Aboriginal Affairs and Northern Development Canada
Affaires autochtones et Développement du Nord Canada
PO Box 1500
Yellowknife, NT
X1A 2R3

Northwest Territories Environment and Natural Resources

March 13, 2014

File: MV20112-0004
EA1314-002

Mark Cliffe-Phillips
Executive Director
Mackenzie Valley Environmental Impact Review Board
200 Scotia Centre; 5102-50th Ave
Box 938, Yellowknife, NT X1A 2N7

Re: De Beers Canada Incorporated (DBCI) Snap Lake Mine Request to Re-schedule Technical Sessions

On February 28, 2014, De Beers Canada Incorporated (DBCI) advised the Mackenzie Valley Environmental Impact Review Board (the Board) that Dr. Peter Chapman, their technical lead for the application, will be unable to appear at the technical session currently scheduled for April 10, 2014. As such, DBCI requested that the Board consider rescheduling the technical session to Monday, April 7.

Aboriginal Affairs and Northern Development Canada (AANDC) and the Government of the Northwest Territories (GNWT) have been requested to provide comments on the proposed date change and note any concerns. Both AANDC and the GNWT concur that Dr. Chapman's presence at the technical session would be beneficial as he will be representing aspects of the application related to aquatic effects and toxicity, as noted in the request from DBCI.

However, AANDC and the GNWT are concerned with the revised date as proposed by DBCI. As the Board is aware, on April 1, 2014, the GNWT will become the primary land and water manager in the Northwest Territories. This transition period will place additional requirements on staff affected by the devolution transfer. Accordingly, advancing the date of the technical sessions presents issues for ensuring that the appropriate level of internal coordination and preparation is conducted before the session.

Further, and more importantly, the proposed date of April 7 conflicts directly with the date set by the Mackenzie Valley Land and Water Board for submission of technical interventions regarding the Gahcho Kue Diamond Mine water licence application. This presents an issue in the availability of technical staff on the proposed date.

As such, AANDC and the GNWT request the technical sessions be re-scheduled to a date after the currently scheduled date of April 10 when Dr. Chapman is available. Both parties believe this rescheduling is justifiable and would also ensure Dr. Chapman's participation.

AANDC and the GNWT would also like to take this opportunity to identify its concern with the amount of time proposed for the technical sessions. As the technical session is intended to cover both environmental assessment and regulatory amendment processes, one day will likely be insufficient to adequately discuss the proposed changes and amendments. Additional dates should be added to ensure complete review and technical discussion of these proposed regulatory amendments.

If you have any questions or concerns, please feel free to contact the undersigned Mr. Robert Jenkins at 669-2574 or Robert.Jenkins@aandc-aadnc.gc.ca or Ms. Mary Tapsell at 920-8675 or Mary_Tapsell@gov.nt.ca.

Sincerely,

Robert Jenkins
Director,
Renewable Resources
and Environment
Aboriginal Affairs and
Northern Development Canada

For Mary Tapsell
Director,
Land and Water
Environment and Natural Resources
Government of the Northwest Territories

YELLOWKN#630644 - v1
YELLOWKN#630644 - v3

Northwest Territories Environment and Natural Resources

March 14, 2014 VIA ONLINE SUBMISSION

Simon Toogood
Environmental Assessment Officer
Mackenzie Valley Environmental Impact Review Board
PO Box 938, 5102-50th Avenue
Yellowknife, NT X1A 2N7

AND

Rebecca Chouinard
Regulatory Manager
Mackenzie Valley Land and Water Board
PO Box 2131, 4922-48th Street
Yellowknife, NT X1A 2P6

Dear Mr. Toogood and Ms.Chouinard,

Re. Comments on the De Beers Canada Incorporated Snap Lake Project, File Number EA1314-002 and MV2011L2-0004.

The Government of the Northwest Territory (GNWT) has reviewed the information provided by the Mackenzie Valley Land and Water Board and the Mackenzie Valley Environmental Impact Review Board (the Boards) as part of the coordinated regulatory and environmental assessment review of the Snap Lake Water Licence amendment submitted by De Beers Canada Inc. The GNWT is submitting comments via the online review system, as per the direction from the Boards.

The GNWT and Aboriginal Affairs and Northern Development Canada (AANDC) met to discuss their technical comments prior to submission to the Boards. Although each government is submitting their comments separately, post-devolution the GNWT will adopt the recommendations made by AANDC for those areas of responsibility devolved to them.

At this time, the GNWT comments are focused on the *Draft Review Board Proposed Scope of the Environmental Assessment* (February 2014) document. Further technical comments will be provided at the technical session once a more thorough review of all materials has been completed.

If you require any further details, please contact Lindsay Luke, Environmental Assessment Analyst, at Lindsay_luke@gov.nt.ca or (867) 920-6340.

Sincerely,

Joel Holder, Manager
Environmental Assessment and Monitoring
Department of Environment and Natural Resources
Government of the Northwest Territories
e: joel_holder@gov.nt.ca / t: (867) 873-7108

Aboriginal Affairs and Northern Development Canada
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File: MV2011L2-0004
EA1314-002

March 14th, 2014

Simon Toogood
Environmental Assessment Officer
Mackenzie Valley Review Board
200 Scotia Centre; 5102-50th Avenue
Box 938, Yellowknife, NT X1A 2N7

Mr. Toogood,

Re: Aboriginal Affairs and Northern Development Canada – Comments MV2011L2-0004 – De Beers Canada Inc –Scope of Environmental Assessment and Water Licence Amendment Application

As requested by the Mackenzie Valley Land and Water Board and the Mackenzie Valley Review Board (the Boards), Aboriginal Affairs and Northern Development Canada (AANDC) has reviewed the February 24th, 2014 *Draft Review Board Proposed Scope of Environmental Assessment* as well as the Water Licence Amendment Application for the Snap Lake Mine as submitted by De Beers Canada Inc. under Water Licence MV2011L2-0004.

As previously communicated, AANDC maintains that an increase to the Total Dissolved Solids (TDS) criteria in the water licence requires an environmental assessment as the current regulatory limit for TDS was included as a measure in the Report of Environment Assessment for Snap Lake. Accordingly, review of this parameter must be scoped within the Environmental Assessment.

The Board has also proposed to include Effluent Quality Criteria for the following parameters within the scope of the Environmental Assessment:

- Chloride
- Fluoride
- Nitrate
- Nitrite
- Sulphate

The Department is not opposed to the inclusion of these parameters within the scope of the Environmental Assessment, as they all contribute to TDS levels in water. Accordingly, an assessment of these parameters within the context of evaluating the effects of TDS levels in Snap Lake is appropriate. The Department

recommends that ammonia be added to this list, as this parameter may also contribute to TDS concentrations in water (Note - DeBeers requested an increase to the ammonia limits within their water licence amendment application). However, it is important to note that the Department feels that the determination of Effluent Quality Criteria is not a matter for inclusion within the Environmental Assessment, but rather dealt with during the regulatory component of this process.

Attached are AANDC's comments on the scoping document and the water licence amendment application. It is our anticipation that these areas will be discussed in greater detail at the upcoming technical session and throughout the environmental assessment and regulatory processes.

It is important to note that AANDC's responsibilities for land and water management in the NWT will be devolving to the Government of the Northwest Territories (GNWT) on April 1st, 2014, prior to the technical sessions being held. The GNWT will use the information contained in this Technical Intervention, other Interventions and the water licence proceeding to support their role as primary land and water manager in the NWT post-devolution.

Thank you for providing AANDC with the opportunity to comment on the above mentioned documents. If you have any questions or concerns, please contact Mr. Nathen Richea at Nathen.Richea@aandc.gc.ca or 669-2657.

Sincerely,

Robert Jenkins
Director
Renewable Resources and Environment
Aboriginal Affairs and Northern Development Canada

Yellowknives Dene First Nation

P.O. Box 2514, Yellowknife, NT X1A 2P8

March 14th, 2014

Alan Ehrlich
Mackenzie Valley Environmental Impact Review Board
Box 938
Yellowknife, Northwest Territories
X1A 2N7
Fax: (867) 766-7074

Dear Mr. Ehrlich:

Re: Snap Lake Scope/Workplan Comments (EA1314-002)

The Yellowknives Dene First Nation (YKDFN) has reviewed the draft scope and workplan comments and have some concerns

1. Workplan

The workplan is extremely tight with very little flexibility, which presents a difficulty for organizations such as the YKDFN who have limited capacity and no redundancy. With the proposed schedule, YKDFN will be hard pressed to meaningfully participate because the process itself is set up to limit opportunity. YKDFN do not have available staff resources to meet the deadlines for the period May 13th, 2014 to June 18th.

Naturally the proponent's response will note that this not a 'full blown' Environmental Assessment. YKDFN acknowledge this fact. However, while the process has been abridged to attempt to narrow the steps and amount of material that form the scope of the assessment, the reality is that the narrow setting is offset by the complexity of the issues. For example, the review effort associated with the TDS response plan materials are comparable to the Tyhee Developers Assessment Report that was last accepted by the Review Board.

The concerns surrounding TDS have been known for years and YKDFN has repeatedly advocated for a route forward. The MVEIRB was clearly and necessarily the gatekeeper on this amendment. The company has failed to act in a timely manner.

We understand the Board and proponent's desire for reduced timelines, but to compress a process which limits the First Nation's ability to participate is to reward the company with a lower level of scrutiny for poor environmental stewardship. If the work plan cannot be amended

to provide for additional flexibility, we ask that the Board to acknowledge and recognize the challenges that communities will face. It goes without saying that YKDFN will seek to meet all of the Board's deadlines, but should the work plan remain unchanged, we ask the board, proponent, and other parties to understand these limitations and permit flexibility.

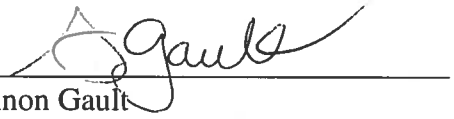
As a proposed alternative, YKDFN suggest to De Beers that there may be an opportunity to withdraw their application and resubmit it in two phases. The first to deal with the matters within the MVLWB mandate (EQC related issues which represent the more significant near term limitation for the continued operation of the mine), while the second many deal with only the TDS measure, which would be referred to EA. YKDFN acknowledges that this is far from ideal, however given the unique circumstances, YKDFN would support this action if parties will not accept changes to the work plan and timelines.

2. Scope

YKDFN support the proposed scope.

If there are any questions or if we could provide additional clarification, please don't hesitate to contact the YKDFN Lands and Environment Department at (867) 766-3496.

Sincerely,



Shannon Gault
Director, Lands and Environment

DE BEERS
GROUP OF COMPANIES

February 28, 2014 File: MV2011L2-0004/EA1314-002

Simon Toogood
Environmental Assessment Officer
Mackenzie Valley Review Board
Mackenzie Valley Environmental Impact Review Board
200 Scotia Centre; 5102-50th Ave
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Rebecca Chouinard
Regulatory Manager
Mackenzie Valley Land and Water Board
7th Floor - 4922, 48th Street
Box 2130, Yellowknife NT X1A 2P6

Dear Mr. Toogood and Ms. Chouinard:

Re: Draft Combined Workplan for Water Licence Amendment – Proposed Date for Technical Session

De Beers has one initial comment on the Draft Workplan for the Environmental Assessment and Water Licence Amendment process proposed by the Mackenzie Valley Review Board and the Mackenzie Valley Land and Water Board on February 24, 2014. Additional comments will be provided per the workplan.

The De Beers team's Technical Lead for the Application, Dr. Peter Chapman will be unavailable to present evidence and respond to questions during the Technical Session on April 10 as proposed, due to a previously-scheduled international commitment. As Dr. Chapman is a key member of our team, representing aspects of the Application related to aquatic effects and toxicity, De Beers requests that the boards consider rescheduling the Technical Session to Monday, April 7.

DE BEERS CANADA INC.
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GROUP OF COMPANIES

This comment has also been added by way of the online review system. Your timely consideration and response to this request is very much appreciated.

Sincerely,

DE BEERS CANADA INC.

Erica Bonhomme
Manager, Environment
Snap Lake Mine

Copied to:

R. Nichols	MVLWB
A. Hood; P. Chapman (Golder Associates)	DBCI

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March 21, 2014

File: L020

Simon Toogood
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Box 938, #200 Scotia Centre 5102-50th Avenue
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Rebecca Chouinard
Mackenzie Valley Land and Water Board
PO Box 2130
Yellowknife, NT X1A 2P6

Dear Mr. Toogood and Ms. Chouinard:

Re: De Beers Canada Inc. Submission on the Draft Review Board Proposed Scope of the Environmental Assessment, Snap Lake Amendment Project ("Project"), (EA1314-02)

De Beers Canada Inc. ("De Beers") is writing in regard to the Mackenzie Valley Environmental Impact Review Board's ("Review Board") "Draft Review Board Proposed Scope of the Environmental Assessment, Snap Lake Amendment Project" ("Scoping Document")[1] and in response to comments by the Yellowknives Dene First Nation ("YKDFN"), the Department of Aboriginal Affairs and Northern Development Canada ("AANDC") and the Government of the Northwest Territories ("GNWT") on the proposed review schedule.

1. Scope of the Environmental Assessment

In the Scoping Document, the Review Board states that the proposal to change the allowable discharge of Total Dissolved Solids ("TDS") should be included within the scope of the Environmental Assessment ("EA") because:

> *These measures specific to TDS were approved by the federal Minister and as a result it is mandatory that they be included in the Snap Lake water*

[1] Mackenzie Valley Environmental Impact Review Board, "Draft Review Board Proposed Scope of the Environmental Assessment: Snap Lake Amendment Project", EA1314-02, February 24, 2014 ["Scoping Document"].

> *licence because of section 62 of the MVMRA. Consequently, the MVLWB ruled that it cannot amend the water licence to allow TDS to exceed the limit approved by the Minister*.[2]

Furthermore, the Review Board states that the proposed amendments to the Effluent Quality Criteria ("EQC") for nitrite, nitrate, chloride, fluoride and sulphate are to be included in the EA because:

> *The proposed changes to these five EQC are included because they would result in an impact to the environment that was not previously assessed.*[3]

De Beers acknowledges that section 62 of the *Mackenzie Valley Resource Management Act*,[4] ("MVRMA") requires that an environmental assessment be carried out for the proposed changes to the limit for TDS concentration. De Beers previously indicated in its letter of January 6 to the Mackenzie Valley Land and Water Board, that should an environmental assessment of the specific aspect of the application related to TDS be required, De Beers would anticipate that the boards would conduct an efficient and focused process to review this specific aspect of the application.

De Beers disagrees that the changes to the five EQCs should also be included within the scope of the EA. De Beers submits that the effects of the discharge of the other five ions, and the assignment of EQCs have previously been considered, and that the proposed changes are completely within the Land and Water Board's jurisdiction to review. At the time when the original EA was carried out for the Snap Lake Diamond Project in July 2003,[5] the Review Board contemplated the effects of some of the five EQCs but decided not place conditions on them. For example, the Review Board noted that the Dogrib Treaty 11 Council expressed concerns about chloride.[6] The Review Board also observed that calcium and chloride ions will increase on a whole lake average basis.[7] In its report, the Review Board made a suggestion that the Aquatic Effects Monitoring Program should include nitrate and nitrite as indicators of nutrient enrichment in Snap Lake.[8] This makes it clear that the Review Board did consider the effects of other parameters discharged to Snap Lake, but chose only to make recommendations on the whole lake average TDS concentration (350 mg/L), and not on the other parameters, nor specific EQC.

De Beers further submits that following the environmental assessment in 2003, the Mackenzie Valley Land and Water Board must have determined that the requirements under

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[2] *Ibid*, p 5.
[3] *Ibid*.
[4] SC 1998, c 25.
[5] Mackenzie Valley Environmental Impact Review Board, "Report of Environmental Assessment and Reasons for Decision on the De Beers Canada Mining Inc. Snap Lake Diamond Project," July 24, 2003.
[6] *Ibid*, p 72.
[7] *Ibid*, p 77.
[8] *Ibid*, p 92.

part 5 of the MVRMA were fulfilled, since they proceeded to issue De Beers a water licence in 2004 with specific EQCs related to the noted 5 parameters. This would apply also to the renewal of the water licence in 2012.

Prior to approving the Water Licence Renewal in 2012, the Mackenzie Valley Land and Water Board ("MVLWB") undertook a technical review and a public hearing process and in the Reasons for Decision,[9] the MVLWB stated:

> *In its renewal application, De Beers did not recommend changes to any of the EQC in Water Licence MV2001L2-0002. However, t<u>o ensure consistency with the Board's Water and Effluent Quality Management Policy (the Policy), the Board hired an independent third-party consultant, EcoMetrix Inc., to review and recommend effluent quality criteria (EQC) for the Snap Lake Diamond Mine</u>. [...] EcoMetrix submitted its <u>report containing EQC recommendations</u> on October 19, 2011. The EcoMetrix report was placed on the Public Registry so that it was available for parties to use and comment on in their interventions to the public hearing. A representative of EcoMetrix, Dr. Don Hart, was also present at the hearing to answer questions on the report and recommendations.[10] [emphasis added]*

During this MVLWB review process, no one raised concerns regarding the MVLWB's jurisdiction to address the EQC without any Review Board involvement. All of this strongly suggests that the impacts of the five discharge parameters (other than TDS) for which De Beers proposes to amend EQCs have previously been considered and that the MVLWB is the correct administrative body to review these impacts. For reference, Part F of the renewal to the Snap Lake Water Licence, MV2011L2-0004[11] ("Water Licence Renewal") has a condition that lists the EQC requirements for the Project. Condition 9 of Part F of the Water Licence Renewal contains a table of 16 Parameters of Potential Concern ("POPC") with associated EQC, including nitrite, nitrate, chloride, fluoride and sulphate.

With regards to recommendations by AANDC and GNWT in the Online Review Comment Table[12] that the scope of EA be expanded to include ammonia,[13] De Beers wishes to clarify that it is not requesting an amendment of EQCs for ammonia. As such, De Beers disagrees with the recommendations that the scope of the EA include this parameter.

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[9] Mackenzie Valley Land and Water Board, "Decision from Mackenzie Valley Land and Water Board (the Board) Panel Meeting of April 4, 2012," MV2011L2-0004.

[10] *Ibid*, p 14.

[11] Mackenzie Valley Land and Water Board, "Type A Water Licence: MV2011L2: 0004", May 25, 2012.

[12] Mackenzie Valley Environmental Review Impact Board, "Online Review System Comment Table for the EA Scoping Document and Water Licence Amendment Application", March 17, 2014 ["Review Comment Table"].

[13] See Review Comment Table at AANDC items 1, 2 and 3 and GNWT item 4.

In summary, consistent with the MVLWB's Reasons for Decision dated January 21, 2014, the only reason the EA is being conducted is because De Beers is proposing an amendment to the one licence condition previously made binding by the Review Board. As such, the discharge of TDS at concentrations as proposed in the application should be the only issue considered within the scope of the present EA.

2. Public Participation

De Beers expects that the application will undergo a thorough technical review, and that there will be opportunities for public participation. This can be achieved without including the 5 additional EQCs within the scope of the EA. The Scoping Document states:

> *In addition to the current EA process, the public will also have the opportunity to participate in the MVLWB water licence process, including a public hearing, which will include any proposed amendments that may be outside the scope of this EA.*[14]

Accordingly, even if the changes to the five EQC are not included within the scope of the EA, the public will still have the opportunity to participate in the MVLWB public hearing and communicate any issues or concerns about the proposed amendments. Through the MVLWB's public hearing process, the additional 5 EQC will undergo rigorous regulatory review, and as noted above, it is the MVLWB which is which is not only the correct administrative body, but one with the expertise to specifically review the proposed EQCs.

For all of the above reasons, De Beers submits that the impacts from the proposed changes to nitrite, nitrate, chloride, fluoride and sulphate EQCs have previously been considered and can be further reviewed during the public hearing process. As a result, De Beers requests that the Review Board omit the proposed changes to the five EQC from the scope of the EA. The scope of the EA should be limited to the issue of TDS.

3. Technical Sessions

Submissions from YKDFN, AANDC and the GNWT comment on the timing of the technical sessions. The Review Board has proposed to reschedule the technical sessions from April 10, 2014 to April 14 and April 15, 2014.[15], and recently, the GNWT has asked to reschedule the sessions to April 23-24.

The proposed postponement of the technical sessions should allow reviewers more time to review the material and prepare for the technical sessions. However, De Beers also notes that the materials have been available for review on the MVLWB's registry since December 2013, and that De Beers held an information session on the application, particularly the items related to TDS, on January 6, 2013. Representatives from AANDC, GNWT, YKDFN, as well as other government agencies, the Snap Lake Monitoring Agency and MVLWB

[14] Scoping Document, p 2.
[15] Review Comment Table.

attended this session. It is our view that the overall schedule for the Project, as set out by the Review Board, is quite reasonable given this is not a full blown EA for a proposed new development, and given that the material has been available for review for almost three months. In response to the concerns raised by the YKDFN in their letter dated March 14, De Beers is committed to working with the YKDFN to facilitate their understanding of the material, and involvement in the review process.

We trust that a delay in the technical session dates address AANDC and the GNWT's concerns, however De Beers would like to add that given the mandates and assignments of government agencies such as AANDC and GNWT to participate and provide expert advice in regulatory reviews, De Beers believes that the rescheduled dates should allow ample opportunity for these agencies to effectively participate in the environmental assessment and regulatory review of the application.

Finally, De Beers proposes to present a comprehensive overview of the application supporting information, and address comments received on the application, during the technical session. De Beers is of the opinion that addressing some of the key comments on the application in this manner will provide effective discussion during the technical session. De Beers notes however, that a number of comments received March 14 are generally vague and non-specific. In advance of the technical session, De Beers welcomes suggestions from reviewing parties on any specific issues that require particular focus, in the proposed presentation form, or otherwise.

4. Conclusion

In closing De Beers thanks the Review Board for this opportunity to respond to the Scoping Document and the comments made by the YKDFN, EC, AANDC and the GNWT. De Beers appreciates the Review Board's efforts to undertake the review process for this water licence amendment in an efficient and timely manner. If you have any questions in response to the foregoing, please do not hesitate to contact the undersigned by phone at (867)766-7331 or by email at erica.bonhomme@debeersgroup.com .

Sincerely,

DE BEERS CANADA INC.

Erica Bonhomme
Manager, Environment
Snap Lake Mine

Review Comment Table

Board:	MVEIRB
Review Item:	De Beers Snap Lake - EA Scoping Document and Water Licence Amendment Application
File(s):	MV2011L2-0004
Proponent:	De Beers Canada Inc. - Snap Lake
Document(s):	Evaluation of Effluent Quality Criteria Report (1 MB) Nitrogen Response Plan Report (4 MB) Site Water Quality Report - 2013 udpate (34 MB) Hydrodynamic and Water Quality Model Report (9 MB) Water Licence application form (.07 MB) Mining Industry Questionnaire (6 MB) Community Engagement Report (27 MB) Snap Lake Site Water Balance Model Report (1 MB) Underground water model memo (6 MB) Water Licence Concordance Table (0.3 MB) Snap Lake Site Water Model Report - North Pile Long Term Water Storage and Release (0.4 MB) Total Dissolved Solids Response Plan Report (27 MB) Joint Cover letter (0.1 MB) Draft Workplan (0.4 MB) MVEIRB Draft EA Scoping Document (0.5 MB) Snap Lake Strontium Response Plan (1 MB) Final Workplan (.4 MB)
Item For Review Distributed On:	Feb 24 at 17:23 Distribution List
Reviewer Comments Due By:	Mar 14, 2014
Proponent Responses Due By:	Mar 21, 2014
Item Description:	De Beers Canada Inc. submitted a water licence amendment application to the Mackenzie Valley Land and Water. This application was referred to the Mackenzie Valley Environmental Impact Review Board on Jan 22, 2014. Please see the cover letter for more details regarding the joint Review Board and MVLWB process. In order to determine which amendments should undergo assessment the Review Board is providing a draft EA Scoping Document. Please note that all proposed amendments, including those considered in the

	EA, will undergo the water licencing process. The Water Licence amendment application is provided for reviewer comment. Please note that comments on the water licence amendment applcation will be used for both the Review Board EA process and the MVLWB water licence amendment process.
General Reviewer Information:	The MVLWB and the Review Board invites reviewers to submit comments on the De Beers Canada Inc. Water Licence **(MV2011L2-0004)** and environmental assessment **(EA1314-002)** via the Online Review System. These documents include the EA Scoping document and the Water Licence Amendment Application including supplemental documents. For more details on this joint review please see the Cover Letter. Reviewers are requested to review the water licence application keeping in mind that comments, questions, or concerns will be considered by both the Review Board environmental assessment process and the MVLWB water licence process. The Review Board would like participants to make their first round of information requests in the present comment period. Please review the water licence application and use this Online Review System to issue your information requests, including a clear rationale for each request. The developer will provide a thorough response to each question posed to it. In the event of a dispute, the Review Board has the right to rule on the relevance of information requests and the acceptability of the responses. Parties may also use the present comment period to submit recommendations to the Review Board and/or the MVLWB With respect to the Review Board's EA scoping document you are requested to provided recommendations to the Review Board regarding which proposed amendments should be considered for the scope of the assessment. • To access please follow this link: MVERIB Online Review System • The deadline for reviewers to submit comments is March 14 at 9:59pm Mountain Time. • The deadline for the proponent to submit responses is March 21 at 9:59pm Mountain Time. • The User Manual for the Online Review System is available here. This request is being distributed by email only. If you require materials to be mailed or faxed, or require other assistance, please contact the Review Board or MVLWB: • Review Board - Simon Toogood: 867-766-7053 stoogood@reviewboard.ca

	• Rebecca Chouinard: 867 766-7459 rchouinard@mvlwb.com Please sign in to update your notification preferences and note that this is a system generated email, so any feedback should be directed to permits@mvlwb.com.
Contact Information:	Mark Cliffe-Phillips 867-766-7055 Rebecca Chouinard 867-766-7459 Simon Toogood 867 766-7053

Comment Summary

De Beers Canada Inc. - Snap Lake (Proponent)				
ID	**Topic**	**Reviewer Comment/Recommendation**	**Proponent Response**	**Board Staff Response**
3	General File	**Comment** (doc) De Beers cover letter **Recommendation**		
4	General File	**Comment** (doc) Attachment 1 **Recommendation**		
5	General File	**Comment** (doc) (Submitted after Due Date) EA accidents and malfunctions **Recommendation**		
6	General File	**Comment** (doc) (Submitted after Due Date) October 2013 ITASCA Memo **Recommendation**		
7	General File	**Comment** (doc) (Submitted after Due Date) May 19, 2008 Snap Lake Water Treatm,ent Alternatives Report **Recommendation**		
8	General File	**Comment** (doc) (Submitted after Due Date) December 2012 CH2MHill Aternatives Assessment **Recommendation**		
9	General File	**Comment** (doc) (Submitted after Due Date) December 2012 CH2MHill Aternatives		

		Assessment Appendix **Recommendation**		
10	General File	**Comment** (doc) (Submitted after Due Date) April 2014 MSE Grouting Memo **Recommendation**		
11	General File	**Comment** (doc) (Submitted after Due Date) 2003 Summary of Water Treatment Process Development, Selection and Comparison of Alternatives **Recommendation**		
12	General File	**Comment** (doc) (Submitted after Due Date) 2013 Draft Water Management Plan **Recommendation**		
13	General File	**Comment** (doc) (Submitted after Due Date) Cover letter and IR responses **Recommendation**		
1	Draft Workplan - Date of Technical Session	**Comment** (doc) The De Beers team's Technical Lead for the Application, Dr. Peter Chapman will be unavailable to present evidence and respond to questions during the Technical Session on April 10 as proposed, due to a previously-scheduled international commitment. As Dr. Chapman is a key member of our team, representing aspects of the Application related to aquatic effects and toxicity, De Beers requests that the boards consider rescheduling the Technical Session to Monday, April 7. **Recommendation** De Beers requests that the Technical Session be rescheduled to Monday, April 7.	**Mar 3:** (doc) The Review Board requests that if reviewers have any concerns with the developer's proposed date of April 7 for the technical session to let the Review Board know by March 14. **Mar 25:** (doc) The Technical Session will be held on Tuesday April 15 and Wednesday 16. The location is the Copper Room in the Yellowknife Inn.	

AANDC: Paul Green				
ID	**Topic**	**Reviewer Comment/Recommendation**	**Proponent Response**	**Board Staff Response**
1	Rescheduling of the DeBeers Snap Lake Technical Session	**Comment** (Submitted after Due Date) The dates proposed by the MVEIRB (April 14th and 15th) conflict with the availability of our consultant. AANDC and the GNWT request that the MVEIRB and MVLWB consider rescheduling to allow our technical expert participate in the Technical Sessions. We apologize for not being more clear in our ealier comments regarding the April 7th date. **Recommendation** AANDC and the GNWT recommend that the Technical Session be rescheduled to a later date to allow participation of our and DeBeers consultants. The dates could potentially be moved to the week of April 22-25th.	**Mar 21:** Please refer to the attached cover letter. It is De Beers preference to hold the technical sessions April 15-16.	**Mar 28:** Review Board - The Technical Session will be held on Tuesday April 15 and Wednesday 16. The location is the Copper Room in the Yellowknife Inn.

