April 14, 2022

Randy Bates
Director, Division of Water
Alaska Department of Environmental Conservation
555 Cordova Street, Anchorage, AK 99501-2617
Email: randy.bates@alaska.gov

RE: Submission of Technical Memoranda Responding to ONC Comments

Dear Mr. Bates,

Donlin Gold LLC (Donlin) respectfully requests that the Division of Water (the Division) consider the attached expert technical memoranda that respond to the comments submitted by Orutsararmiut Native Council (ONC) on March 29, 2022, pursuant to the Order Granting Interlocutory Remand in *Orutsararmiut Native Council v. Alaska Department of Environmental Conservation*, No. 3AN-21-06502CI (Dec. 29. 2021).

ONC's comments take issue with the two draft[1] reports that were commissioned by Donlin to further define the potential impacts of the Donlin Gold Project (the Project) on stream temperatures in Crooked Creek and mercury concentrations in the Crooked Creek watershed. To ensure the Division proceeds with its review of Donlin's Certificate of Reasonable Assurance with a clear understanding of the analyses and methodologies presented in those reports, Donlin submits the following:

1. A memorandum[2] prepared by BGC Engineering Inc. responding to ONC's review of its September 28, 2021 report, "Analysis of Crooked Creek Stream Temperature."

2. A memorandum[3] prepared by Ramboll US Consulting, Inc. responding to ONC's review of its October 22, 2021 report, "Donlin Gold Mine Supplemental Mercury Modeling and Mass Balance Analysis."

[1] The two reports on mercury and temperature were submitted as "draft" documents pending review by parties. At this time these reports are considered "final" documents.
[2] BGC Engineering Inc., "Review of BGC's Crooked Creek Stream Temperature Analysis — Response" (April 14, 2022), included as Attachment 1 to this letter.

[3] Ramboll US Consulting, Inc., "Response to Mercury Comments in Letter from Orutsararmiut Native Council dated March 29, 2022" (April 14, 2022), included as Attachment 2 to this letter.

3. A memorandum[4] prepared by Air Sciences Inc. also responding to ONC's review of Ramboll US Consulting, Inc.'s October 22, 2021 report. Air Sciences Inc. helped develop and review the mercury emissions calculations presented in Ramboll's mercury modeling report.

The curriculum vitae of the authors of the memoranda are provided with their respective documents. Each is recognized nationally for their knowledge and experience in their fields. It is noteworthy that their work has consistently been relied upon by Federal and State government agencies to support impact evaluation and permitting for mining projects throughout North America.

Donlin would also like to reemphasize the standard applicable to the Division's decision-making process. The Division is tasked to determine whether there is "reasonable assurance" that the Project will comply with applicable Alaska water quality standards. Importantly, a reasonable assurance finding does not mean that the Division is required "to provide absolute certainty that permittees will never violate water quality standards, assuming this sort of guarantee is even possible."[5] ONC derisively criticizes the use of "modelling" to address future compliance with mercury and temperature water quality standards. But this criticism ignores the nature of a section 401 certification and the necessity of utilizing predictive modeling tools. The Division is tasked with determining whether there is reasonable assurance of compliance after a future project is completed and begins operations. "The inherent predictive nature of a § 401 certification cannot be avoided; each § 401 certification must address future events and the likelihood that those events will result in violations of water quality standards."[6] The FEIS and the agency review for the purposes of the 401certification relied on modeling to make reasonable predictions about the future. This is an appropriate way to assess the likelihood of future compliance.[7] The information and models offered by Donlin represent the most accurate assessment of the potential impacts of the Project on stream temperatures and mercury concentrations in the watersheds. ONC offers no superior alternative for making the necessary predictions. Nor does ONC offer any alternative models that would provide the Division with better predictions. As for ONC's specific criticisms of the modeling conducted by BGC and Ramboll, these criticisms are fully rebutted by the attached memoranda.

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[4] Air Sciences Inc., "Review of March 29, 2022 Comments from Earthjustice Related to Donlin's Mercury Emissions Inventory" (April 14, 2022), included as Attachment 3 to this letter.

[5] *Miners Advocacy Council, Inc. v. State, Dep't of Environmental Conservation*, 778 P.2d 1126, 1138 (Alaska 1989).

[6] *Port of Seattle v. Pollution Control Hearings Board*, 90 P.3d 659, 676 (Wash. 2004).

[7] For example, in the *Port of Seattle* case, the Port provided a modeling analysis to predict future streamflow. The PCHB accepted the Port's modeling and observed the challengers' failure to carry *their* burden of showing that the modeling assumptions were unreasonable or would lead to violation of water quality standards.

Across both mercury and temperature, ONC argues that because the current and predicted levels approach their respective water quality standards, there is an even greater combined likelihood of exceedances. There is no basis for such an argument and the analyses for each parameter are procedurally and technically sound, based on available data, reasonable (and often conservative) assumptions, and the best analytical tools and information available, supporting a finding of reasonable assurance.

The baseline water quality includes measured concentrations for total mercury that approach or even exceed the 12 mg/L standard, but the focus of the studies was to evaluate the project's impact on those baseline conditions. The best information available demonstrates that the project will result in an overall decrease to the baseline concentrations or its impacts will be otherwise insignificant, as a result of the project's proposed water management measures.

Donlin appreciates the opportunity to submit the attached materials and is available to answer any questions the Division may have during its review. Thank you for your time and consideration.

Sincerely,

Enrique Fernandez
Permitting and Environmental Manager

CC: Dan Graham, General Manager – Donlin Gold LLC

Eric Fjelstad, Attorney for Donlin Gold – Perkins Coie LLP

Jim Leik, Attorney for Donlin Gold – Perkins Coie LLP

ATTACHMENT 1

BGC Engineering Inc., "Review of BGC's Crooked Creek Stream Temperature Analysis — Response" (April 14, 2022)

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AN APPLIED EARTH SCIENCES COMPANY
Suite 500 - 980 Howe Street, Vancouver, BC Canada V6Z 0C8
Telephone (604) 684-5900 Fax (604) 684-5909

Project Memorandum

To:	**Perkins Coie**	**Doc. No.:**	
Attention:	**Eric Fjelstad**	**cc:**	**Ron Rimelman** **Enric Fernandez**
From:	**Hamish Weatherly**	**Date:**	**April 14, 2022**
Subject:	**Review of BGC's Crooked Creek Stream Temperature Analysis – Response**		
Project No.:	**0011341**		

1.0 INTRODUCTION

In the spring of 2021, BGC Engineering Inc. (BGC) was retained by Donlin Gold to complete a quantitative analysis to define potential changes in Crooked Creek stream temperatures that may occur because of the proposed Donlin Gold Project (Project). Results of that analysis and the methodology used by BGC were provided to Donlin Gold in a draft report dated September 28, 2021. That report was subsequently submitted to the Alaska Department of Environmental Conservation (ADEC) for their consideration. ADEC also submitted the report to the Orutsaramiut Native Council (ONC) for comment, pursuant to the Order Granting Interlocutory Remand in *Orutsararmiut Native Council v. Alaska Department of Environmental Conservation*, No. 3AN-21-06502CI (Dec. 29, 2021).

Comments on BGC's September 28, 2021 report were received from Earthjustice (on behalf of the ONC) on March 29, 2022. Those comments include Exhibit 6, a technical memorandum prepared by Tom Myers, Ph.D. for Earthjustice. Dr. Myer's memorandum provides a technical review of BGC's analysis of potential changes in Crooked Creek stream temperatures that may occur because of the proposed Project. Donlin Gold has subsequently requested that BGC respond to Dr. Meyer's review comments. The following memorandum provides that requested response.

2.0 BGC RESPONSE TO MYER REVIEW COMMENTS

2.1. Comment 1 – Data Record

On Page 2 of this report, Dr. Meyer notes the following:

> *The first assumption is that stream flows will not be any lower than analyzed. The year 2005 had the lowest flows of the presented record but there is no indication as to the probability of those low flows being exceeded. If the background streamflow is lower than occurred in 2005, the mine would have more substantial effects on the stream temperatures than predicted by BGC.*

BGC did not make assumptions about stream flow or temperatures. Instead, BGC used actual continuous stream flow and temperature data, measured over the summer months for 5 years. It is clearly recognized that BGC's analysis does not include all potential combinations of streamflow

and stream temperature, given both the type of analysis conducted and the length of record available (2005, 2006, 2007, 2009 and 2011). However, it is not productive to replace the actual data with speculation about whether lower or higher levels might be observed. Actual data is a strong foundation for assessing likely future compliance with water quality standards. Moreover, Dr. Myers's comment assumes that there is a direct correlation between streamflow and stream temperatures. This assumption is not borne out by the actual observations. For example, the 2005 data includes two days with identical streamflow at CCAC (53.3 cfs on both July 23 and August 4). Despite identical streamflow on these two days, the stream temperatures were significantly different: 51.7°F on July 23 and 46.5°F on August 4. Because of these complexities, BGC's analysis focused on dates where corresponding streamflow and stream temperature data through the summer months in Crooked Creek, American Creek, and Anaconda Creek were available.

It is further noted that the available data does cover a wide range of summer stream temperatures in Crooked Creek, as demonstrated in Figure 2-1. Of the years analyzed, an average increase in stream temperature for the months of July and August was only predicted for 2005, with an average increase of 1°F. There was no predicted increase in average stream temperature for the other years analyzed (see Appendix C of BGC, September 28, 2021). Therefore, the analysis of BGC (September 28, 2021) provides a reasonable interpretation of a range of conditions, while recognizing that the analysis does not include every theoretically possible range of streamflow and stream temperature combinations.

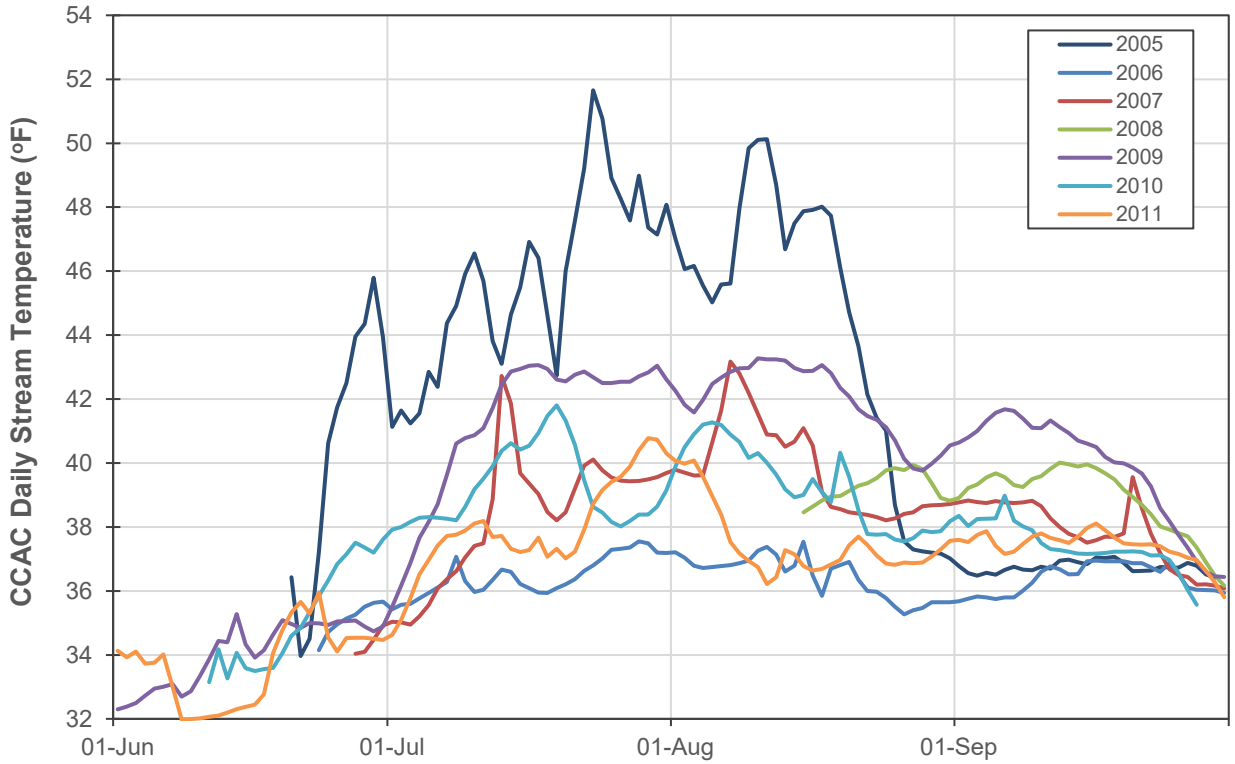

Figure 2-1. Crooked Creek daily stream temperature at CCAC for the period 2005-2011.

2.2. Comment 2 – Streamflow as a Function of Watershed Area

On Page 2 of his report, Dr. Meyer notes the following:

> *BGC assumed a linear flow to area relationship which means the stream gains flow as a function of area. While correct on a broad scale in the Donlin area, the reality is that the relationship varies with length and with the wetness in the watershed. During dry periods, most flow enters in select gaining reaches or at points of inflow. During storm runoff periods, for streams of this size and topography, there are probably discrete inflow points but they probably spread along the stream reach so the area relationship may be more accurate. BGC should have done a synoptic analysis on Crooked Creek to determine the actual relationship of flow with area during both wet and dry conditions.*

It is assumed that when referring to a synoptic study, Dr. Myer is describing coordinated, intensive sampling over a short time period (several days) during wet and dry periods where streamflow would be measured in Crooked Creek at a number of locations between American Creek and Anaconda Creek. A sensitivity analysis demonstrates that such additional streamflow data would not have a significant influence on the analysis.

BGC's September 28, 2021 analysis showed that the critical day with respect to maximum stream temperatures in the 2005-2011 period was July 23, 2005. Measured discharge on that day was 53.3 cfs at the Crooked Creek station (CCAC). Assuming a linear relationship between streamflow and watershed area, the discharge of Crooked Creek before the confluence with American Creek is estimated at 32.1 cfs, a difference of 21.2 cfs compared to CCAC. Of that 21.2 cfs, 8.8 cfs comes from American Creek and Anaconda Creek (pro-rated from AMER and ANDA). So, there is an assumed discharge of 12.4 cfs coming from other tributaries to Crooked Creek and valley sideslopes between American Creek and Anaconda Creek. As a sensitivity analysis, the contribution of these additional areas was varied using the following equation (Watt, 1989):

$$Q_2 = Q_1 \left(\frac{A_2}{A_1}\right)^n \qquad \text{[Eq. 2-1]}$$

where: Q_2 is the area-adjusted streamflow along Crooked Creek and Q_1 is the observed streamflow at station CCAC. A_2 represents the drainage area at the various modelling nodes along Crooked Creek and A_1 (111.9 mi^2) represents the drainage area at CCAC. As a sensitivity analysis, n was varied between 0.7 and 1.3.

