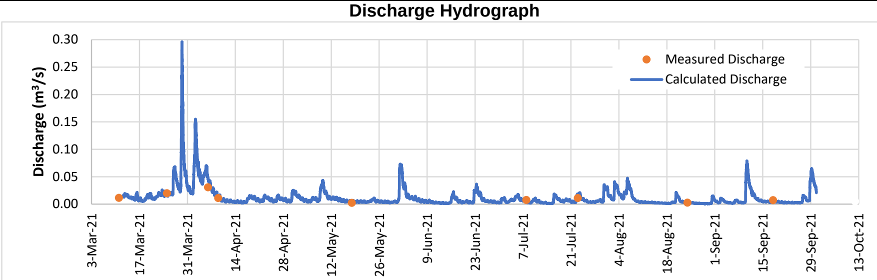


Benchmark Elevation Surveys

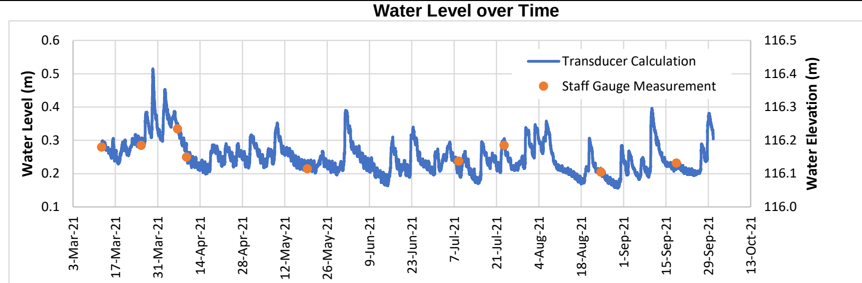


Top of 1m Staff Gauge	West Benchmark	East Benchmark	Date
116.883	116.294	117.11	6-Aug-21

Discharge Hydrograph



Water Level over Time



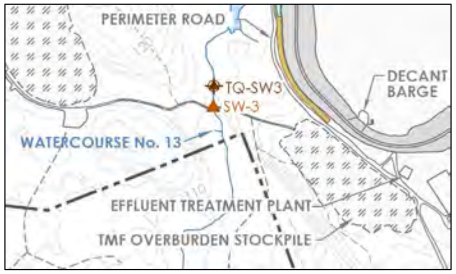
Stantec

Hydrometric Station Summary

Hydrometric Station ID	SW-3	**Flow meter used**	OTT MF Pro
Location	Unnamed Tributary (WC4) to Moose River DS	**Time Averaging**	40 seconds
Installation Date	11-Mar-2021	**Data Collected at site**	Water temperature, water level, atm. pressure
Coordinates	20T 505586E, 4980396N	**Main channel**	Clean, well cut banks
Access	Perimeter Road, past Scraggy Stockpile area	**Channel Bottom**	Rubble 70%, Silt 20%, Cobble, Gravel
Drainage Area	1.041 km²	**Flood Plain**	Mixed wood forest, grasses, and mosses
Period of Record	2021 - present	**Comments**	Widest station on WC4, more natural vegetation than other sites

Water Level

Date: October 15, 2021



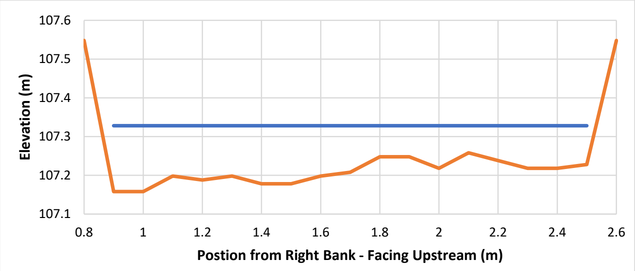
Map: SW-3 Watercourse No. 4

SW-3 facing Upstream, Oct 15 2021

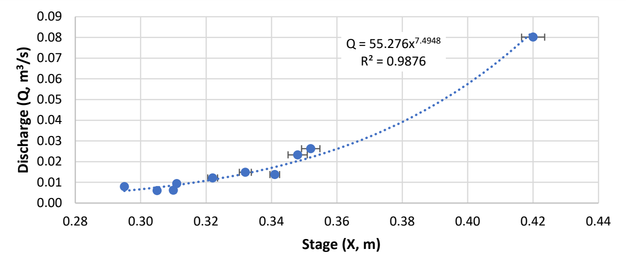
SW-3 facing Downstream, Oct 15 2021

Date	Stage (m)	Discharge (m^3/s)	Discharge Accuracy (%)
3/11/2021 11:20	0.322	0.012	12.4
3/25/2021 12:45	0.352	0.026	10.7
3/31/2021 0:00	---	---	---
4/6/2021 13:09	0.420	0.080	4.4
4/9/2021 12:22	0.348	0.023	12.6
5/19/2021 12:20	0.295	0.008	6.9
7/8/2021 13:00	0.311	0.009	4.5
7/23/2021 13:35	0.341	0.014	10.7
8/24/2021 12:45	0.310	0.006	12.7
9/13/2021 12:25	0.332	0.015	12.3
10/15/2021 12:15	0.305	0.006	10.4

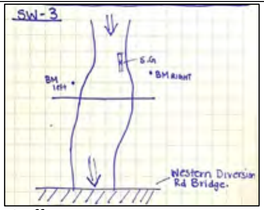
Cross Section and Water Elevation, March 25 2021



Stage-Discharge Curve

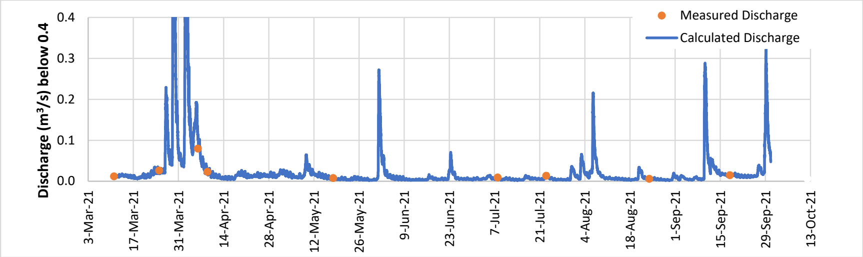


Benchmark Elevation Surveys



Top of 1m Staff Gauge	West Benchmark	East Benchmark	Date
107.976	108.438	107.775	6-Aug-21

Discharge Hydrograph



Water Level over Time