AANDC: Rick Walbourne				
ID	**Topic**	**Reviewer Comment/Recommendation**	**Proponent Response**	**Board Staff Response**
1	General File	**Comment** (doc) A letter from AANDC and the GNWT requesting rescheduling of the Technical Session. **Recommendation** GENERALFILE		

CanNor NWT Region: Matthew Spence				
ID	**Topic**	**Reviewer Comment/Recommendation**	**Proponent Response**	**Board Staff Response**
1	General File	**Comment** (doc) Cover letter - AANDC Review Comments		

		Recommendation GENERALFILE		
1	Aboriginal Affairs and Northern Development Canada ("AANDC") AANDC-1 Scope of EA - Ammonia	**Comment** AANDC notes that ammonia may also contribute to TDS levels in water and that the proponent has requested a proposed amendment to the ammonia limit. However, ammonia is not included as a parameter within the EA scope. Other nutrients such as Nitrate and Nitrite are included in the scope. **Recommendation** AANDC recommends that ammonia be added to the list of parameters to be included in the scope of EA.	**Mar 21:** Please see De Beers attachment 1 for the response to this question.	**Mar 28:** Review Board - The Review Board will consider all evidence provided by Parties with respect to the effects of TDS, and all its constituents, to Snap Lake and potentially affected downstream waterbodies.
2	AANDC-2 Scope of EA - TDS and Nitrogen Response Plans	**Comment** Response plans for TDS and Nitrogen will need to be established to ensure water quality downstream remains protected. **Recommendation** AANDC recommends that the details of the TDS Response Plan and Nitrogen Response Plan be determined during the water licencing review. However, that consideration of significance thresholds pertinent to these plans be included within the scope of the EA	**Mar 21:** The TDS Response Plan and Nitrogen Response Plan were required to be submitted per water licence MV2011L2-0004. These plans were submitted to the MVLWB for review on December 19, 2013, in accordance with licence requirements and require approval by the MVLWB. As such, De Beers agrees that all Response Plans should undergo a review process directed by the MVLWB. The Significance Thresholds were approved by the MVLWB November	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendments will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.

			2013 through an extensive review process (De Beers 2013). De Beers believes these thresholds are relevant, appropriate, and that they are protective of downstream lakes regardless of potential changes to SSWQO or EQCs. De Beers recommends that the Significance Thresholds be revisited during the AEMP Re-evaluation and Design Plan process in 2015-2016. De Beers believes that Medium Action Levels will need to be set and reviewed through the Response Plan, but that the approved Significance Thresholds are valid. Reference: De Beers (De Beers Canada Inc). 2013. 2013 Aquatics Effects Monitoring Program Design Plan in Support of Water Licence (MV2011L2-0004), Snap Lake Project. Snap Lake Project. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.	Review Board - the EA can consider the significance thresholds of the TDS and Nitrogen response plans.
3	AANDC-3 Scope of	**Comment** AANDC notes	**Mar 21:** Please see	**Mar 28:** Review

	EA - TDS	that Total Dissolved Solids (TDS) is a measurement of all organic and inorganic substances in water including chlorides, sulphates, phosphates, calcium, etc. It is important to note that when assessing impacts of TDS all the individual constituents must be considered as well as their proportions. **Recommendation** AANDCs recommends that all constituents of TDS related to the Snap Lake mine site be considered within the scope of EA with attention to their relative proportions.	De Beers response to AANDC 1.	Board - The Review Board will consider all evidence provided by Parties with respect to the effects of TDS, and all its constituents, to Snap Lake and potentially affected downstream waterbodies.
4	AANDC-4 Scope of EA- downstream environment	**Comment** While the scope as outlined is specific to Snap Lake, it is important to note than any alterations to the water quality in Snap Lake will also impact waterbodies downstream of Snap Lake. AANDC notes the extent and magnitude of impacts beyond Snap Lake must be defined and considered. AANDC makes this recommendation as it is a combination of both the concentration of COPC and the overall loadings to Snap Lake that are causing concerns for Snap Lake and the downstream receiving environment. Increasing the whole lake average concentrations of COPCs in Snap Lake will inherently also increase COPCs in the downstream receiving environment and the spatial extent of these increases. Spatial extent of impacts are a key consideration for an EA	**Mar 21:** Please see De Beers attachment 1 for the response to this question.	**Mar 28:** Review Board - The geographic scope will include Snap Lake and potentially affected downstream water bodies.

		and assist in the determination of Significance. In addition to the concerns noted above, TDS should be assessed within the area originally considered in the 2003 Report on EA for Snap Lake Diamond Project. For that assessment, DeBeers provided "predictions on the potential for increase in TDS for lakes in the Regional Study Area (RSA) downstream of Snap Lake in the Lockhart River Watershed" (p. 68 of Report on EA and Reasons for Decision on the Snap Lake Diamond Project). DeBeers should be required to amend those historic predictions to include the new data available and to reflect the proposed increases in TDS. **Recommendation** AANDC recommends that the areal extent of the scope be expanded to include the receiving environment downstream of Snap Lake. Specifically, the geographic scope should reflect the scope originally assessed in the 2003 Environmental Assessment - the Regional Study Area (RSA) - which includes lakes in the RSA downstream of Snap Lake in the Lockhart River watershed.		
5	AANDC-5 Part A: Definitions - Modifications	**Comment** De Beers has proposed a change to definition of Modification to include an expansion. AANDC notes that should an	**Mar 21:** De Beers agrees that a change in footprint could constitute an amendment. De	**Mar 28:** MVLWB Staff: These recommendations will be

		expansion include a change of the footprint of the operations, Board approval and or a possible amendment could be required. **Recommendation** AANDC recommends that the definition not be changed as an expansion may include an alteration of the project footprint which could require an amendment. AANDC notes that water licences in the NWT include specific wording related to Project Modifications that should remain.	Beers however maintains that any other change to an approved structure that does not alter the function or purpose of a structure should be included in the definition of a modification.	considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this definition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
6	AANDC-6 Part D: Construction	**Comment** De Beers requests that a condition previously removed in 2011 be reintroduced to allow small scale changes to be approved by the Inspector. AANDC has concern with this request as "small scale" is difficult to define. If this request is accepted a descriptive definition of "small scale" must be included and agreed to by all parties. Further, the Reasons for Decision from 2011 should be reviewed to assess why the condition was removed from the water licence at that time. **Recommendation** At this time, AANDC has concern that this condition could be misinterpreted and therefore can not support it. If the Board wishes to include it,	**Mar 21:** The intent of De Beers request is to re-include Part D, Item 7 under Water License MV2001L2-004 which states that "changes to the construction of engineered structures can be made on approval of the Inspector and notice to the Board." This condition was removed by the MVLWB at the request of De Beers but has since proven to be operationally constraining as changes cannot be made as quickly as was carried out previously. The intent	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will

		the Reasons for Decision in 2011 should be reviewed and a descriptive definition of "small scale" changes must be provided for reviewers to review and comment on.	of this condition would be identical to that as approved by the Board in 2004.	follow the conclusion of the EA process.
7	AANDC-7 Part E: Item 3	**Comment** De Beers requests that wording around Inspection Reporting be amended to apply clarity and correctness regarding the responsibilities of the Engineer and the Geoprofessional. **Recommendation** AANDC has no concerns with the proposed amendment	**Mar 21:** De Beers and AANDC are in agreement.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
8	AANDC-8 Part E: Item 10	**Comment** De Beers requests that the condition related to risk assessment for the North Pile be removed as the requirement has been satisfied. Note the condition of the North Pile has changed over the years since it was first designed, constructed and operated. At this time it is not clear to AANDC whether this condition has	**Mar 21:** The North Pile is designed to accept all waste from the mine. An approved change in the design, construction and operation under the guidance of a geotechnical engineer does not cause a risk to the integrity of the	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA.

		been appropriately satisfied. Further, the completion of a plan is not sufficient rationale for removing its requirement from a water licence. For example, AEMPs and Water Management Plans will be reviewed and approved as part of the water licence but they still remain as a component of the Water Licence. **Recommendation** AANDC does not support this request.	facililty. The condition for the North Pile risk assessment has been satisfied as written in the current water license, and no additional submissions are required. De Beers notes that this plan was not submitted to the Board for approval. Comments were received from SLEMA on October 21 2012 (available on the MVLWB website) stating "De Beers made impressive efforts in risk assessment and management. SLEMA appreciates these efforts and hopes De Beers continue to manage the North Pile with great caution." Additionally the internal risk logs are updated on a regular basis based on changes to operational plans.	Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
9	AANDC-9 Part E, Item 3 a) (Incorrectly listed as 13 a)	**Comment** De Beers requests that the condition requiring the Engineers Field Inspection Report specify priority recommendations to differentiate between necessity items and suggestions. In AANDC's experience an Engineers Report includes recommendations and	**Mar 21:** The Engineers Inspection report as submitted presents all recommendations within one section, However not all recommendations made by the engineer require action on this based that there is	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion

		suggestions. The recommendations are items that should be addressed by the company as soon as practical. Suggestions are things that can be considered and prioritized by the operator. **Recommendation** AANDC recommends that the condition remain as is and that all recommendations from the Engineer be addressed. AANDC notes that it is DeBeers option to prioritize any suggestions from the Engineers Report.	risk to the integrity of the facility. Recommendations that are directed to the operational management of the facility should identifies as lower priority. . For clarification, there has never been a separate section for "suggestions" as noted by AANDC, however that could be an acceptable method for dealing with the concern.	of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
10	AANDC-10 Part F, Item 8	**Comment** De Beers requested a re-naming of Station Number 02-16 to reflect the relocation of the Sewage Treatment Plant. **Recommendation** AANDC has no comments and is not opposed to this request.	**Mar 21:** De Beers and AANDC are in agreement.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.

11	AANDC-11 Part F: EQCs (metals and PHC)	**Comment** De Beers has requested that arsenic, chromium, copper, lead, nickel and zinc, as well as F1 and F2 hydrocarbons, be removed as EQC as monitoring has shown that concentrations have been an order of magnitude lower than established EQCs. De Beers recommends that while monitoring of these parameters should remain, a formal EQC is not required. AANDC disagrees that non-exceedances to date are sufficient rationale for removal of EQC. EQCs are set for COPCs that have the potential to effect the downstream receiving environment. Further, the water licence authorizes the deposit of waste therefore, the EQCs dictate under what conditions this discharge of waste can occur for all COPC. **Recommendation** AANDC recommends that EQCs remain in the water licence for all metals listed as well as F1 and F2 hydrocarbon fractions.	**Mar 21:** Please see De Beers attachment 1 for the response to this question.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
12	AANDC-12 Part F: item 9b	**Comment** De Beers requests that the pH requirement for surface water management be amended to account for the presence of bog and seepage sites which have reported values below 4.0 at 02-07 and 02-09 While AANDC agrees that bog areas are acidic by nature and could be excluded from pH criteria, "seepage" sites as defined in the licence	**Mar 21:** Please see De Beers attachment 1 for the response to this question.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA.

		should not be areas of high natural acidity. The rationale for sampling pH in "seepage" areas, such as the North Pile, is to identify if samples are acidic which is a by-product of acid rock drainage. The surface water management areas listed by De Beers are identified in the water licence as "surface water run-off facilities". AANDC does not believe these areas are seepage sites. To help address this concern, seepage sites should be specifically defined and identified within the licence and monitored as part of the SNP. **Recommendation** To help AANDC understand this concern, AANDC recommends De Beers provide information on causes of low acidity reading at sites 02-07 and 02-09. AANDC does not agree with the proposed amendment of pH at defined "seepage" sites.		Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
13	AANDC-13 Part F, Item 12	**Comment** De Beers requests the exclusion of land-locked stations from a requirement to direct non-compliant water to the Water Treatment Plant or Water Management Pond as there is no threat to the receiving environment. AANDC is unclear of the concern from De Beers regarding the potential for non-compliant water at these SNP stations as it is our understanding that the intent of these stations is to monitor for potential project impacts within and or immediately	**Mar 21:** Please see De Beers attachment 1 for the response to this question.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to

		outside of the mine footprint. As such, AANDC understands the intent of the condition is to ensure that any water retained on site or surface run-off from the site to the immediate area outside the mine footprint should report to the WTP or WMP. AANDC stresses that this requirement should not extend to natural bodies of water that may be nearby the mine that have not been impacted by the operation. **Recommendation** AANDC recommends that the condition remain. The Board should consider including additional information within its Reason for Decision to ensure that the intent of the condition is clear.		this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
14	AANDC-14 Part F, Item 13	**Comment** De Beers has requested the replacement of TDS whole lake average and the addition of average and maximum concentrations at end of pipe. AANDC has concern over the increase in TDS, Chloride, etc from the operation and the resulting increase of these COPCs in Snap Lake over time. AANDC is also concerned with the water quality predictions for TDS, Chloride, etc. **Recommendation** AANDCs anticipates discussing this at greater length at the upcoming technical sessions and throughout the EA process.	**Mar 21:** De Beers has provided comprehensive technical information to support the proposed amendments and will be prepared to answer questions at the upcoming technical session. It would assist De Beers to know, in advance of the technical session, the specific concerns that AANDC has with the proposed increases in TDS and chloride, so that De Beers may be prepared to specifically address these.	**Mar 28:** Review Board - The Review Board aknowledges that AANDC/GNWT will discuss this topic at the Technical Session.

15	AANDC-15 Part 5, Item 15 - Strontium Response Plan	**Comment** De Beers requests that the condition relating to the submission of a Strontium Response Plan be removed as the requirement has been satisfied. AANDC notes that the Strontium Response Plan has not yet been reviewed and approved by the Board. Further, additional discussion must take place in regards to this plan as part of its review process before it can be for approval. It is AANDCs opinion that the water licence amendment process is not the appropriate mechanism to review and approve the plan. **Recommendation** AANDC recommends that the condition remain in the Water Licence and that a formal plan review be undertaken as directed by the Board.	**Mar 21:** The Strontium Response Plan was a required submission per water licence MV2011L2-0004. This plan was submitted to the MVLWB for review in accordance with licence requirements on December 19, 2013, and requires approval by the MVLWB. As such, De Beers agrees that the Strontium Response Plan should undergo a review process directed the MVLWB. Should the plan be approved prior to, or concurrent with a decision on the proposed licence amendments, De Beers recommends that this condition be removed.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
16	AANDC-16 Part 5, Item 16 - Nitrogen Response Plan	**Comment** De Beers requests that the condition relating to the submission of a Nitrogen Response Plan be removed as the requirement has been satisfied. AANDC notes that the Nitrogen Response Plan has not yet been reviewed and approved by the Board. Further, additional discussion must take place in regards to this plan as part of its review process before it can be for approval. It is AANDCs opinion that the water licence amendment process is not the appropriate mechanism to review and approve the plan.	**Mar 21:** The Nitrogen Response Plan was a required submission per water licence MV2011L2-0004. This plan was submitted to the MVLWB for review in accordance with licence requirements on December 19, 2013, and requires approval by the MVLWB. As such, De Beers agrees that the Nitrogen Response Plan should undergo a review	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition

		Recommendation AANDC recommends that the condition remain in the Water Licence and that a formal plan review be undertaken as directed by the Board. Further, AANDC believes that the Nitrogen Response Plan and its contents are contingent on outcomes of the request to amend nitrate, nitrite and ammonia EQCs.	process directed the MVLWB. De Beers expects that the MVLWB will review De Beers' recommended Nitrogen site-specific water quality objectives - as required elements of the response plan during its regulatory review of the application. Should the plan be approved prior to, or concurrent with a decision on the proposed amendments, De Beers recommends that this proposed condition be removed.	will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
17	AANDC-17 Part F, Item 17 - TDS Response Plan	**Comment** De Beers requests that the condition relating to the submission of a TDS Response Plan be removed as the requirement has been satisfied. **Recommendation** AANDC recommends that the condition remain in the Water Licence and that a formal plan review be undertaken as directed by the Board. Further, AANDC believes that the TDS Response Plan and its contents are contingent on outcomes of the request to amend TDS EQCs and sampling methods.	**Mar 21:** The TDS Response Plan was required to be submitted per water licence MV2011L2-0004. The plan was submitted to the MVLWB for review on December 19, 2013, in accordance with licence requirements, and requires approval by the MVLWB. As such, De Beers agrees that the TDS Response Plan should undergo a review process directed by the MVLWB. The development of, site-specific water quality objectives for TDS is	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory

			a required element of the TDS Response Plan, and De Beers, in undertaking these studies, has evidence to support higher TDS EQCs. The research into site-specific water quality objectives and the resulting recommended EQCs are supporting information to the application to amend the TDS limit, and must be reviewed by the MVEIRB. It is De Beers' position that the TDS Response Plan contains a summary of this information, and while it can be used during the MVEIRB process to support the proposed EQC amendment, the review of the Plan itself should be undertaken by the MVLWB. Should the plan be approved prior to, or concurrent with a decision on the proposed licence amendment, De Beers maintains that this condition can be removed.	process that will follow the conclusion of the EA process.
18	AANDC-18 Part F, Item 19 - Plans	**Comment** De Beers request implies that the Nitrogen and TDS response plans as submitted are approved and that the requirement for the Strontium Plan is satisfied	**Mar 21:** The Nitrogen, Strontium and TDS Response Plans were required to be submitted per water licence	**Mar 28:** MVLWB Staff: These recommendations will be considered

		and can be removed. **Recommendation** AANDC recommends that the condition remain in the Water Licence and that formal plan reviews be undertaken as directed by the Board.	MV2011L2-0004. The TDS and Nitrogen Response Plans were submitted to the MVLWB for review on December 19, 2013 and the Strontium Plan on December 30, in accordance with licence requirements. As the plans require approval by the MVLWB, De Beers submits that these plans should undergo a review process directed by the MVLWB. Should the plans be approved prior to, or concurrent with a decision on the proposed licence amendments, De Beers maintains that these conditions can be removed.	during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
19	AANDC-19 Part G - AEMP	**Comment** De Beers requests that the AEMP Design Plan and reevaluation documents be combined into one document. AANDC has administrative concern with this request given the scope and nature of the 3 Year AEMP re-evaluation document. **Recommendation** AANDC requests that De Beers provide rationale on the request to combine the AEMP design plan and the re-evaluation. AANDC wishes to discuss this request further at the upcoming technical sessions before	**Mar 21:** De Beers understands AANDC's concern. As such De Beers requests that the AEMP re-evaluation and the AEMP redesign be required to be submitted under separate cover approximately 2 months apart from each other (eg October 31 and December 31) in the year that they are to be submitted.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available

		providing a recommendation on this request.		during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
20	AANDC-20 Schedule 1, Part B	**Comment** In relation to the Water Management Plan, De Beers requests that hydrogeololgical modeling occur every 3 years as opposed to every year. During the three year period, data will be compared to predictions every year and if there was a divergence, further investigation would be triggered. If data were at or below predictions, additional investigations would not be required during the three years. Given ongoing issues surrounding TDS and water balance modeling, AANDC is concerned that modeling on a 3-year cycle is insufficient. A quicker review and response time is required to ensure predictions are verified. Note the amount of water entering the underground workings is a real concern and it is likely to increase in volume and quality the deeper the workings get. Over time this can effect the company's ability to continuously meet EQC and loadings to Snap Lake and the downstream receiving environment. **Recommendation** AANDC recommends that hydrogeological modeling	**Mar 21:** De Beers agrees that operational data should be compared to modelling predictions in a timely manner to identify potential divergence. To increase confidence, De Beers collects samples in various mined areas to collect groundwater information from planned future mining areas. The data collected will be used to update and calibrate the groundwater model and subsequently the water quality model for Snap Lake. In addition, on an annual basis, De Beers will: 1) Compare flow volumes and loadings from the underground to the hydrogeological model predictions [and will report findings as part of the Water Licence Annual Report (WLAR)]; 2)	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this schedule will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.

		continue to occur on an annual basis to determine if predictions are validated, and to input into an appropriate response framework, when approved.	Compare flow volumes and loadings in the discharge to Snap Lake (WLAR); and, 3) Compare observed concentrations in Snap Lake with updated model predictions (report findings as part of the Aquatic Effects Monitoring Program report). Should a divergence be identified in any of those three comparisons, further investigation would be triggered. If volumes, loadings, and lake concentrations are equal to or less than model predictions, De Beers maintains that a full update of all three models is not required.	
21	AANDC-21 SNP revisions - SNP Station 02-02 and 02-03	**Comment** De Beers has requested that the requirement for continuous monitoring be removed from this condition as the water licence currently states that in-line monitoring is required. AANDC agrees with De Beers concern as in-line monitoring is not achievable in an open drainage ditch. Regarding SNP Station 02-02 it is AANDC's understanding that the water from the collection ditch reports to Perimeter Sump 5 (PS5) from which it	**Mar 21:** De Beers appreciates and agrees with AANDC's recommendation.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to

		is pumped into the Water Management Pond. The rationale for this sampling location is related to the quantity and quality of water associated with the North Pile. As such, AANDC recommends relocating this station to in-line monitoring at the pump. While non-continuous, the in-line sampling would provide information on all water associated with the drainage ditch and PS5. Regarding SNP Station 02-03, it is AANDC's understanding the this collection ditch is more of a depression from which water reports directly to the Water Management Pond. As such, it does appear feasible to conduct continuous in-line monitoring at this site. De Beers proposal for opportunistic sampling at this site when flows are observed is reasonable. **Recommendation** AANDC recommends that SNP Station 02-02 be relocated to in-line monitoring at the pump from Perimeter Sump 5 to the Water Management Pond. This monitoring would include quality and quantity of water reporting from the North Pile Drainage collection ditch. AANDC recommends that requirements for SNP Station 02-03 be amended from continuous in-line monitoring to monitoring when flows are observed as requested by De Beers.		the SNP will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.

22	AANDC-22 SNP revisions - SNP Station 02-17	**Comment** De Beers requests that the station be listed as inactive as the sample station is located prior to discharge into the pH adjustment tank. However, discharge from this tank is measured as SNP 02-17B. **Recommendation** AANDC has no concerns with the proposed amendment.	**Mar 21:** De Beers and AANDC are in agreement.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to the SNP will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
23	AANDC-23 SNP revisions - Removal of requirements	**Comment** De Beers has requested that arsenic, chromium, copper, lead, nickel and zinc, as well as F1 and F2 hydrocarbons, be removed as EQC and SNP as monitoring has shown that concentrations have been an order of magnitude lower than established EQCs. AANDC disagrees that non-exceedances to date are sufficient rationale for removal of EQC and SNP requirements. **Recommendation** AANDC recommends that the monitoring requirements currently outlined in the SNP	**Mar 21:** Please refer to the response to CanNor NWT Region 11.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to the SNP will be available during

		remain.		the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
24	Environment Canada ("EC") EC-1 Draft Review Board Proposed Scope of Environmental Assessment Snap Lake Amendment Project EA1314-02	**Comment** The proponent has proposed to remove the condition 2.7. Part F, Item 15 - Strontium response plan, from the Snap Lake Mine Water Licence. The Strontium Response Plan has not been reviewed or approved by the board. EC was not convinced the latest iteration fulfilled the condition set out in the water licence. **Recommendation** EC recommends the condition for a Strontium response plan remain in the water licence.	**Mar 21:** See response to AANDC 15.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
25	EC-2 Description of groundwater flow model update. Reference: Underground Model MemoSection: Technical memorandum	**Comment** The proponent stated in the model limitations that the lack of measured ground water levels “may limit the confidence level of the groundwater flow model”. The proponent also states that measured groundwater levels and groundwater flow rate are	**Mar 21:** During regular underground headwall face mapping, mine geologists record groundwater inflow rates as and when observed, and report seepage status. The groundwater flow	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence

		both important in the calibration of groundwater flow model. Yet, the report did not recommend collection of measured groundwater levels. How confident is the proponent in presenting the conclusions resulting from this groundwater flow model? Please explain. **Recommendation** EC recommends that the Board require the proponent to collect and integrate "measured groundwater levels" in the groundwater flow model calibration, or explain why its absence will not affect the results of the groundwater flow model.	model is update on a yearly basis using this, as well as structural information.	after completion of the EA. Further opportunities to provide input on this matter will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
26	EC-3 Draft Work plan	**Comment** EC is concerned with the proposed change of the Technical Session to April 7th from April 10th 2014. EC technical staff may not be available. **Recommendation** EC supports AANDC and GNWT's request to reschedule the session to a later date when Dr. Chapman is available.	**Mar 21:** Please see attached cover letter.	**Mar 28:** Review Board - The Technical Session will be held on Tuesday April 15 and Wednesday 16. The location is the Copper Room in the Yellowknife Inn.
GNWT - Environment and Natural Resources: Lindsay Luke				
ID	**Topic**	**Reviewer Comment/Recommendation**	**Proponent Response**	**Board Staff Response**
1	General File	**Comment** (doc) GNWT cover letter for comments submissions. **Recommendation**		
2	Time Available for Review	**Comment** Environment and Natural Resources (ENR) understands that the Mackenzie Valley Environmental Impact	**Mar 21:** Please see response to AANDC 1.	**Mar 28:** MVLWB Staff: ENR's comments are noted.

		Review Board (MVEIRB) and the Mackenzie Valley Land and Water Board (MVLWB) intend to hold technical sessions jointly for both the Environmental Assessment (EA) and the amendments for the Water Licence. ENR would like to inform the boards that the review time allocated is not sufficient to complete a thorough review for this submission. ENR will strive to have a complete review finalized prior to the technical sessions. However, the comments and recommendations in this document will be focused to the Scope of the EA document. **Recommendation** 1. To note for the boards (MVEIRB and MVLWB).		
3	Section 1.1 Total Dissolved Solids	**Comment** ENR concurs with the scoping document that the proposed changes to total dissolved solids (TDS) should be included in the scope of the EA. ENR understands that the proponent's amendment request is to remove the whole lake average TDS water licence limit of 350 mg/L and replace it with an Average Monthly Limit of 684 mg/L and Maximum Daily Limit of 1,003 mg/L. ENR would like to inform the boards (MVEIRB and MVLWB) that further technical comments will be provided on this topic during the technical session.	**Mar 21:** De Beers submitted its application to the MVLWB on December 19, 2013, and hosted an information and discussion session on January 6, and again on March 20, which GNWT attended. De Beers has provided comprehensive technical information to support the proposed amendments and submits that its own initiation of the review of the material should have allowed	**Mar 28:** MVLWB Staff: ENR's comments are noted. Further discussion of the proposed amendments and supporting documentation is expected to take place at the upcoming technical sessions.

		Recommendation 1. ENR notes that further technical comments will be provided during the technical sessions upon a complete review of the amendment application.	reviewers to advance their knowledge and review of the material prior to the MVRB and MVLWB's formal initiation of the review.	
4	Section 1.2 Other Proposed Changes to Effluent Quality Criteria	**Comment** ENR concurs with the scoping document that the parameters for nitrite, nitrate, chloride, fluoride and sulphate should be included in the scope of the EA. However, the effluent quality criteria (EQC), for all parameters, should be subject to review through the regulatory process following the completion of the EA. ENR notes that ammonia has not been included in the list for inclusion in the EA. Ammonia is one of the main contributors of nitrogen into Snap Lake. Additionally, ENR notes the proponent has requested that the ammonia EQC be raised. **Recommendation** 1. ENR recommends that ammonia be included in the scope of the EA.	**Mar 21:** Please refer to the response to CanNor NWT Region 1 for information on the ammonia EQC. De Beers is not requesting changes to the existing ammonia limits.	**Mar 28:** Review Board - The Review Board will consider all evidence provided by Parties with respect to the effects of TDS, and all its constituents, to Snap Lake and potentially effected downstream waterbodies.
5	2.8 Part F, Item 16 â€“ Removal of Requirement for TDS Response Plan From Water Licence	**Comment** ENR requests that Part F, Item 16 - TDS Response Plan be included in the EA. The TDS Response plan, in addition to the toxicological assessment, forms the basis of the proponent's position on TDS in Snap Lake. ENR notes that the TDS response plan has not been stakeholder reviewed, nor MVLWB approved.	**Mar 21:** Please see De Beers response to AANDC 17.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further

		Recommendation 1. ENR requests that the TDS Response Plan be included in the scope of the EA as supplementary information, but that any approvals and review of plans be conducted following the EA through the regulatory process. 2. ENR notes that the proponentÃ¢Â€Â™s request to remove Part F, Item 16 from its water licence is premature as the plans have not been stakeholder reviewed nor approved by the MVLWB.		opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
6	2.9 Part F, Item 17 Removal of Nitrogen Response Plan From Water Licence	**Comment** ENR requests that Part F, Item 17 - The Nitrogen Response Plan be included in the EA. The Nitrogen Response Plan, in addition to the toxicological assessments, form the basis of the nitrogen EQC amendments for Snap Lake. ENR notes that the Nitrogen Response Plan has not been stakeholder reviewed, nor MVLWB approved. **Recommendation** 1. ENR requests that the Nitrogen Response Plan be included in the scope of the EA as supplementary information, but that any approvals and review of plans be conducted following the EA through the regulatory process. 2. ENR notes that the proponentÃ¢Â€Â™s request to remove Part F, Item 17 from its water licence is premature as the plans have not been stakeholder reviewed nor approved by the	**Mar 21:** Please see De Beers response to AANDC 16.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.