Using an exponent of 0.7, the maximum modelled stream temperature on Crooked Creek on July 23, 2005 is 54.5°F, compared to 54.8°F as reported in BGC (September 28, 2021). Using an exponent of 1.3, the maximum modelled stream temperature on Crooked Creek on July 23, 2005 is 55.1°F, compared to 54.8°F. Therefore, even when accounting for a non-linear flow to watershed area relation, the impacts on stream temperature are relatively minor, with predicted stream temperatures in Crooked Creek remaining below the State of Alaska's water quality temperature standard of 55.4°F for egg/fry incubation in the years with available data.

2.3. Comment 3 – Failure to Consider Thermal Effects

On Page 3 of his report, Dr. Meyer notes the following:

> *The second assumption is there will be no thermal effects on the stream, meaning BGC ignored sources of heat that would add to stream temperatures. … At the latitude of Donlin, longwave atmospheric radiation and conduction of heat from the atmosphere during warm days are likely to be the largest source of heating. Shortwave radiation, including direct sunlight onto the creek, reflects from surface water such that at lower than a 30-degree angle little heat would be absorbed. Reflected shortwave radiation however could hit the riparian vegetation thereby heating it thereby increasing long-wave radiation to the creek. At the low temperatures considered here, evaporation would remove only a small amount of heat. It seems likely that at least during warm weather periods with long days there would be a net gain of heat in the creek. Additionally, the stream meanders substantially, as seen on BGC (2021) Figure 2-4; the meandering increases the surface area of the stream exposed to the factors listed above. By ignoring thermal effects, BGC ignored a substantial source of heat and has underestimated the temperature at the downstream end of the stream reach affected by the mine.*

Dr. Meyer's comment is overly simplistic in that the measured discharge and stream temperature at CCAC implicitly accounts for the upstream radiation impacts on stream temperature. With reference to Figure 2-2, BGC did not underestimate stream temperature at the downstream end of the reach given that stream temperature at CCAC is known and the estimated stream temperature at modelling node Q_1 is the stream temperature at CCAC minus the recorded temperature of Anaconda Creek water (ANDA). Also, accounting for thermal effects between model nodes Q_5 and Q_a would result in lower modelled stream temperatures in the vicinity of American Creek (i.e., less conservative results). Therefore, thermal effects have not been accounted for as they would result in less conservative results. Furthermore, riparian and stream conditions on Crooked Creek would not be directly impacted by the proposed Project.

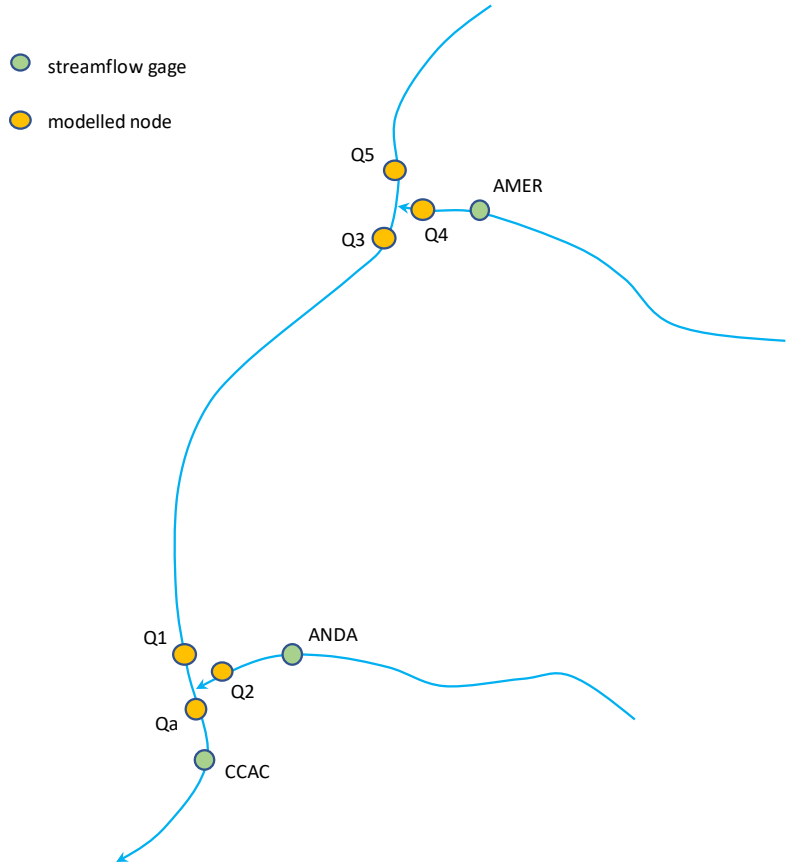

Figure 2-2. Modelling framework.

2.4. Comment 4 – Effluent Discharge to the Stream

On Page 3 of his report, Dr. Meyer notes the following:

> *The third unjustified assumption is that effluent temperatures would not be high enough to affect the stream. BGC provided no references to support the assumption. Effluent includes tailings decant water and runoff from waste rock and pit walls which could all be warmer than the stream temperatures during the summer due to radiation from the sun having warmed the source. There is also no discussion or evidence regarding heat that could be added to the water during treatment.*

The proposed water treatment includes a high-rate clarifier (HRC) and greensand filter, followed by reverse osmosis (RO). Neither of these treatment methods involve the addition of heat to the water. Therefore, the effluent temperature will generally be determined by the temperature of the water inputs fed through the water treatment plant (WTP). To date, Donlin Gold has not modelled what the potential range of the treated effluent could be. However, for the September 28, 2021 report, we assumed a temperature of 55°F for the treated effluent. This temperature is a very conservative (i.e., high) assumption because:

- The proposed treatment methods do not involve the application of heat to the process.
- A majority of the predicted treatment volumes are modelled to be sourced from perimeter pit groundwater wells (29%), in-pit groundwater wells (19%), and the TSF Seepage

Recovery System (SRS) (24%) (BGC, December 7, 2016). Together, these groundwater sources account for 72% of the modelled treatment volumes in July and August. As noted in BGC (September 28, 2011) groundwater has an average temperature of 35.6°F based on temperatures measured in the wells and vibrating wire piezometers installed in the immediate vicinity of the Donlin Project. Given that these three groundwater sources will be pumped directly to the WTP for treatment and will not be temporarily held in storage ponds, an assumed temperature of 55°F for the treated effluent is conservatively high.

Furthermore, Donlin Gold can control the temperature of the treated effluent by managing the quantity (i.e., flow) of the water sources that are fed to the WTP. That is, the temperature of the effluent could be made as low as, or close to, that of the source groundwater temperature (i.e., 35.6°F) by using groundwater alone, or warmed up by increasing the surface water sources (i.e., water stored in ponds). BGC's modeling showed that with a 40°F effluent, stream temperatures below the mine were reduced. This result suggests that ensuring the treated water is relatively cool could act as a potential mitigation strategy if monitored stream temperatures approach the Alaska water quality standard for egg/fry incubation.

2.5. Comment 5 – Climate Change

On Page 3 of his report, Dr. Meyer notes the following:

> *BGC also ignored the potential that climate change would affect the thermal factors considered above. It could affect the stream in two ways. It could decrease flows during warm, dry periods and increase the air temperature and therefore the flux of heat from the air to the water. Both would increase the stream temperature. Because climate change would affect the stream temperatures regardless of the mine, it is necessary to consider it as part of any analysis of the impacts of the mine.*

The intent of BGC's analysis was to model potential increases in Crooked Creek stream temperature as a result of mining operations using **available** streamflow and stream temperature data. It is clearly recognized that BGC's analysis does not include all potential combinations of streamflow and stream temperature, including the potential impacts of climate change, given both the type of analysis being conducted and the length of record available.

The highest stream temperature measured at CCAC during the 2005-2011 period was 51.7°F on July 23, 2005. Given the projected increases to air temperatures for northern climates in the coming century, it is possible that higher stream temperatures will occur in the future even if the Donlin Project does not proceed. At the same time, it is important to recognize that there is a non-linear relation between stream temperature and discharge, as demonstrated in Section 2.1. Regardless, there are strategies that Donlin Gold can implement, if needed, to mitigate the Project's possible impact on stream temperature especially given that the predicted inflow losses are relatively small compared to typical stream flows during the summer months. Potential monitoring and mitigation strategies include:

- Developing a monitoring program to measure streamflow and stream temperature at several locations along the study reach.

- Cooling treated effluent, if needed, to a target temperature prior to release to Crooked Creek.
- Releasing cooler, impounded water from the Snow Gulch Dam into Crooked Creek.
- Adding groundwater from newly developed wells outside the mine area.
- Assessing options to reduce the potential for the loss of water from the hyporheic zone of Crooked Creek due to the dewatering wells.

2.6. Comment 6 – Uncertainty in the Projections

On Pages 4, 5, and 6 of his report, Dr. Meyer states that BGC should have considered uncertainty for the following variables:

- Higher effluent temperatures
- Lower flow on Crooked Creek, which could make moderating temperatures on the effluent more difficult
- More cold water removed due to dewatering than the estimated 0.79 cfs.

The comment on higher effluent temperatures is addressed in Section 2.4. Effluent temperatures can be controlled by Donlin Gold and therefore represents a potential mitigation strategy.

We assume the second bullet refers to issues already addressed in Sections 2.1 and 2.2.

The final bullet refers to BGC's model assumption that the pit dewatering wells could remove 0.79 cfs from the hyporheic zone of Crooked Creek during operations, with the temperature of the captured water assumed to be at a typical groundwater temperature of 35.6°F. It is first noted that in BGC's analysis of September 28, 2021, a loss in Crooked Creek water of 2 cfs was entered into the calculation, rather than the actual value of 0.79 cfs. At the same time, the model results did not account for the potential loss of groundwater flows in smaller tributaries adjacent to the open pit BGC, May 6, 2016). From south to north these tributaries are Unnamed SE1, Omega Gulch, Queen Gulch, and Snow Gulch (see Figure 1 in BGC, May 6, 2016). Total average groundwater loss from these tributaries is approximately 0.34 cfs over the life-of-mine. Combined with the Crooked Creek losses of 0.79 cfs, the average loss in groundwater inflows is then 1.13 cfs. Looking at the maximum annual values over the life-of-mine, which would occur in about Year 20 (Table 1 of BGC, May 6, 2016), this value of 1.13 cfs increases to 1.66 cfs, which is less than the 2 cfs used in the September 28, 2021 report. Therefore, this effectively results in another area of conservativeness in the calculations – using a number above the predicted maximum annual value.

BGC's groundwater model analysis documented in the May 6, 2016 memorandum did include a sensitivity analysis where the alluvium hydraulic conductivity (K) was increased by a factor of 5. BGC found that the results were similar to those of the base case, with the exception that during the early Mine Years (-1 to 3) reductions in groundwater discharge and increases in stream leakage were higher for the sensitivity scenario. The greater alluvium K resulted in a quicker lowering of heads due to dewatering; however, the bedrock K, which remained unchanged from

the base case run limited the overall rate of groundwater flow towards the pit (i.e., limits the overall impacts).

If the amount of captured Crooked Creek streamflow and tributary groundwater flows is greater than anticipated, then the modelled maximum stream temperature would increase. However, any excess water captured by the pit dewatering wells would be sent to the WTP and discharged, as the mine is projected to operate with a water surplus. Further, as noted in Section 2.4, the assumed temperature of the treated effluent is conservative given its predominantly groundwater origin and the fact that Donlin Gold could control the temperature of the treated effluent.

3.0 CLOSURE

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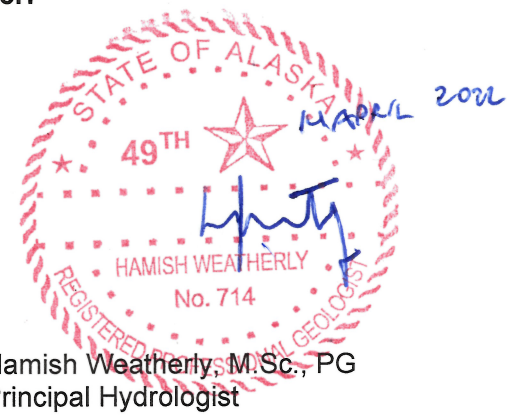
Yours sincerely,

BGC ENGINEERING INC.
per:



Hamish Weatherly, M.Sc., PG
Principal Hydrologist

Reviewed by:

Trevor Crozier, M.Eng., P.Eng. (BC)
Principal Hydrogeological Engineer

HW/TWC

REFERENCES

BGC Engineering Inc. (2021, September 28). *Donlin Project, Analysis of Crooked Creek Streamflow Temperature (Draft)* [Report]. Prepared for Donlin Gold LLC.

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Earthjustice. (2022, March 29). *Donlin Gold Mine Certificate of Reasonable Assurance*. Letter to Alaska Department of Environmental Conservation, Division of Water.

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Watt, W.E. (Ed.). (1989*). Hydrology of floods in Canada: a guide to planning and design*. Ottawa, Canada: National Research Council Canada, Associate Committee on Hydrology.

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CURRICULUM VITAE

HAMISH WEATHERLY, M.Sc., P.Geo.
Principal Hydrologist

Education

M.Sc., Geological Sciences, University of British Columbia (1998)

B.Sc., Applied Earth Sciences, University of Waterloo (1996)

Experience

2005-Present Principal Hydrologist, BGC Engineering Inc.

2001-2005 Hydrologist and Fluvial Geomorphologist, KWL Associates Ltd.

1999-2001 Research Associate, University of British Columbia

1996-1998 Slope Stability Analyst, EBA Engineering

Affiliations

Engineers and Geoscientists of British Columbia (P.Geo.)

Association of Professional Engineers and Geoscientists of Alberta (P.Geo.)

Professional Geoscientists Ontario (P.Geo.)

American Institute of Professional Geologists (CPG)

State of Washington (Licensed Geologist)

State of Alaska (Professional Geologist)

Years of Relevant Experience: 25

Mr. Weatherly's main areas of expertise are hydrology and fluvial geomorphology. He has worked extensively on the development of water management plans for proposed, in construction and existing mines, as well as closure activities. This work includes diverse climatic environments such as Alaska, Canada, Chile, Argentina, Russia, and the Dominican Republic. Hamish has been involved in all aspects of water management including the development of site water balance models, water management strategies (in wet, arid and northern environments), and the design of infrastructure such as pond volumes, pumping capacities, diversion channels and spillways. Hamish has also completed extensive work on channel stability problems in Western Canada, with a particular emphasis on anthropogenic and natural influences on channel planform and sediment transport rates. Mr. Weatherly's geomorphology expertise is complemented by his knowledge of river engineering including:

- hydrologic analysis for the design of bank protection works, diversion channels, etc.
- hydraulic assessment of bridge, pipeline and culvert crossings
- hydraulic modeling of flooding hazards
- the integration of river morphology and flow hydraulics in assessing bank erosion and scour.

River and Creek Studies

Lytton Creek Fire, BC, Canada (2021)

Project manager and technical review for a detailed post-wildfire natural hazard risk assessment of five creeks impacted by the Lytton Fire in 2021. The work included: quantifying changes in clearwater peak flow; estimating post-wildfire debris-flow probability and magnitude with associated modelling; compiling elements at risk; and completing a partial risk assessment for selected elements at risk. The work was completed for the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

Lake Koocanusca, BC, Canada (2020)

Project manager and technical lead for the evaluation of a proposed dam on Lake Koocanusa, a reservoir impounded by the Libby Dam in Montana. Local residents and water users have expressed concern regarding the impact of operational changes on summer water levels in Lake Koocanusa. Therefore, they proposed construction of a dam across the lake directly upstream of the U.S. border to maintain the reservoir level at a specified level. Hamish evaluated the impacts of the dam operations on lake level, assessed the impacts of the proposed dam, and provided a high-level cost estimate.

Chawuthen Creek, BC, Canada (2020)

Project mananger and technical lead for a hydrotechnical and geomorphic assessment of the Chawuthen Creek culvert crossing of Highway 1 near Hope BC. The purpose of this study was to assess the capacity of the culvert, the debris risk to the structure, and to evaluate whether mitigation measures are warranted. The work was conducted for MoTI and included a hydrologic assessment with an adjustment for climate change.

Skaret Creek, BC, Canada (2019)

Hamish was retained by the BC Ministry of Justice (MoJ) to provide an independent opinion of the geomorphology and hydrology of the Skaret Creek watershed. At issue was an unauthorized diversion of Skaret Creek in 1993 that a homeowner alleged resulted in sporadic flooding of their property. Air photo interpretation was an important component of the analysis. The MoJ was successful in this case and the claim was dismissed.

Zeballos, BC, Canada (2018 to 2019)

The Village of Zeballos is located on a river fan-delta, which is subject to the combined hazards of coastal (i.e., ocean-borne) and riverine floods. In addition, Zeballos is surrounded by steep mountainsides, especially on the eastern flanks of the Village where bedrock underlain slopes rise to almost 800 m. These slopes are prone to rock fall, rock slides and debris flows. BGC was

retained to characterize the fluvial, ocean, and hillslope geohazards, with the objective of transparently comparing the risks associated with each. Hamish was the project manager and hydrotechnical lead for this project.

Flood and Geohazard Risk Review, Southwestern Alberta, Canada (2013 to 2015)

Hydrotechnical lead/review for a risk-based prioritization of steep creek fans, encroachment and flood hazards in a 70,000 km^2 region of Southwestern Alberta. The assessment included the first complete inventory of over 700 fans intersecting major roads or development, and analysis of encroachment and flood inundation hazards affecting 3,400 linear km of highways.

Albion and Road Thirteen Dike, BC, Canada (2012 to 2013)

Project manager and hydrotechnical lead for a flood hazard and risk assessment of the Albion Dike. This dike protects a largely industrial area adjacent to the Fraser River in Maple Ridge, BC.

Kootenay River, BC, Canada (2009 to 2012)

Project manager and hydrotechnical lead for a flood risk study completed for the Kootenay River south of Kootenay Lake (Creston Valley). This work was conducted for the Lower Kootenay Band and the end product was a floodplain management plan that balances flood risk management with consideration of economic, ecological, social, and cultural values. The key deliverable was a floodplain management plan (FMP) that could be realistically implemented by the local community. The work occurred over a four year period (2009 to 2012) and included: hydrologic analysis hydraulic modelling assessment of bank erosion, dike stability and evaluation of repair costs for almost 100 km of diking economic consequence assessment of valley-wide flooding due to a dike breach an environmental assessment and quantitative flood risk assessment (QFRA), including a cost-benefit analysis, to evaluate various strategies for flood management and mitigation.

Upper Clowhom River, BC, Canmada (2010)

Geomorphic analysis of the impacts of a run-of-river project on sediment transport rates and channel morphology (Upper Clowhom River, BC).

Donlin Gold Mine, Alaska, USA (2010)

Analysis of potential bank erosion due to waves generated from barges, Lower Kuskokwim River, Alaska.

Lower Nooksack River, Washington, USA (2006)

Sediment budget (bedload) for a 35 km reach of the Lower Nooksack River, Washington State.

Lilloet River, BC, Canada (2001 to 2002)

Lower reaches of Lillooet River have been severely affected by engineering works over the past 60 years, including meander cutoffs, base lowering of Lillooet Lake, dyking and extensive bank protection. Historic changes in channel cross-section and planform (using orthorectified airphotos dating back to 1947) were analyzed to determine to determine sediment transport rates, and predict future trends in bank erosion and channel stability. This work was conducted for the Pemberton Valley Dyking District.

Lower Fraser River, BC, Canada (1999 to 2001)

Assisted in the development of a sediment budget for a 60 km reach of the Lower Fraser River using bathymetric surveys from 1952, 1984 and 1999. Analysis of potential channel changes at a number of bank erosion sites on Lower Fraser River using channel mapping that extends back to 1913.

Hydrologic and Hydraulic Studies – Mining

Asanko Gold Mine, Ghana (2021)

Member of an independent tailings review board (ITRB) for the tailings storage facility (TSF) at the Asanko Gold Mine in central Ghana. Hamish's role on the board includes water balance and hydrotechnical aspects of the TSF design and operation.

Pamour Project, Ontario, Canada (2021)

Project manager and technical lead for the detailed hydrotechnical/geotechnical design of water management infrastructure at the Dome Mine near Timmins. Contact water ditches and containment structures are required to collect surface and near-surface runoff from two areas located down gradient of exsiting waste rock facilities (WRFs). Design elements included a diversion channel, an HDD pipe to convey contact water to an open pit, and vinyl sheet pile cutoff wall for containment of contact water. Vinyl sheet pile is proposed at one of the sites due to a thick sequence of organics (up to 5 m thick) overlying a glaciolacustrine unit.

Kumtor Gold Mine, Kyrgyz Republic (2020-2021)

Technical lead for the development of a monthly water balance model (WBM) for the TSF and an hourly WBM for the Central Pit. A watershed area of about 15 km^2 report to this pit, of which 6 km^2 is glaciated. Annual dewatering volumes are on the order of 20 Mm^3. Seasonal melt of the glaciers is the primary source of runoff to the pit with precipitation being of lesser significance. The pit water system is represented by a combination of sumps, ditches, pumps (with a combined capacity of about 10,000 l/s), dewatering wells and pipelines. Runoff from snowmelt and glacier melt was simulated with an hourly timestep in GoldSim using an energy-

based model based on the SNOW module within the Hydrologic Simulation Program Fortran (HSPF) package. Model calibration was provided by annual mass balance surveys of the upslope glaciers and daily dewatering volumes. The model was used to assess whether the existing dewatering system is suitably sized to prevent the base of the open pit from being inundated.

Porcupine Gold Mines, Ontario, Canada (2019-2021)

Project manager and technical review for the development of a WBM and water management plan (WMP) for the proposed expansion of the Porcupoine Gold Mine. The WBM was developed in GoldSim with a daily timestep and covers construction through post-closure. The WBM includes the tailings management area (TMA), the surrounding catchments of the Porcupine River, and the Pamour area. The latter is an area of former mining which includes several TMAs, WRFs and an open pit, which has slowly filled with runoff since the cessation of mining in the late 2000s. The WBM is actively being used to develop dewatering and treatment strategies for the contact water accumulating in the open pit.

Resolution Copper, Arizona, USA (2017 to 2020)

Technical lead to develop a WBM for the proposed Resolution Copper Mine (RCM). RCM is a joint venture owned by Rio Tinto and BHP Billiton formed to develop and operate an underground copper mine near Superior, Arizona. As part of the EIS (Environmental Impact Statement) for the project, streamflow impacts needed to be quantified for five mining alternatives. The Australian Water Balance Model (AWBM) was calibrated to regional and local streamflow data, and then applied to the five alternatives to quantify potential impacts to streamflow for both tributaries and major valley bottom rivers.

Pascua, Chile (2017 to 2021)

Technical lead to develop a snowmelt and hydrological model for various locations in the Rio del Estrecho at the proposed Pascua mine site. An energy balance snowmelt module developed by BGC for use in GoldSim (HSPF-SNOW module) was used to simulate daily snowmelt and glacier melt volumes, while a modified version of the AWBM was used to route the melt volumes to the downstream river network. Model results were used for both a pre-feasibility study and an in-process Environmental Impact Assessment, which is required for closure of the site.

Veladero Mine, Argentina (2016 to 2017)

Technical lead for the development of a snowmelt prediction model in support of operational aspects related to the water management of the Heap Leach Facility (HLF) at the Veladero mine site. The request followed well above average snowpacks developing in both 2015 and 2016. The snowmelt modelling exercise was approached using two different models: an energy-based model based on the SNOW module within the Hydrologic Simulation Program Fortran (HSPF) package and the temperature index GoldSim-SRM model. The energy balance model provided a superior fit to the observed snowpack evolution.

Brucejack Gold Mine Project, BC, Canada (2014 to 2019)

Development of a water management plan and site-wide WBM for a proposed underground gold mine in northern BC. The work included feasibility-level assessments for Environmental Assessment (EA) and Mines Act (MA)-Environmental Management Act (EMA) permitting. Hydrologic and hydraulic design of a contact water pond and a low level weir at the lake outlet. The project received final provinical and federal permits in 2017, and is currently in operation.

Faro Mine Site, Yukon, Canada (2016 to 2020)

The Faro Mine Site is an abandoned zinc mine located in northern Canada. The mine site is currently under care and maintenance, but an urgent project is currently being completed to improve water quality in the receiving environment. The objective of the North Fork of Rose Creek Realignment Project is to separate non-contact water from a 124 km^2 watershed and contact water seeping from historic waste rock dumps. To support separation between the non-contact NFRC flows and impacted seepage water, a non-contact diversion channel is being designed to an IFC level. The diversion channel will be raised above the valley floor to provide vertical separation from the contact water. Hamish is the hydrotechnical lead for this project: design elements include an ice pilot channel, a steep step-pool section (5%) and fish habitat considerations. The diversion channel is currently under construction

Kootenay West Mine (KWM), BC, Canada (2016 to 2021)

Hydrotechnical lead for federal and provinical permitting of a proposed gypsum quarry located in southeast BC. The work has involved: detailed design of hydrotechnical structures (two sedimentation ponds, contact water collection ditches, diversion ditches, debris flow berm), a site-wide WBM, a geohazards asessment (two of the watercourses are subject to debris flows), and a water management plan for all phases of the project – construction through post-closure. The project is currently under construction. Hamish has provided the client with ongoing technical support during the permitting process, responding to numerous information requests (IRs) from provincial regulators.

Pipeline and Cortez Hills Mines, Nevada, USA (2015)

Barrick operates the Pipeline and Cortez Hills mine complexes as part of the overall Cortez Operations in southern Crescent Valley, Nevada. The mineralized zones occur below the historical water table at both the Pipeline and Cortez Hills complexes, so dewatering is required in advance of mining. Hamish developed a water balance model to evaluate the potential impacts to a regional creek from the simulated groundwater discharge reduction.

Giscome Quarry, BC, Canada (2014 to 2016)

Hydrotechnical lead for federal and provinical permitting of a limestone quarry located near Prince George, BC. The work involved detailed design of four sedimentation ponds, including pipeline and pumping infrastructure, a site-wide WBM and a water management plan for all phases of the project – construction through post-closure. Hamish provided the client with ongoing technical support during the permitting process. The project was issued an Environmental Assessment Certificate (EAC) by the Province in 2016.

Ajax Mine Project, BC, Canada (2013 to 2017)

Technical lead for development of a site-wide WBM for a proposed copper mine outside of Kamloops, BC. The work included a detailed WBM and water management plan for provincial EA and ME-EMA permitting. This site is complicated in that much of the streamflow is generated at higher elevations, upgradient of the mine site, while local tributaries show no evidence of surficial runoff

New Afton Mine, BC, Canada (2012 to present)

Technical lead for the ongoing development and calibration of a WBM for the New Afton Mine in Kamloops, BC. This underground mine has subaerial tailings disposal and uses fresh water from the Thompson River, which is a sensitive resource.

Detour Lake Gold Mine, Ontario, Canada (2012 to 2020)

Technical lead for development and ongoing calibration of a WBM for Detour Lake Mine in northern Ontario, which began production in January 2014. The model is being used to guide future development of the facility (a total of three tailings cell are currently proposed) and the potential need for water treatment.

Porcupine Gold Mine, Ontario, Canada (2012 to present)

Technical lead for development and ongoing calibration of a WBM for Porcupine Gold Mine in northern Ontario. The probabilistic WBM is used by operations to determine the extent of water treatment of supernatant tailings pond water in late summer and fall. The guiding principle of water management is to prevent spills of tailings water to the environment. Hamish has also provided both technical review and technical design for ongoing raises of the TMA spillway.

Donlin Gold Mine, Alaska, USA (2007 to present)

As hydrotechnical lead, Hamish has been involved with all hydrotechnical aspects of the proposed Donlin Gold Project in Alaska, USA since 2007. This work has involved: development of a calibrated site-wide WBM; development of water management strategies; peak flow estimates; detailed hydraulic design for surface water infrastructure; dam breach analyses. Numerous iterations of the mine plan have been assessed at PFS, FS, and permitting levels. An EIS was published in 2018. Hamish provided support to Donlin Gold through this environmental review process, as numerous questions were brought forward by regulators on an ongoing basis. In 2021, Hamish assessed potential changes in streamflow temperature in Crooked Creek, which is the main environmental receptor located downgradient of the proposed project.