		MVLWB.		
7	2.1 Part A Definitions - Change the Definition of â€˜Modificationâ€™	**Comment** ENR concurs with the scoping document that the change in definition of 'modification' should be excluded from the EA. ENR notes that the proponent has requested that the definition of 'modification' be altered to remove the item 'other than an expansion'. **Recommendation** 1. ENR supports the proponentÃ¢Â€Â™s request for clarity on the definition; however, modifications cannot expand the footprint of the operations without approval by the board. ENR does not support the proposed amendment as written.	**Mar 21:** Please see De Beers response to AANDC 5.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
8	2.2 Part D: Conditions Applying to Construction	**Comment** ENR concurs with the scoping document that the amendment request be excluded from the EA. ENR notes that the proponent has proposed an addition for the 2013 amendment that 'changes to the construction of engineered structures be made on the approval of an Inspector and notice to the board'. **Recommendation** 1. ENR does not support the amendment as written, as any construction should be accompanied with an	**Mar 21:** Please see De Beers response to AANDC 6 - the intent of the change is not to circumvent the reqirement for an engineers design and approval on engineered structures, but rather to use wording as approved in the previous Water License MV2001L2-0004.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to

		engineering stamped report/as built drawing(s). The liability of approval should not solely reside with an Inspector who may or may not be registered as a professional engineer in the Northwest Territories.		this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
9	2.3 Part E, Item 3: Conditions Applying to Waste Management, Designation of Engineer and Geoprofessional	**Comment** ENR concurs with the scoping document that the amendment request be excluded from the EA. ENR understands that the proponent recommends the Geochemical and Geotechnical Inspection Report to be written and approved by its discipline (Engineer and Geoprofessional). **Recommendation** 1. ENR supports the recommendation submitted by the proponent; however, notes that both the engineering and geoprofessional must be registered to practice in the Northwest Territories.	**Mar 21:** De Beers agrees with ENR, the engineering and geoprofessional are and will continue to be registered to practice in the NWT.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
10	2.4 Part E, Item 10- Risk Assessment of North Pile, Remove From Water Licence	**Comment** ENR concurs with the scoping document that the amendment request be excluded from the EA. ENR notes that the completion of a document does not constitute the removal of the condition from a water licence. ENR	**Mar 21:** Please refer to the response to CanNor NWT Region 8. The risk assessment as requested by the MVLWB was submitted September	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of

		notes that the risk assessment of the North Pile document does not appear to be on the Public Registry. **Recommendation** 1. ENR requests that the MVLWB confirm whether the condition of the water licence has been satisfied. 2. ENR does not support the removal of the condition until it can be demonstrated that the requirements of the licence have been met to the satisfaction of the MVLWB.	15, 2012.	the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
11	2.5 Part E, Item 3 (not 13) a) - Field Inspection Report, Implementation of Recommendations	**Comment** ENR concurs with the scoping document that the amendment request be excluded from the EA. ENR notes a typographical error in the scoping document; the item in question is Item 3 not 13. This is provided for the board's information. ENR understands from the requested amendment that the proponent would like to provide implementation plans for priority recommendations. The proposed change does not correspond to the proponent's reasons that this will differentiate between necessity items and suggestions. A recommendation provided in the Field Engineering Inspection Report should be implemented where a suggestion may not be required.	**Mar 21:** Please see De Beers response to AANDC 12.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.

		Recommendation 1. ENR considers all recommendations in the Field Engineering Inspection Report to be a priority and suggestions may be considered by the proponent for inclusion or exclusion with sufficient rationale. ENR suggests that the Field Engineering Inspection Report clearly differentiate between recommendations and suggestions for clarity.		
12	2.6 Part F, Item 8 â€“ Conditions Applying to Water and Wastewater Management	**Comment** ENR concurs with the scoping document that the amendment request be excluded from the EA. ENR does not have any technical comments on the proposed name change of the surveillance network program (SNP) station number at this time. **Recommendation** 1. To note for the boards (MVEIRB and MVLWB).	**Mar 21:** De Beers and GNWT are in agreement.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
13	2.7 Part F, Item 15 - Strontium Response Plan - Remove From Water Licence	**Comment** ENR concurs with the scoping document that the amendment request be excluded from the EA. ENR	**Mar 21:** Please see De Beers response to AANDC 15.	**Mar 28:** MVLWB Staff: These recommendations

		notes that the Strontium Response Plan has not been provided nor approved by the MVLWB. Approval of the plan from the MVLWB is required to determine whether the removal of this condition is appropriate. **Recommendation** 1. ENR requests that the proponent submit the Strontium Response Plan to the MVLWB through the preliminary screening process for stakeholder review, allowing for adequate review time, and board approval prior to considering this amendment.		will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
14	2.11 Part G â€“ Combine Aquatic Effects Monitoring Program (AEMP) and Re-Evaluation Plans Into One	**Comment** ENR notes that the AEMP and re-evaluation plans have historically been separated for administrative purposes. ENR notes that no rationale was provided to justify the amalgamation of the two reports. **Recommendation** 1. ENR requests that the proponent clarify how it intends to amalgamate the reports. ENR supports the reduction of duplicity in submissions, however it must be demonstrated that this is an appropriate amendment.	**Mar 21:** Please refer to the response to CanNor NWT Region 19.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory

				process that will follow the conclusion of the EA process.
15	Schedule 1, Part B, s) - Update Water Management Plan Every Three Years	**Comment** ENR concurs with the scoping document that the amendment request be excluded from the EA. ENR understands that the proponent proposes to provide its water management plan on a three year cycle. ENR notes that the current TDS issue is a result of increased water flows in the underground resulting in excess TDS discharge being sent to Snap Lake. Updating the model annually allows for long term predictions to be continually validated. This ensures long term forecasting will meet the EA predictions (or not). **Recommendation** 1. ENR does not support the amendment; the site has not met past EA predictions based on water inflows. Stakeholders require an annual model update to ensure that the proponent will meet its EA predictions and to indicate whether adaptive management will be required.	**Mar 21:** Please refer to the response to CanNor NWT Region 20.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
16	2.13 Proposed Surveillance Network Program (SNP) Revisions	**Comment** ENR concurs with the scoping document that the amendment request be excluded from the EA. The proponent has requested that continuous flow measurements (pH, EC, turbidity) be removed for SNP stations 02-02 and 02-03. ENR notes that no	**Mar 21:** De Beers requested that inline monitoring be removed from SNP 02-02 and 02-03 as water cannot be measured in line in an open ditch. Currently De Beers collects samples from a	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence

		justification has been provided. **Recommendation** 1. ENR understands that if no water is present, then the proponent is not required to report on each station. ENR requests that the proponent provide clarity on why continuous flow measurements should be removed from the licence.	depression created within the ditch when water is present and deep enough to sample, but this not the most useful sample location, nor does it provide consistent results. At SNP 02-02 De Beers suggests that the samples should be collected from the sumps that act as a collection facility for the North Pile when water is being pumped, rather than from the ditch itself. At 02-03, sampling in the depression is still the best method for collecting a sample, although it is still not continuous. Please see De Beers response to AANDC 21.	after completion of the EA. Further opportunities to provide input on the proposed amendments to the SNP will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
17	02-17- Temporary WTP (Auxiliary)	**Comment** ENR concurs with the scoping document that the amendment request be excluded from the EA. Based upon discussions with AANDC, ENR understands that the SNP station is an intermediate, internal station that does not discharge to the environment. **Recommendation** 1. ENR requests that the proponent confirm the location of the SNP station 02-17 and whether water reports to the environment. If this is confirmed, ENR supports the removal of the SNP station.	**Mar 21:** Please see De Beers attachment 1 for the response to this question.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendments to the SNP will be

				available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
18	Stations 02-02, 02-03, 02-04, 02-05, 02-06, 02-07, 02-08, 02-09, 02-10, 02-11, 02-12, 02-13, 02-04	**Comment** ENR concurs with the scoping document that the amendment request be excluded from the EA. ENR understands from the amendment application that the proponent requests that monitoring for BTEX, F1 and F2 be removed from these thirteen stations. **Recommendation** 1. ENR notes to the MVLWB that the listed parameters and stations are meant to provide a regulatory quantitative measurement for constituents that may pose a risk to the environment. ENR does not support the removal of parameters from the SNP network.	**Mar 21:** Please see De Beers response to AANDC 21.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendments to the SNP will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
19	2.14 Part F, Item 9 a) â€“ Remove Requirement to Monitor For	**Comment** ENR concurs with the scoping document that the amendment request be excluded from the EA. ENR understands from the amendment application that the proponent proposes to remove the requirement to monitor for eight parameters	**Mar 21:** Please refer to the response to CanNor NWT Region 11.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended

		of potential concern, including: arsenic, chromium, copper, lead, nickel, zinc, and F1 and F2 fractions. **Recommendation** 1. ENR notes to the MVLWB that the listed parameters are meant to provide a regulatory quantitative measurement for constituents that may pose a risk to the environment. ENR does not support the removal of parameters from the SNP network.		water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
20	3.1 Part F, Item 9b â€“ pH in Bogs	**Comment** ENR concurs with the scoping document that the amendment request be excluded from the EA. ENR notes that the proponent has indicated two distinct types of water discharges in its proposed amendment, bog water vs. seepage water. Bog water is naturally acidic and may produce acidic drainage. ENR notes that the SNP stations that the proponent has described as having low pH are both located on-site and may be seepage water. **Recommendation** 1. ENR requests that the proponent clarify the source of the water at both stations that have pH of less than 5. ENR does not support the amendment based on seepage water as it may be acid rock drainage. 2. ENR requests that the proponent provide site specific information on bog water indicating that the pH is less	**Mar 21:** Please see De Beers response to AANDC 12.	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.

		than 5. If natural bog water in the region is below pH 5, ENR would consider the proposed amendment once all information is provided.		
21	3.2 Part F, Item 12 â€“ Water Quality and Disposal of Land Locked Areas	**Comment** ENR concurs with the scoping document that the amendment request be excluded from the EA. ENR understands the proposed amendment is for an exclusion of site water that is land locked, does not pose a threat to the receiving environment, and will not have to report to engineered control structures. **Recommendation** 1. ENR requests that the proponent further clarify the basis of this amendment. 2. ENR notes that the SNP stations identified by the proponent in its reasoning are for drainage ditches and the water management pond. ENR does not support the amendment as written. Any water on-site that is in the project footprint should report to water control structures.	**Mar 21:** For item, please see De Beers response to AANDC 21 .	**Mar 28:** MVLWB Staff: These recommendations will be considered during the development of the amended water licence after completion of the EA. Further opportunities to provide input on the proposed amendment to this condition will be available during the joint technical session and during the regulatory process that will follow the conclusion of the EA process.
Mackenzie Valley Environmental Impact Review Board: Simon Toogood				
ID	**Topic**	**Reviewer Comment/Recommendation**	**Proponent Response**	**Board Staff Response**
1	Scheduling for Technical Session	**Comment** The the GNWT and AANDC requested that the date for the technical session be after April 10, 2014. The Review Board proposes April 14 and 15 for the technical session. **Recommendation** Please let the Review Board know if you have concerns with these	**Mar 21:** Please see attached cover letter.	**Mar 28:** Review Board - The Technical Session will be held on Tuesday April 15 and Wednesday 16. The location is the Copper Room in the

		proposed dates.		Yellowknife Inn.
MVLWB: MVLWB RO				
ID	**Topic**	**Reviewer Comment/Recommendation**	**Proponent Response**	**Board Staff Response**
1	Predicted temporal-spatial trend in water hardness in Snap Lake	**Comment** While some of the proposed SSWQOs are hardness-dependent, we have not found a detailed forecast for how hardness is expected to vary over time in the different lake areas. We do find the calculated SSWQO over time by area, but have no way to check the calculation. **Recommendation** Please provide plots of hardness under the various scenarios, from 2004 through 2029, for the diffuser area, main basin and outlet.	**Mar 21:** Please see De Beers attachment 1 for the response to this question.	**Mar 28:** MVLWB Staff: The requested information was provided for review. Board staff expect that modelling will be discussed in further detail at the upcoming joint technical sessions. Information gathered throughout the joint review process and the subsequent regulatory process will be considered in developing the amended Licence.
2	Effectiveness of proposed water management measures to achieve compliance with the proposed SSWQO for TDS in Snap Lake	**Comment** The proposed SSWQO for TDS is expected to be exceeded in Snap Lake as early as 2015 to 2016 (Scenario A). A water management strategy is proposed, including segregation of dirty and clear water, and WTP expansion. It is unclear if the proposed strategy will allow the proposed SSWQ objective to be met in Snap Lake. **Recommendation** Please provide plots of expected TDS in the diffuser area,	**Mar 21:** De Beers will provide the requested plots, in advance of the Technical Session.	**Mar 28:** MVLWB Staff: The requested information is not yet available for review. Board staff expect that it will be provided in advance of the technical session as per De Beers' response, and that modelling will be discussed in further detail

		main basin and outlet, from 2004 through 2029, with the proposed enhanced water treatment in place.		at the upcoming joint technical sessions. Information gathered throughout the joint review process and the subsequent regulatory process will be considered in developing the amended Licence.
3	Derivation of DF of 12	**Comment** The proponent has assumed a dilution factor (DF) of 12 based on the EAR (2002) and the fact that a DF of 12 is more conservative than the minimum DFs derived by DeBeers (2013e) and Golder (2013). We note that the DF of 16 provided by Golder was based on measurements taken during the ice-covered period in 2012, and that more conservative DFs of 7 and 9 were estimated for the early open water period in 2012. **Recommendation** Since the EQCs should be applicable throughout all months of the year, not just the ice-covered period, the rationale for limiting the DF selection to ice-covered months only should be provided, or a more conservative DF, such as those presented for July and August 2012 in Golder (2013), should be used.	**Mar 21:** Please see De Beers attachment 1 for the response to this question.	**Mar 28:** MVLWB Staff: Board staff expect that the EQC calculations will be discussed in further detail at the upcoming joint technical sessions. Information gathered throughout the joint review process and the subsequent regulatory process will be considered in developing the amended Licence.
4	2014 Plume Characterization	**Comment** We note that the proponent has indicated on	**Mar 21:** Based on the information	**Mar 28:** MVLWB Staff:

	Study	page 2-10 of the EQC report that a plume study is planned for summer 2014 to investigate the dilution factors resulting from two operating diffusers. **Recommendation** The proponent should indicate whether the results of the 2014 study will have any effect on the EQCs developed in 2013.	provided in MVLWB 3, De Beers expects that the results of the 2014 plume characterization study will have a negligible effect on the recommended EQCs.	Board staff expect that mixing and dilution in relation to EQC will be discussed in further detail at the upcoming joint technical sessions. Information gathered throughout the joint review process and the subsequent regulatory process will be considered in developing the amended Licence.
5	Air entrainment in the diffuser	**Comment** The 2012 Plume Characterization Study (Golder 2013) indicates that air entrainment in the diffuser may have reduced the dilutions achieved in that year. **Recommendation** The proponent should provide information on what has been done to correct the issue, and should provide assurance and evidence that the dilutions required to achieve the proposed SSWQOs or WQGs will be achieved.	**Mar 21:** The source of significant air entrainment into the diffuser line observed in 2012, was found to be the vacuum-breaking action of the combination air valve located at on the surface of the outfall, just upstream of the Outfall Diffuser Pump. As of September 19, 2012 air entrainment as identified in the Plume Characterization Study has since been eliminated from the diffuser outfall. This was confirmed in the De Beers letter to SLEMA dated March	**Mar 28:** MVLWB Staff: Board staff expect that mixing and dilution in relation to EQC will be discussed in further detail at the upcoming joint technical sessions. Information gathered throughout the joint review process and the subsequent regulatory process will be considered in developing the amended Licence.

			21, 2013 in response to concerns over air entrainment at the diffuser. As noted in the Plume Characterization Study, the performance of the existing minewater outfall is expected to meet the accepted EAR predictions for mixing, so long as air is minimized in the discharge line. As such De Beers has concluded that the diffuser is working as designed to dilute effluent with into the lake. This will be verified in 2014 through Plume Characterization Study committed to as a part of the 2nd Diffuser installation package. For information on the second part of the question, please see De Beers attachment 1.	
6	Groundwater flow report	**Comment** The August 2013 Itasca memo describing the groundwater flow model update appears to be an Executive Summary of the work. In order to evaluate the work it is necessary to review the full report. The full report seems to be a 2012 draft. **Recommendation** Provide the following key document for review: Itasca. 2012. Groundwater flow model	**Mar 21:** Please see De Beers attachment 2. **Mar 27:** Review Board staff uploaded this document on behalf of De Beers. The document is attachment #2 from the March 21 response from De Beers.	**Mar 28:** MVLWB Staff: The requested document was provided for review. Board staff expect that modelling will be discussed in further detail at the upcoming joint technical sessions.

		update for Snap Lake mine. Draft report prepared for DeBeers Canada by Itasca Denver, Inc., 21 December.		Information gathered throughout the joint review process and the subsequent regulatory process will be considered in developing the amended Licence.
7	Groundwater flow - supporting documents	**Comment** A number of supporting documents are mentioned in the August 2013 memo on groundwater flow. It may be necessary to consider these documents in reviewing the groundwater flow model update report. **Recommendation** Please provide the following supporting documents for review: 1) HCI. 2005a. Predicted inflow to Snap Lake. Technical memorandum prepared for SRK Consulting by Hydrologic Consultants, Inc., 17 February. 2) HCI. 2005c. 2005 hydrogeologic framework of Snap Lake project area and predicted inflow to proposed mine - September 2005 update based on data from P1PP. Prepared by Hydrologic Consultants, Inc., September. 3) HCI. 2006a. Predicted quantity and quality of mine water discharge from planned Snap Lake mine. Technical memorandum prepared for SRK Consulting by Hydrologic Consultants, Inc., 19 May. 4) HCI. 2006b.	**Mar 21:** The references were cited in the 2013 updated model to demonstrate the improved knowledge of Snap Lake hydrogeology over time since the first models were completed. Â For example, HCI's 2005 model did not simulate structural zones and only included the Snap fault. The 2013 updated model simulates significantly more structures and faults. HCI's 2005 model assumed that backfilling would reduce water inflow, and that upper and lower contact zones are less permeable than the country rock.Â The 2013 updated model did not simulate these "throttle" effects. HCI's 2006 model simulated only five	**Mar 28:** MVLWB Staff: The requested documents were not provided. Board staff note De Beers' response. If further information regarding these documents is required, it will be requested.

		Predicted quantity of mine water discharge from planned Snap Lake mine. Technical memorandum prepared for SRK Consulting by Hydrologic Consultants, Inc., 28 June. 5) Fracflow. 2011a. Simulation of existing and future mine water inflows and mass loadings to the mine workings. Technical memorandum prepared for De Beers Canada by Fracflow Consultants, 31 May.	structural zones, whereas additional structural zones were added to the updated model.Â The 2006 model did not extend Snap and Crackle faults to the model boundary as has since been done in the updated model. Additional hydraulic conductivity values were provided in Fracflow's report and were incorporated into the updated model.Â De Beers considers these models to be outdated for the purpose of this application and as such recommends that the ITACSA 2013 current model be referenced for this review. As such, the reports cited are not representative of current knowledge of conditions and De Beers refers the MVLWB to the 2013 Itasca groundwater model for current information.	
8	Effectiveness of proposed water management measures to achieve compliance with the proposed SSWQO for Chloride in Snap Lake	**Comment** The proposed SSWQO for Chloride is expected to be exceeded in Snap Lake as early as 2016 to 2017 (Scenario A). A water management strategy is proposed, including segregation of dirty and clear water, and WTP expansion. It is unclear if the proposed	**Mar 21:** De Beers will provide them when available, the requested plots in advance of the Technical Session.	**Mar 28:** MVLWB Staff: The requested information is not yet available for review. Board staff expect that it will be provided in advance of the

		strategy will allow the proposed SSWQ objective to be met in Snap Lake. **Recommendation** Please provide plots of expected Chloride in the diffuser area, main basin and outlet, from 2004 through 2029, with the proposed enhanced water treatment in place.		technical session as per De Beers' response, and the proposed mitigations will be discussed in further detail at the upcoming joint technical sessions. Information gathered throughout the joint review process and the subsequent regulatory process will be considered in developing the amended Licence.
9	Inconsistent definition of dilution factor	**Comment** In the 2012 Plume Characterization report (Golder 2013), the dilution factor is defined as DF = (Ce - Cb)/(C - Cb). In the EQC report, Equation 2 on page 2-10, when rearranged algebraically for DF, implies that DF = (Ce - C)/(C - Cb). These definitions are inconsistent. **Recommendation** The reviewer believes that the definition for DF in the Plume report makes sense and is defensible. Equation 2 in the EQC report should be Cmz=((DF-1)*Csl+Cte)/DF in order to be consistent with the definition in the 2012 Plume report. Note that Equations 3 and 5 are also affected by this change. Please revise the EQCs	**Mar 21:** Please see De Beers attachment 1 for the response to this question.	**Mar 28:** MVLWB Staff: Board staff expect that the EQC calculations will be discussed in further detail at the upcoming joint technical sessions. Information gathered throughout the joint review process and the subsequent regulatory process will be considered in developing the amended Licence.

		accordingly, or explain the noted inconsistency.		
10	Exceedence of SSWQO for TDS, chloride and nitrate	**Comment** DBCI has predicted that TDS, chloride and nitrate concentrations in Snap Lake will exceed the proposed SSWQO in the years 2016, 2016 and 2025 respectively without additional mitigations. Although DBCI has proposed some potential mitigations, there is no guarantee that any of them will work so the potential to exceed these WQOs is very real. **Recommendation** Please describe the potential effects on aquatic life in Snap Lake and downstream if and when the SSWQO for TDS, chloride and nitrate are exceeded.	**Mar 21:** De Beers has proposed EQCs for TDS, chloride and nitrate that are protective of the aquatic life in Snap Lake and in downstream lakes. These limits, if adopted in the licence, are key to establishing the design criteria needed to advance feasibility studies, and eventual design and implementation of mitigation technologies as identified in the TDS Response Plan that will ensure that mine effluent does not exceed these limits. De Beers does not intend to exceed the limits if approved as proposed, as such, assessing the effects under this scenario is uneccessary.	**Mar 28:** MVLWB Staff: Board staff expect that the proposed mitigations will be discussed in further detail at the upcoming joint technical sessions. Information gathered throughout the joint review process and the subsequent regulatory process will be considered in developing the amended Licence.
11	Effectiveness of proposed mitigations	**Comment** In the Response Plans submitted, DBCI has proposed some mitigation options for reducing TDS and nitrate in the discharge. However, in neither case has DBCI provided an analysis of how effective these mitigations would actually be - that is, there are no predictions of what the discharge quality would be if	**Mar 21:** De Beers has proposed EQCs for TDS, chloride and nitrate that are protective of the aquatic life in Snap Lake and in downstream lakes. These limits, if adopted in the licence, are key to establishing the	**Mar 28:** MVLWB Staff: The requested information is not yet available for review. Board staff expect that it will be provided in advance of the technical session as per De Beers'

		those mitigations were implemented. For example, the TDS Response Plan submitted by DBCI describes a mitigation option whereby they would segregate and treat that fraction of underground water that is highest in TDS. That fraction of water represents about 10-20% of the total amount of the discharge. No information is given, however, on what the concentration of TDS is in that fraction or what reduction in TDS we would expect to see if the proposed treatment option (i.e., reverse osmosis) was implemented. Finally, there is no prediction of whether, if they implemented this option, the TDS water quality objective could be achieved or not. We already know that if no mitigation is applied then the TDS SSWQO will be exceeded in Snap Lake. **Recommendation** Can DBCI provide an evaluation of what the water quality in Snap Lake would be in future if any of the proposed mitigations are implemented? Without this information it may be difficult for the Board to conclude that DBCI has a viable plan or option for reducing TDS (or chloride) should levels exceed an acceptable level.	design criteria needed to advance feasibility studies, and eventual design and implementation of mitigation technologies as identified in the TDS Response Plan that will make certain that mine effluent does not exceed these limits. De Beers will provide water quality plots showing what the water quality in Snap Lake would be in the future if the proposed mitigations are implemented. These plots will be provided in advance of the Technical Session.	response, and the proposed mitigations will be discussed in further detail at the upcoming joint technical sessions. Information gathered throughout the joint review process and the subsequent regulatory process will be considered in developing the amended Licence.
12	EQC calculations	**Comment** Section 2.4.1 of the Evaluation of Effluent Quality Criteria report states that waste load allocations were calculated using treated	**Mar 21:** The two scenarios represent the upper and lower bounds of the range of possibilities; De	**Mar 28:** MVLWB Staff: Board staff expect that the EQC Report will

		effluent discharge flow predictions for the Lower Bound Scenario. It is unclear why the Lower Bound Scenario was used in these calculations. **Recommendation** Please explain the rationale for the use of Lower Bound Scenario as opposed to Upper Bound Scenario discharge flows.	Beers expects that actual flows and loading will be intermediate between the two scenarios. The Lower Bound Scenario was presented in the EQC Report because, even at the lower end of expected flows and loadings (i.e., Lower Bound Scenario), mitigation will be required to meet the proposed EQCs over the life of the mine. Note that in the Lower Bound Scenario, the EQC for TDS is essentially equivalent to the site-specific water quality objective. .	be discussed in further detail at the upcoming joint technical sessions. Information gathered throughout the joint review process and the subsequent regulatory process will be considered in developing the amended Licence.
Yellowknives Dene First Nation: shannon gault				
ID	**Topic**	**Reviewer Comment/Recommendation**	**Proponent Response**	**Board Staff Response**
1	General File	**Comment** (doc) A letter from the Yellowknives Dene First Nation regarding the draft scope of EA and workplan. **Recommendation** GENERALFILE		

Attachment 1: Additional Information as referenced in Excel Comment Table

CanNor NWT Region 1

De Beers disagrees that ammonia be added to the scope of the environmental assessment. The regulatory review of the application by the Mackenzie Valley Land and Water Board is the appropriate mechanism by which to review specific water quality limits such as EQCs for ammonia. For additional clarification, De Beers is not requesting changes to the existing ammonia limits. However, it appears that the presentation of recommended EQC for ammonia in the WL Amendment document has caused confusion. For clarity, a summary of the process and terminology used for the ammonia EQC is provided:

- Recommendations and rationale for revised EQC for ammonia were specifically required under Schedule 5: Part F, 3b (ii) and 4b (ii) of the Water Licence (MVLWB 2013).

- The existing limits (MVLWB 2013) for ammonia include an average monthly limit (AML) of 10 mg-N/L and a maximum daily limit (MDL) of 20 mg-N/L (MVLWB 2013).

- De Beers re-visited the existing limits using the methods outlined in the EQC report (De Beers 2013a), selected an appropriate benchmark, a location in Snap Lake where benchmarks should be met, and then calculated an appropriate EQC that is protective of the aquatic communities in Snap Lake.

- The AML and MDL for ammonia were set equal to the acute benchmark (i.e., an AML and MDL of 21 mg/L were considered protective). The acute benchmark, which protects against acute effects prior to discharge, was more conservative than calculating an MDL and AML based on the chronic benchmark with processes such as nitrification applied.

- In the final step of the EQC derivation process, the "proposed"[1] EQC were compared to existing EQC in the Water Licence and predicted treated effluent discharge concentrations. During this step, it was determined that ammonia concentrations in the effluent discharge are not expected to exceed the existing limits (AML = 10 mg-N/L and MDL = 20 mg-N/L); therefore, there was no reason to change the existing EQC. The final recommendation was **not** to change the ammonia EQC through the amendment process.

It is recognised that the term "proposed" in Table 3-1 and Table 3-2 of the EQC Report (De Beers 2013a) and Tables 3-2 and 3-3 of the Nitrogen Response Plan (De Beers 2013b) has been interpreted to be the final EQC recommendation. The footnotes on the term "proposed" in those tables specify that "the final list of recommended EQC for inclusion in the Water Licence is presented in Section 3.3; the final list was developed based on the comparisons of existing and proposed EQC", but this is apparently not clear to the reviewers. The Water Licence

[1] "Proposed" refers to the AML and MDL both equal to 21 mg-N/L, which was considered protective.

Concordance Table presents the correct EQC (i.e., AML = 10 mg-N/L and MDL = 20 mg-N/L). This represents “no change, based on review of EQC”.

References:

De Beers (De Beers Canada Inc.). 2013a. Evaluation of Effluent Quality Criteria. Submitted to the Mackenzie Valley Environmental Impact Review Board, Yellowknife, NWT, Canada.

De Beers. 2013b. Nitrogen Response Plan. Water Licence Amendment Application. Submitted to the Mackenzie Valley Environmental Impact Review Board, Yellowknife, NWT, Canada.

MVLWB (Mackenzie Valley Land and Board). 2013. Mackenzie Valley Land and Water Board Water License # MV2011L2-0004. Yellowknife, NWT, Canada.

CanNor NWT Region, 4

De Beers monitors lakes downstream of Snap Lake for water and sediment quality (De Beers 2013) and has an Water license monitoring station at King Lake downstream of Snap Lake. De Beers also regularly includes this geographic area in its water quality predictions. De Beers is currently completing modelling to update water quality predictions presented in the Snap Lake Environmental Assessment Report (De Beers 2002) and in the De Beers 2010 Water License Renewal (De Beers 2010) on the potential for increase in total dissolved solids (TDS) concentrations for lakes in downstream of Snap Lake in the Lockhart River Watershed downstream to Great Slave Lake assuming a TDS of 684 mg/L in the treated effluent. De Beers will provide a Figure showing the areal extent of the potential for increase in TDS concentrations for lakes downstream of Snap Lake prior to the technical sessions. As outlined in the 2012 Aquatics Effects Monitoring Program (AEMP) report and the 2013 AEMP Design Plan (De Beers 2013; De Beers 2014), De Beers plans to use these modelling predictions and existing water and sediment quality monitoring in the downstream lakes to design appropriate monitoring programs downstream of Snap Lake.

References: De Beers. 2002. The Snap Lake Diamond Mine Environmental Assessment Report. Submitted to the Mackenzie Valley Environmental Impact Review Board. Yellowknife, NWT, Canada.

De Beers. 2010. Water license renewal application to the Mackezie Valley Land and Water Board. Yellowknife, NWT, Canada.

De Beers. 2013. 2012 Annual Report. Aquatic Effects Monitoring Program Snap Lake Mine. Type A Water License MV2001L2-0002. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT.

De Beers. 2014. 2013 Aquatic Effects Monitoring Program Design Plan- FINAL. Submitted to the Mackenzie Valley Land and Water Board, Yellowknife, NWT, Canada.

CanNor NWT Region 11 Golder
Topic: AANDC-11 Part F: EQCs (metals and PHC)

Aluminum, arsenic, chromium, copper, lead, nickel, and zinc were carried forward in the EQC assessment to determine whether existing EQC are appropriate and conservative based on anticipated operational changes at the Mine (De Beers 2013a). The most important operational change will be an increasing rate of treated effluent discharge beyond discharge levels previously used to derive EQC, thereby increasing loadings to Snap Lake.

The flow-weighted average arsenic, chromium, copper, lead, nickel, and zinc concentrations in 2013 were at least an order of magnitude lower than the proposed and existing EQC. Modelling indicates that those metals and metalloids will remain well below benchmarks throughout the operational period and are therefore unlikely to pose a threat to the aquatic environment of Snap Lake. Additionally, concentrations are not even expected to exceed the more conservative AEMP benchmarks in treated effluent (De Beers 2013b). Given these factors, arsenic, chromium, copper, lead, nickel, and zinc would not be considered contaminants of potential concern (COPC) as AANDC suggests; therefore, it was recommended that EQC for these metals be removed from the Water Licence. This is consistent with Appendix C, Section 5.1 of the Reasons for Decision from the 2012 Water Licence Renewal (MVLWB 2012), which states that "*Based on effluent and AEMP data since mine construction, EQC for arsenic, cadmium, lead and zinc, may no longer be necessary; however, no party requested removing these regulated parameters in the renewal WL MV2011L2-0004."* The Board eliminated the cadmium EQC at that time because concentrations continued to be below the detection limit. EQC for arsenic, lead, nickel and zinc were retained the use of the CCME water quality guidelines (WQG) for generating EQC was recommended, which is consistent with the approach used by De Beers (De Beers 2013a).

De Beers does not propose to discontinue monitoring, Ongoing monitoring of these metals will establish on-going trends and confirm model predictions. De Beers does suggest however, that monitoring frequency could be reduced The Water Licence currently requires that any metal with an EQC be monitored every six days; all other metals are to be monitored on a monthly basis. Monitoring frequency for arsenic, chromium, copper, lead, nickel, and zinc could be reduced from "every six days" to "monthly" to be consistent with the other metals.

Extractable petroleum hydrocarbons were not carried forward in the EQC assessment. The EQC for extractable petroleum hydrocarbons does not appear to be based on toxicity data, and this parameter is typically not detected in the treated effluent; consequently, it is recommended that monitoring of this parameter continue on a monthly basis but that the EQC be removed.

For aluminum, the recommendation was to retain the AML and MDL. The proposed EQC were equal to the existing EQC in the Water Licence and total aluminum concentrations in the treated effluent discharge have been variable and, on occasion, have exceeded the existing EQC. Total aluminum concentrations are correlated to TSS, which has a best available technologies limit. If TSS levels are maintained at low concentrations through operational processes (i.e., sedimentation or filtering), aluminum concentrations should, correspondingly, remain low.

Reference:

De Beers (De Beers Canada Inc.). 2013a. Evaluation of Effluent Quality Criteria. Submitted to the Mackenzie Valley Environmental Impact Review Board, Yellowknife, NWT, Canada.

De Beers. 2013b. Snap Lake Site Model Water Quality Report. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

MVLWB (Mackenzie Valley Land and Water Board). 2103. Reasons for Decision MV2011L2-0004. Snap Lake Diamond Mine. Yellowknife, NWT, Canada.

CanNor NWT Region 12
Topic: AANDC-12 Part F: item 9b

Acid Rock Drainage (ARD) is defined as "Acidic pH drainage derived from materials with an insufficient capacity to neutralize the acidic products of sulphide and elemental sulphur oxidation and the dissolution products of acidic minerals and amorphous materials" (MEND, 2009). Bodies of water affected by ARD generally show several trends in water quality, including an increase in sulphate concentrations due to the oxidation of sulphide minerals, as well as a potential increase in trace metal concentrations due to both sulphide oxidation and mineral dissolution at acidic pH values. The bogs in the vicinity of the explosives storage facility (SNP 02-07 and SNP 02-09) do not show evidence of ARD based on trends in pH values, sulphate concentrations and dissolved metal concentrations.
Samples collected from bogs including SNP 02-07, SNP 02-07.1, SNP 02-07.2, SNP 02-07.3, SNP 02-07.4, SNP 02-07.5, SNP 02-07.6, SNP 02-09, SNP 02-09.1, SNP 02-09.2, SNP 02-09.3, SNP 02-09.4 and SNP 02-09.5 between 2006 and 2013 had pH values ranging from 4.2 to 7.7 (Figure 1a). There is no general trend in pH values at these locations throughout monitoring. The pH values of bogs in the vicinity of SNP 02-07 and SNP 02-09 are compared to the pH of reference bogs located on the North Shore of Snap Lake (Figure 1). These bogs were established to determine "background" concentrations of bogs in the region but outside of the influence of the Snap Lake mine. Samples collected from the Reference Bogs had pH values ranging from 4.6 to 6.8 from 2006 to 2013, similar to the values observed at bogs in the vicinity of SNP 02-07 and SNP 02-09.

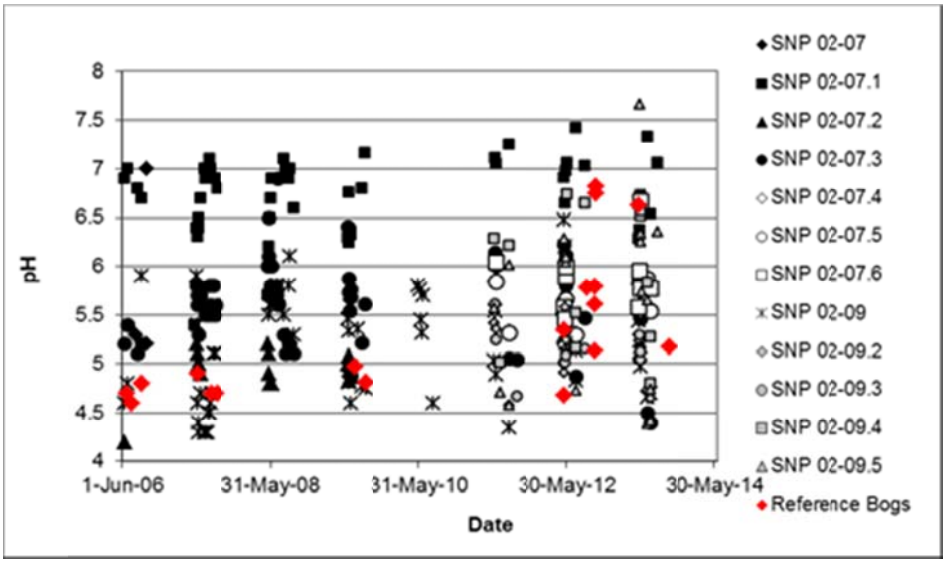


Figure 1 – pH Values at Bogs in the Vicinity of SNP 02-07 and SNP 02-09 and Reference Bogs

The presence of ARD can also be assessed using trends of other parameters, primarily the products of sulphide mineral oxidation including sulphate and iron. Figure 2 presents sulphate concentrations at bogs in the vicinity of SNP 02-07 and SNP 02-09, as well as the Reference Bogs located on the North Shore. Bogs near SNP 02-07 and SNP 02-09 generally had a higher variability in sulphate concentrations than those observed in Reference Bogs, in particular samples collected from 2011 to present. However, no relationship between pH values and sulphate concentrations is evident (Figure 3). Sulphate values associated with acidic ARD are generally in the range of several hundred to several thousand mg/L (Plumlee et al., 1999) as such

it is evident based on the observed pH and sulphate concentrations that the low pH values are not associated with ARD (i.e. high sulphate concentrations resulting from the oxidation of sulphide minerals).

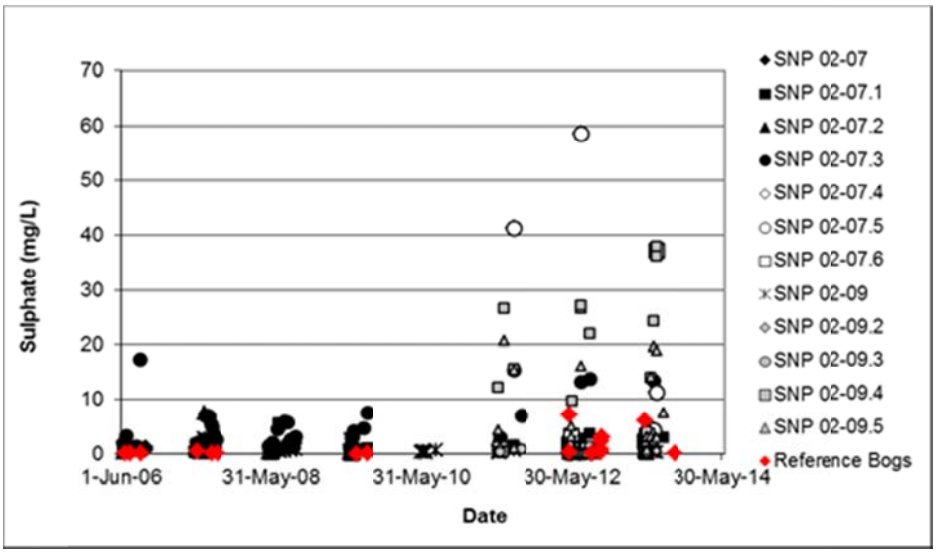


Figure 2 – Sulphate concentrations at Bogs in the Vicinity of SNP 02-07 and SNP 02-09 and Reference Bogs

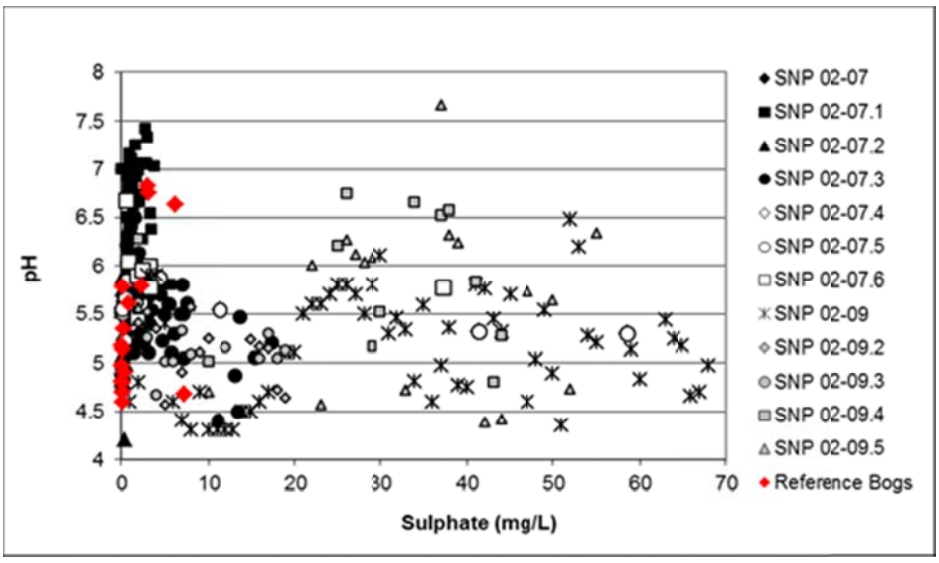


Figure 3 – pH Values vs. Sulphate Concentrations at Bogs in the Vicinity of SNP 02-07 and SNP 02-09 and Reference Bogs

Iron is one of the more common metals associated with ARD as noted in MEND (2009). Figure 4 shows iron concentrations at both the bogs in the vicinity of SNP 02-07 and SNP 02-09 and the Reference Bogs. There is no general increase in iron concentrations at the SNP 02-07 and SNP 02-09 bogs over time, and iron concentrations in these bogs are generally lower than in the Reference Bogs.

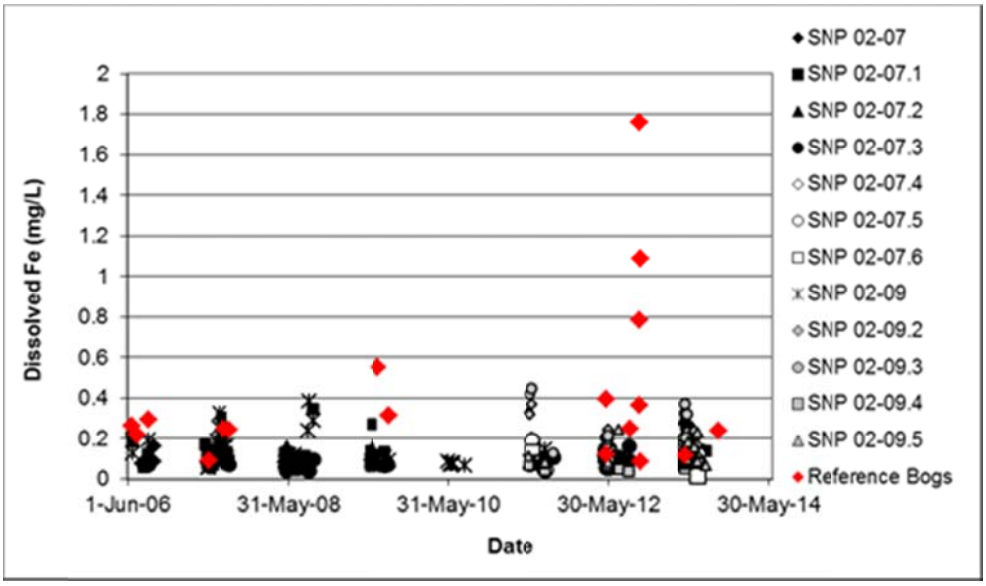


Figure 4 – Iron concentrations at Bogs in the Vicinity of SNP 02-07 and SNP 02-09 and Reference Bogs

Based on the comparison of the bogs in the vicinity of SNP 02-07 and SNP 02-09 to the Reference Bogs, the low pH values may be a result of natural variability in the region. Low pH values were observed in the SNP 02-07 and SNP 02-09 at several points throughout monitoring, with no general increase in acidity over time. Though sulphate concentrations in these bogs were highest from 2011 to present, these concentrations were not associated with a decrease in pH values.

Bogs near SNP 02-07 and SNP 02-09 are in the vicinity of the explosives storage facility and generally have higher nitrate concentrations than those observed in Reference Bogs (Figure 5). One of the possible factors affecting the pH of these bogs could be the oxidation of ammonia to nitrate to the presence of Ammonium Nitrate/Fuel Oil (ANFO) explosives. As noted in MEND (2009), “other oxidation reactions that may generate acid include the decomposition of organic matter and the oxidation of ammonium from blasting powder and cyanide decomposition. Acid generation should not be confused with the generation of acidity or generation of acidic drainage or ARD.” The oxidation of ammonium to nitrate may be one of the factors affecting the pH of the water. Figure 5 below suggest that there may be a subtle relationship between increased nitrate concentrations and a decrease in pH values, however overall the values for pH could also be explained by natural variability or degradation of organic matter (i.e. organic acids) typical of bog environments.

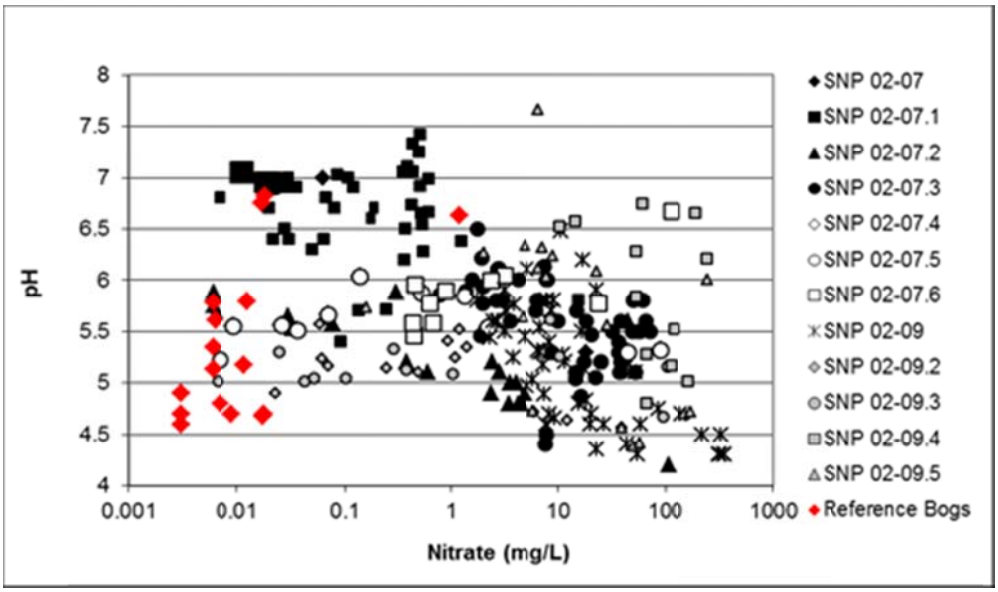


Figure 5 – pH Values vs. Nitrate Concentrations at Bogs in the Vicinity of SNP 02-07 and SNP 02-09 and Reference Bogs

In conclusion, based on a review of the observed values for parameters typically elevated in ARD when pH is low, it is considered that the pH values observed are not indicative of ARD, but are rather a function of natural variability or as a result of degradation of organic matter as typically occurs in bog materials, or due to oxidation of ammonia from blasting residuals. As stated by the UTRCA (2009) "Bog water typically has a pH range of 3.3 - 5.5, and transitional bog waters have a pH in the range of 4.5 - 6.0.", and bogs located at the Snap Lake site fall within this range. Given that the values are similar to the range observed naturally, and that further mitigation of these areas are likely to cause more harm than good (i.e. through destruction of tundra and potential sediment release) it is recommended that continued monitoring of these sites be conducted and the results continue to be compared to natural variability in the area.

References

MEND. 2009. Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials. MEND Report 1.20.1. December 2009.

Plumlee, G.S., Smith, K.S., Montour, M.R., Ficklin, W.H., and Mosier, E.L., 1999, Geologic controls on the composition of natural waters and mine waters draining diverse mineral-deposit types, in Filipek, L.H., and Plumlee, G.S., eds., The Environmental Geochemistry of Mineral Deposits, Part B: Case Studies and Research Topics: Reviews in Economic Geology
Upper Thames River Conservation Authority (UTRCA). 2009. Sifton Bog Environmentally Significant Area Conservation Master Plan 2009 – 2019. http://www.thamesriver.on.ca/wetlands_and_natural_areas/sifton_MP_update.htm. Accessed March 20, 2014

The intent of the request by De Beers was to prevent a misunderstanding as to how EQCs are applied to seepage stations, which occurred on July 11th, 2011 and October 2, 2012 by the previous AANDC Inspector. It is also intended to take into account regional variability such as what is observed at the Snap Lake Mine site.

In July 2011, concerns were raised over elevated copper values at 02-05, a small landlocked SNP station that is about 1 m², and seasonally reports water in a bolder area. The elevated copper levels observed in that area were due to regional variability, seasonal concentrating and the nature of the sampling site.

The technical memorandum Review of Dam Seepage and Receiving Environment Implications as submitted to the Board and AANDC on January 30, 2013 discussed:

- seepage contributions at the shore of Snap Lake and reasons why a particular seepage site may not just capture seepage;
- suitability of sample locations in defining contributions to the receiving environment;
- sampling protocols (sediment and total suspended solids [TSS] in well water samples) – flow through groundwater removes sediment and may cause adsorption of some metals;
- natural variability of bogs in that area that could account for high aluminum, zinc, copper, TSS; and,
- correlation between well waters and WMP water.

A review of the 2012 water licence identified three primary clauses that influence the acceptability of seepage from Dam 1 relative to off-site discharge:

- Part F, Section 9a;
- The definition of “Receiving Environment”; and,
- The definition of the “Project”.

Part F Section 9 a) states that “All Water or waste from the Project that enters the Receiving Environment... shall meet the following effluent criteria...” The effluent criteria referred to are provided in Part F Section 9 a). Part F is, however, influenced by the definition of the “Receiving Environment” which is provided in Part A of the water licence as follows: ““Receiving Environment” means the **aquatic** environment that receives any Water or Waste released from the **Project.**” (emphasis added), where the Project is defined as “the Snap Lake Diamond project as outlined in the Snap Lake Diamond Project Environmental Assessment Report...”. In assessing site maps, the area immediately downstream of Dam 1 appears to be within the boundary of the Project and is clearly not aquatic habitat. Based on existing mapping data the nearest aquatic habitat relative to Dam 1 is the shoreline of Snap Lake located approximately 150m to the south of Dam 1.

The seepage definition for the WMP in the EA was simple and conservative as was appropriate at the time and the resulting expected impact was considered to be negligible (De Beers 2002). As such there was no need to consider the seepage quantity or quality estimates in more detail. In reviewing the changes to the April 13, 2012 updated water licence and lower limits contained therein, it is clear that more consideration must be given to the actual seepage characteristics around and downgradient of Dam 1, including the potential for downgradient dilution and/or natural attenuation prior to discharge to the receiving environment.

In defining an appropriate sampling location that will characterize water release to the receiving environment it is relevant to consider the distribution and typical behaviour of seepage in northern environments and at this specific location, including that:

- The area near Dam 1 is underlain by bedrock which will confine shallow groundwater flow to near surface.
- The soils downstream of Dam 1 consist of loose peat, boulders, and organic materials, in some instances sand gravel and pebbles are present. These materials directly overly bedrock and have much higher hydraulic conductivity than the bedrock, thus flow will be confined to the upper layers primarily within the peat boulders and organic materials.
- The topography of the location is such that runoff from the hillsides will enter the low-lying area downstream of Dam 1, and seepage from the WMP will be substantially diluted by precipitation and runoff from the surrounding higher ground.
- Water quality entering the receiving environment is expected to be primarily composed of, and influenced by, the bog waters and runoff waters entering the bog area downstream of Dam 1 and will therefore have only a small influence from the WMP seepage water.

When considering the influencing factors above coupled with monitoring data as presented in the technical memo it is considered reasonable and appropriate to establish a monitoring point(s) further downgradient of Dam 1, possibly in the vicinity of “Bog East”, which would provide a better estimate of water discharging to the receiving environment. Furthermore definition of “discharge water quality” should also take into account the natural variability of the bog waters.

Provided below is a list of relevant conclusions based on a review of the water licence, EA documents, and monitoring data:

- The EA seepage estimates were simple and conservative; as such, the influencing factors on receiving environment discharge need to be re-considered in light of the new water licence limits.
- TSS and results for “total” concentrations are not appropriate for use when discussing seepage analyses.
- Dissolved analyses should be evaluated, and ASTM D 4448-01 standard sampling protocol for groundwater should be referenced and used as appropriate for groundwater sampling (ASTM 2001).
- The lack of consistent trends downstream of the WMP appears to be more indicative of natural material variability and natural trends in this area, including seasonality, resulting in temporal elevated concentrations of key parameters in several of the downstream bogs, rather than from direct influence or connection with the WMP.

On October 10, 2013 De Beers received a letter from the AANDC Inspector stating that based on the information provided (and summarized above) that the concern over landlocked stations and seepage not meeting EQCs was addressed and the conditions satisfied. Based on the above review and discussion it is recommended that locations downstream continue to be used as routine monitoring locations to define water concentrations entering the receiving environment from the WMP, and that the natural variability of surrounding waters be used to help define whether a value is truly an “exceedance” of a discharge parameter.

References:

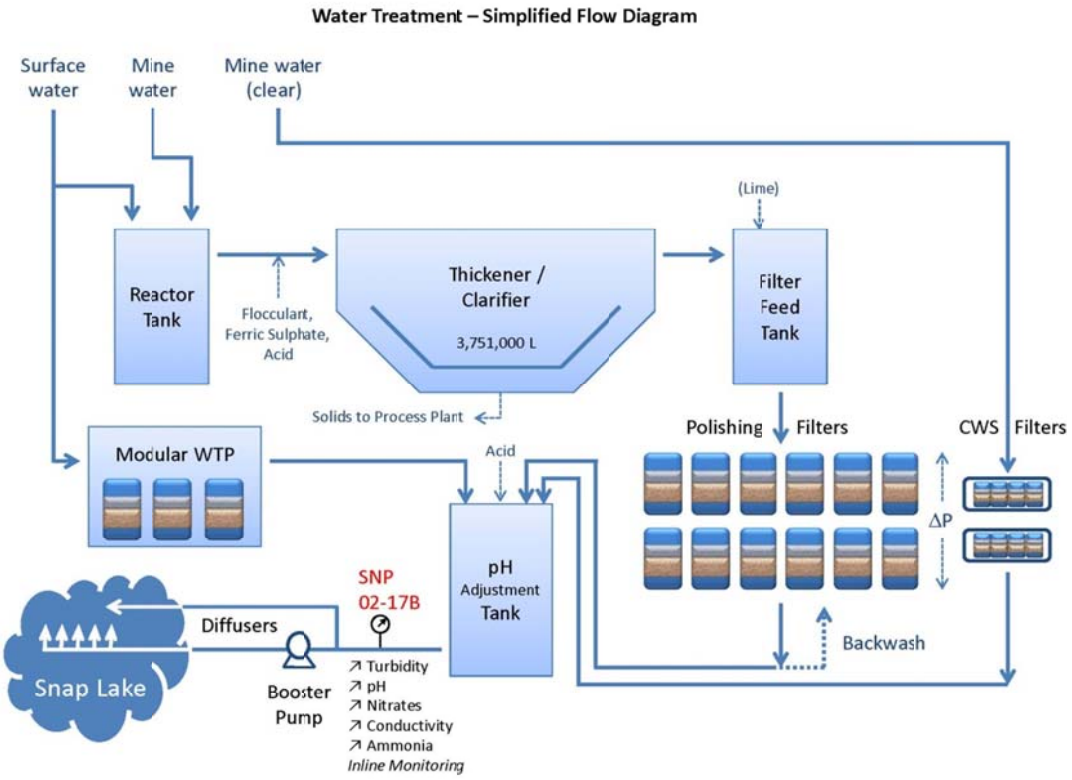
ASTM. 2001. D 4448-01, Standard Guide for Sampling Ground-Water Monitoring Wells.
De Beers (De Beers Canada Inc.). 2002. Environmental Assessment Report: Environmental Assessment Part 1.

Submitted February 2002 to the Mackenzie Valley Environmental Impact Review Board.
`De Beers. 2003. Consolidated Project Description. Submitted November 24, 2003 to the Mackenzie Valley Land and Water Board.