Mildred Lake, AB, Canada (2008 to 2014)

Hydrotechnical lead for development of a detailed closure drainage plan (CDP) for Syncrude's Mildred Lake Operations in the Oil Sand Area of Fort McMurray. The work estimating streamflows for a closure landscape using the hydrologic model – Hydrologic Simulation Program-Fortran (HSPF), which has been calibrated to site conditions. The synthetic streamflows were then used for detailed channel and end pit lake (EPL) design. As evaporation can exceed precipitation is many years, soil moisture storage is an important component of the hydrologic cycle. Several iterations of the CDP have been developed since 2008.

Gibraltar Mine, BC, Canada (2013)

Technical lead for detailed hydrotechnical design of a 6 km containment ditch at Gibraltar Mine in central British Columbia. The ditch is used to contain surface contact runoff from a waste rock dump. Erosion control included sediment ponds, riprap and turf-reinforced mats (TRMs).

Cochenour Gold Mine, Ontario, Canada (2011 to 2013)

Development and calibration of a WBM for Cochenour Mine in northwestern Ontario. Also development of a tailings management plan, which involved hydrologic routing and hydraulic calculations for spillways.

Natalka Gold Project, Russia (2012)

Development of a feasibility-level WBM for the Natalka gold deposit in Russia, as technical lead. This work included teaching a 2-day course on WBMs and water management strategies to Polyus Gold employees in Moscow, Russia. Technical issues included constructing a 10 km long, low-gradient freshwater diversion channel through permafrost terrain.

Pueblo Viejo Gold Mine, Dominican Republic (2008 to 2012)

Hydrotechnical lead for detailed hydrologic and hydraulic design (storage and pumping capacity, spillways) of cofferdams (2) and dams (3) for the Pueblo Viejo project in the Dominican Republic. BGC was the engineer of record for these structures, construction of which was completed in 2012. Annual rainfall in the area is around 2000 mm with the hydraulic design criteria governed by high

intensity storms of short duration and Class IV hurricanes in the Caribbean. Additional work completed included: development of a calibrated site-wide WBM and development of water management strategies for operations (with a particular emphasis on extremely wet and dry periods). Production at this mine started in late 2012.

Cerro Casale, Northern Chile (2009 to 2012)

This proposed gold mine is located in northern Chile in a region with low annual precipitation on the order of 80 to 150 mm. The work involved feasibility-level studies for the proposed mine including: development of a calibrated site-wide WBM; development of water management strategies; peak flow estimates; and hydraulic design for surface water infrastructure (freshwater diversion channels and contact water collection ditches).

Wabush Mine, Labrador, Canada (2010 to 2011)

Project manager and hydrotechnical lead for detailed design and construction supervision of two settling basins at the Wabush iron ore mine in Labrador. The first phase of the project involved the evaluation of repeated TSS exceedances at the mine site and the identification of mitigation options. Settling ponds with flocculent dosing was identified as the only viable option to reduce TSS levels. Design and construction of these ponds was completed in late 2011.

La Coipa Mine, Northern Chile (2010 to 2011)

This operating gold mine is located at the southern fringes of the Atacama Region of northern Chile, a very arid region with less than 100 mm of annual precipitation. A groundwater contamination plume, related to tailings disposal, extends downstream of the mine site in an alluvial aquifer. Recharge estimates were conducted for the site as part of an assessment of the groundwater contamination.

Fedorovo Project, Northwest Russia (2009 to 2010)

This proposed gold mine is located in northwest Russia above the Arctic circle. The scope of work included: development of a calibrated site-wide WBM; development of water management strategies; peak flow estimates; and hydraulic design for surface water infrastructure (freshwater diversion channels and contact water collection ditches).

Pascua Lama Project, Chile, (2006 to 2007)

Investigation into cryosphere reserves (glaciers, permafrost and rock glaciers) at the proposed gold mine in the Argentine Andes. The work involved the identification of cryosphere reserves at this high altitude, arid site, followed by an assessment of the role of these reserves in contributing runoff to the downstream stream network.

Dam Outbreak Studies

Hamish has been involved in numerous dam outbreak studies in his career for both natural landslide dams and constructed dams. Critical to this process is the development of a breach hydrograph, followed by routing the flood downstream. Hamish has used a number of modelling packages over the years but is currently focused on GoldSim and HEC-HMS to generate breach hydrographs and FLO-2D and HEC-RAS 2D for flood routing. Recent projects include:

- landslide dam outbreak flood (LDOF) at Glacier Creek, WA, USA (2020)
- tailings dam outbreak flood at the Kumtor Gold Mine, Kyrgyz Republic (2020)
- tailings dam outbreak flood at Porcupine Gold Mine, Ontario, Canada (2019-2021)
- tailings dam outbreak floods at Pueblo Viejo Gold Mine, Dominican Republic (numerous from 2013 to present)
- LDOF at Elbow River, AB, Canada (2019)
- LDOF at Britannia Creek, BC, Canada (2018)
- LDOF at Cougar Creek, BC, Canada (2018)

Pipeline Studies

River Crossing, Wisconsin, USA (2021)

Hamish has been retained by legal counsel of Enbridge Pipelines to provide an independent opinion of the geomorphology, hydraulics and hydrology of a river crossing in Wisconsin intersected by the Line 5 pipeline.

River Crossings, North America (2011 to present)

Hydrotechnical and geomorphic assessment of existing pipeline river crossings throughout western North America (British Columbia, Alberta, Montana, Wyoming, Missouri, Kansas) for numerous clients including Enbridge, Plains Midstream, Terasen Gas, Kinder Morgan, Pembina, Alliance, Specta Energy, and Suncor. Assessments include evaluation of potential scour depth for different return period floods and bank erosion rates that could expose or rupture pipelines. Bank erosion is assessed using

historical air photographs and a bank erosion model developed internally by BGC. Hamish is BGC's main hydrotechnical lead and reviewer for a comprehensive program, which typically includes on the order of 100 detailed studies a year.

Mitigation Design, North America (2011 to present)

Hydrotechnical lead and reviewer for mitigation design of numerous pipeline exposures in North American rivers that are subject to scour and bank erosion.

Line 9B Reversal, Ontario, Canada (2015)

Senior hydrotechnical review for over 300 river crossings along Line 9B, which is an existing 639 km long pipeline. This pipeline section runs from North Westover, Ontario to Montreal, Quebec, and Enbridge has applied to the National Energy Board (NEB) to reverse the flow of oil in the pipeline. As part of this application, hydrotechnical hazards have been assessed in detail at each watercourse rossing. This work has included floodplain delineation, peak flow estimates, scour assessments for the regulatory flood, and geomorphic characterization.

Trans Mountain Expansion Pipeline (TMEP), BC, Canada (2014 to present)

Senior hydrotechnical review for over 800 river crossings along the TMEP for Kinder Morgan. This pipeline would twin an existing pipeline, which runs from northwest Alberta to Vancouver, BC. Hazards assessed include scour, bank erosion, avulsion and channel degradation. The primary deliverable of this work is recommended burial depths and setback distances for sagbends. This work has included a quantitative risk assessment (QRA) of all geohazards, including hydrotechnical hazards.

Prince Rupert Gas Tramsission Line (PRGT), BC, Canada (2013 to 2015)

BGC's technical lead for detailed hydrotechnical (scour, bank erosion, avulsion and channel degradation) assessments for the proposed PRGT. The approximately 900 km pipeline is expected to deliver natural gas from a point near the District of Hudson's Hope to the proposed Pacific NorthWest LNG facility within the District of Port Edward on Lelu Island. The primary deliverable of this work was recommended burial depths and setback distances for sagbends.

Pacific Trails Pipeline (PTP), BC, Canada (2013)

Hydrotechnical lead for detailed river crossing assessments for the proposed gas pipeline in British Columbia, the PTP, including the evaluation of aerial crossings. The PTP is a proposed 480 km natural gas pipeline that will deliver gas from Summit Lake, B.C. to the Kitimat LNG facility site at Bish Cove on the northwest coast of British Columbia.

Donlin Gold Mine, Alaska, USA (2012)

Evaluation of potential scour depths for a proposed gas pipeline in Alaska, USA, which would deliver gas to the Donlin Gold Project.

Cerro Casale, Chile (2010)

Conducted a hydrotechnical assessment of river crossings and provided recommendations regarding burial depth and sagbend locations for two mine-related pipelines (total length = 335 km) and a transmission line that cross high Andean terrain in northern Chile (Cerro Casale).

Steep Creek Investigations

Glacier Creek, Washington, US (2019-2021)

Project manager and main hydrotechnical lead for a hazard and risk assessment of debris floods at Glacier Creek in the town of Glacier, WA. Significant debris floods in 1989 and 1990 caused extensive damage on the fan and almost resulted in the severing of Highway SR542. To mitigate these hydrogeomorphic risks, the current bridge (which constricts the floodplain) is to be replaced with a single 270 m structure that spans the entire width of the active floodplain. BGC was retained to identify and evaluate alternative levee configurations that would: reduce flood hazard and risk for the community of Glacier, restore natural alluvial fan processes, and improve critical salmon spawning and rearing habitat on the alluvial fan.

Various Creeks, RDCK, BC, Canada (2019-2020)

BGC was retained by the RDCK to conduct detailed hazard assessments of nine steep creeks in the Kootenays that are subject to debris flows and debris floods. Frequency-magntiude relations were developed for return periods of up to 500 years, and numerical modellinmg conducted. Hamish was the primary technical review for the nine studies.

Various Creeks, District of North Vancouver, BC, Canada (2016)

The District of North Vancouver (DNV) retained BGC to complete quantitative flood, debris flood and debris flow risk assessment and conceptual risk reduction designs for 35 steep creeks within the District of North Vancouver. The lower portion of these creeks flow through areas containing over 20,000 buildings and a network of roads, utilities, and stormwater management infrastructure. Technical lead for the flood and debris flood hazard assessment, which included estimates of the peak flow threshold for full mobilization of the channel substrate for debris-flood prone creeks.

Exshaw Creek, AB, Canada (2014 to 2015)

Project manager and main hydrotechnical lead for a hazard and risk assessment of debris floods at Exshaw Creek and Jura Creek in the town of Exshaw, AB. A significant debris flood in June 2013 deposited over 20,000 m^3 on the fan and damaged a number of homes. Debris flood magntiude (peak flows and sediment volume) was defined for various return periods. A detailed risk assessment was also conducted based on hydraulic modelling, followed by conceptual design options to mitigate againts future hydrogeomorphic events.

Cougar Creek, AB, Canada (2013 to 2014)

Detailed forensic and hazard assessment of debris floods at Cougar Creek in Canmore, AB. A significant debris flood in June 2013 deposited 90,000 m^3 on the fan and damaged a number of homes. Short-term mitigation was recommended, including a debris net at the fan apex, bank protection with cabled concrete mats and grade control structures. These works were constructed in 2014.

Town of Canmore, Alberta, Canada (2013 to 2014)

Forensic analyses for 9 creeks within the Town of Canmore that were impacted by debris floods and debris flows in 2013.

Cheekye River, BC, Canada (2010 to 2011)

Debris flow modelling (FLO-2D) of Cheekye Fan, Brackendale for return periods of up to 1:10,000 years.

Swift Creek, Washington, USA (2004 to 2005)

Investigation of a large earthflow at Swift Creek in Whatcom County, Washington State and associated sedimentation and debris flow hazards.

Canyon Creek, Washington, USA (2002 to 2003)

Debris flood study for Canyon Creek, Whatcom County, Washington including: 1-D modelling of landslide dam outbreak floods 2-D modelling on Canyon Creek fan for 1:500 year event determination of debris flood magnitude for various return periods and preparation of a debris flood hazard map.

Jones Creek, Washington, USA (2003 to 2004)

Detailed debris flow investigation of Jones Creek, Whatcom County, Washington including radiocarbon dating of debris flow deposits on the fan.

District of North Vancouver, BC, Canada (2002 to 2003)

Detailed debris flow and debris flood studies of ten creeks within the District of North Vancouver, BC. This work included debris flow modelling to delineate the fan hazards of Mackay Creek and Percy Creek in the District of North Vancouver, and Jones Creek in Whatcom County.

Gravel Removal Studies

Lower Fraser River, BC, Canada (2002 to 2006)

Design of gravel removals from various gravel bars on Lower Fraser River from 2002 to 2006. Excavations were designed to minimize adverse habitat and morphological impacts.

Lower Nooksack River, Washington, USA (2005 to 2006)

Development of a Sediment Management Plan for Lower Nooksack River, Whatcom County, Washington State.

Lillooet River, BC, Canada (2004 to 2005)

Development of a Sediment Management Plan for Lillooet River within the town of Pemberton.

Gravel Removal Design, BC, Canada (2003 to 2004)

Design of gravel removal at Fitzsimmons Creek, Whistler and Lynn Creek, District of North Vancouver.

Selected Publications and Conferences

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ATTACHMENT 2

Ramboll US Consulting, Inc., "Response to Mercury Comments in Letter from Orutsararmiut Native Council dated March 29, 2022" (April 14, 2022)

RAMBOLL

ENVIRONMENT
& HEALTH

MEMO

To	Enric Fernandez, Donlin Gold; Ron Rimelman, Novagold; Eric Fjelstad, Perkins Coie
From	Krish Vijayaraghavan, Christopher Stubbs, and Alison O'Connor, Ramboll
RE:	Response to Mercury Comments in Letter from Orutsararmiut Native Council dated March 29, 2022

Date April 14, 2022

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We have provided below our responses to comments from Orutsararmiut Native Council (ONC) on the October 2021 Ramboll mercury report. Our responses are grouped for clarity.

1. Response to comments related to conservativeness, uncertainty, "outcomes close to standards", and "ignoring real-world conditions that would increase the risk of violations"

The Ramboll (2021) mercury study (hereafter, Study) uses real-world measurements of site conditions and, where data are not available, it uses conservative assumptions. Even with these conservative assumptions, the Study concludes that the Donlin Gold Mine (Project) will have negligible (if any) adverse impacts on stream mercury concentrations.

The Study supplements the Final Environmental Impact Statement (FEIS) analysis by incorporating new Project site data, new studies published since the FEIS was issued, peer reviewed literature and other publicly available reports to better characterize site conditions to make a more accurate estimate of the potential mercury concentrations in the Crooked Creek watershed resulting from the Project.