Golder. 2013. Review of Dam Seepage and Receiving Environment Implications. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

GNWT - Environment and Natural Resources 17
Topic: 02-17- Temporary WTP (Auxiliary)

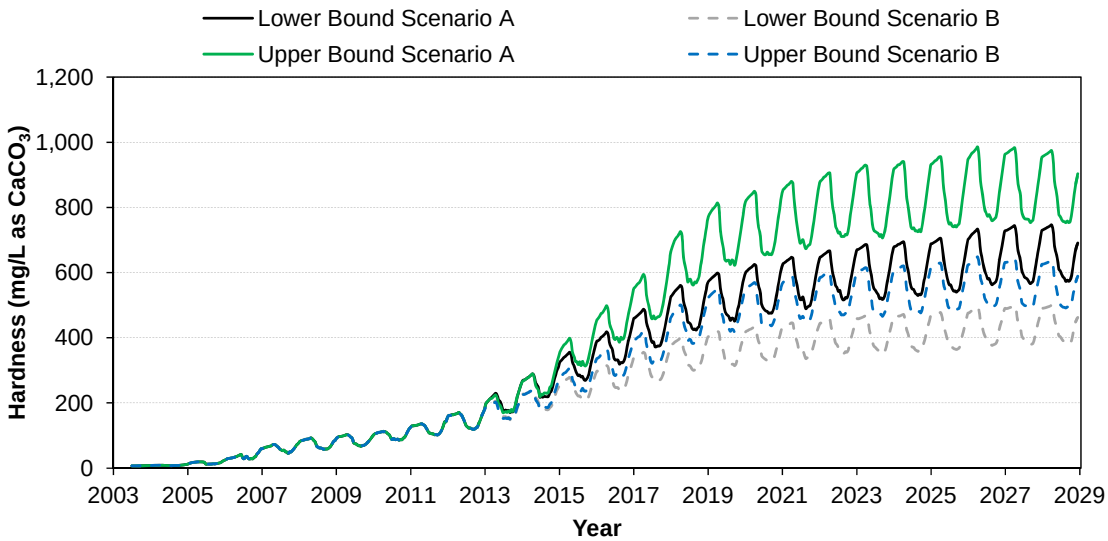
Previously the modular water treatment plant final effluent reported directly to the minewater outfall to the lake. This required an additional compliance point, listed as 02-17. Since that time, the flow of water has been revised so treated water from the modular WTP is tied into the pH adjustment tank in the main plant, allowing the two treated streams to mix prior to discharge. As this happens prior to the compliance monitoring point 02-17B, it is unnecessary to maintain the additional sampling location. Please see the attached schematic which visually shows the linkage between the two plants, the minewater outfalls and the diffusers.



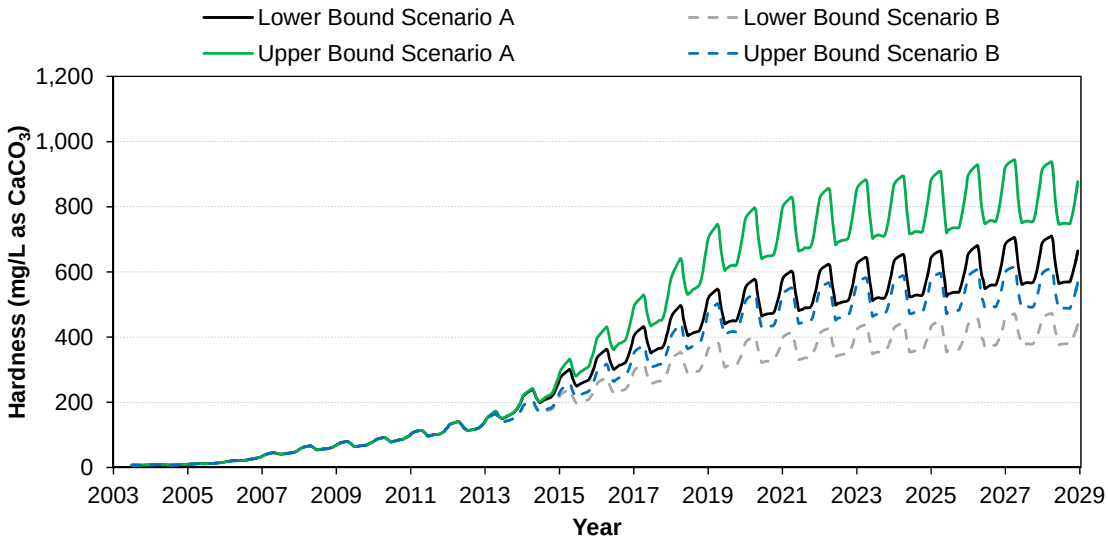
MVLWB 1
Topic: Predicted temporal-spatial trend in water hardness in Snap Lake

Predicted hardness concentrations are provided in Figure 1.

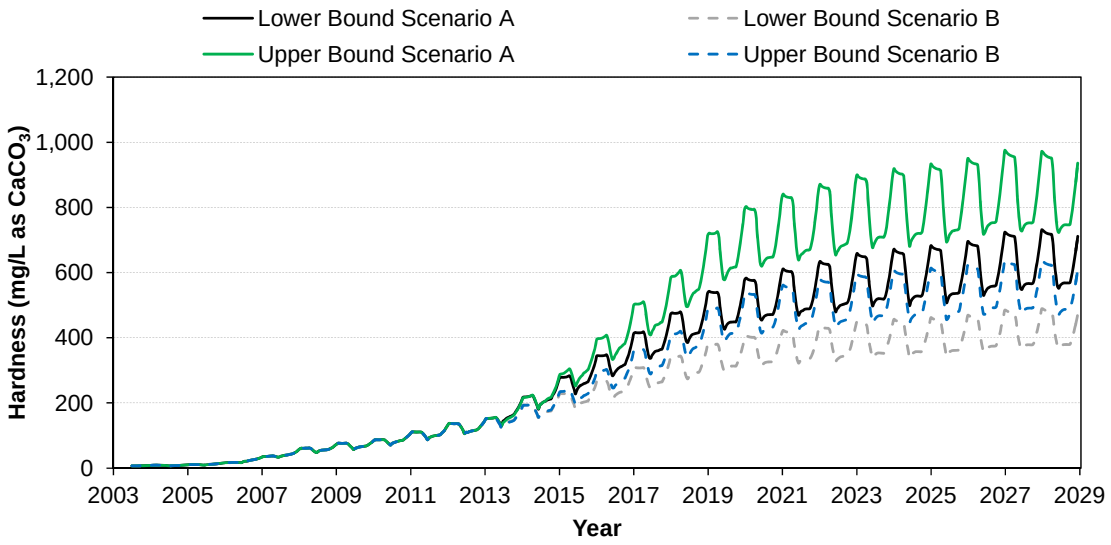
Figure 1: Predicted Depth-Averaged Hardness Concentrations in Snap Lake



(a) Near diffuser, SNP 02-20e



(b) Main Basin, SNAP09



(c) Outlet, SNAP07

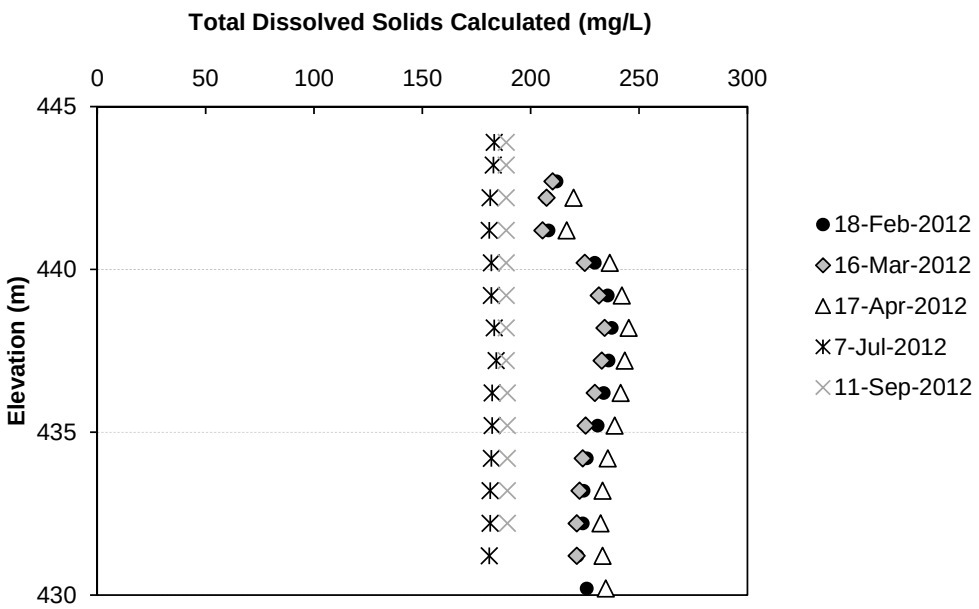
mg/L = milligrams per litre; $CaCO_3$ = calcium carbonate; SNP = surveillance network program.

MVLWB 3
Topic: Derivation of DF of 12

Using a dilution factor (DF) applicable for the ice-covered period in the effluent quality criteria (EQC) calculations was appropriate because:

1. The factor that has the largest effect on EQC calculations is the proportion of treated effluent in Snap Lake. The EQC were calculated during ice-covered conditions at the end of Mine life (i.e., 2028) when the proportion of treated effluent in Snap Lake was predicted to be 90 percent (%) and water quality parameters in Snap Lake were predicted to be at maximum concentrations.
2. For consistency, a DF was selected during ice-covered conditions because maximum concentrations have been observed late in the ice-covered season (Figure 1).

Figure 1 Total Dissolved Solids Concentrations at SNAP05 in 2012.



mg/L = milligrams per litre; m = metre.

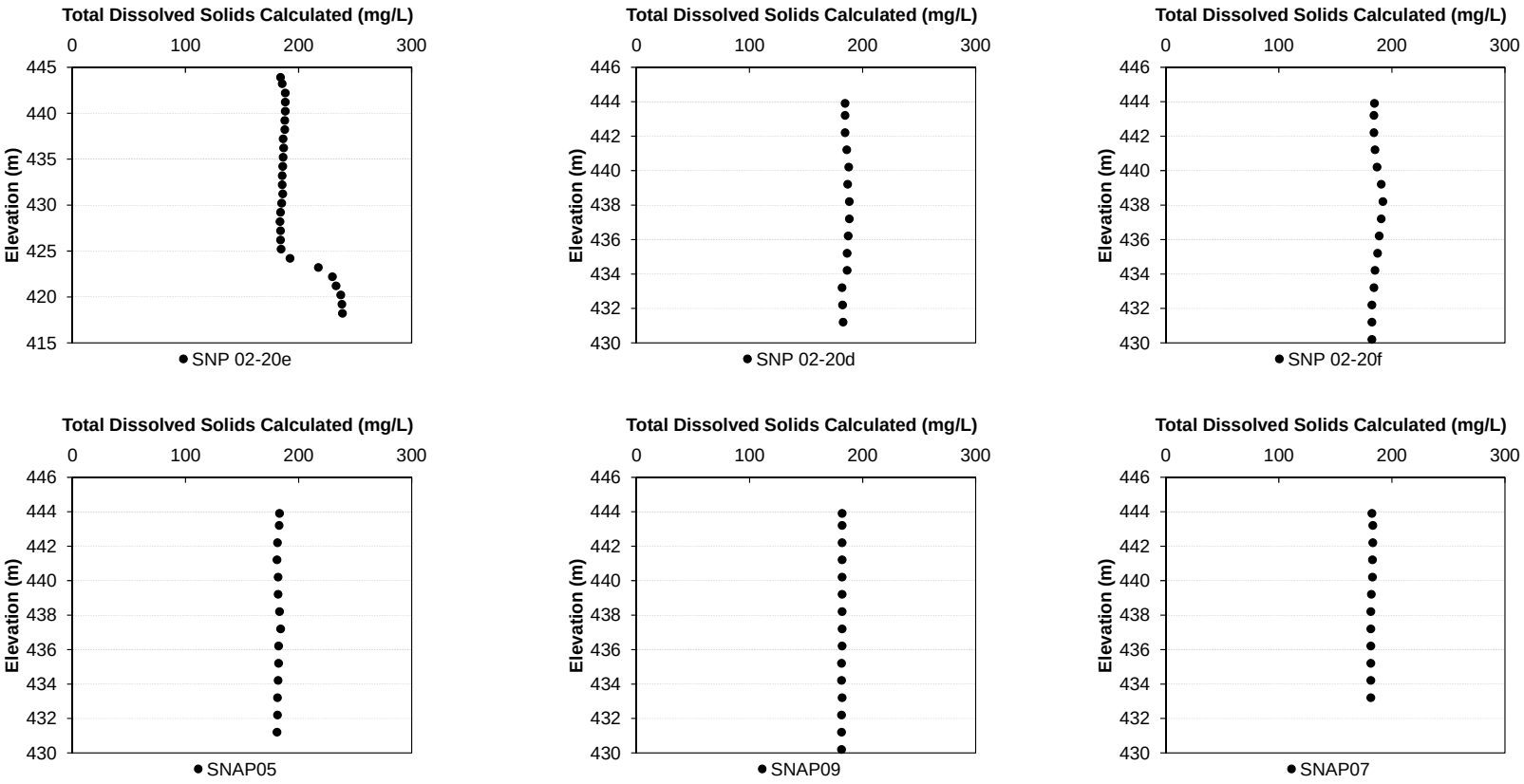
1. In 2012, the lowest calculated DFs were 9 in July and 7 in August. In 2013, the lowest calculated DF was 7 in July. These lower DFs are the result of a larger difference between the maximum concentration at the diffuser stations and the background concentration in Snap Lake in July and August than at other times in the year. The DFs calculated in July and August were influenced by a short-term conductivity gradient at one diffuser station (i.e., Surveillance Network Program [SNP] 02-20e) compared to the remainder of the main basin of Snap Lake, which was relatively well mixed (Figure 2). If data from SNP 02-20e were removed from the DF calculation, the DF in July 2012 would increase from 9 to 35, and the DF in August 2012 would increase from 7 to 20.

2. The EQC were calculated during ice-covered conditions at the end of Mine life when water quality parameters in Snap Lake were predicted to be at maximum concentrations.

In 2012, maximum water quality concentrations at SNP 02-20e occurred late in the ice-covered season, not in July and August (Figure 3).

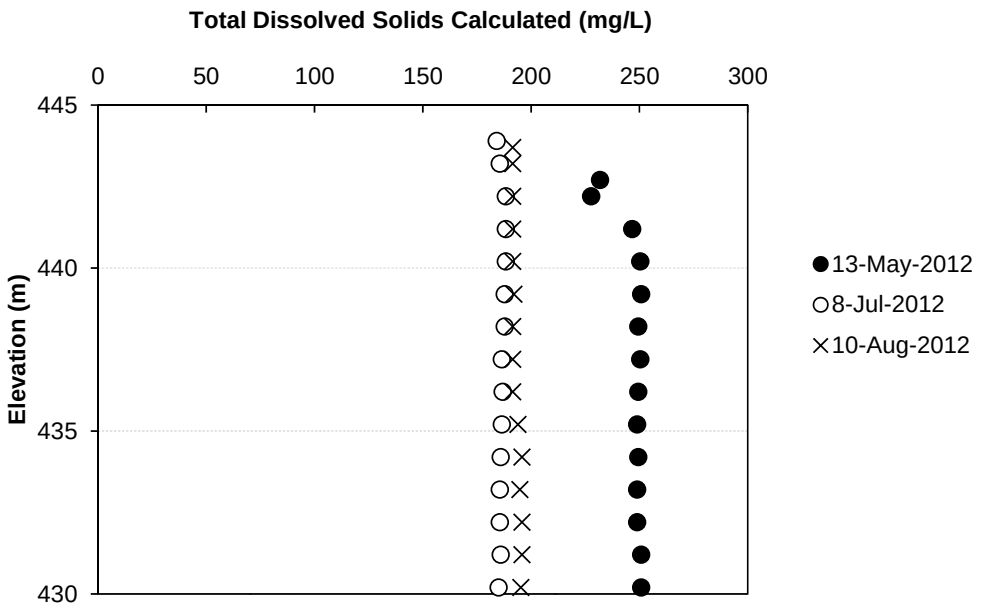
3. Changing the dilution factor from 14 to 7 decreases the average monthly limit (AML) and the maximum daily limit (MDL) for total dissolved solids (TDS) by less than one percent (Table 1). This is because the EQC were calculated during ice-covered conditions at the end of Mine life when the proportion of treated effluent in Snap Lake is predicted to be approximately 90% (i.e., the largest driver in the calculation). Calculating EQC using a proportion of treated effluent in Snap Lake of 90% and a dilution factor of 11 resulted in an AML for TDS that was essentially equivalent to the site-specific water quality objective (SSWQO). De Beers will implement mitigation to meet the proposed EQC, thereby maintaining TDS concentrations in the lake below the SSWQO.

Figure 2 Total Dissolved Solids Concentrations in the Main Basin of Snap Lake in July 2012.



mg/L = milligrams per litre; m –metre; SNP = surveillance network program.

Figure 3 Total Dissolved Solids Concentrations at SNP 02-20e in 2012.



mg/L = milligrams per litre; m = metre; SNP = surveillance network program.

Table 1 Effect of Dilution Factor on Recommended Effluent Quality Criteria

Dilution Factor	Total Dissolved Solids			
	Average Monthly Limit (mg/L)	Change From Recommended Average Monthly Limit (%)[(a)]	Maximum Daily Limit (mg/L)	Change From Recommended Maximum Daily Limit (%)[(a)]
14	685	0.1	1,004	0.1
13	685	0.1	1,003	0.0
12	684	0.0	1,003	0.0
11	684	0.0	1,002	-0.1
10	683	-0.1	1,001	-0.2
9	683	-0.1	1,000	-0.3
8	682	-0.3	999	-0.4
7	681	-0.4	997	-0.6

mg/L = milligrams per litre; % = percent.

(a) As recommended in the EQC Report (De Beers 2013)

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References:

De Beers. 2013. Evaluation of Effluent Quality Criteria. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

Golder. 2013. 2012 Plume Characterization Study Report. Submitted to Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

MVLWB 6 DBCI
Topic: Air entrainment in the diffuser

To address the second part of the comment and demonstrate that De Beers will be able to meet the proposed site-specific water quality objectives (SSWQOs) or water quality guidelines (WQGs) for parameters of concern in Snap Lake, total dissolved solids (TDS) concentrations at the mixing zone boundary were calculated using Equation 2 from the Evaluation of Effluent Quality Criteria Report (De Beers 2013) using a range of dilution factors (i.e., 1 to 20). The proposed SSWQO for TDS in Snap Lake is 684 milligrams per litre (mg/L). The following assumptions were made:

1. the concentration of TDS in the treated effluent (C_{TE}) is equal to the recommended average monthly limit (AML) of 684 mg/L; and,

2. the background concentration in Snap Lake (C_{SL}) is 650 mg/L (arbitrarily selected as a TDS concentration near, but not exceeding, the SSWQO of 684 mg/L).

Based on this calculation, De Beers will be able to meet the proposed SSWQO for TDS in Snap Lake at a range of dilution factors (DFs) if the recommended EQCs are achieved (Table 1). Further support that the proposed SSWQOs or WQGs will be achieved at the mixing zone boundary will be provided as part of the Response to **MVLWB 2.** Plots will be provided, when available, in advance of the Technical Session to be held in April.

Table 1 Effect of Dilution Factor on Mixing Zone Boundary Concentrations in Snap Lake

C_{TE} (mg/L)	C_{SL} (mg/L)	DF	C_{MZ} (mg/L)	C_{MZ} < SSWQO
684	650	20	652	Y
684	650	15	652	Y
684	650	12	653	Y
684	650	11	653	Y
684	650	10	653	Y
684	650	9	653	Y
684	650	8	654	Y
684	650	7	654	Y
684	650	6	655	Y
684	650	5	656	Y
684	650	4	657	Y
684	650	3	659	Y
684	650	2	661	Y
684	650	1	667	Y

C_{SL} = background concentration of parameter “x” in Snap Lake; C_{TE} = concentration of parameter “x” in the treated effluent; C_{MZ} = concentration of parameter “x” at the mixing zone boundary in Snap Lake; DF = dilution factor (i.e., volume of lake water that mixes with one volume of treated effluent

discharged from the Mine to Snap Lake); SSWQO = site-specific water quality objective; mg/L = milligrams per litre; < = less than; “Y” = yes.

References:

De Beers. 2013. Evaluation of Effluent Quality Criteria. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

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MVLWB 9
Topic: Inconsistent definition of dilution factor

De Beers acknowledges that the formulae to calculate dilution factors (DF) at the edge of the mixing zone in the 2012 Plume Characterization Report (Golder 2013) and Equation 2 on page 2-10 of the Evaluation of Effluent Quality Criteria Report (EQC Report) (De Beers 2013) are different. However, these differences are not material. This Response derives each equation, demonstrates using an example that the two equations result in the same concentration at the edge of the mixing zone, and evaluates the lack of effect on the proposed EQC.

1.1 Derivation of Equations for Calculating Concentrations at the Edge of the Mixing Zone and Dilution Factors

A description of the symbols used in the DF equation in the 2012 Plume Characterization Report and in Equation 2 on page 2-10 of the EQC Report are presented in Table 1.

Table 1 Symbols in Equations for Calculating Concentrations at the Edge of the Mixing Zone

Equation 2 on Page 2-10 of the EQC Report	Equation in the 2012 Plume Characterization Report	Description
Q_{SL}	Q_b	number of volumes of Snap Lake water that mix with the treated effluent discharged from the Snap Lake Mine (Mine)
Q_{TE}	Q_e	flow of treated effluent discharged from the Mine to Snap Lake
C_{SL}	C_b	background concentration of parameter “x” in Snap Lake
C_{TE}	C_e	concentration of parameter “x” in treated effluent discharged from the Mine to Snap Lake
C_{MZ}	C	concentration of parameter “x” at the mixing zone boundary in Snap Lake
DF	-	dilution factor (i.e., volume of lake water that mixes with one volume of treated effluent discharged from the Mine to Snap Lake)
-	DF	dilution factor (i.e., reduction in concentration of treated effluent discharged from the Mine to Snap Lake from its end-of-pipe concentration)

“-“ = not presented in the equation

Equation 2 on Page 2-10 of the Evaluation of Effluent Quality Criteria Report

To derive Equation 2 on page 2-10 of the EQC Report, begin with a steady-state mass balance equation around the mixing zone in Snap Lake (Equation 1).

$$C_{MZ} = \frac{(Q_{SL} \times C_{SL}) + (Q_{TE} \times C_{TE})}{Q_{SL} + Q_{TE}}$$ Equation 1

In Equation 2 on page 2-10, the DF is defined as the number of volumes of lake water that mix with one volume of treated effluent (Table 1). Therefore, Equations 2 and 3 are substituted into Equation 1 to produce Equation 4.

$$Q_{SL} = DF \times Q_{TE}$$ Equation 2

$$Q_{TE} = 1$$ Equation 3

$$C_{MZ} = \frac{(DF \times Q_{TE} \times C_{SL}) + (Q_{TE} \times C_{TE})}{DF \times Q_{TE} + Q_{TE}}$$

$$C_{MZ} = \frac{(DF \times 1 \times C_{SL}) + (1 \times C_{TE})}{DF \times 1 + 1}$$ Equation 4

Equation 4 is simplified to produce Equation 5, which is the same as Equation 2 on page 2-10 of the EQC Report.

$$C_{MZ} = \frac{DF \times C_{SL} + C_{TE}}{DF + 1}$$ Equation 5

Equation 5 can be rearranged to solve for the DF (Equation 6).

$$DF = \frac{C_{TE} - C_{MZ}}{C_{MZ} - C_{SL}}$$ Equation 6

Dilution Factor Equation in the 2012 Plume Characterization Report

To derive the DF equation in the 2012 Plume Characterization Report, begin with a steady-state mass balance equation around the mixing zone in Snap Lake (Equation 7, which is the same as Equation 1, just using notation/symbols from the Plume Characterization Study).

$$C = \frac{(Q_b \times C_b) + (Q_e \times C_e)}{Q_b + Q_e}$$ Equation 7

Substitute Equation 8 into Equation 7 to produce Equation 9.

$$Q_{Total} = Q_b + Q_e$$ Equation 8

$$C = \frac{(Q_b \times C_b) + (Q_e \times C_e)}{Q_{Total}}$$ Equation 9

Substitute Equation 10 into Equation 9 to produce Equation 11.

$$Q_b = Q_{Total} - Q_e \qquad \text{Equation 10}$$

$$C = \frac{(Q_{Total} - Q_e)(C_b) + (Q_e \times C_e)}{Q_{Total}} \qquad \text{Equation 11}$$

Equation 11 is simplified to produce Equation 12.

$$C = \frac{(Q_{Total} \times C_b) - (Q_e \times C_b) + (Q_e \times C_e)}{Q_{Total}}$$

$$C = \frac{(Q_{Total} \times C_b)}{Q_{Total}} - \frac{(Q_e \times C_b)}{Q_{Total}} + \frac{(Q_e \times C_e)}{Q_{Total}}$$

$$C = C_b + \frac{Q_e}{Q_{Total}}(C_e - C_b) \qquad \text{Equation 12}$$

In the 2012 Plume Characterization Report, the DF refers to the reduction in concentration of treated effluent discharged to Snap Lake from its end-of-pipe concentration (Table 1). Mixing of the treated effluent and Snap Lake water results in a reduction in concentration of treated effluent by a factor of 1/DF at the mixing zone boundary in Snap Lake. Therefore, Equation 13 is substituted into Equation 12 to produce Equation 14.

$$\frac{Q_{TE}}{Q_{Total}} = \frac{1}{DF} \qquad \text{Equation 13}$$

$$C = \frac{(C_e - C_b)}{DF} + C_b \qquad \text{Equation 14}$$

Equation 14 can be rearranged to solve for the DF (Equation 15).

$$DF = \frac{C_e - C_b}{C - C_b} \qquad \text{Equation 15}$$

The difference between Equations 5 and 14 is the way that each equation defines the DF (Table 1). In both equations, the DF is obtained from the minimum dilution predicted in Snap Lake from the USEPA Cormix Mixing Zone Model (Cormix). In the Snap Lake Environmental Assessment Report (De Beers 2002), the minimum dilution predicted by Cormix was 12. In Equation 5, DF is defined as the number of volumes of lake water that mix with one volume of effluent (i.e., 11 parts lake water plus one part effluent = 12 parts). Therefore, DF in Equation 5 is equal to 11. In Equation 14, DF is defined as the reduction in concentration of treated effluent discharged to Snap Lake from its end-of-pipe concentration. Mixing of the discharge water and lake water results in a reduction in

concentration of discharge water by a factor of 1/12 at the mixing zone boundary in Snap Lake. Therefore, DF in Equation 14 is equal to 12 as per the output from Cormix (De Beers 2002).

1.2 Example Calculations

As shown in the example calculations, both equations provide the same results for the concentration at the edge of the mixing zone.
Where:

Dilution from Cormix (dimensionless):	12
DF in Equation 6 (dimensionless):	12 – 1 = 11
DF in Equation 14 (dimensionless):	12
C_{SL} and C_b (milligrams per litre [mg/L]):	325
C_{TE} and C_e (mg/L):	700

The concentration at the edge of the mixing zone as calculated using Equation 5:

$$C_{MZ} = \frac{DF \times C_{SL} + C_{TE}}{DF + 1}$$

$$C_{MZ} = \frac{(11 \times 325) + 700}{11 + 1}$$

$$C_{MZ} = 356 \text{ mg/L}$$

The concentration at the edge of the mixing zone as calculated using the Equation 14:

$$C = \frac{(C_e - C_b)}{DF} + C_b$$

$$C = \frac{(700 - 325)}{12} + 325$$

$$C = 356 \text{ mg/L}$$

1.3 No Effect on Proposed EQC

The recommended EQC for parameters of potential concern were calculated using a DF of 11, rather than 12 to determine the effect of the inconsistency. The EQC remain the same as those presented in Table 3-3 of the EQC Report except for TDS, for which there was a negligible change in the maximum daily limit (MDL) from 1,003 mg/L to 1,002 mg/L. These results demonstrate that the EQC are not influenced by slight changes to the dilution factor.
De Beers regrets any confusion that the presentation of two different equations to calculate concentrations at the edge of the mixing zone may have caused.

References:

De Beers (De Beers Canada Inc.). 2002. The Snap Lake Diamond Mine Environmental Assessment Report. Submitted to the Mackenzie Valley Environmental Impact Review Board. Yellowknife, NWT, Canada.

De Beers. 2013. Evaluation of Effluent Quality Criteria. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

Golder. 2013. 2012 Plume Characterization Study Report. Submitted to Mackenzie Valley Land And Water Board. Yellowknife, NWT, Canada.

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TECHNICAL MEMORANDUM

TO: **Julie L'Heureux – De Beers Canada** **1780**

FROM: **Houmao Liu**
Dong Ding

DATE: **3 October 2013**

SUBJECT: **Predicted TDS Concentration in Mine Water Discharge Based on Calculated TDS Values**

INTRODUCTION

In the 2013 Snap Lake groundwater model update, Itasca Denver, Inc., (Itasca) used a predicted groundwater flow rate to the mine from the groundwater flow model (Itasca 2013) and the measured TDS concentrations from 2008 to 2013 at various locations and depths to predict the TDS concentration of the mine discharge water. De Beers Canada and Golder Associates Ltd. (Golder) recently requested that Itasca update the predicted TDS concentration based on the calculated TDS concentrations provided by the laboratory ("Calculated TDS" hereafter) instead of the measured values.

The Calculated TDS were available for the data set in 2008 and 2010 but not for the 2013 data set. The Calculated TDS for the 2013 data set were estimated as follows:

1. Established a linear correlation between the Calculated TDS versus the measured TDS concentration based upon the 2008 and 2010 data set (provided by De Beers on 1 October 2013).
2. Obtained the ratio of Calculated to measured TDS from the linear relation (0.9258 as shown in Figure 1).
3. Used this ratio to estimate the Calculated TDS for the 2013 data set.

Tables 1 and 2 summarize the measured and Calculated TDS values for 2008 and 2010, and 2013, respectively. For your reference, the geometric mean and arithmetic mean of the TDS values using the Calculated TDS is about 7% less than the means using the measured TDS values. The Calculated TDS values were used for the prediction of the TDS concentration in the mine discharge. The detailed description of the calculation was discussed in Itasca (2013).

Instead of providing all of the sensitivity simulations described in Itasca (2013), Itasca has provided the results of two groundwater model simulations based on the discussion with you. One simulation is the Base Case. The other is the simulation that assumes the hydraulic conductivity values of structure zones related to the Crackle and Snap faults outside of the current mining extent were increased by an order of magnitude from the Base Case (which was referred to as Simulation 4 in Itasca (2013)). The predicted inflow rate for the Base Case and Simulation 4 are summarized in Tables 3 and 5.

For each of the groundwater model simulations, the TDS concentrations in the mine discharge were estimated using both arithmetic and geometric mean values of the Calculated TDS. The predicted TDS concentrations of the mine discharge are summarized in Tables 4 and 6, respectively for both flow simulations.

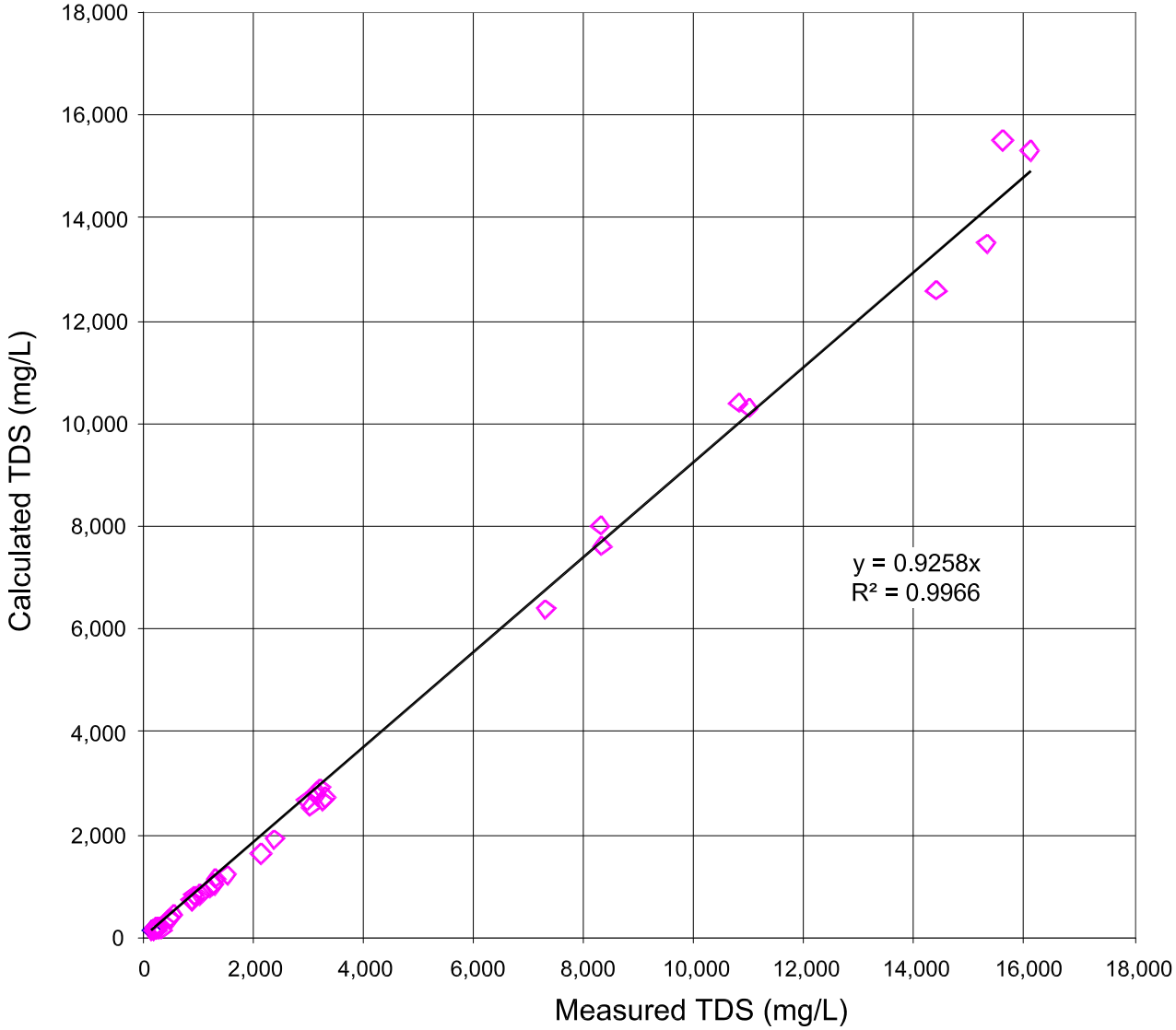
CLOSURE

Itasca hopes that this memorandum addresses your needs. Please contact us if you have any comments or questions.

REFERENCES

Itasca Denver. 2013. Prediction of mine water inflow and concentration of total dissolved solids at Snap Lake. Technical memorandum prepared for De Beers Canada by Itasca Denver, Inc., 30 August.

Attachments: Figure 1 – Relationship Between Measured vs. Calculated TDS (2008-2010)
Table 1 – Summary of Measured and Calculated TDS Concentrations for 2008 and 2010
Table 2 – Summary of Measured and Calculated TDS Concentrations in 2013
Table 3 – Predicted Groundwater Inflow Components to the Mine Workings - Base Case
Table 4 – Predicted TDS Concentrations of the Mine Water Discharge - Base Case
Table 5 – Predicted Groundwater Inflow Components to the Mine Workings - Sensitivity Simulation 4
Table 6 – Predicted TDS Concentrations of the Mine Water Discharge - Sensitivity Simulation 4



PROJECT NO.	1780
BY	DD
CHECKED	HL
DRAWN	SAC
DRAWING NAME	MEAS–VS–CALC–TDS
DRAWING DATE	2 OCT 2013
REVISION DATE	--

ITASCA™ Denver, Inc.

Relationship between
Measured vs. Calculated TDS (2008-2010)

CLIENT:
De Beers Canada - Snap Lake Mine

FIGURE NO.
1

TABLE 1

ITASCA Denver, Inc.

Summary of Measured and Calculated TDS Concentrations for 2008 and 2010

(Page 1 of 2)

Sample	Date	Collar Elevation (melev)[1]	End of Hole Elevation (melev)[1]	Collar Depth (m)	End of Hole Depth (m)	Average Depth Below Lake (m)	Measured TDS (mg/L)	Calculated TDS (mg/L)	Related to Dyke
DW5	13-Jun-08	5280	5280	164	164	164	216	200	Above
	6-Nov-08						162	150	
	28-Aug-10						243	225	
GP08-1	14-Jun-08	5314	5314	130	130	130	181	168	
	7-Nov-08						160	148	
UG04-305	23-Aug-08	5285	5292	159	152	152	187	173	
UG04-306	24-Aug-08	5284	5289	160	155	155	182	168	
UG04-310	23-Aug-08	5284	5336	160	108	129	206	191	
	9-Nov-08						159	147	
UG04-311	24-Aug-08	5284	5316	160	128	128	184	170	
UG04-312	24-Aug-08	5284	5298	160	146	146	190	176	
UG05-413	16-Jun-08	5294	5213	150	231	125	218	202	
	6-Nov-08						157	145	
UG05-464	13-Jun-08	5282	5282	162	162	162	203	188	
	9-Nov-08						162	150	
	28-Aug-10						257	238	
UG06-496	13-Jun-08	5321	5378	123	66	97	210	194	
	27-Aug-10						245	227	
	7-Nov-08						338	313	
UG06-531	16-Jun-08	5229	5229	215	215	215	208	193	
UG06-532 (surrogate for 502)	16-Jun-08	5257	5288	187	156	156	175	162	
UG06-532	7-Nov-08	5257	5288	187	156	156	176	163	
UG06-535	14-Jun-08	5234	5286	210	158	182	204	189	
	6-Nov-08						153	142	
	29-Aug-10						212	196	
UG06-536	15-Jun-08	5212	5219	232	225	229	200	185	
	8-Nov-08						181	168	
	31-Aug-10						254	235	
UG06-536 (duplicate)	31-Aug-10	5212	5219	232	225	229	257	238	
UG07-670	16-Jun-08	5230	5230	214	214	214	210	194	
	6-Nov-08						169	156	
UG08-736	23-Aug-08	5289	5334	155	110	125	186	172	
	7-Nov-08						176	163	
UG08-737	23-Aug-08	5289	5342	155	102	306	274	254	
	7-Nov-08						224	207	
	27-Aug-10						246	228	

TABLE 1

ITASCA Denver, Inc.

Summary of Measured and Calculated TDS Concentrations for 2008 and 2010

(Page 2 of 2)

Sample	Date	Collar Elevation (melev)[1]	End of Hole Elevation (melev)[1]	Collar Depth (m)	End of Hole Depth (m)	Average Depth Below Lake (m)	Measured TDS (mg/L)	Calculated TDS (mg/L)	Related to Dyke
DW11A-N	15-Jun-08	5183	5183	261	261	261	3320	3074	Below
	5-Nov-08						3260	3018	
DW11A-S	15-Jun-08	5183	5183	261	261	261	2130	1972	
	5-Nov-08						2370	2194	
FLT65/020	14-Jun-08	5234	5234	210	210	210	192	178	
UG07-650	13-Jun-08	5280	5223	164	221	200	199	184	
	9-Nov-08						151	140	
	28-Aug-10						256	237	
UG07-711	15-Jun-08	5196	4924	248	520	520	1280	1185	
UG07-711-W (duplicate)	15-Jun-08	5196	4924	248	520	520	1270	1176	
UG07-711-Z1	2-Aug-10	5196	4924	248	520	520	11000	10184	
UG07-711-Z3	2-Aug-10	5196	4924	248	520	520	8330	7712	
UG07-711-Z5	2-Aug-10	5196	4924	248	520	520	7300	6758	
UG08-720 (696-716 ft~Zone 3)	16-Jun-08	5196	4995	248	449	356	3030	2805	
UG08-720-Z1	25-Aug-08	5196	4995	248	449	409	3140	2907	
	8-Nov-08						3220	2981	
	2-Aug-10						4910	4546	
UG08-720-Z3	25-Aug-08	5196	4995	248	449	356	2970	2750	
	8-Nov-08						3140	2907	
	2-Aug-10						5100	4722	
UG08-720-Z3 (duplicate)	2-Aug-10	5196	4995	248	449	356	4910	4546	
UG08-720-Z5	25-Aug-08	5196	4995	248	449	294	1190	1102	
	8-Nov-08						1310	1213	
	2-Aug-10						3810	3527	
UG08-720-Z6	25-Aug-08	5196	4995	248	449	269	1040	963	
UG08-724	15-Jun-08	5196	5174	248	270	268.5	877	812	
UG08-730	5-Nov-08	5196	5209	248	235	238	537	497	
UG08-730 (Dis) - filtered	15-Jun-08	5196	5209	248	235	238	492	455	
UG08-730 (Tot) - unfiltered	15-Jun-08	5196	5209	248	235	238	481	445	
UG08-734	14-Jun-08	5230	5192	214	252	234	202	187	
UG08-740	14-Jun-08	5230	5109	214	335	275	1520	1407	
UG08-756	22-Jun-08	5171	5171	273	273	273	14400	13332	
UG08-762 (pre-grout)	12-Jul-08	5172	5180	272	264	264	15300	14165	
UG08-762G (post-grout)	13-Jul-08	5172	5180	272	264	264	16100	14905	
UG08-763G	14-Jul-08	5172	5180	272	264	268.5	14400	13332	
UGO8-762GD (duplicate)	13-Jul-08	5172	5180	272	264	264	15600	14442	

Note: 1. melev = meters above mean sea level + 5000 m

TABLE 2

ITASCA Denver, Inc.

Summary of Measured and Calculated TDS Concentrations in 2013

Sample	Date	Collar Elevation (melev)[1]	Average Depth Below Lake (m)	Measured TDS (mg/L)	Calculated TDS (mg/L)	Related to Dyke
UG ORE 1	6/15/2013	5126	318	481	445	Above
UG ORE 2	6/15/2013	5293	151	379	351	
UG ORE 3	6/15/2013	5298	146	482	446	
UG ORE 4	6/15/2013	5295	149	470	435	
UG ORE 5	6/15/2013	5283	161	415	384	
UG ORE 6	6/15/2013	5306	138	402	372	
UG ORE 7	6/30/2013	5158	286	427	395	
UG ORE 8	6/30/2013	5193	251	416	385	
UG ORE 9	6/30/2013	5266	178	387	358	
UG FW1	6/14/2013	4936	508	5350	4953	Below
UG FW2	6/14/2013	4936	508	8070	7471	
UG FW3	6/14/2013	4981	463	7790	7212	
UG FW4	6/14/2013	4980	464	8700	8054	
UG FW5	6/14/2013	4991	453	18100	16757	
UG FW5	6/30/2013		453	19200	17775	
UG FW6	6/14/2013	5000	444	18100	16757	
UG FW6	6/30/2013		444	18500	17127	
UG FW7	6/14/2013	5019	425	14800	13702	
UG FW7	6/30/2013		425	13800	12776	
UG FW8	6/14/2013	5108	336	7830	7249	
UG FW9	6/14/2013	5158	286	3590	3324	
UG FW10	6/15/2013	5160	284	3430	3175	
UG FW10	6/30/2013		284	3240	3000	

Note: 1. melev = meters above mean sea level + 5000 m

TABLE 3

Predicted Groundwater Inflow Components to the Mine Workings - Base Case
(Page 1 of 7)

Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
Jan-04	0	0	0	0	0	0	0	0	0
Feb-04	0	0	0	0	0	0	0	0	0
Mar-04	0	0	0	0	0	0	0	0	0
Apr-04	0	0	0	0	0	0	0	0	0
May-04	346	346	0	0	0	298	298	0	0
Jun-04	346	346	0	0	0	298	298	0	0
Jul-04	432	432	0	0	0	399	399	0	0
Aug-04	1382	1210	86	86	173	1362	1362	0	0
Sep-04	2160	1987	86	86	173	2141	2141	0	0
Oct-04	2938	2678	173	86	259	2931	2931	0	0
Nov-04	3283	3024	173	86	259	3283	3283	0	0
Dec-04	3370	3110	173	86	259	3370	3370	0	0
Jan-05	4147	3802	259	86	346	4027	4027	0	0
Feb-05	4147	3802	259	86	346	3999	3999	0	0
Mar-05	4406	4061	259	86	346	4367	4367	0	0
Apr-05	4752	4406	259	86	346	4621	4621	0	0
May-05	5184	4838	259	86	346	5184	5184	0	0
Jun-05	5702	5270	346	86	432	5669	5669	0	0
Jul-05	6048	5270	346	432	778	5875	5875	0	0
Aug-05	6394	5702	259	432	691	6307	6307	0	0
Sep-05	6653	5875	259	518	778	6566	6566	0	0
Oct-05	6653	5789	259	605	864	6653	6653	0	0
Nov-05	6826	5789	259	778	1037	6653	6653	0	0
Dec-05	6826	5789	259	778	1037	6653	6653	0	0
Jan-06	7258	6221	259	778	1037	6998	6998	0	0
Feb-06	7344	6221	259	864	1123	7171	7171	0	0
Mar-06	7517	6394	259	864	1123	7258	7258	0	0
Apr-06	7517	6307	259	950	1210	7258	7258	0	0
May-06	8208	6998	259	950	1210	7949	7949	0	0
Jun-06	8122	6826	259	1037	1296	7949	7949	0	0
Jul-06	8554	6998	259	1296	1555	8208	8208	0	0
Aug-06	8813	7258	259	1296	1555	8640	8640	0	0
Sep-06	8726	7171	259	1296	1555	8640	8640	0	0
Oct-06	8813	7171	259	1382	1642	8640	8640	0	0
Nov-06	10454	8899	259	1296	1555	10022	10022	0	0
Dec-06	12182	10454	346	1382	1728	11405	11405	0	0
Jan-07	13306	11664	259	1382	1642	12182	12182	0	0
Feb-07	13910	12269	346	1296	1642	12355	12355	0	0
Mar-07	13824	12269	259	1296	1555	12269	12269	0	0
Apr-07	13651	12182	173	1296	1469	12182	12182	0	0
May-07	13910	12355	259	1296	1555	12528	12528	0	0
Jun-07	13651	12096	259	1296	1555	12528	12528	0	0
Jul-07	13133	11578	173	1382	1555	12442	12442	0	0
Aug-07	13910	12442	173	1296	1469	13046	13046	0	0
Sep-07	13910	12355	259	1296	1555	13046	13046	0	0

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Predicted Groundwater Inflow Components to the Mine Workings - Base Case
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Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
Oct-07	13824	12269	259	1296	1555	13046	13046	0	0
Nov-07	13392	11837	259	1296	1555	12874	12787	86	0
Dec-07	13306	11750	259	1296	1555	12787	12701	86	0
Jan-08	13392	11837	259	1296	1555	12787	12701	86	0
Feb-08	13738	12269	259	1210	1469	12960	12874	86	0
Mar-08	13651	12182	259	1210	1469	13133	13046	86	0
Apr-08	13824	12355	259	1210	1469	13219	13133	86	0
May-08	14083	12614	259	1210	1469	13306	13219	86	0
Jun-08	13738	12269	259	1210	1469	13306	13219	86	0
Jul-08	14342	12874	346	1123	1469	13651	13565	86	0
Aug-08	14861	13392	259	1210	1469	14170	14083	86	0
Sep-08	15206	13824	259	1123	1382	14602	14515	86	0
Oct-08	15466	14083	259	1123	1382	14947	14861	86	0
Nov-08	17280	15811	346	1123	1469	16157	16070	86	0
Dec-08	18403	16762	346	1296	1642	17280	17194	86	0
Jan-09	18576	17021	346	1210	1555	17366	17280	86	0
Feb-09	18490	16934	346	1210	1555	17194	17107	86	0
Mar-09	18490	16934	346	1210	1555	17280	17194	86	0
Apr-09	18403	16762	346	1296	1642	17280	17194	86	0
May-09	18576	16848	432	1296	1728	17366	17280	86	0
Jun-09	18490	16934	259	1296	1555	17453	17366	86	0
Jul-09	18922	17194	346	1382	1728	17798	17712	86	0
Aug-09	18230	16589	259	1382	1642	17626	17539	86	0
Sep-09	17885	16243	259	1382	1642	17453	17366	86	0
Oct-09	17971	16157	259	1555	1814	17453	17366	86	0
Nov-09	18058	16243	259	1555	1814	17539	17453	86	0
Dec-09	18230	16330	259	1642	1901	17626	17539	86	0
Jan-10	19786	17712	346	1728	2074	18662	18576	86	0
Feb-10	19786	17626	432	1728	2160	18749	18662	86	0
Mar-10	19613	17366	432	1814	2246	18749	18662	86	0
Apr-10	20045	17885	432	1728	2160	19094	19008	86	0
May-10	20650	18576	432	1642	2074	19440	19354	86	0
Jun-10	20218	18144	432	1642	2074	19526	19440	86	0
Jul-10	20304	18144	432	1728	2160	19526	19440	86	0
Aug-10	21859	19786	432	1642	2074	20390	20304	86	0
Sep-10	23069	20822	518	1728	2246	21168	21082	86	0
Oct-10	22723	20563	432	1728	2160	21082	20995	86	0
Nov-10	23069	20909	432	1728	2160	21427	21341	86	0
Dec-10	23846	21686	432	1728	2160	22118	22032	86	0
Jan-11	23674	21427	432	1814	2246	22378	22291	86	0
Feb-11	23501	21254	432	1814	2246	22464	22291	173	0
Mar-11	24019	21514	432	2074	2506	22723	22550	173	0
Apr-11	24624	22118	432	2074	2506	23242	23069	173	0
May-11	24624	21859	432	2333	2765	23501	23328	173	0
Jun-11	25142	22291	432	2419	2851	23846	23674	173	0

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Predicted Groundwater Inflow Components to the Mine Workings - Base Case
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Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
Jul-11	25229	22291	432	2506	2938	24106	23933	173	0
Aug-11	25488	22464	518	2506	3024	24192	24019	173	0
Sep-11	26352	23414	518	2419	2938	24538	24365	173	0
Oct-11	26438	23501	518	2419	2938	24797	24624	173	0
Nov-11	26957	23846	518	2592	3110	25315	25142	173	0
Dec-11	26957	24019	432	2506	2938	25488	25315	173	0
Jan-12	27130	24106	432	2592	3024	25661	25488	173	0
Feb-12	27648	24538	518	2592	3110	26006	25834	173	0
Mar-12	27821	24624	518	2678	3197	26179	26006	173	0
Apr-12	28339	25229	518	2592	3110	26438	26266	173	0
May-12	27907	24710	518	2678	3197	26266	26093	173	0
Jun-12	27994	24797	518	2678	3197	26179	26006	173	0
Jul-12	28512	25229	518	2765	3283	26438	26266	173	0
Aug-12	28512	24883	518	3110	3629	26698	26525	173	0
Sep-12	31882	28080	605	3197	3802	27907	27734	173	0
Oct-12	31882	28080	518	3283	3802	28685	28426	259	0
Nov-12	31450	27389	605	3456	4061	28944	28685	259	0
Dec-12	32573	28598	605	3370	3974	29462	29203	259	0
Jan-13	33523	29549	605	3370	3974	29981	29722	259	0
Feb-13	33869	29808	691	3370	4061	30326	30067	259	0
Mar-13	35165	30931	864	3370	4234	30931	30672	259	0
Apr-13	34301	29894	864	3542	4406	31277	31018	259	0
May-13	34301	29894	864	3542	4406	31450	31190	259	0
Jun-13	37843	33523	864	3456	4320	32659	32400	259	0
Jul-13	39658	35424	864	3370	4234	33264	33005	259	0
Aug-13	39658	35338	864	3456	4320	33869	33610	259	0
Sep-13	40003	35683	864	3456	4320	34646	34301	346	0
Oct-13	39658	35251	778	3629	4406	35078	34733	346	0
Nov-13	40781	36634	691	3456	4147	35683	35338	346	0
Dec-13	40435	36374	691	3370	4061	35942	35597	346	0
Jan-14	40608	36634	605	3370	3974	36115	35770	346	0
Feb-14	43286	39571	605	3110	3715	37238	36893	346	0
Mar-14	44410	40781	605	3024	3629	38102	37670	346	86
Apr-14	42941	39312	605	3024	3629	38448	37930	432	86
May-14	42509	38707	605	3197	3802	38707	38189	432	86
Jun-14	43200	39485	605	3110	3715	39053	38534	432	86
Jul-14	43891	40003	605	3283	3888	39485	38966	432	86
Aug-14	43286	39226	605	3456	4061	39830	39312	432	86
Sep-14	43632	39226	605	3802	4406	40003	39485	432	86
Oct-14	51062	46742	691	3629	4320	41040	40435	518	86
Nov-14	53827	49766	605	3456	4061	42163	41558	518	86
Dec-14	53482	49248	605	3629	4234	43027	42336	518	173
Jan-15	51494	47174	605	3715	4320	43373	42682	518	173
Feb-15	51322	46397	605	4320	4925	43546	42854	518	173
Mar-15	51581	46829	605	4147	4752	44064	43373	518	173

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Predicted Groundwater Inflow Components to the Mine Workings - Base Case
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Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
Apr-15	50976	46310	605	4061	4666	44237	43459	605	173
May-15	50198	45187	605	4406	5011	44323	43546	605	173
Jun-15	50371	45187	605	4579	5184	44582	43805	605	173
Jul-15	50112	45014	605	4493	5098	44928	44064	605	259
Aug-15	54000	49248	691	4061	4752	45187	44323	605	259
Sep-15	52877	48298	691	3888	4579	45014	44150	605	259
Oct-15	52704	47779	691	4234	4925	45014	44064	691	259
Nov-15	51494	46570	691	4234	4925	45101	44150	691	259
Dec-15	58579	53482	691	4406	5098	45878	44928	691	259
Jan-16	56592	52013	691	3888	4579	45878	44842	691	346
Feb-16	53827	49421	605	3802	4406	45878	44842	691	346
Mar-16	53395	48384	605	4406	5011	46051	45014	691	346
Apr-16	53309	48211	605	4493	5098	46397	45360	691	346
May-16	52963	47002	605	5357	5962	46656	45533	778	346
Jun-16	52272	46483	605	5184	5789	46829	45706	778	346
Jul-16	53914	47434	605	5875	6480	47347	46138	778	432
Aug-16	55296	48384	605	6307	6912	47779	46570	778	432
Sep-16	63850	57715	605	5530	6134	48470	47261	778	432
Oct-16	58579	51322	605	6653	7258	48384	47174	778	432
Nov-16	56333	49421	605	6307	6912	48384	47174	778	432
Dec-16	61603	55987	605	5011	5616	49162	47952	778	432
Jan-17	56765	51494	605	4666	5270	48902	47693	778	432
Feb-17	57629	52531	691	4406	5098	49421	48038	864	518
Mar-17	55728	50717	691	4320	5011	49507	48125	864	518
Apr-17	56419	50803	605	5011	5616	49766	48384	864	518
May-17	54864	49334	691	4838	5530	49680	48298	864	518
Jun-17	55814	50717	691	4406	5098	49766	48384	864	518
Jul-17	54864	49853	691	4320	5011	49853	48470	864	518
Aug-17	55382	49680	691	5011	5702	50026	48643	864	518
Sep-17	55037	49507	691	4838	5530	50285	48816	864	605
Oct-17	54864	48643	691	5530	6221	50285	48816	864	605
Nov-17	54605	48557	691	5357	6048	50371	48902	864	605
Dec-17	54605	47952	691	5962	6653	50371	48902	864	605
Jan-18	57629	50544	691	6394	7085	50544	48989	950	605
Feb-18	56592	48902	691	6998	7690	50630	49075	950	605
Mar-18	56765	49421	778	6566	7344	50717	49162	950	605
Apr-18	55987	48816	778	6394	7171	50976	49334	950	691
May-18	57802	51494	778	5530	6307	50976	49334	950	691
Jun-18	55469	49421	691	5357	6048	50976	49334	950	691
Jul-18	55555	49939	691	4925	5616	50976	49334	950	691
Aug-18	54778	49248	691	4838	5530	50976	49334	950	691
Sep-18	54950	48730	691	5530	6221	50976	49334	950	691
Oct-18	54778	48557	691	5530	6221	50976	49334	950	691
Nov-18	54346	48211	691	5443	6134	50976	49334	950	691
Dec-18	54778	48643	691	5443	6134	51235	49507	950	778

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Predicted Groundwater Inflow Components to the Mine Workings - Base Case
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Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
Jan-19	56074	50717	691	4666	5357	51235	49507	950	778
Feb-19	54173	48902	691	4579	5270	51235	49507	950	778
Mar-19	54173	48902	691	4579	5270	51235	49507	950	778
Apr-19	54346	49075	691	4579	5270	51322	49594	950	778
May-19	54000	48730	691	4579	5270	51322	49594	950	778
Jun-19	54173	48902	691	4579	5270	51235	49507	950	778
Jul-19	53914	48643	691	4579	5270	51322	49507	1037	778
Aug-19	53827	48643	691	4493	5184	51322	49507	1037	778
Sep-19	55296	50630	778	3888	4666	51494	49680	1037	778
Oct-19	54173	49680	691	3802	4493	51494	49594	1037	864
Nov-19	54173	49680	691	3802	4493	51581	49680	1037	864
Dec-19	54173	49594	691	3888	4579	51667	49766	1037	864
Jan-20	54432	49853	691	3888	4579	51754	49853	1037	864
Feb-20	55037	50285	691	4061	4752	51926	50026	1037	864
Mar-20	54173	49421	691	4061	4752	51667	49766	1037	864
Apr-20	54173	49421	691	4061	4752	51667	49766	1037	864
May-20	54086	49334	691	4061	4752	51754	49853	1037	864
Jun-20	54173	49421	691	4061	4752	51667	49853	950	864
Jul-20	54000	49334	691	3974	4666	51667	49853	950	864
Aug-20	54605	50026	691	3888	4579	51754	49939	950	864
Sep-20	53827	49248	691	3888	4579	51667	49853	950	864
Oct-20	56074	51581	691	3802	4493	52013	50112	950	950
Nov-20	54432	49939	691	3802	4493	52013	50112	950	950
Dec-20	54346	49939	691	3715	4406	52099	50198	950	950
Jan-21	54086	49680	691	3715	4406	52099	50112	1037	950
Feb-21	53827	49421	691	3715	4406	52099	50112	1037	950
Mar-21	53914	49507	691	3715	4406	52099	50112	1037	950
Apr-21	53827	49421	691	3715	4406	52013	50026	1037	950
May-21	53568	49248	691	3629	4320	52013	50026	1037	950
Jun-21	53568	49162	778	3629	4406	52013	50026	1037	950
Jul-21	53568	49162	778	3629	4406	52013	50026	1037	950
Aug-21	53741	49334	778	3629	4406	52099	50112	1037	950
Sep-21	54518	50112	864	3542	4406	52013	50026	1037	950
Oct-21	53309	48989	778	3542	4320	52013	50026	1037	950
Nov-21	53568	49248	778	3542	4320	51754	49766	1037	950
Dec-21	53482	49075	864	3542	4406	51754	49766	1037	950
Jan-22	53482	49162	864	3456	4320	51754	49766	1037	950
Feb-22	53568	49248	864	3456	4320	51840	49853	1037	950
Mar-22	53568	49248	864	3456	4320	52013	49939	1037	1037
Apr-22	53568	49248	864	3456	4320	52013	49939	1037	1037
May-22	53568	49248	864	3456	4320	52099	50026	1037	1037
Jun-22	53309	48989	864	3456	4320	52013	49939	1037	1037
Jul-22	53482	49162	864	3456	4320	52099	50026	1037	1037
Aug-22	53395	49075	864	3456	4320	52099	50026	1037	1037
Sep-22	53482	49162	864	3456	4320	52099	50026	1037	1037