Examples of site-specific measurements applied in the calculations include:

- New sampling data for water, soil, sediment, and Crooked Creek suspended particulates collected in the summer of 2021 (Arcadis 2021), as well as prior water quality data, all in the Crooked Creek basin.
- Long-term streamflow records that incorporate a wide range of actual conditions observed in the Crooked Creek basin.
- New solar radiation data at the Project site.
- Waste rock and ore mercury concentrations at the Project site.

In any modeling there are a variety of valid methods for characterizing uncertainty. In environmental risk assessment, conservative estimates can be used as a method of accounting for uncertainty because they present a high-end, rather than central tendency, estimate of outcomes. This Study makes conservative assumptions to determine the effects on mercury in the streams, examples of which are provided below. When these conservative assumptions are incorporated in the modeling and analysis, the outcome is a conservative estimate that likely represents the upper bounds of potential effects. Therefore, the results presented are high-end characterizations (i.e., over-estimates) of effects. Adding uncertainty values around these results would overstate the upper limit of the potential effects; hence, the calculation of uncertainty measures such as confidence intervals would not be appropriate and is not necessary.

Examples of conservative assumptions applied in the Study are provided below.

- The modeled emissions from the Donlin Gold mine pit in the Study are conservatively high because they do not account for the in-pit retention of dust particles which would lower the estimated mercury deposition of fugitive dust emissions from the Project.
- The modeled tailings pond mercury concentration is conservatively high (likely as much as seven times too high) because it does not account for Donlin Gold's plan to use mercury settling-enhanced reagents. This is discussed further below in the tailings discussion (#3).
- The Project mercury mass balance omits some activities that would reduce mercury mass loading to streams, such as the retention of stream water at the Snow Gulch reservoir and the effect of groundwater extraction for pit dewatering outside areas with runoff management.
- The mercury concentration in the Wastewater Treatment Plant (WTP) effluent is set equal to the State of Alaska Water Quality Standard (AWQS) of 12 ng/l to derive a conservatively high estimate of mercury mass loading at the WTP outfall on Crooked Creek. The mercury concentration is unlikely to be this high because the majority (~72%) of the water fed to the WTP will be groundwater which includes low levels of mercury. As described in the WRMP (SRK 2017), the WTP is designed to treat 95th percentile mercury concentrations in pit dewatering, Seepage Recovery Pond (SRS) and Contact Water Dam (CWD) source waters, and steady state concentrations from tailings storage facility reclaim (a minor source). Given the predicted flow rates from these sources during Project operation, and a 96% removal efficiency by reverse osmosis, the actual mercury concentration in WTP effluent is likely to be far lower than the AWQS.
- Estimation of mercury loading from the WTP outfall to Crooked Creek makes use of projected flow rates presented in the WRMP (SRK 2017) under the most conservative water balance analysis scenario, i.e., above average precipitation case. In addition, although the WTP is only planned to operate seasonally (WRMP Section D-2), the Project mass balance estimates mercury mass loading from the WTP with the assumption that it would operate year-round. As shown in Table ES-3 in Ramboll (2021), even with these conservative assumptions, the predicted mercury mass loading from the WTP outfall is low relative to loading from background atmospheric and geogenic sources to areas downstream of the outfall.
- The geochemical fingerprinting analysis in the Study using site-specific data including new sampling data collected after the FEIS determined that the current background contribution of atmospheric mercury to soils, sediments, and suspended particulates was too small to be

distinguished from the contribution of the background geologic sources. This supports the conclusion that Project atmospheric deposition impacts on water quality would be negligible. The baseline mercury mass balance (Table ES-2 in Ramboll (2021)) estimated a background atmospheric loading of 11% to 29% (depending on watershed) using a combination of Crooked Creek watershed data and the peer reviewed literature. Although these estimated loadings were much higher than the (negligible) contribution identified from the geochemical fingerprinting analysis using site-specific data, the estimated loadings of 11% to 29% were included in the Study to be conservative.

The predicted changes in the Study indicate that the Project would result in significantly reduced mercury mass loading in two watersheds (ANDA (Anaconda) and AMER (American)), and very small changes at DCBO (Donlin Creek below Ophir Creek), CCAC (Crooked Creek above Crevice Creek), and CCAK (representative of the entire Crooked Creek watershed), relative to current conditions. Thus, they do not suggest an increased risk of exceeding the mercury AWQS in the Project vicinity, even with the conservative assumptions described above. This is also supported by the analyses in Sections 3.4.1 and 3.4.2 of the Study, which present how the reductions in surface water flows in the vicinity of the mine described in the FEIS would be associated with decreases in average mercury concentrations in surface water in the ANDA, AMER, CCAC and CCAK watersheds and negligible impacts at DCBO and other upgradient watersheds.

2. Response to comments related to the model "seeking to eliminate the principal conservative assumptions of the FEIS" and "focused on predicting minimum mercury releases and water concentrations".

The FEIS assumed that the correlation between atmospheric mercury deposition and mercury concentration in surface water is linear in the vicinity of the Project but caveated this assumption by noting that "only a small fraction [of the mercury deposited from atmospheric sources] would be present as aqueous mercury in surface water." Additional study, data gathering, and analysis show that the FEIS assumption was very conservative and, in fact, that only a very small fraction of the atmospherically deposited mercury reaches surface waters. At the time of the FEIS, there was no empirical data at the time to quantify how much atmospheric mercury ultimately migrates to the surface water versus the input of geologic mercury. A new literature review indicated that there was significant retention and provided specific retention rates for this type of watershed. Additionally, an analysis from Arcadis (2020) showed that mercury in Crooked Creek is primarily associated with the suspended solid load and suspended iron in particular, suggesting geologic origin. Based on this information, new data were collected in 2021 to determine the geologic versus atmospheric contributions of mercury in Crooked Creek. These new results showed that mercury in Crooked Creek carried a strong geologic, rather than atmospheric, signature (Ramboll 2021, section 3.1.3), demonstrating that atmospheric mercury was strongly retained in the soils. This evidence informed the assessment of the contribution of geologic mercury to Crooked Creek (see above for details on conservative estimation) and validated the high mercury retention value estimated from the literature review. This provided a compelling scientific basis for updating the FEIS assumption. Ignoring this new evidence to maintain a prior assumption, now properly understood to be overly conservative, would be poor scientific practice. The bases for other revisions from the FEIS are documented in Table 2.2-1 in Ramboll (2021). As noted in #1 above, the Study continues to include a series of conservative assumptions that will result in higher estimate of Project impacts.

3. Response to comments related to the tailings mercury

ONC's assertion that Ramboll's "draft model significantly underestimates mercury emissions from the tailings pond, because it apparently fails to consider the cyanide in the tailings fluid" is incorrect. In fact, cyanide is accounted for in estimating mercury concentration in the tailings leachate. Tailings filtrates were generated in pilot-scale studies of the actual Project process plant operations that included treatment with cyanide, and a mercury concentration of 0.0242 mg/L was measured (Donlin Creek, 2011). This measured concentration was further increased by a factor of 3 to account for recycling of the pond water, to obtain a final tailings pond concentration of 0.073 mg/L (SRK 2017). Therefore, mercury availability due to the presence of cyanide was accounted for in the Project tailings mercury emissions calculations.

Additionally, the tailings pond mercury concentration used in the Study is conservatively high because it does not take into account the proposed use of mercury settling-enhanced reagents (i.e., University of Nevada – Reno (UNR)-921) to reduce dissolved mercury concentrations. Pilot tests of the UNR reagent added to the tailings water at a Barrick facility showed reduction of mercury concentrations to less than 0.010 mg/L (SRK 2017, p. C-26). Therefore, the use of 0.073 mg/L for the modeled tailings pond concentration is a conservative estimate – conservatively high by about a factor of seven.

The Donlin Gold tailings pond mercury emissions were reasonably estimated using best available data and robust methods as discussed in Ramboll (2021). Also importantly, increasing these emissions would not have a material impact on estimated Project water quality impacts because (i) they constitute a relatively small fraction of total Project emissions (5%, see Table 3.2-12 in Ramboll (2021)), (ii) they consist of gaseous elemental mercury which has negligible solubility in water, and (iii) the atmospheric loading contribution to creek mercury loading is very small compared to geogenic loading in this region as discussed in the Study.

The Study does not ignore the contribution to mercury "loss" (emissions) from dry tailings. It includes an assessment of mercury emissions from dry surfaces of tailings. In general, tailings mercury emissions are highly dependent on soil moisture (Eckley et al. 2011). So, the Study applies different correlations for wet and dry surfaces at the Project tailings storage facility recognizing that the moisture level affects the mercury emission flux.

The ONC comments attempt to compare measured mercury emissions from a tailings facility at a Nevada gold mine to the estimated tailings emissions for Donlin Gold. However, there are several differences between the Donlin Gold and Twin Creeks/Goldstrike mine sites which would cause lower tailings emissions at the Donlin Gold mine:

- The average mercury concentration in ore is significantly lower at Donlin Gold (1.27 parts per million (ppm)) than Twin Creeks (24 ppm[1]) and Goldstrike (24.6 ppm[1]).
- As noted by Eckley et al. (2011), lower solar radiation results in lower mercury emission fluxes. Solar radiation is typically lower at Donlin Gold than at Twin Creeks and Goldstrike. The effect of

[1] The mercury concentrations for Twin Creeks and Goldstrike were obtained from the stack test reports used for 2020 annual emissions reporting, available from the Nevada Division of Environmental Protection.

sunlight on emissions is accounted for in the Ramboll modeling using observations of solar radiation at the Donlin Gold site.

- The presence of ice cover during winter months (roughly half the year) at Donlin Gold reduces tailings emissions considerably.
- The tailings solution mercury concentration at Donlin Gold (0.073 mg/L) is approximately 15% that of Twin Creeks (0.496 mg/L; Eckley et al. 2010).

4. Response to comments related to thermal mercury emissions

ONC's assertion that the "Ramboll draft model relies on emission factor estimates from the companies making the control equipment rather than on actual emissions from operating mines like Goldstrike" is incorrect. In fact, the mercury emissions estimates for the autoclaves and carbon regeneration kiln at Donlin Gold used source test data from similar units at the Goldstrike Mine (while accounting for Project-specific stack flow data) and emissions estimates for the other units at Donlin Gold are based on the Nevada Mercury Control Program Permitting Guidance, General Industry NvMACT Determinations, which includes documented mercury emission rates for mercury control technologies (NDEP 2016) (NDEP 2016). Moreover, the modeled Project mercury speciation profiles are based on mercury speciation test data from the Goldstrike Mine. Additional details on the Project thermal emissions and reasons for differences in total emissions from the Nevada mines are provided in Air Sciences (2021, 2022).

5. Response to comments related to linearity of stream response, absorption of mercury to soil and naturally-enriched mercury in the soil

Exhibit 5 from the ONC letter concludes with the erroneous assertion that because "it is generally the case that higher concentrations of mercury in the surface soils will result in higher amounts of mercury delivered to the streams," that "twice as much mercury released from the mine will result in approximately twice as much mercury released to streams." In this response, we assume that "released from the mine" refers to mercury emissions to the atmosphere from mine-related activities. The concentration of mercury in water in the stream does depend on the overall amount of mercury in the soils surrounding the streams. However, the overall amount of mercury in those soils is not proportionally affected by changes in the atmospheric deposition resulting from any mine-related mercury emissions. The large amount of existing geologic mercury (as also noted in the ONC letter, page 6, "high concentrations of mercury occurring naturally in the environment") in the Crooked Creek area means that changes in the atmospheric deposition rate only slightly affect the total mercury in the surface soils. Moreover, there is significant retention in the soil (as also noted in the ONC letter Exhibit 5, page 8, "a good portion of the mercury is sorbed onto the surrounding soils"). Therefore, changes in the atmospheric deposition rate only minimally affect mercury concentrations in the streams. The net effect on stream water quality is negligible (and in some cases beneficial) as shown in the Study when considering Donlin Gold's runoff control measures (which reduce both geogenic and anthropogenic mercury loadings) under Project conditions.

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KRISH VIJAYARAGHAVAN

Principal

Mr. Krish Vijayaraghavan has 25 years' experience in atmospheric fate, transport and deposition modeling, with additional expertise in linkages of atmospheric deposition with watershed models and input to human health and ecological risk assessments. He has directed modeling studies on the atmospheric chemistry and deposition of mercury, sulfur, nitrogen, and other gases, exposure to airborne mercury, arsenic and selenium, and photochemical air pollution due to ozone and secondary particulate matter. He has coordinated or contributed to Environmental Impact Statements under the National Environmental Policy Act for assessments of hazardous and criteria air pollutants and precursors for mining, power plant, oil and gas, and transportation projects.

Mr. Vijayaraghavan was a co-author on the first global source attribution study of mercury and on a United Nations Environment Programme book chapter on the contribution of mercury emissions from different global source regions to deposition. He has conducted modeling studies to investigate the relationship between atmospheric mercury emissions and water column, sediment and fish tissue mercury. He has published more than 40 peer-reviewed papers in scientific journals, including more than 15 on atmospheric mercury and co-authored two technical books on mercury. He has made or co-authored over 50 technical presentations at air quality conferences and workshops. He has provided expert witness testimony on atmospheric mercury deposition, provided comments on federal mercury rules, and has chaired technical sessions on mercury at the annual Energy and Environment Conference in Arizona.

EDUCATION

1994-1996
MS, Environmental Engineering
Georgia Institute of Technology, Atlanta, Georgia

1992-1994
MS, Chemical Engineering
University of Kansas, Lawrence, Kansas

1988-1992
BTech, Chemical Engineering
Indian Institute of Technology, Mumbai

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SELECTED PROJECT EXPERIENCE

Mercury Transport and Deposition to the Florida Everglades
Published two book chapters on mercury contributions to the Florida Everglades. Conducted literature review and analysis and examined the role of long-range transport of atmospheric mercury to widespread historical mercury contamination in the fragile Everglades ecosystem.

Remedial Investigation and Feasibility Study, New Idria Mercury Mine Superfund Site
Leading the proposed mercury deposition modeling and analysis for the historic New Idria mercury mine site in California. Prepared the atmospheric work plan for the Remedial Investigation and Feasibility Study (RI/FS) to identify historic and current mercury emission sources during ore extraction, processing and disposal and model the mercury emissions to assess the effect of atmospheric dispersion and deposition on water and soil mercury concentrations.

Mercury Modeling and Analysis for Donlin Gold Mine
Led a mercury monitoring and modeling study to inform the EIS for the proposed Donlin Gold open pit gold mine in Alaska. Technical work included meteorological modeling, design of a mercury air monitoring program, preparation of mercury emission inventories for autoclave, tailings, stockpiles and fugitive dust and global, regional and local-scale mercury air modeling of the mine and other sources using AERMOD, CALPUFF, CMAQ and GEOS-Chem.

Environmental Assessment for Navajo Generating Station
Provided a diverse suite of technical services for the Environmental Assessment (EA) for the lease extension of the Navajo Generating Station in Arizona. Support included air quality modeling with AERMOD and CMAQ and analysis of air deposition data for mercury, arsenic, and selenium and other substances, assessments of mercury deposition to surface waters, and human health risk and ecological risk due to atmospheric deposition from the emission sources, and preparation of Technical Support Documents for the EA under NEPA.

Gold Mine Environmental Assessment, California
Senior technical advisor for Environmental Assessmentrequired under NEPA related to a proposed gold mine expansion in southern California. Reviewed responses to EPA comments on the prior EA and proposed modifications to the technical support documentation for the EA that included criteria pollutants and greenhouse gases. Provided oversight of the emissions inventory development and dispersion and deposition modeling for the mine.

Mercury Deposition over Great Lakes Region
Co-investigator in a study led by Environment Canada that assessed mercury air concentrations and dry deposition over the Great Lakes and neighboring states/provinces in USA and Canada including Ontario, Minnesota, Wisconsin and others. Applied and provided data from the CMAQ-MADRID atmospheric mercury chemistry transport model. Results from the study showed that models tended to over-predict surface-layer concentrations of gaseous oxidized mercury and particulate bound mercury when compared with measurements of speciated mercury air concentrations in the region. The study also examined the relative importance of the different forms of mercury dry deposition over the Great Lakes region.

Gold Mine Air Permitting and EIS, Idaho
Senior technical advisor on the air permitting and Environmental Impact Statement (EIS) required under NEPA for a gold mine in Idaho. Provided technical oversight for review of emissions inventories of criteria and hazardous air pollutants and greenhouse gases and the design of the baseline air quality analysis study. Prepared technical support document discussing the potential for tiering the assessment for proposed underground mine exploration to an existing environmental assessment.

Environmental Impact Statement for Four Corners Power Plant and Navajo Mine
Studied the potential impact of mercury, arsenic and selenium emissions from coal-fired power plants and other sources on water quality and fish tissue concentrations in the San Juan River basin in New Mexico. Prepared technical support documentation on atmospheric mercury to inform the EIS for the Four Corners Power Plant and Navajo Mine.

Environmental Impact Statement and Resource Management Plan for Oklahoma, Texas and Kansas.
Conducted air quality modeling and data analysis and prepared the air quality and climate change sections of the Environmental Impact Statement (EIS)/ Resource Management Plan (RMP) for the U.S. Bureau of Land Management (BLM) and Bureau of Indian Affairs (BIA) to guide the management of BLM- and BIA-administered lands in the states of Oklahoma, Texas and Kansas.

Mendums Pond Mercury Study
Applied a suite of atmospheric and aquatic cycling/bioaccumulation models and monitoring data to understand the contribution of deposition to mercury contamination in a remote freshwater lakein the northeastern U.S. Modeled global and local Hg transport, chemistry and deposition and subsequent Hg concentrations in the water column, sediment and fish tissue. Results were presented at the 11th International Conference on Mercury as a Global Pollutant in Edinburgh, Scotland.

Mercury Multimedia Modeling
Leading the development of a multi-media (air, surface water and ground water) model to study the human health impacts of mercury and other emissions from coal-fired power plant stacks.

Mercury Impacts in Western Australia
Evaluated the contributions of natural gas treatment facilities to mercury concentrations and deposition over a sensitive ecosystem.

North American Mercury Model Inter-comparison Study (NAMMIS)
Co-Principal Investigator in the North American Mercury Model Inter-comparison Study (NAMMIS) by US EPA, Environment Canada, New York State and US institutions to study the effect of mercury background concentrations on atmospheric mercury deposition.

Environmental Impact Statement for Greater Mooses Tooth-2 (GMT-2) Project
Conducted air quality modeling and preparing the Affected Environment and Environmental Consequences (Air Quality) chapters of the DEIS on behalf of BLM for the proposed Greater Mooses Tooth 2 (GMT2) oil wells within the National Petroleum Reserve in Alaska.

Florida Mercury TMDL Study
Assisted Florida electric utilities in a study of the sources of atmospheric mercury deposition to Florida and conducted discussions with the Florida DEP on the proposed statewide mercury Total Maximum Daily Load (TMDL) regulations. The Florida mercury TMDL was derived after examination of other TMDLs including the Minnesota statewide TMDL, the Northeast regional TMDL and the Arkansas TMDL. Performed a statistical analysis of temporal trends in mercury emissions and deposition in Florida and presented findings at the 10th International Conference on Mercury in Halifax, Canada.

Air Watershed Model Linkage
Designed, developed and applied an interface between two advanced atmospheric and aquatic models in coordination with watershed modelers to trace the fate of mercury, sulfur and nitrogen compounds from air emissions to ecosystem impacts.

Mercury and Air Toxics Standards Rulemaking
Prepared comments to USEPA for proposed mercury regulations under the Clean Air Mercury Rule and the Mercury and Air Toxics Standards.

Climate change and Regional Pollution
Conducted a NASA-sponsored research study on the relation between global climate change and regional pollution using satellite remote sensing data and models.

Multi-scale Modeling of Mercury
Conducted multi-scale (global/continental/regional) atmospheric modeling studies with mercury chemistry transport models to investigate the long-range transport of mercury and the effect of mercury emissions in the U.S. and other countries on mercury deposition in the U.S.

CAREER

2010-present
Ramboll

1997-2010
Atmospheric and Environmental Research, Inc.

PUBLICATIONS

Vijayaraghavan, K., S. Libicki, R. Beardsley, J. Jung, S. Ojha. 2020. "Modeling of Atmospheric Mercury Deposition in India." Book Chapter in "Urban Air Quality Monitoring, Modelling and Human Exposure Assessment". Eds. S. Nagendra, U. Schlink, A. Müller, M. Khare. Springer Transactions in Civil and Environmental Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-15-5511-4_13.

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RAMBOLL

ENVIRONMENT & HEALTH

CHRISTOPHER M. STUBBS, PHD, PE

Principal

Dr. Chris Stubbs has over 20 years of experience in environmental science and engineering, with special emphasis on hydrology and chemical fate and transport in the environment. Specific areas of expertise include groundwater modeling, statistical analysis and data science, and exposure analysis and human health risk assessment. He has extensive experience with the investigation and clean-up of large and complex contaminated sites. Dr. Stubbs has been an instructor for courses on groundwater statistics and geospatial statistics for the Interstate Technology & Regulatory Council.

EDUCATION

1996-2000
PhD in Hydrology and Water Resources Engineering
Massachusetts Institute of Technology, Cambridge, MA, USA

1994-1996
MS in Environmental Engineering
Massachusetts Institute of Technology, Cambridge, MA, USA

1994-1996
MS in Technology and Policy
Massachusetts Institute of Technology, Cambridge, MA, USA

1984-1988
BA in Physics
University of California, Berkeley, CA, USA

CAREER

1989-1992 Superfund Project Manager, US Environment Protection Agency

REGISTRATIONS

Professional Civil Engineer, California

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PROJECTS

Remedial Investigation and Feasibility Study, Former Perchlorate Manufacturing Facility
Performing a CERCLA remedial investigation and feasibility study (RI/FS) of a 350-acre chemical manufacturing facility that formerly produced perchlorate located in Clark County, Nevada. Serving as a Project Director, responsible for the RI and risk assessment of soil, soil gas, groundwater, and surface water contamination over a 5,000-acre study area. Chemicals of concern include perchlorate, chromium, and volatile organic compounds. Ramboll developed a 3D geostatistical model of chemical distribution and geological structure to illustrate the conceptual site model and support the RI/FS. The project includes development of a groundwater flow and contaminant transport model that considers complex geology and stream-aquifer interactions. Ramboll is also performing a pilot test of in-situ remediation using zero valent iron (ZVI).

Remedial Investigation and Feasibility Study, New Idria Mercury Mine Superfund Site
Performing the RI/FS for the investigation and evaluation of potential remedies at one of the largest former mercury mines in the US. Located in central California, major issues include the control of acid mine drainage and the investigation of the impacts of atmospheric deposition of mercury released during ore processing.

Groundwater Modeling, MTBE Site
Developed a 3D numerical groundwater model of an MTBE-contaminated Charnock Basin in the Los Angeles area resulting from leaking underground storage tanks. Evaluated cleanup times and the performance of remedial alternatives for an integrated system of ground water supply for municipal use and regional MTBE remediation.

Statistical and Geochemical Evaluation, San Fernando Valley Superfund Site
Evaluated statistical trends and geochemical conditions as part of the quarterly groundwater monitoring program at a site within the San Fernando Valley Superfund site impacted by VOCs and hexavalent chromium. Results were submitted to the USEPA and Regional Water Quality Control Board.

Groundwater Modeling, Perchlorate Site
Developed an updated 3D regional groundwater model of the Santa Clarita Basin using MODFLOW. Based on the updated regional model, two focused models were developed to support evaluations of capture zones and contaminant transport in order to optimize the design of remediation systems.

Human Health and Ecological Risk Assessment, Jet Fuel Spill
Conducted a human health and ecological risk assessment of a 175,000-gallon spill of jet fuel from a pipeline into an ephemeral stream in the Negev Desert, Israel. Evaluated fate and transport of petroleum hydrocarbons in surface water and groundwater under alternative scenarios.

Feasibility Study, Stringfellow Superfund Site
Conducted an evaluation of remediation options for the Stringfellow Acid Pits Superfund Site, a former liquid hazardous waste disposal area. The waste was released into a canyon when it overtopped a dam after heavy rains. Chemicals released included organic acids, volatile organic compounds, and perchlorate. Developed a three-dimension groundwater flow model of the area downgradient of the Stringfellow Superfund Site using Modflow. The effectiveness of existing groundwater extraction systems and potential future system enhancements were evaluated using particle tracking.

Pesticide Fate and Transport, Italy
Evaluated potential impacts on groundwater of the use of the pesticide 1,3-D in tomato production in Southern Italy. Conducted fate and transport modeling using the FOCUS models and site-specific modeling using Hydrus.

Sediment Investigation, Hackensack River
Evaluated data from a large-scale soil, sediment, surface water investigation in the Hackensack River, New Jersey. Using geostatistical methods, the extent of chemical impacts in sediment was estimated to support risk assessment and remediation options.

Other Project Experience

- Conducted risk assessments at numerous sites considering vapor intrusion of volatile contaminants into indoor and outdoor air.
- Prepared an expert opinion on the potential costs of remediating a dry cleaner site that had impacted groundwater with PCE.
- Prepared an expert report and gave deposition testimony on the potential health risks from indoor air vapor intrusion from contaminated groundwater associated with a landfill for a litigation matter in California.
- Developed plans for the investigation of off-site soil gas, ambient air, and groundwater impacts at the BKK Hazardous Waste Landfill in California.
- Conducted a risk assessment considering exposure to mercury and PCBs in sediments and fish at a former paper mill on Lake Superior in Canada. A fish consumption and fishing habits survey was developed and analyzed in order to provide a site-specific fish consumption rate.
- Prepared an assessment of the potential impacts on water resources of a proposed oil shale development project near the White River in Utah. Evaluated the effect of groundwater pumping on surface water flows and groundwater levels.
- Developed a Modflow model of ground water flow and a HELP model of infiltration to evaluate capping and pump-and-treat remedial alternatives. This work was part of a technical review of a feasibility study for a former steelworks site in southeastern Australia.
- Evaluated perchlorate transport times through a 100-foot vadose zone at a site in a semi-arid region of California for an expert report. The evaluation was based on modeling of water flow and perchlorate transport performed with the Hydrus model using daily climate inputs.
- Provided data management for a large field program investigating the nature and extent of the contamination of riverine sediments by metals and organic chemicals (including dioxins, PCBs, and PBDEs).
- Developed risk-based screening concentrations for total petroleum hydrocarbons for use by the Fire Department of Santa Fe Springs, California.
- Evaluated the potential for transport of leachate from a waste pile through groundwater into the Delaware River.
- Prepared an analysis of waste disposal records as part of a rebuttal to a USEPA-proposed Superfund cost allocation.
- Developed risk-based target concentrations for crude oil in soil based on site-specific crude oil composition. This work was the basis for expert testimony on the estimated cost to cleanup a former oil field in southern California.
- Evaluated the performance of in-situ neutralization and pump-and-treat remediation at a South Carolina site with heavy metals in soil and ground water.

PUBLICATIONS & PRESENTATIONS

Luis, S., C. Stubbs, K. Zhao. 2013. Assessing the Implications for Vapor Intrusion Evaluation of NRC's "Alternatives for Managing the Nation's Complex Contaminated Groundwater Sites". Paper presented at AEHS 23rd Annual International Conference on Soil, Water, Energy, and Air, March 18-21, San Diego, CA.

Stubbs, C., S. Song, F.C. Ramacciotti, B.A. Schnoor, M. Bock. 2011. Evaluation of USEPA's Empirical Attenuation Factor Database. Paper presented at AEHS 21rd Annual International Conference on Soil, Water, Energy, and Air, March 14-17, San Diego, CA.

Stubbs, C., M. Keinath, A. DeLorme. 2011. Risk of Remedy Analysis and Green Remediation. Paper presented at Sustainable Remediation Conference, June 1-3, Amherst, MA.

Song, S., F.C. Ramacciotti, B.A. Schnoor, M. Bock, and C.M. Stubbs. 2010. Evaluation of USEPA's Empirical Attenuation Factor Database. EM Magazine, Air & Waste Management Association. February.

Song, S., C.M. Stubbs, F.C. Ramacciotti, B.A. Schnoor, and M. Bock. 2010. Evaluation of USEPA's Empirical Attenuation Factor Database. Paper presented at Air & Waste Management Association (AWMA) Vapor Intrusion 2010, September 29-30, Chicago, IL.

Chu, J., C.M. Stubbs, and A. DeLorme. 2009. A Case Study of Vapor Intrusion into a Future Office Building with Underground Parking. Poster presented at Brownfields 2009, November 16-18, New Orleans, LA. [Poster won award as Best Community Redevelopment Project.]

Benekos, I., M.Y.J. Chu, and C.M. Stubbs. 2008. A Case Study of Capture Zone Delineation in a Multi-Aquifer System Based on Inverse Modeling of Pump Test Data. Paper presented at National Ground Water Association (NGWA) 2008 Summit, March 31 – April 3, Memphis, TN.