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Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
Oct-22	53482	49162	864	3456	4320	52099	50026	1037	1037
Nov-22	53309	48989	864	3456	4320	52099	50026	1037	1037
Dec-22	53654	49334	864	3456	4320	52099	50026	1037	1037
Jan-23	53309	48989	864	3456	4320	52099	50026	1037	1037
Feb-23	53395	49162	864	3370	4234	52099	50026	1037	1037
Mar-23	53222	48989	864	3370	4234	52272	50112	1123	1037
Apr-23	53395	49162	864	3370	4234	52272	50112	1123	1037
May-23	53395	49162	864	3370	4234	52272	50112	1123	1037
Jun-23	53309	49162	864	3283	4147	52272	50112	1123	1037
Jul-23	53222	49075	864	3283	4147	52272	50112	1123	1037
Aug-23	53222	49075	864	3283	4147	52272	50112	1123	1037
Sep-23	53309	49248	864	3197	4061	52272	50112	1123	1037
Oct-23	53136	49075	950	3110	4061	52272	50112	1123	1037
Nov-23	53050	48989	950	3110	4061	52272	50112	1123	1037
Dec-23	53050	48989	950	3110	4061	52272	50112	1123	1037
Jan-24	53050	48989	950	3110	4061	52272	50112	1123	1037
Feb-24	53050	48989	950	3110	4061	52272	50112	1123	1037
Mar-24	53050	48989	950	3110	4061	52272	50112	1123	1037
Apr-24	53050	48989	950	3110	4061	52272	50112	1123	1037
May-24	53050	48989	950	3110	4061	52272	50112	1123	1037
Jun-24	53050	48989	950	3110	4061	52272	50112	1123	1037
Jul-24	53136	49075	950	3110	4061	52358	50198	1123	1037
Aug-24	53050	48989	950	3110	4061	52445	50198	1123	1123
Sep-24	53050	48989	950	3110	4061	52445	50198	1123	1123
Oct-24	53050	48989	950	3110	4061	52358	50112	1123	1123
Nov-24	53050	48989	950	3110	4061	52358	50112	1123	1123
Dec-24	53050	48989	950	3110	4061	52358	50112	1123	1123
Jan-25	52963	48902	950	3110	4061	52358	50112	1123	1123
Feb-25	52963	48902	950	3110	4061	52358	50112	1123	1123
Mar-25	52963	48902	950	3110	4061	52358	50112	1123	1123
Apr-25	53050	48989	950	3110	4061	52445	50198	1123	1123
May-25	53050	48989	950	3110	4061	52445	50198	1123	1123
Jun-25	53050	48989	950	3110	4061	52358	50112	1123	1123
Jul-25	53050	48989	950	3110	4061	52445	50198	1123	1123
Aug-25	53050	48989	950	3110	4061	52445	50198	1123	1123
Sep-25	53136	49075	950	3110	4061	52445	50198	1123	1123
Oct-25	52963	48902	950	3110	4061	52445	50198	1123	1123
Nov-25	53136	49075	950	3110	4061	52445	50198	1123	1123
Dec-25	53050	48989	950	3110	4061	52445	50198	1123	1123
Jan-26	53309	49248	1037	3024	4061	52531	50285	1123	1123
Feb-26	54950	48816	3110	3024	6134	53914	51667	1123	1123
Mar-26	55037	49075	2938	3024	5962	54173	51926	1123	1123
Apr-26	54864	48989	2851	3024	5875	54173	51926	1123	1123
May-26	55037	49162	2851	3024	5875	54346	52099	1123	1123
Jun-26	56851	49334	4493	3024	7517	55469	53222	1123	1123

TABLE 3

Predicted Groundwater Inflow Components to the Mine Workings - Base Case
(Page 7 of 7)

Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
Jul-26	57197	49853	4320	3024	7344	55901	53654	1123	1123
Aug-26	56851	49507	4320	3024	7344	55901	53654	1123	1123
Sep-26	61258	54605	4234	2419	6653	56506	54259	1123	1123
Oct-26	57715	51235	4147	2333	6480	56160	53914	1123	1123
Nov-26	57542	52445	2765	2333	5098	55814	53568	1123	1123
Dec-26	57197	52099	2765	2333	5098	55728	53482	1123	1123
Jan-27	56938	53136	1469	2333	3802	55469	53222	1123	1123
Feb-27	56765	52963	1469	2333	3802	55382	53136	1123	1123
Mar-27	56506	52704	1469	2333	3802	55210	52963	1123	1123
Apr-27	56333	52531	1469	2333	3802	55296	53050	1123	1123
May-27	56160	52445	1382	2333	3715	55382	53136	1123	1123
Jun-27	56160	52445	1382	2333	3715	55382	53136	1123	1123
Jul-27	56160	52445	1382	2333	3715	55469	53222	1123	1123
Aug-27	56074	52358	1382	2333	3715	55469	53222	1123	1123
Sep-27	56419	52618	1469	2333	3802	55555	53309	1123	1123
Oct-27	56506	52704	1469	2333	3802	55642	53395	1123	1123
Nov-27	56246	52445	1469	2333	3802	55642	53395	1123	1123
Dec-27	56506	52790	1469	2246	3715	55728	53482	1123	1123
Jan-28	56246	52531	1469	2246	3715	55555	53309	1123	1123
Feb-28	56160	52445	1469	2246	3715	55555	53309	1123	1123
Mar-28	55814	52099	1469	2246	3715	55469	53222	1123	1123
Apr-28	55987	52272	1469	2246	3715	55469	53222	1123	1123
May-28	55901	52272	1469	2160	3629	55555	53309	1123	1123
Jun-28	55901	52272	1469	2160	3629	55555	53309	1123	1123
Jul-28	55901	52272	1469	2160	3629	55555	53309	1123	1123
Aug-28	55901	52272	1469	2160	3629	55555	53309	1123	1123
Sep-28	56074	52445	1469	2160	3629	55555	53309	1123	1123
Oct-28	55814	52186	1469	2160	3629	55555	53309	1123	1123
Nov-28	55901	52272	1469	2160	3629	55555	53309	1123	1123
Dec-28	55814	52186	1469	2160	3629	55555	53309	1123	1123

TABLE 4

Predicted TDS Concentrations of the Mine Water Discharge - Base Case
(Page 1 of 7)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
Jan-04	214.7	2490.2		228.7	5727.9	
Feb-04	214.7	3490.2		228.7	5727.9	
Mar-04	214.7	3490.2		228.7	5727.9	
Apr-04	214.7	3490.2		228.7	5727.9	
May-04	214.7	3490.2	214.7	228.7	5727.9	228.70
Jun-04	214.7	3490.2	214.7	228.7	5727.9	228.70
Jul-04	214.7	3490.2	214.7	228.7	5727.9	228.70
Aug-04	214.7	3490.2	624.1	228.7	5727.9	916.10
Sep-04	214.7	3490.2	476.7	228.7	5727.9	668.64
Oct-04	214.7	3490.2	503.7	228.7	5727.9	713.92
Nov-04	214.7	3490.2	473.3	228.7	5727.9	662.85
Dec-04	214.7	3490.2	466.7	228.7	5727.9	651.72
Jan-05	214.7	3490.2	487.7	228.7	5727.9	686.97
Feb-05	214.7	3490.2	487.7	228.7	5727.9	686.97
Mar-05	214.7	3490.2	471.6	228.7	5727.9	660.01
Apr-05	214.7	3490.2	452.9	228.7	5727.9	628.64
May-05	214.7	3490.2	433.1	228.7	5727.9	595.31
Jun-05	214.7	3490.2	462.8	228.7	5727.9	645.31
Jul-05	214.7	3490.2	635.8	228.7	5727.9	935.74
Aug-05	214.7	3490.2	568.8	228.7	5727.9	823.21
Sep-05	214.7	3490.2	597.6	228.7	5727.9	871.46
Oct-05	214.7	3490.2	640.1	228.7	5727.9	942.88
Nov-05	214.7	3490.2	712.2	228.7	5727.9	1064.02
Dec-05	214.7	3490.2	712.2	228.7	5727.9	1064.02
Jan-06	214.7	3490.2	682.6	228.7	5727.9	1014.30
Feb-06	214.7	3490.2	715.7	228.7	5727.9	1069.75
Mar-06	214.7	3490.2	704.1	228.7	5727.9	1050.42
Apr-06	214.7	3490.2	741.8	228.7	5727.9	1113.63
May-06	214.7	3490.2	697.4	228.7	5727.9	1039.11
Jun-06	214.7	3490.2	737.4	228.7	5727.9	1106.23
Jul-06	214.7	3490.2	810.2	228.7	5727.9	1228.55
Aug-06	214.7	3490.2	792.7	228.7	5727.9	1199.15
Sep-06	214.7	3490.2	798.5	228.7	5727.9	1208.76
Oct-06	214.7	3490.2	824.8	228.7	5727.9	1253.06
Nov-06	214.7	3490.2	702.0	228.7	5727.9	1046.76
Dec-06	214.7	3490.2	679.3	228.7	5727.9	1008.73
Jan-07	214.7	3490.2	618.8	228.7	5727.9	907.17
Feb-07	214.7	3490.2	601.2	228.7	5727.9	877.67
Mar-07	214.7	3490.2	583.2	228.7	5727.9	847.36
Apr-07	214.7	3490.2	567.1	228.7	5727.9	820.39
May-07	214.7	3490.2	580.9	228.7	5727.9	843.52
Jun-07	214.7	3490.2	587.9	228.7	5727.9	855.19
Jul-07	214.7	3490.2	602.6	228.7	5727.9	879.92
Aug-07	214.7	3490.2	560.6	228.7	5727.9	809.36

TABLE 4

Predicted TDS Concentrations of the Mine Water Discharge - Base Case
(Page 2 of 7)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
Sep-07	214.7	3490.2	580.9	228.7	5727.9	843.52
Oct-07	214.7	3490.2	583.2	228.7	5727.9	847.36
Nov-07	214.7	3490.2	595.1	228.7	5727.9	867.32
Dec-07	214.7	3490.2	597.6	228.7	5727.9	871.46
Jan-08	214.7	3490.2	595.1	228.7	5727.9	867.32
Feb-08	214.7	3490.2	564.9	228.7	5727.9	816.66
Mar-08	214.7	3490.2	567.1	228.7	5727.9	820.39
Apr-08	214.7	3490.2	562.7	228.7	5727.9	812.99
May-08	214.7	3490.2	556.3	228.7	5727.9	802.24
Jun-08	214.7	3490.2	564.9	228.7	5727.9	816.66
Jul-08	214.7	3490.2	550.1	228.7	5727.9	791.87
Aug-08	214.7	3490.2	538.4	228.7	5727.9	772.23
Sep-08	214.7	3490.2	512.5	228.7	5727.9	728.63
Oct-08	214.7	3490.2	507.5	228.7	5727.9	720.25
Nov-08	214.7	3490.2	493.1	228.7	5727.9	696.13
Dec-08	214.7	3490.2	506.9	228.7	5727.9	719.24
Jan-09	214.7	3490.2	488.9	228.7	5727.9	689.10
Feb-09	214.7	3490.2	490.2	228.7	5727.9	691.25
Mar-09	214.7	3490.2	490.2	228.7	5727.9	691.25
Apr-09	214.7	3490.2	506.9	228.7	5727.9	719.24
May-09	214.7	3490.2	519.4	228.7	5727.9	740.25
Jun-09	214.7	3490.2	490.2	228.7	5727.9	691.25
Jul-09	214.7	3490.2	513.8	228.7	5727.9	730.91
Aug-09	214.7	3490.2	509.7	228.7	5727.9	723.89
Sep-09	214.7	3490.2	515.3	228.7	5727.9	733.46
Oct-09	214.7	3490.2	545.4	228.7	5727.9	783.91
Nov-09	214.7	3490.2	543.8	228.7	5727.9	781.25
Dec-09	214.7	3490.2	556.2	228.7	5727.9	802.08
Jan-10	214.7	3490.2	558.0	228.7	5727.9	805.04
Feb-10	214.7	3490.2	572.3	228.7	5727.9	829.05
Mar-10	214.7	3490.2	589.9	228.7	5727.9	858.56
Apr-10	214.7	3490.2	567.7	228.7	5727.9	821.29
May-10	214.7	3490.2	543.6	228.7	5727.9	780.92
Jun-10	214.7	3490.2	550.6	228.7	5727.9	792.72
Jul-10	214.7	3490.2	563.2	228.7	5727.9	813.72
Aug-10	214.7	3490.2	525.4	228.7	5727.9	750.36
Sep-10	214.7	3490.2	533.7	228.7	5727.9	764.20
Oct-10	214.7	3490.2	526.1	228.7	5727.9	751.44
Nov-10	214.7	3490.2	521.4	228.7	5727.9	743.61
Dec-10	214.7	3490.2	511.4	228.7	5727.9	726.82
Jan-11	214.7	3490.2	525.5	228.7	5727.9	750.52
Feb-11	214.7	3490.2	527.8	228.7	5727.9	754.36
Mar-11	214.7	3490.2	556.4	228.7	5727.9	802.36
Apr-11	214.7	3490.2	548.0	228.7	5727.9	788.27

TABLE 4

Predicted TDS Concentrations of the Mine Water Discharge - Base Case
(Page 3 of 7)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
May-11	214.7	3490.2	582.5	228.7	5727.9	846.15
Jun-11	214.7	3490.2	586.1	228.7	5727.9	852.32
Jul-11	214.7	3490.2	596.1	228.7	5727.9	869.02
Aug-11	214.7	3490.2	603.3	228.7	5727.9	881.15
Sep-11	214.7	3490.2	579.8	230.7	5727.9	841.73
Oct-11	214.7	3490.2	578.6	233.7	5727.9	841.46
Nov-11	214.7	3490.2	592.6	237.0	5727.9	867.63
Dec-11	214.7	3490.2	571.6	239.9	5727.9	835.34
Jan-12	214.7	3490.2	579.8	243.0	5727.9	851.65
Feb-12	214.7	3490.2	583.2	246.2	5727.9	860.06
Mar-12	214.7	3490.2	591.1	249.5	5727.9	876.09
Apr-12	214.7	3490.2	574.2	252.7	5727.9	850.81
May-12	214.7	3490.2	589.9	255.9	5727.9	879.85
Jun-12	214.7	3490.2	588.8	259.1	5727.9	880.80
Jul-12	214.7	3490.2	591.9	262.5	5727.9	888.87
Aug-12	214.7	3490.2	631.6	266.4	5727.9	958.07
Sep-12	214.7	3490.2	605.3	270.5	5727.9	917.59
Oct-12	214.7	3490.2	605.3	274.6	5727.9	921.24
Nov-12	214.7	3490.2	637.6	279.1	5727.9	978.72
Dec-12	214.7	3490.2	614.4	283.4	5727.9	943.92
Jan-13	214.7	3490.2	603.0	287.6	5727.9	928.87
Feb-13	214.7	3490.2	607.4	292.0	5727.9	939.92
Mar-13	214.7	3490.2	609.0	296.6	5727.9	946.45
Apr-13	215.8	3490.2	635.5	301.5	5727.9	994.34
May-13	218.6	3490.2	635.5	306.3	5727.9	998.57
Jun-13	221.2	3490.2	588.6	310.9	5727.9	925.19
Jul-13	223.7	3490.2	565.6	315.3	5727.9	889.19
Aug-13	226.3	3490.2	574.9	319.9	5727.9	904.93
Sep-13	228.7	3490.2	574.0	324.3	5727.9	903.88
Oct-13	231.3	3490.2	586.4	328.9	5727.9	924.74
Nov-13	233.5	3490.2	558.0	333.0	5727.9	877.98
Dec-13	235.6	3490.2	555.9	337.0	5727.9	874.84
Jan-14	237.6	3490.2	549.5	340.7	5727.9	864.60
Feb-14	239.3	3490.2	512.1	344.0	5727.9	803.10
Mar-14	240.9	3490.2	500.3	347.1	5727.9	783.94
Apr-14	242.5	3490.2	510.9	350.2	5727.9	801.84
May-14	244.3	3490.2	528.4	353.6	5727.9	831.14
Jun-14	245.9	3490.2	518.9	356.7	5727.9	815.75
Jul-14	247.8	3490.2	528.9	360.1	5727.9	832.51
Aug-14	249.7	3490.2	547.6	363.8	5727.9	863.70
Sep-14	252.0	3490.2	572.7	368.0	5727.9	905.53
Oct-14	254.2	3490.2	521.6	372.0	5727.9	821.47
Nov-14	256.1	3490.2	494.0	375.6	5727.9	776.09
Dec-14	258.2	3490.2	507.8	379.4	5727.9	799.28

TABLE 4

Predicted TDS Concentrations of the Mine Water Discharge - Base Case
(Page 4 of 7)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
Jan-15	260.3	3490.2	525.1	383.3	5727.9	828.10
Feb-15	263.0	3490.2	566.1	388.2	5727.9	896.18
Mar-15	265.5	3490.2	556.2	392.7	5727.9	880.11
Apr-15	267.9	3490.2	556.6	397.1	5727.9	881.01
May-15	270.6	3490.2	585.6	401.9	5727.9	929.22
Jun-15	273.4	3490.2	598.0	407.0	5727.9	950.05
Jul-15	276.2	3490.2	596.8	411.9	5727.9	948.29
Aug-15	278.6	3490.2	555.1	416.2	5727.9	879.74
Sep-15	280.7	3490.2	552.8	420.2	5727.9	876.23
Oct-15	283.2	3490.2	576.8	424.7	5727.9	916.18
Nov-15	285.7	3490.2	586.2	429.2	5727.9	931.90
Dec-15	288.3	3490.2	560.8	433.9	5727.9	890.27
Jan-16	290.4	3490.2	543.7	437.7	5727.9	862.24
Feb-16	292.3	3490.2	548.6	441.2	5727.9	870.74
Mar-16	294.8	3490.2	588.8	445.6	5727.9	937.32
Apr-16	297.3	3490.2	596.7	450.1	5727.9	950.71
May-16	300.7	3490.2	653.2	456.0	5727.9	1044.19
Jun-16	303.8	3490.2	650.4	461.5	5727.9	1039.83
Jul-16	307.6	3490.2	683.4	468.1	5727.9	1094.52
Aug-16	311.8	3490.2	702.1	475.4	5727.9	1125.61
Sep-16	315.1	3490.2	613.7	481.3	5727.9	980.01
Oct-16	319.6	3490.2	705.2	488.9	5727.9	1131.30
Nov-16	323.6	3490.2	705.4	495.9	5727.9	1131.74
Dec-16	326.4	3490.2	609.0	500.8	5727.9	972.90
Jan-17	328.7	3490.2	616.8	505.1	5727.9	986.11
Feb-17	330.9	3490.2	605.1	509.0	5727.9	967.04
Mar-17	333.0	3490.2	611.8	512.8	5727.9	978.29
Apr-17	335.7	3490.2	644.1	517.5	5727.9	1031.88
May-17	338.2	3490.2	650.5	522.0	5727.9	1042.60
Jun-17	340.3	3490.2	623.0	525.7	5727.9	997.43
Jul-17	342.3	3490.2	624.9	529.3	5727.9	1000.89
Aug-17	345.0	3490.2	663.4	534.0	5727.9	1064.60
Sep-17	347.4	3490.2	658.0	538.3	5727.9	1055.83
Oct-17	350.5	3490.2	700.8	543.7	5727.9	1126.76
Nov-17	353.4	3490.2	695.3	548.8	5727.9	1117.93
Dec-17	356.8	3490.2	732.7	554.8	5727.9	1179.80
Jan-18	360.7	3490.2	739.2	561.4	5727.9	1190.75
Feb-18	365.0	3490.2	783.1	568.9	5727.9	1263.39
Mar-18	369.0	3490.2	766.6	575.7	5727.9	1236.31
Apr-18	372.8	3490.2	766.1	582.2	5727.9	1235.64
May-18	375.7	3490.2	710.2	587.3	5727.9	1143.71
Jun-18	378.3	3490.2	712.6	591.9	5727.9	1147.81
Jul-18	380.5	3490.2	690.2	595.8	5727.9	1111.12
Aug-18	382.6	3490.2	691.8	599.6	5727.9	1113.89

TABLE 4

Predicted TDS Concentrations of the Mine Water Discharge - Base Case
(Page 5 of 7)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
Sep-18	385.3	3490.2	731.8	604.3	5727.9	1180.12
Oct-18	388.0	3490.2	735.4	609.0	5727.9	1186.18
Nov-18	390.6	3490.2	735.6	613.6	5727.9	1186.85
Dec-18	393.2	3490.2	735.2	618.1	5727.9	1186.32
Jan-19	395.0	3490.2	686.5	621.3	5727.9	1106.22
Feb-19	396.7	3490.2	693.6	624.4	5727.9	1118.11
Mar-19	398.4	3490.2	695.2	627.4	5727.9	1120.88
Apr-19	400.1	3490.2	695.8	630.4	5727.9	1122.04
May-19	401.7	3490.2	699.2	633.4	5727.9	1127.91
Jun-19	403.3	3490.2	699.8	636.3	5727.9	1129.01
Jul-19	405.0	3490.2	702.7	639.2	5727.9	1134.04
Aug-19	406.5	3490.2	699.7	642.0	5727.9	1129.30
Sep-19	407.5	3490.2	664.3	643.9	5727.9	1071.09
Oct-19	408.4	3490.2	660.8	645.5	5727.9	1065.52
Nov-19	409.2	3490.2	661.6	647.1	5727.9	1067.01
Dec-19	410.1	3490.2	667.3	648.8	5727.9	1076.59
Jan-20	411.0	3490.2	666.9	650.6	5727.9	1076.13
Feb-20	412.0	3490.2	674.6	652.5	5727.9	1088.95
Mar-20	413.1	3490.2	679.8	654.5	5727.9	1097.73
Apr-20	414.1	3490.2	680.8	656.4	5727.9	1099.51
May-20	415.2	3490.2	682.2	658.3	5727.9	1101.98
Jun-20	416.2	3490.2	682.7	660.2	5727.9	1103.01
Jul-20	417.1	3490.2	679.6	661.9	5727.9	1098.04
Aug-20	417.9	3490.2	672.7	663.5	5727.9	1086.77
Sep-20	418.7	3490.2	677.2	665.1	5727.9	1094.35
Oct-20	419.5	3490.2	662.7	666.5	5727.9	1070.73
Nov-20	420.2	3490.2	670.8	667.9	5727.9	1084.27
Dec-20	420.8	3490.2	667.0	669.2	5727.9	1078.18
Jan-21	421.5	3490.2	668.9	670.4	5727.9	1081.30
Feb-21	422.1	3490.2	670.7	671.7	5727.9	1084.43
Mar-21	422.7	3490.2	670.8	672.9	5727.9	1084.91
Apr-21	423.3	3490.2	671.8	674.1	5727.9	1086.69
May-21	423.9	3490.2	668.7	675.2	5727.9	1081.65
Jun-21	424.5	3490.2	674.1	676.3	5727.9	1090.78
Jul-21	425.1	3490.2	674.7	677.5	5727.9	1091.88
Aug-21	425.7	3490.2	674.5	678.7	5727.9	1091.62
Sep-21	426.3	3490.2	671.5	679.8	5727.9	1086.79
Oct-21	426.8	3490.2	672.7	680.9	5727.9	1088.92
Nov-21	427.2	3490.2	671.9	681.9	5727.9	1087.87
Dec-21	427.8	3490.2	677.8	683.0	5727.9	1097.60
Jan-22	428.3	3490.2	673.4	684.0	5727.9	1090.49
Feb-22	428.8	3490.2	673.4	684.9	5727.9	1090.73
Mar-22	429.3	3490.2	673.9	685.9	5727.9	1091.62
Apr-22	429.7	3490.2	674.3	686.8	5727.9	1092.51

TABLE 4

Predicted TDS Concentrations of the Mine Water Discharge - Base Case
(Page 6 of 7)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
May-22	430.2	3490.2	674.8	687.8	5727.9	1093.38
Jun-22	430.7	3490.2	676.4	688.7	5727.9	1096.22
Jul-22	431.1	3490.2	676.1	689.6	5727.9	1095.76
Aug-22	431.6	3490.2	676.9	690.6	5727.9	1097.27
Sep-22	432.0	3490.2	676.9	691.5	5727.9	1097.45
Oct-22	432.5	3490.2	677.4	692.4	5727.9	1098.29
Nov-22	432.9	3490.2	678.6	693.3	5727.9	1100.43
Dec-22	433.3	3490.2	677.4	694.1	5727.9	1098.62
Jan-23	433.8	3490.2	679.4	695.0	5727.9	1102.06
Feb-23	434.1	3490.2	674.5	695.7	5727.9	1094.06
Mar-23	434.5	3490.2	675.6	696.5	5727.9	1096.03
Apr-23	434.8	3490.2	675.2	697.2	5727.9	1095.40
May-23	435.1	3490.2	675.5	697.9	5727.9	1096.06
Jun-23	435.4	3490.2	671.2	698.5	5727.9	1089.20
Jul-23	435.6	3490.2	671.9	699.0	5727.9	1090.36
Aug-23	435.9	3490.2	672.1	699.6	5727.9	1090.89
Sep-23	436.0	3490.2	667.0	700.0	5727.9	1082.62
Oct-23	436.2	3490.2	668.0	700.4	5727.9	1084.25
Nov-23	436.4	3490.2	668.5	700.8	5727.9	1085.26
Dec-23	436.5	3490.2	668.7	701.2	5727.9	1085.64
Jan-24	436.7	3490.2	668.8	701.6	5727.9	1086.0
Feb-24	436.8	3490.2	669.0	702.0	5727.9	1086.4
Mar-24	437.0	3490.2	669.1	702.4	5727.9	1086.8
Apr-24	437.2	3490.2	669.3	702.8	5727.9	1087.1
May-24	437.3	3490.2	669.5	703.2	5727.9	1087.5
Jun-24	437.5	3490.2	669.6	703.6	5727.9	1087.9
Jul-24	437.6	3490.2	669.4	704.0	5727.9	1087.6
Aug-24	437.8	3490.2	669.9	704.4	5727.9	1088.6
Sep-24	437.9	3490.2	670.1	704.8	5727.9	1088.9
Oct-24	438.0	3490.2	670.2	705.1	5727.9	1089.3
Nov-24	438.2	3490.2	670.4	705.5	5727.9	1089.6
Dec-24	438.3	3490.2	670.5	705.9	5727.9	1089.9
Jan-25	438.5	3490.2	671.0	706.2	5727.9	1090.9
Feb-25	438.6	3490.2	671.2	706.6	5727.9	1091.2
Mar-25	438.8	3490.2	671.3	706.9	5727.9	1091.6
Apr-25	438.9	3490.2	671.1	707.3	5727.9	1091.3
May-25	439.0	3490.2	671.2	707.6	5727.9	1091.6
Jun-25	439.2	3490.2	671.3	708.0	5727.9	1091.9
Jul-25	439.3	3490.2	671.5	708.3	5727.9	1092.2
Aug-25	439.4	3490.2	671.6	708.6	5727.9	1092.5
Sep-25	439.6	3490.2	671.4	709.0	5727.9	1092.2
Oct-25	439.7	3490.2	672.3	709.3	5727.9	1093.8
Nov-25	439.8	3490.2	671.6	709.6	5727.9	1092.8
Dec-25	439.9	3490.2	672.1	710.0	5727.9	1093.8