Stubbs, C., I. Benekos, M. Henning, T. Barber, R. Santiago. 2007. An Integrated Approach to the Management of Contaminated Sediment: Peninsula Harbour Human Health Risk Assessment. In: 28th Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC) Proceedings. Milwaukee, WI. November 15.

Henning, M., M. Bock, E. Martin, A. Glessner, C. Stubbs, I. Benekos, T. Barber, R. Santiago. 2007. Determining Sediment Management Goals and Remediation Scenarios to Minimize Human Health Risk from Contaminated Sediment in Peninsula Harbour, Lake Superior, Canada. Paper presented at 2007 National Forum on Contaminants in Fish, Portland, ME. July.

Bowie, T., D. Daugherty, M. Keinath, E. Miesner, C. Stubbs. 2006. Validation of the Johnson and Ettinger Vapor Intrusion Model Applied to Commercial Buildings. Paper presented at AIHce 2006, Chicago, IL. May.

Tai, T.O. and C.M. Stubbs. 2004. Assessing the Significance of Subsurface Vapour Migration Into Indoor Air: A Case Study. Paper presented at Brownfield Asia 2004: International Conference on Remediation and Management of Contaminated Land. Kuala Lumpur, Malaysia. June 8.

Stubbs, C.M. 2004. Vapor Intrusion Screening With the Johnson & Ettinger Model: Too Many Parameters for Good Decision-Making? Paper presented at Association for Environmental Health and Sciences (AEHS) Fourteenth Annual West Coast Conference on Soils, Sediments and Water. San Diego, CA. March 15-18.

Stubbs, C.M. and R. Powell. 2003. A Flushing Model of the Remediation of MTBE From Gasoline Impacted Soils. Paper presented at National Ground Water Association (NGWA) Conference on MTBE: Assessment, Remediation, and Public Policy. Baltimore, MD. June 5-6.

Khan, S., C. Stubbs, and D. McLaughlin. 2001. A regional hydrologic economic framework for investigating sustainable irrigated landscape futures. In: F. Ghassemi, D. White, S. Cuddy and Nakanis, Integrated

Models for Natural Resources Management across Disciplines, Issues and Scales, MODSIM 2001, Canberra, 10-13 December 2001. pp. 1165-1170.

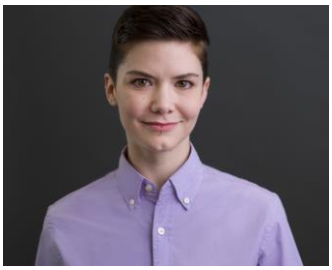
Stubbs, C.M. 2000. Hydrologic-Economic Modeling of Irrigated Agriculture in the Lower Murrumbidgee Basin, Australia: Investigations into Sustainability. PhD Thesis. Massachusetts Institute of Technology.

Stubbs, C.M. 1999. Sustainability of Irrigated Agriculture in the Lower Murrumbidgee Basin. Paper presented at the American Geophysical Union Fall Meeting. San Francisco.

Stubbs, C.M. 1996. Opportunities for Integrated Water Resources Management in the Chao Phrya Basin, Thailand. MS Thesis. Massachusetts Institute of Technology.

ALISON O'CONNOR

Senior Consultant



Alison O'Connor is an environmental chemist with ten years of research and data analysis experience. She has conducted biogeochemical research in a variety of terrestrial and coastal environments, assessing the fate and transport of metals, organic compounds, and nutrients. She also has expertise in redox chemistry of metals and metalloids, the role of microbes in metals cycling, and colloidal transport of chemical constituents.

EDUCATION

2012-2016
Ph.D., Marine Science (Aquatic Geochemistry)
College of William and Mary/Virginia Institute of Marine Science, Gloucester Point, Virginia, United States

2008-2012
B.A., Chemistry and Environmental Studies. High Honors.
Oberlin College, Oberlin, Ohio, United States

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EXPERIENCE

Risk Assessment

Metals

- Developed and implemented a novel sampling and analysis method used, along with statistical comparison of literature and site-specific data, to support permitting and litigation for a mine site (2021)
- Supported data analysis for copper, lead, and zinc bioavailability predictions (2020)
- Supported data review and analysis for benthic natural resource damage assessment for a mercury-contaminated estuary. (2018)
- Assessing ecological risk to wildlife in a former zinc smelter site in northern Illinois. Helped to develop toxicity reference values for birds, mammals, reptiles, and amphibians exposed to a range of heavy metals. Led statistical modelling effort to quantify metal uptake from soil into plants and prey organisms. (2017 - 2018)

PCBs and PAHs

- Supported data review and analysis for benthic natural resource damage assessment for a PCB-contaminated river. (2018-present)
- Developed an application of the target lipid model for PCB toxicity (2018-present)
- Conducted biological sampling (soil invertebrates) at a PCB-contaminated site in Indiana, USA. Used results to prepare a human and ecological risk assessment for PCBs. Conducted statistical analysis to determine bioaccumulation relationships. (2018-2019)
- Organize and carry out sampling at a PAH-contaminated creek. (2018)

Groundwater Monitoring

- Developed industry guidance for using novel geochemical methods and multivariate statistical analysis for use in preparing alternate source demonstrations for coal combustion residual sites (2022)
- Conducted statistical analysis, data visualization, and report preparation to meet federal and state coal combustion residue compliance standards. (2020-present)
- Created R code to automate statistical analyses in accordance with site-specific statistical analysis plans and the USEPA Unified Guidance for Groundwater Statistics
- Assessed novel statistical methods to use in demonstrating alternate contamination sources in groundwater for inclusion in industry documentation (2021-present)
- Used statistical comparisons, trend tests, and principal component analysis of organic and metal contaminants composition in groundwater to identify source signature (2021)
- Evaluated proposed remedy and arsenic speciation for a contaminated groundwater site (2021)

Product Stewardship

- Compiling environmental risk analysis and data gap identification for three topical antimicrobial substances. Following removal of triclosan from many products, this project takes a proactive approach to assess potential environmental risks of replacement antimicrobial substances. (2017 – present)
- Planned laboratory studies for environmental assessment of proposed new drugs, and reviewed laboratory protocols and results. Data were used to complete environmental assessments for the FDA and EMA in support of new drug marketing applications. (2017-2018)

Research

- Determined biogeochemical controls on the fate and transport of redox-sensitive trace metals (Fe, Mn, V, Cr, Mo, and U) and nutrients in from coastal groundwater to the ocean using fieldwork, geochemical modelling, and statistical analysis. This work included analysis of colloidal transport and the role of microbial populations. (2012-2017, Virginia Institute of Marine Science)
    - Responsible for leading project planning and execution, securing funding, managing and analyzing large data sets, and preparing manuscripts for publication.
- Characterized the distribution and speciation of mercury in Ashument Valley, MA, in groundwater historically impacted by wastewater. (2011, Woods Hole Oceanographic Institution)

SOFTWARE PROFICIENCES

- R (including data organization, linear regression, principal component analysis, dose-response analysis, and figure generation)
- PHREEQC (thermodynamic and kinetic modeling)

PUBLICATIONS

O'Connor A.E., Canuel, E.A., Beck, A.J. 2022. Drivers and Seasonal Variability of Redox-Sensitive Metal Chemistry in a Shallow Subterranean Estuary. *Frontiers in Environmental Science: Biogeochemical Dynamics*. https://doi.org/10.3389/fenvs.2021.613191.

O'Connor A.E., Krask, J.K., Canuel, E.A., Beck, A.J. 2018. Seasonality of Major Redox Constituents in a Shallow Subterranean Estuary. *Geochimica et Cosmochimica Acta* 224: 344-361.

O'Connor, A.E., Beck, A.J., Luek, J.L., and McIntosh, H. 2015. Geochemisty of Redox-Sensitive Trace Elements in a Shallow Subterranean Estuary. *Marine Chemistry* 172: 70-81

Lamborg, C. H., Kent, D.B., Swarr, G.J., Munson, K.M., Kading, T., **O'Connor, A.E.**, Fairchild, G.M., LeBlanc, D.R., and Wiatrowski, H. 2013. Mercury speciation and mobilization in a wastewater-contaminated groundwater plume. Environmental Science and Technology 47(23): 13239-13249.

Goni, M.A., **O'Connor, A.E.**, Kuzyk, Z.Z., Yunker, M.B. Gobeil, C., and Macdonald, R.W. 2013. Distribution and sources of organic matter in surface marine sediments across the North American Arctic margin. *Journal of Geophysical Research: Oceans* 118(9): 4017-4035.

ATTACHMENT 3

Air Sciences Inc., "Review of March 29, 2022, Comments from Earthjustice Related to Donlin's Mercury Emissions Inventory" (April 14, 2022)

PRIVILEGED AND CONFIDENTIAL ATTORNEY-CLIENT
WORK PRODUCT/COMMUNICATION

AIR SCIENCES INC.
DENVER • PORTLAND • LOS ANGELES

TECHNICAL MEMORANDUM

REVIEW OF MARCH 29, 2022 COMMENTS FROM EARTHJUSTICE RELATED TO DONLIN GOLD'S MERCURY EMISSIONS INVENTORY

PREPARED FOR:	Eric Fjelstad, Perkins Coie
PREPARED BY:	Kevin Lewis, Air Sciences
PROJECT NO.:	281-22B-1
DATE:	April 14, 2022

In a letter dated March 29, 2022 (Letter), Earthjustice provided comments to the Alaska Department of Environmental Conservation (ADEC)[1] regarding the Donlin Gold LLC (Donlin Gold) mercury modeling report.[2] Section E of the Letter suggests that mercury emissions are being underestimated in the Donlin Gold mercury modeling report based on a review conducted by Dr. Glenn C. Miller (Exhibit 5).[3] This memorandum addresses those assertions.

In summary:

- The estimated mercury emissions from the Donlin Gold tailings storage facility were not underestimated. The emissions are lower than the Twin Creeks emissions due to several relevant factors, including the ore mercury content at Donlin Gold that is more than an order of magnitude less than the Twin Creeks ore.
- Cyanide chemistry was considered in the mercury emission estimate for the tailings storage facility.

[1] Thomas S. Waldo, Attorney for Orutsararmiut Native Council, Letter to ADEC (March 29, 2022) (Waldo, Thomas S. 2022).

[2] Ramboll US Consulting, Inc., "Draft Report: Donlin Gold Mine Supplemental Mercury Modeling and Mass Balance Analysis" (Oct. 22, 2021) (Ramboll 2021).

[3] Glenn C. Miller, "Review of Draft Report: Donlin Gold Mine Supplemental Mercury Modeling and Mass Balance Analysis, By Ramboll U.S. Consulting, Inc." (March 4, 2022) (Miller, Glenn C. 2022).

- The estimated mercury emissions for the Donlin Gold thermal units were not underestimated.

- An implausibly high mercury capture efficiency percentage was not assumed in the mercury emission estimates for the thermal units. In fact, the mercury emissions as a percentage of the total mercury in the feed ore at Donlin Gold are more conservative (i.e., lower) than the percentages for Twin Creeks and Goldstrike.

- The Donlin Gold thermal units do not process 30% more autoclave ore than Goldstrike; they process slightly less.

- The mercury emission estimates for the Donlin Gold thermal units did not rely solely on emission factors from the companies making the control equipment. The estimates were based on engineering process modeling, Nevada mercury control guidance, actual emissions data from equivalent units, and consideration of the site-specific conditions at the Donlin Gold facility.

- Donlin Gold is not predicted to be the second largest producer of byproduct mercury.

The mercury emission calculations discussed in this memorandum and presented in the Donlin Gold mercury modeling report were developed and reviewed by Kevin Lewis of Air Sciences Inc. and Ramboll US Consulting, Inc. Professional qualifications for Kevin Lewis are provided in Appendix A.

1.0 Mercury Emission Calculations for the Tailings Storage Facility

The first assertion in the Letter is that mercury emissions from the tailings storage facility pond are underestimated based on the following assumptions:

1. "[T]he draft model significantly underestimates mercury emissions from the tailings pond, because it apparently fails to consider the cyanide in the tailings fluid." "If, as appears to be the case, the Ramboll report failed to take the cyanide into account, the estimates of mercury concentrations in the tailings pond may be off by orders of magnitude'" (Waldo, Thomas S. 2022, p. 17).

2. "He [Dr. Miller] also compares the proposed Donlin project to the Twin Creek[s] tailings facility, which has measured mercury emissions of 63 kg/year, far greater than the 7.5 kg/year Ramboll predicts for Donlin. Miller concludes, 'Ultimately, the combination of a much higher mercury content in tailings from the Donlin Mine and the larger tailings

surface area suggest that the mercury volatilization from the tailings is dramatically underestimated'" (Waldo, Thomas S. 2022, p. 17).

1.1 Assumption 1 Discussion

Regarding the Donlin Gold tailings liquid mercury content, as explained in Ramboll's responses to the Letter, there was no failure to consider cyanide chemistry. The differences between the estimated mercury emissions for the Twins Creeks and Donlin Gold tailings storage facilities are explained by other relevant considerations, such as: 1) the differences in mercury concentrations described below, and 2) the differences in environmental factors described in Section 1.2.

Table 1 summarizes the mercury content of the ore, tailings solids, and tailings liquid at the Twin Creeks and Donlin Gold tailings storage facilities. As shown in Table 1, the Donlin Gold ore has significantly lower mercury content than the Twin Creeks ore. As a result, the mercury content in the Donlin Gold tailings solids and liquid are also lower. Lower mercury concentrations result in lower mercury emissions.

Table 1. Tailings Storage Facility Mercury Contents for Twin Creeks and Donlin Gold

Facility	Ore	Tailings Solids	Tailings Liquid
Twin Creeks	24[1]-33[2] ppm	58 ppm[2]	0.496 mg/L[3]
Donlin Gold	1.27 ppm[4]	0.7 ppm[5]	0.073 mg/L[5]

[1] Twin Creeks stack test report used for annual emissions reporting (2020) available from the Nevada Division of Environmental Protection.
[2] (Eckley et al 2010, p. F).
[3] (Eckley et al 2011, p. 519).
[4] (Miller, Glenn C. 2022, p. 6)
[5] (SRK 2017, pp. C-11, C-26).

The Donlin Gold mercury emission calculations for the tailings storage facility pond are based on a liquid concentration of 0.073 mg/L. This is a conservatively high estimate because it does not consider the use of the mercury settling-enhanced reagent (i.e., the University of Nevada – Reno (UNR)-921) that will be applied to the tailings solution. When accounting for the application of this reagent, the expected concentration is 0.010 mg/L or lower (SRK 2017, p. C-26).

1.2 Assumption 2 Discussion

As discussed in Section 1.1, the Donlin Gold tailings mercury content is significantly lower than Twin Creeks tailings mercury content. Because mercury emissions are "positively correlated with material Hg concentrations" (Eckley et al 2011, p. 514), Donlin Gold is expected to have a

lower mercury emission flux rate than Twin Creeks. Similarly, mercury flux is positively correlated with solar radiation (Eckley et al 2011, p. 518). The lower solar radiation in Alaska compared to Nevada will result in lower mercury flux at Donlin Gold. In addition, Alaska has lower temperatures and more snow and ice cover than Nevada. All these factors contribute to lower mercury flux and emissions at Donlin Gold. Even though the overall tailings surface area at Donlin Gold is larger, the reduced mercury flux at Donlin Gold results in lower mercury emissions than Twin Creeks.

As stated in the Donlin Gold mercury modeling report, "vapor mercury emissions (in the form of gaseous elemental mercury) from the proposed Donlin Gold Tailings Storage Facility (TSF) were estimated using methods similar to the studies for two active gold mines in Nevada … but using Donlin Gold-specific data and accounting for differences in solar radiation and geochemistry/mercury content between Donlin Gold and the Nevada mines." (Ramboll 2021, p. 3-12). Utilizing this methodology with site-specific data provides the best available estimation of mercury emissions from the Donlin Gold tailings storage facility.

2.0 Mercury Emission Calculations for the Thermal Units

The second assertion in the Letter is that mercury emissions from the thermal units are underestimated based on the following assumptions:

1. "[T]he draft model also significantly underestimates mercury emissions from thermal sources at the mine by assuming an implausibly high 99.8% efficiency in capturing mercury" (Waldo, Thomas S. 2022, p. 17).

2. "While Goldstrike emits 60 pounds (27 kg) of mercury per year from the autoclaved ore based on actual measurements, the Ramboll draft mercury model predicts only 35 pounds (16 kg) from Donlin. Miller concludes that 'the Donlin Mine is likely to emit at least 60 lbs of mercury, and perhaps more, since 30% more ore is being subjected to the autoclave based process'" (Waldo, Thomas S. 2022, p. 17).

3. "Miller attributes the underestimate in part to the fact that the Ramboll draft model relies on emission factor estimates from the companies making the control equipment rather than on actual emissions from operating mines like Goldstrike" (Waldo, Thomas S. 2022, p. 17).

2.1 Assumption 1 Discussion

The capture efficiency cited in the Letter and Exhibit 5 of "greater than 99.8% efficiency" (Waldo, Thomas S. 2022, p. 17) (Miller, Glenn C. 2022, p. 6) appears to be derived from the mercury emissions of 15.9 kg (Miller, Glenn C. 2022, p. 6) divided by the total amount of

mercury in the ore of 15.7 metric tons (Miller, Glenn C. 2022, p. 6).[4] Although, this is a useful metric for comparison to other mines, it is not representative of the capture efficiency or removal efficiency of the mercury control systems. For gold ore processing facilities that do not use roasters, the majority of mercury in the ore remains with the ore and is released to the tailings storage facility. Nonetheless, using Dr. Miller's metric of *overall mercury control efficiency*, Table 2 provides a comparison of the Donlin Gold facility to the two mines discussed in the Letter (Twin Creeks and Goldstrike). This table shows that the Donlin Gold *overall mercury control efficiency* is conservatively low, and the mercury air emissions are conservatively high.

Table 2. Overall Mercury Control Efficiency for Equivalent Thermal Units

Facility	Hg Emissions (lb/yr)(1)	Ore Process (ton/yr)(1)	Ore Hg (ppm)(2)(3)	Ore Hg (lb/yr)(4)	Overall Hg Control Efficiency(5)
Twin Creeks	30.3028	4,122,443	24.0	197,835	99.985%
Goldstrike	15.4861	13,617,314	24.6	671,178	99.998%
Donlin Gold	35	23,738,293 (3.7 million)(6)	1.27	60,295	99.942%

(1) (Miller, Glenn C. 2022, pp. 6, 22, 51-52). The Goldstrike emissions are based solely on equivalent thermal units found at Donlin Gold, which excludes two roasters and three uncontrolled autoclaves.
(2) The mercury concentrations for Twin Creeks and Goldstrike were taken from the stack test reports used for 2020 annual emissions reporting. These reports are available from the Nevada Division of Environmental Protection.
(3) (Miller, Glenn C. 2022, p. 6) for the Donlin Gold mercury concentration.
(4) Total amount of mercury in the ore processed: (tons per year of ore processed) * (2000 lb per ton) * (Hg ppm) / 1,000,000.
(5) The *overall mercury control efficiency* equals: 1 – (pounds of air emissions) / (total mercury in the ore processed).
(6) Of the total 23.7 million tons of ore crushed, milled, and sent to flotation, roughly 15% is autoclaved and further processed for gold recovery. The maximum throughput of the Donlin Gold autoclaves, combined, is 3.7 million tons per year: (210 ton/hr * 2 units * 8,760 hr/yr).

2.2 Assumption 2 Discussion

With regards to Assumption 2, the following points are important to consider:

- The Goldstrike thermal units (excluding the two roasters and three uncontrolled autoclaves, which do not have corresponding equipment at the Donlin Gold project) emit only 15.5 pounds (7 kg) (Miller, Glenn C. 2022, p. 51-52), not 60 pounds (27 kg) as asserted by Dr. Miller.

[4] 1 – (15.9 kg of air emissions) / (15.7 metric tons of mercury in the ore processed) = 99.8987%

- The Donlin Gold autoclaves process slightly less ore (3.7 million tons) than the equivalent Goldstrike autoclaves (3.8 million tons) (Miller, Glenn C. 2022, p. 51), not 30% more.

The amount of ore processed at Goldstrike versus Donlin Gold for the equivalent thermal units is summarized in Table 3.

Table 3. Annual Goldstrike and Donlin Gold Ore Process Rates for Equivalent Thermal Units

Thermal Unit	Goldstrike[1]	Donlin Gold[2]
Autoclaves	3.8 million tons	3.7 million tons
Kiln, EW Cells, Retorts, Furnaces	13.6 million tons	3.7 million tons

[1] (Miller, Glenn C. 2022, p. 51). The Goldstrike autoclave throughput is based on Autoclaves 4-6.
[2] The maximum process rate for the two Donlin Gold autoclaves is 210 ton/yr * 2 autoclaves * 8,760 hr/yr = 3.7 million tons per year.

For Goldstrike, the ore process amounts in Table 3 are based on the following:

- Autoclaves: The process rate of Autoclaves 4-6.

- Kiln, EW Cells, Retorts, Furnaces: the sum of all the ore processed at Goldstrike of 13.6 million tons, which includes Autoclaves 1-3 (3.5 million tons), Autoclaves 4-6 (3.8 million tons), and Roasters 1-2 (6.3 million tons) (Miller, Glenn C. 2022, p. 51).

Only Goldstrike Autoclaves 4-6 are comparable to the Donlin Gold autoclaves because they utilize the same control system of carbon filters. Goldstrike Autoclaves 1-3 are not equipped with carbon filters. The feed material for the Goldstrike kiln, EW cells, retorts, and furnaces is produced from all the ore processed by both roasters and all six autoclaves (13.6 million tons).

The Donlin Gold autoclave's maximum ore processing rate is based on the design capacity of 210 tons per hour per autoclave (two autoclaves), and a conservatively high estimate of each autoclave operating 8,760 hours per year. This equates to 3.7 million tons per year of ore autoclaved, which is roughly 15% of the total ore crushed, milled, and sent to the flotation circuit. Only the ore concentrate from the flotation circuit is autoclaved and further processed for gold recovery. The remaining ore is sent to the tailings storage facility.

2.3 Assumption 3 Discussion

Assumption 3's assertion that the Ramboll model relies on emission factor estimates from the companies making the control equipment, rather than on actual emissions from operating mines like Goldstrike, is not correct. The Donlin Gold mercury emission estimates for the thermal units are based on the following information:

- The Hatch Ltd. engineering consulting company process modeling.
- The Nevada Mercury Control Program Permitting Guidance, General Industry NvMACT Determinations, which includes documented mercury emission rates for mercury control technologies (NDEP 2016).
- Three years of stack test data (actual emissions data) from the Goldstrike Autoclaves 4-6, Kiln, EW Cells, Retorts 1-4, and Furnaces East and West.
- The lower mercury content in the Donlin Gold ore of 1.27 ppm versus the Goldstrike ore of 24.6 ppm. See Table 2.

In summary, the mercury emission estimates for the Donlin Gold thermal units were based on engineering process modeling, Nevada mercury control guidance, actual emissions data from equivalent units, and consideration of the site-specific conditions at the Donlin Gold facility. For the Donlin Gold autoclaves, as an example, the engineering process modeling predicted a mercury stack concentration of 5.7E-7 gr/dscf. However, Goldstrike test data showed higher stack concentrations of 5.2E-7 to 8.0E-7 gr/dscf. Although the Goldstrike stack concentration is expected to be higher due to the higher mercury content of the ore, the Donlin Gold stack concentration was doubled to 1.14E-7 gr/dscf to provide a conservatively high estimate.

3.0 Donlin Gold Mercury Recovery

Another assertion that is not mentioned in the Letter but is discussed in Exhibit 5 warrants clarification: "[t]he mercury present in the ore is quite high, and the byproduct mercury projected to be recovered is 34,600 lbs (15.7 metric tons)[5] and would make the Donlin Gold mine (if located in Nevada) the second largest producer of byproduct mercury in the state (and perhaps in the nation)" (Miller, Glenn C. 2022, p. 5).

[5] Correctly calculated, these numbers are: 1.62 mg/kg * 21,535,000 metric tons * 1,000 kg/metric ton = 34,900 kg (34.9 metric tons) (Miller, Glenn C. 2022, p. 6).

The amount of mercury recovered cited above assumes that 100 percent of mercury in the ore will be recovered by Donlin Gold's mercury control systems. The actual fraction of mercury recovered depends on the gold ore processing method. Roasting facilities will recover the largest fraction because of the high ore roasting temperature. Autoclaving facilities will recover a much smaller fraction. For the Donlin Gold autoclaves, the mercury recovery will be further reduced because only a portion of the total ore mined (roughly 15%) is autoclaved and further processed for gold recovery.

Twin Creeks recovered 2.7 to 16.5 tons (2.4 to 15.0 metric tons)[6] of mercury byproduct from processing roughly 4 million tons of autoclave ore (Miller, Glenn C. 2022, p. 22). At an ore mercury concentration of approximately 24 to 33 ppm (see Table 1), the total amount of mercury in the ore processed is 99 tons (90 metric tons) to 136 tons (123 metric tons). The mercury recovery in this example is 2% to 17% percent, well below 100%. Donlin Gold would be expected to recover less total mercury than Twin Creeks because of the lower ore mercury concentration.

In summary, the Donlin facility is not predicted to be the second largest producer of byproduct mercury for the following two main reasons:

1. The Donlin Gold facility does not utilize roasters to process its ore.
2. The Donlin Gold ore contains low levels of mercury.

[6] 15-year high and low

4.0 References

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Professional Qualifications

EXPERTISE

Air quality permitting, compliance, modeling, emission estimation and control, and regulatory development.

EDUCATION

BS in Chemical Engineering, University of Wisconsin – Madison

EXPERIENCE

Over 29 years of experience in working with governmental agencies and the private sector in air quality permitting, compliance, modeling, emission estimation and control, and regulatory development.

AIR QUALITY CONSULTING

- Developed PSD, Title V, and/or minor source applications/air permits and other air quality documents (including NEPA air quality reports) for facilities located in Alabama, Alaska, Arkansas, California, Colorado, Georgia, Idaho, Illinois, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nevada, New Mexico, Oklahoma, Oregon, South Carolina, South Dakota, Texas, Utah, Virginia, Washington, and Wyoming. These facilities included open-pit and underground mines; coal-, gas-, oil-, waste-, and biomass-fired boilers; gas, oil, and oil shale production and processing plants; wood products facilities; coating facilities; and cryogenic air separation plants.
- Developed air permit applications for over 30 power generation and gas/oil production facilities. Provided overall management for each project and developed key technical analyses for air emission inventories, modeling compliance plans, and regulatory applicability.
- Performed compliance audits and developed monitoring plans for several industry types, including mining, power generation, and oil and gas production.
- Provided expert testimony on PSD regulations and BACT determinations.
- Prepared multiple technical documents on behalf of the Nevada Mining Association for submittal to the Nevada Bureau of Air Quality Planning and the U.S. EPA. These documents addressed quantification of hydrogen cyanide air emissions from leach pads and other fugitive mining sources, mercury control technologies, and mercury control system monitoring.
- Worked with state and federal agencies to assist with mercury regulatory development. For example, performed technical analyses and worked directly with the U.S. EPA on behalf of the Nevada Mining Association for the development of the Mercury National Emissions Standards for Hazardous Air Pollutants (NESHAP), Subpart EEEEEEE of 40 CFR 63.
- Prepared and presented Title V program development training sessions for the air program personnel of several western U.S. tribes.

- Performed criteria pollutant and hazardous air pollutant emissions impact and risk analyses on multi-source facilities using U.S. EPA–approved computer models.

ENGINEER FOR THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES

- Reviewed permit applications, drafted and issued permits, and evaluated BACT for air toxins.
- Performed inspections and evaluated stack tests on a variety of sources.
- Evaluated RACT for VOC sources located in ozone non-attainment areas.
- Drafted and issued administrative orders allowing companies to participate in air emissions trading.

CHEMICAL PROCESS ENGINEERING

- Developed mass and energy balances for large-scale chemical manufacturing processes.
- Designed pilot plant reaction protocols.
- Performed research in the area of organic chemistry and utilized analytical instrumentation such as infrared and nuclear magnetic resonance spectrometers, and gas and high-pressure liquid chromatograms.

MISCELLANEOUS AIR QUALITY EXPERIENCE

Addressed air quality–related issues for the multiple industry types including:

- Precious metals and phosphate mining
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- Natural gas and oil production/processing
- Chemical manufacturing
- Fuel conversion
- Pulp and paper
- Concrete batching
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- Steel pipe manufacturing
- Ship building
- Asphalt production
- Food processing
- Electric motor manufacturing
- Lumber milling
- Cryogenic air separation