TABLE 4

Predicted TDS Concentrations of the Mine Water Discharge - Base Case
(Page 7 of 7)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
Jan-26	440.1	3490.2	671.1	710.3	5727.9	1092.2
Feb-26	442.1	3490.2	779.5	713.8	5727.9	1270.4
Mar-26	444.0	3490.2	771.2	717.0	5727.9	1256.9
Apr-26	445.8	3490.2	769.1	720.0	5727.9	1253.6
May-26	447.5	3490.2	769.7	723.0	5727.9	1254.6
Jun-26	450.8	3490.2	848.8	728.5	5727.9	1384.8
Jul-26	453.9	3490.2	840.0	733.7	5727.9	1370.4
Aug-26	456.9	3490.2	845.1	738.8	5727.9	1378.8
Sep-26	459.3	3490.2	785.3	742.8	5727.9	1280.6
Oct-26	461.5	3490.2	798.6	746.5	5727.9	1302.5
Nov-26	462.4	3490.2	728.8	748.1	5727.9	1187.8
Dec-26	463.2	3490.2	731.2	749.6	5727.9	1191.9
Jan-27	462.9	3490.2	664.3	749.1	5727.9	1082.0
Feb-27	462.6	3490.2	664.6	748.7	5727.9	1082.6
Mar-27	462.2	3490.2	665.2	748.3	5727.9	1083.7
Apr-27	461.9	3490.2	665.6	747.8	5727.9	1084.3
May-27	461.5	3490.2	661.2	747.2	5727.9	1077.3
Jun-27	461.1	3490.2	660.9	746.7	5727.9	1076.7
Jul-27	460.7	3490.2	660.5	746.1	5727.9	1076.2
Aug-27	460.3	3490.2	660.5	745.6	5727.9	1076.2
Sep-27	460.0	3490.2	663.5	745.2	5727.9	1081.3
Oct-27	459.7	3490.2	662.9	744.7	5727.9	1080.4
Nov-27	459.4	3490.2	663.6	744.3	5727.9	1081.6
Dec-27	459.0	3490.2	657.7	743.8	5727.9	1072.0
Jan-28	458.6	3490.2	658.3	743.3	5727.9	1073.0
Feb-28	458.3	3490.2	658.3	742.8	5727.9	1073.0
Mar-28	457.9	3490.2	659.2	742.2	5727.9	1074.6
Apr-28	457.5	3490.2	658.2	741.7	5727.9	1073.1
May-28	457.1	3490.2	653.5	741.1	5727.9	1065.4
Jun-28	456.6	3490.2	653.1	740.4	5727.9	1064.8
Jul-28	456.2	3490.2	652.7	739.8	5727.9	1064.2
Aug-28	455.8	3490.2	652.3	739.2	5727.9	1063.6
Sep-28	455.3	3490.2	651.3	738.6	5727.9	1062.0
Oct-28	454.9	3490.2	651.8	738.0	5727.9	1062.9
Nov-28	454.5	3490.2	651.1	737.3	5727.9	1061.9
Dec-28	454.1	3490.2	651.0	736.7	5727.9	1061.8

TABLE 5

Predicted Groundwater Inflow Components to the Mine Workings - Sensitivity Simulation 4
(Page 1 of 7)

Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
Jan-04	0	0	0	0	0	0	0	0	0
Feb-04	0	0	0	0	0	0	0	0	0
Mar-04	0	0	0	0	0	0	0	0	0
Apr-04	0	0	0	0	0	0	0	0	0
May-04	346	346	0	0	0	298	298	0	0
Jun-04	346	346	0	0	0	298	298	0	0
Jul-04	432	432	0	0	0	399	399	0	0
Aug-04	1382	1210	86	86	173	1362	1362	0	0
Sep-04	2160	1987	86	86	173	2141	2141	0	0
Oct-04	2938	2678	173	86	259	2931	2931	0	0
Nov-04	3283	3024	173	86	259	3283	3283	0	0
Dec-04	3370	3110	173	86	259	3456	3456	0	0
Jan-05	4147	3802	259	86	346	4061	4061	0	0
Feb-05	4147	3802	259	86	346	4061	4061	0	0
Mar-05	4406	4061	259	86	346	4406	4406	0	0
Apr-05	4752	4406	259	86	346	4666	4666	0	0
May-05	5184	4838	259	86	346	5270	5270	0	0
Jun-05	5702	5270	346	86	432	5702	5702	0	0
Jul-05	6048	5270	346	432	778	5875	5875	0	0
Aug-05	6394	5702	259	432	691	6307	6307	0	0
Sep-05	6739	5962	259	518	778	6566	6566	0	0
Oct-05	6739	5875	259	605	864	6653	6653	0	0
Nov-05	6826	5789	259	778	1037	6653	6653	0	0
Dec-05	6826	5789	259	778	1037	6653	6653	0	0
Jan-06	7258	6221	259	778	1037	6998	7085	0	0
Feb-06	7430	6307	259	864	1123	7171	7258	0	0
Mar-06	7517	6394	259	864	1123	7258	7344	0	0
Apr-06	7517	6307	259	950	1210	7344	7430	0	0
May-06	8208	6998	259	950	1210	7949	8035	0	0
Jun-06	8122	6826	259	1037	1296	8035	8122	0	0
Jul-06	8554	6998	259	1296	1555	8208	8294	0	0
Aug-06	8813	7258	259	1296	1555	8640	8726	0	0
Sep-06	8813	7258	259	1296	1555	8640	8726	0	0
Oct-06	8813	7171	259	1382	1642	8640	8726	0	0
Nov-06	10454	8899	259	1296	1555	10022	10109	0	0
Dec-06	12182	10454	346	1382	1728	11405	11491	0	0
Jan-07	13306	11664	259	1382	1642	12096	12182	0	0
Feb-07	13997	12355	346	1296	1642	12355	12442	0	0
Mar-07	13824	12269	259	1296	1555	12269	12355	0	0
Apr-07	13651	12182	173	1296	1469	12182	12269	0	0
May-07	13910	12355	259	1296	1555	12528	12614	0	0
Jun-07	13651	12096	259	1296	1555	12528	12614	0	0
Jul-07	13133	11578	173	1382	1555	12442	12528	0	0
Aug-07	13910	12442	173	1296	1469	13046	13133	0	0

TABLE 5

Predicted Groundwater Inflow Components to the Mine Workings - Sensitivity Simulation 4
(Page 2 of 7)

Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
Sep-07	13910	12355	259	1296	1555	13046	13133	0	0
Oct-07	13824	12269	259	1296	1555	13046	13133	0	0
Nov-07	13478	11923	259	1296	1555	12874	12960	0	0
Dec-07	13478	11923	259	1296	1555	12874	12874	86	0
Jan-08	13478	11923	259	1296	1555	12874	12874	86	0
Feb-08	13738	12269	259	1210	1469	13046	13046	86	0
Mar-08	13738	12269	259	1210	1469	13133	13133	86	0
Apr-08	13910	12442	259	1210	1469	13219	13219	86	0
May-08	14083	12614	259	1210	1469	13392	13392	86	0
Jun-08	13738	12269	259	1210	1469	13306	13306	86	0
Jul-08	14429	12960	346	1123	1469	13651	13651	86	0
Aug-08	14947	13478	259	1210	1469	14256	14256	86	0
Sep-08	15206	13824	259	1123	1382	14602	14602	86	0
Oct-08	15466	14083	259	1123	1382	14947	14947	86	0
Nov-08	17280	15811	346	1123	1469	16243	16243	86	0
Dec-08	18490	16848	346	1296	1642	17280	17280	86	0
Jan-09	18576	17021	346	1210	1555	17280	17280	86	0
Feb-09	18490	16934	346	1210	1555	17194	17194	86	0
Mar-09	18576	17021	346	1210	1555	17194	17194	86	0
Apr-09	18403	16762	346	1296	1642	17280	17280	86	0
May-09	18490	16848	346	1296	1642	17366	17366	86	0
Jun-09	18490	16934	259	1296	1555	17453	17453	86	0
Jul-09	18749	17021	346	1382	1728	17798	17798	86	0
Aug-09	18144	16502	259	1382	1642	17539	17539	86	0
Sep-09	17885	16243	259	1382	1642	17453	17453	86	0
Oct-09	17971	16157	259	1555	1814	17539	17539	86	0
Nov-09	18058	16243	259	1555	1814	17539	17539	86	0
Dec-09	18317	16416	259	1642	1901	17712	17712	86	0
Jan-10	19872	17798	346	1728	2074	18749	18749	86	0
Feb-10	19786	17626	432	1728	2160	18835	18835	86	0
Mar-10	19613	17366	432	1814	2246	18835	18835	86	0
Apr-10	19958	17798	432	1728	2160	19094	19094	86	0
May-10	20650	18576	432	1642	2074	19440	19440	86	0
Jun-10	20218	18144	432	1642	2074	19526	19526	86	0
Jul-10	20304	18144	432	1728	2160	19613	19613	86	0
Aug-10	21946	19872	432	1642	2074	20477	20477	86	0
Sep-10	23069	20909	518	1642	2160	21254	21254	86	0
Oct-10	22896	20736	432	1728	2160	21168	21168	86	0
Nov-10	23069	20909	432	1728	2160	21514	21514	86	0
Dec-10	23760	21600	432	1728	2160	22118	22118	86	0
Jan-11	23760	21514	432	1814	2246	22378	22378	86	0
Feb-11	23587	21341	432	1814	2246	22464	22464	86	0
Mar-11	24192	21686	432	2074	2506	22723	22723	86	0
Apr-11	24624	22118	432	2074	2506	23242	23155	173	0

TABLE 5

Predicted Groundwater Inflow Components to the Mine Workings - Sensitivity Simulation 4
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Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
May-11	24710	21946	432	2333	2765	23587	23501	173	0
Jun-11	25229	22378	432	2419	2851	24019	23933	173	0
Jul-11	25315	22378	432	2506	2938	24192	24106	173	0
Aug-11	25747	22723	518	2506	3024	24365	24278	173	0
Sep-11	26438	23501	518	2419	2938	24624	24538	173	0
Oct-11	26352	23414	518	2419	2938	24797	24710	173	0
Nov-11	27043	23933	518	2592	3110	25315	25229	173	0
Dec-11	27216	24278	432	2506	2938	25661	25574	173	0
Jan-12	27302	24278	432	2592	3024	25920	25834	173	0
Feb-12	27907	24797	518	2592	3110	26266	26179	173	0
Mar-12	27994	24797	518	2678	3197	26438	26352	173	0
Apr-12	28512	25402	518	2592	3110	26784	26698	173	0
May-12	28166	24970	518	2678	3197	26870	26698	173	0
Jun-12	28339	25142	518	2678	3197	26957	26784	173	0
Jul-12	28598	25315	518	2765	3283	26611	26438	173	0
Aug-12	28771	25142	518	3110	3629	26611	26438	173	0
Sep-12	32400	28598	605	3197	3802	27821	27648	173	0
Oct-12	32746	28858	518	3370	3888	28253	28080	173	0
Nov-12	32141	27994	605	3542	4147	28685	28512	173	0
Dec-12	33005	28944	605	3456	4061	29376	29203	173	0
Jan-13	33955	29894	605	3456	4061	30240	29981	259	0
Feb-13	34301	30154	691	3456	4147	30758	30499	259	0
Mar-13	35856	31622	864	3370	4234	31622	31363	259	0
Apr-13	35338	30845	864	3629	4493	32054	31795	259	0
May-13	35424	30845	950	3629	4579	32400	32141	259	0
Jun-13	39398	34906	864	3629	4493	33869	33610	259	0
Jul-13	41299	36893	864	3542	4406	34646	34387	259	0
Aug-13	41213	36720	864	3629	4493	35338	35078	259	0
Sep-13	41818	37238	864	3715	4579	36202	35942	259	0
Oct-13	41472	36893	778	3802	4579	36547	36288	259	0
Nov-13	42854	38621	691	3542	4234	37152	36893	259	0
Dec-13	42854	38621	691	3542	4234	37584	37238	346	0
Jan-14	43027	38880	605	3542	4147	37843	37498	346	0
Feb-14	46397	42509	605	3283	3888	39485	39053	346	86
Mar-14	47866	44064	605	3197	3802	40608	40176	346	86
Apr-14	46570	42768	605	3197	3802	41040	40608	346	86
May-14	46224	42250	605	3370	3974	41645	41213	346	86
Jun-14	47347	43459	605	3283	3888	42163	41731	346	86
Jul-14	49334	44150	605	4579	5184	43027	42509	432	86
Aug-14	48730	43200	605	4925	5530	43546	43027	432	86
Sep-14	49162	43027	605	5530	6134	44064	43546	432	86
Oct-14	58320	52531	691	5098	5789	45533	44928	432	173
Nov-14	63763	58061	691	5011	5702	47606	47002	432	173
Dec-14	65232	58406	605	6221	6826	49594	48989	432	173

TABLE 5

Predicted Groundwater Inflow Components to the Mine Workings - Sensitivity Simulation 4
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Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
Jan-15	62813	55987	605	6221	6826	50803	50112	518	173
Feb-15	62986	55037	605	7344	7949	51926	51235	518	173
Mar-15	63936	56246	605	7085	7690	53222	52531	518	173
Apr-15	63072	55469	605	6998	7603	54086	53309	518	259
May-15	62726	54691	691	7344	8035	54691	53827	605	259
Jun-15	67738	59530	605	7603	8208	55210	54346	605	259
Jul-15	65664	57542	691	7430	8122	55642	54778	605	259
Aug-15	72144	64714	691	6739	7430	56765	55814	605	346
Sep-15	70934	64109	691	6134	6826	57456	56506	605	346
Oct-15	68342	61085	691	6566	7258	57974	56938	691	346
Nov-15	66787	59443	691	6653	7344	58493	57370	691	432
Dec-15	76118	68429	691	6998	7690	60307	59184	691	432
Jan-16	74045	66960	691	6394	7085	61517	60394	691	432
Feb-16	71539	64541	691	6307	6998	62294	61171	691	432
Mar-16	71021	63504	605	6912	7517	62899	61690	691	518
Apr-16	71453	63072	605	7776	8381	63504	62208	778	518
May-16	71107	61949	605	8554	9158	63936	62640	778	518
Jun-16	70157	61258	605	8294	8899	64195	62899	778	518
Jul-16	73526	63850	605	9072	9677	65491	64109	778	605
Aug-16	96682	87005	605	9072	9677	72662	71280	778	605
Sep-16	96854	88214	605	8035	8640	74822	73440	778	605
Oct-16	89597	80179	605	8813	9418	75859	74477	778	605
Nov-16	86400	77242	605	8554	9158	76550	74995	864	691
Dec-16	91757	84067	605	7085	7690	78019	76464	864	691
Jan-17	87091	79747	605	6739	7344	78451	76896	864	691
Feb-17	101779	95040	778	5962	6739	82771	81216	864	691
Mar-17	91411	84931	691	5789	6480	82598	80957	864	778
Apr-17	93917	85104	691	8122	8813	83462	81821	864	778
May-17	90029	81648	778	7603	8381	82771	81130	864	778
Jun-17	92621	85795	691	6134	6826	82944	81302	864	778
Jul-17	90547	83808	778	5962	6739	82944	81302	864	778
Aug-17	90547	82858	778	6912	7690	83203	81562	864	778
Sep-17	89597	82080	778	6739	7517	83462	81648	950	864
Oct-17	90115	80438	691	8986	9677	83808	81994	950	864
Nov-17	89251	79747	691	8813	9504	83722	81907	950	864
Dec-17	90202	78883	691	10627	11318	83894	82080	950	864
Jan-18	93485	79315	691	13478	14170	83981	82166	950	864
Feb-18	93312	77933	691	14688	15379	84067	82253	950	864
Mar-18	93139	78538	778	13824	14602	84240	82339	950	950
Apr-18	92016	78192	691	13133	13824	84413	82512	950	950
May-18	93485	81302	691	11491	12182	84413	82512	950	950
Jun-18	91238	79402	691	11146	11837	84413	82512	950	950
Jul-18	91325	80006	691	10627	11318	84499	82598	950	950
Aug-18	90374	79229	691	10454	11146	84499	82598	950	950

TABLE 5

Predicted Groundwater Inflow Components to the Mine Workings - Sensitivity Simulation 4
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Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
Sep-18	90461	78797	691	10973	11664	84586	82598	950	1037
Oct-18	90374	79056	691	10627	11318	84499	82512	950	1037
Nov-18	89683	78451	691	10541	11232	84499	82512	950	1037
Dec-18	90029	78970	691	10368	11059	84672	82685	950	1037
Jan-19	90979	80784	691	9504	10195	84672	82685	950	1037
Feb-19	89597	79488	691	9418	10109	84758	82685	1037	1037
Mar-19	89251	79229	691	9331	10022	84845	82771	1037	1037
Apr-19	89338	79402	691	9245	9936	84931	82858	1037	1037
May-19	88906	78970	691	9245	9936	84845	82685	1037	1123
Jun-19	88819	78970	691	9158	9850	84931	82771	1037	1123
Jul-19	88474	78624	691	9158	9850	84845	82685	1037	1123
Aug-19	88301	78538	691	9072	9763	84845	82685	1037	1123
Sep-19	91238	84154	691	6394	7085	84931	82858	950	1123
Oct-19	88819	82080	691	6048	6739	84845	82771	950	1123
Nov-19	88819	82166	691	5962	6653	84931	82858	950	1123
Dec-19	88733	81994	691	6048	6739	84931	82858	950	1123
Jan-20	88646	81907	691	6048	6739	85018	82944	950	1123
Feb-20	89597	82685	691	6221	6912	85190	83117	950	1123
Mar-20	88733	81821	691	6221	6912	85190	83030	950	1210
Apr-20	88646	81734	691	6221	6912	85277	83030	1037	1210
May-20	88301	81475	691	6134	6826	85190	82944	1037	1210
Jun-20	88301	81475	691	6134	6826	85190	82944	1037	1210
Jul-20	88387	81562	691	6134	6826	85277	83030	1037	1210
Aug-20	88819	82166	691	5962	6653	85363	83117	1037	1210
Sep-20	88214	81562	691	5962	6653	85363	83117	1037	1210
Oct-20	89856	83203	691	5962	6653	85450	83203	1037	1210
Nov-20	88474	81907	691	5875	6566	85450	83203	1037	1210
Dec-20	88387	81821	691	5875	6566	85536	83290	1037	1210
Jan-21	88214	81648	691	5875	6566	85536	83290	1037	1210
Feb-21	87869	81389	691	5789	6480	85536	83290	1037	1210
Mar-21	88042	81562	691	5789	6480	85622	83376	1037	1210
Apr-21	88042	81562	691	5789	6480	85622	83376	1037	1210
May-21	87782	81302	691	5789	6480	85709	83376	1037	1296
Jun-21	87955	81389	778	5789	6566	85709	83376	1037	1296
Jul-21	87782	81302	778	5702	6480	85709	83376	1037	1296
Aug-21	87955	81475	778	5702	6480	85795	83462	1037	1296
Sep-21	88474	81907	864	5702	6566	85795	83462	1037	1296
Oct-21	87437	81043	778	5616	6394	85795	83462	1037	1296
Nov-21	87610	81216	778	5616	6394	85795	83462	1037	1296
Dec-21	87782	81302	864	5616	6480	85795	83462	1037	1296
Jan-22	87523	81130	864	5530	6394	85795	83462	1037	1296
Feb-22	87523	81130	864	5530	6394	85795	83462	1037	1296
Mar-22	87523	81130	864	5530	6394	85795	83462	1037	1296
Apr-22	87523	81130	864	5530	6394	85795	83462	1037	1296

TABLE 5

Predicted Groundwater Inflow Components to the Mine Workings - Sensitivity Simulation 4
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Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
May-22	87437	81043	864	5530	6394	85882	83462	1123	1296
Jun-22	87437	81043	864	5530	6394	85882	83462	1123	1296
Jul-22	87437	81043	864	5530	6394	85882	83462	1123	1296
Aug-22	87437	81043	864	5530	6394	85882	83462	1123	1296
Sep-22	87437	81043	864	5530	6394	85882	83462	1123	1296
Oct-22	87350	80957	864	5530	6394	85882	83462	1123	1296
Nov-22	87350	80957	864	5530	6394	85882	83462	1123	1296
Dec-22	87610	81216	864	5530	6394	85882	83462	1123	1296
Jan-23	87264	80957	864	5443	6307	85968	83462	1123	1382
Feb-23	87437	81130	864	5443	6307	85968	83462	1123	1382
Mar-23	87264	80957	864	5443	6307	85968	83462	1123	1382
Apr-23	87350	81043	864	5443	6307	85968	83462	1123	1382
May-23	87178	80957	864	5357	6221	85968	83462	1123	1382
Jun-23	87350	81130	864	5357	6221	85968	83462	1123	1382
Jul-23	87264	81043	864	5357	6221	85968	83462	1123	1382
Aug-23	87264	81043	864	5357	6221	85968	83462	1123	1382
Sep-23	87178	81130	864	5184	6048	85968	83462	1123	1382
Oct-23	87091	80957	950	5184	6134	85968	83462	1123	1382
Nov-23	87091	80957	950	5184	6134	85968	83462	1123	1382
Dec-23	87091	80957	950	5184	6134	85968	83462	1123	1382
Jan-24	87091	80957	950	5184	6134	85968	83462	1123	1382
Feb-24	87091	80957	950	5184	6134	85968	83462	1123	1382
Mar-24	87005	80870	950	5184	6134	85968	83462	1123	1382
Apr-24	87005	80870	950	5184	6134	85968	83462	1123	1382
May-24	87005	80870	950	5184	6134	85968	83462	1123	1382
Jun-24	87005	80870	950	5184	6134	86054	83549	1123	1382
Jul-24	87005	80870	950	5184	6134	86054	83549	1123	1382
Aug-24	87005	80870	950	5184	6134	86054	83549	1123	1382
Sep-24	87005	80870	950	5184	6134	86054	83549	1123	1382
Oct-24	87005	80870	950	5184	6134	86054	83549	1123	1382
Nov-24	87005	80870	950	5184	6134	86054	83549	1123	1382
Dec-24	87005	80870	950	5184	6134	86054	83549	1123	1382
Jan-25	86918	80784	950	5184	6134	86054	83549	1123	1382
Feb-25	86918	80784	950	5184	6134	86054	83549	1123	1382
Mar-25	86918	80784	950	5184	6134	86054	83549	1123	1382
Apr-25	86918	80784	950	5184	6134	86054	83549	1123	1382
May-25	86918	80784	950	5184	6134	86054	83549	1123	1382
Jun-25	86918	80784	950	5184	6134	86054	83549	1123	1382
Jul-25	86918	80784	950	5184	6134	86054	83549	1123	1382
Aug-25	86918	80784	950	5184	6134	86054	83549	1123	1382
Sep-25	86918	80784	950	5184	6134	86054	83549	1123	1382
Oct-25	86918	80784	950	5184	6134	86141	83549	1123	1469
Nov-25	86918	80784	950	5184	6134	86141	83549	1123	1469
Dec-25	86918	80784	950	5184	6134	86141	83549	1123	1469

TABLE 5

Predicted Groundwater Inflow Components to the Mine Workings - Sensitivity Simulation 4
(Page 7 of 7)

Date	Total Groundwater Inflow (m^3/day)	Groundwater Flow to the HW (m^3/day)	Groundwater Flow to the FW (m^3/day)			Water Discharge from the Lakes (m^3/day)			
			Upper	Lower	Total	Total	Snap Lake	North Lake	NE Lake
Jan-26	87178	81043	1037	5098	6134	86227	83635	1123	1469
Feb-26	88992	80784	3110	5098	8208	87610	85018	1123	1469
Mar-26	88992	80957	2938	5098	8035	87869	85277	1123	1469
Apr-26	88646	80698	2851	5098	7949	87869	85277	1123	1469
May-26	88992	81043	2851	5098	7949	87955	85363	1123	1469
Jun-26	90461	80870	4493	5098	9590	88906	86314	1123	1469
Jul-26	90806	81389	4320	5098	9418	89424	86832	1123	1469
Aug-26	90374	81130	4234	5011	9245	89251	86659	1123	1469
Sep-26	105408	97891	4234	3283	7517	93312	90720	1123	1469
Oct-26	95386	88042	4147	3197	7344	92534	89942	1123	1469
Nov-26	95386	89424	2765	3197	5962	92794	90202	1123	1469
Dec-26	94954	89078	2678	3197	5875	92966	90374	1123	1469
Jan-27	94954	90374	1382	3197	4579	92794	90202	1123	1469
Feb-27	94435	89942	1382	3110	4493	92880	90288	1123	1469
Mar-27	94435	89942	1382	3110	4493	92966	90374	1123	1469
Apr-27	94176	89683	1382	3110	4493	92794	90202	1123	1469
May-27	93917	89424	1382	3110	4493	92621	90029	1123	1469
Jun-27	94003	89510	1382	3110	4493	92707	90115	1123	1469
Jul-27	93658	89165	1382	3110	4493	92794	90202	1123	1469
Aug-27	93571	89078	1382	3110	4493	92794	90202	1123	1469
Sep-27	94176	89597	1469	3110	4579	92880	90288	1123	1469
Oct-27	94003	89424	1469	3110	4579	92966	90374	1123	1469
Nov-27	93830	89251	1469	3110	4579	92966	90374	1123	1469
Dec-27	93744	89251	1469	3024	4493	93053	90461	1123	1469
Jan-28	93917	89424	1469	3024	4493	92880	90288	1123	1469
Feb-28	93485	88992	1469	3024	4493	92966	90374	1123	1469
Mar-28	93485	88992	1469	3024	4493	92794	90202	1123	1469
Apr-28	93485	88992	1469	3024	4493	92794	90202	1123	1469
May-28	93398	88906	1469	3024	4493	92794	90202	1123	1469
Jun-28	93485	88992	1469	3024	4493	92880	90288	1123	1469
Jul-28	93658	89165	1469	3024	4493	92966	90374	1123	1469
Aug-28	93398	88906	1469	3024	4493	92794	90202	1123	1469
Sep-28	93226	88733	1469	3024	4493	92707	90115	1123	1469
Oct-28	93312	88819	1469	3024	4493	92707	90115	1123	1469
Nov-28	93312	88819	1469	3024	4493	92794	90202	1123	1469
Dec-28	93485	88992	1469	3024	4493	92880	90288	1123	1469

TABLE 6

ITASCA Denver, Inc.

Predicted TDS Concentrations of the Mine Water Discharge - Sensitivity Simulation 4
(Page 1 of 8)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
Jan-04	214.7	3490.2		228.7	5727.9	
Feb-04	214.7	3490.2		228.7	5727.9	
Mar-04	214.7	3490.2		228.7	5727.9	
Apr-04	214.7	3490.2		228.7	5727.9	
May-04	214.7	3490.2	214.7	228.7	5727.9	228.7
Jun-04	214.7	3490.2	214.7	228.7	5727.9	228.7
Jul-04	214.7	3490.2	214.7	228.7	5727.9	228.7
Aug-04	214.7	3490.2	624.1	228.7	5727.9	916.1
Sep-04	214.7	3490.2	476.7	228.7	5727.9	668.6
Oct-04	214.7	3490.2	503.7	228.7	5727.9	713.9
Nov-04	214.7	3490.2	473.3	228.7	5727.9	662.8
Dec-04	214.7	3490.2	466.7	228.7	5727.9	651.7
Jan-05	214.7	3490.2	487.7	228.7	5727.9	687.0
Feb-05	214.7	3490.2	487.7	228.7	5727.9	687.0
Mar-05	214.7	3490.2	471.6	228.7	5727.9	660.0
Apr-05	214.7	3490.2	452.9	228.7	5727.9	628.6
May-05	214.7	3490.2	433.1	228.7	5727.9	595.3
Jun-05	214.7	3490.2	462.8	228.7	5727.9	645.3
Jul-05	214.7	3490.2	635.8	228.7	5727.9	935.7
Aug-05	214.7	3490.2	568.8	228.7	5727.9	823.2
Sep-05	214.7	3490.2	592.6	228.7	5727.9	863.2
Oct-05	214.7	3490.2	634.6	228.7	5727.9	933.7
Nov-05	214.7	3490.2	712.2	228.7	5727.9	1064.0
Dec-05	214.7	3490.2	712.2	228.7	5727.9	1064.0
Jan-06	214.7	3490.2	682.6	228.7	5727.9	1014.3
Feb-06	214.7	3490.2	709.8	228.7	5727.9	1060.0
Mar-06	214.7	3490.2	704.1	228.7	5727.9	1050.4
Apr-06	214.7	3490.2	741.8	228.7	5727.9	1113.6
May-06	214.7	3490.2	697.4	228.7	5727.9	1039.1
Jun-06	214.7	3490.2	737.4	228.7	5727.9	1106.2
Jul-06	214.7	3490.2	810.2	228.7	5727.9	1228.6
Aug-06	214.7	3490.2	792.7	228.7	5727.9	1199.1
Sep-06	214.7	3490.2	792.7	228.7	5727.9	1199.1
Oct-06	214.7	3490.2	824.8	228.7	5727.9	1253.1
Nov-06	214.7	3490.2	702.0	228.7	5727.9	1046.8
Dec-06	214.7	3490.2	679.3	228.7	5727.9	1008.7
Jan-07	214.7	3490.2	618.8	228.7	5727.9	907.2
Feb-07	214.7	3490.2	598.9	228.7	5727.9	873.7
Mar-07	214.7	3490.2	583.2	228.7	5727.9	847.4
Apr-07	214.7	3490.2	567.1	228.7	5727.9	820.4
May-07	214.7	3490.2	580.9	228.7	5727.9	843.5
Jun-07	214.7	3490.2	587.9	228.7	5727.9	855.2

TABLE 6

Predicted TDS Concentrations of the Mine Water Discharge - Sensitivity Simulation 4
(Page 2 of 8)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
Jul-07	214.7	3490.2	602.6	228.7	5727.9	879.9
Aug-07	214.7	3490.2	560.6	228.7	5727.9	809.4
Sep-07	214.7	3490.2	580.9	228.7	5727.9	843.5
Oct-07	214.7	3490.2	583.2	228.7	5727.9	847.4
Nov-07	214.7	3490.2	592.6	228.7	5727.9	863.2
Dec-07	214.7	3490.2	592.6	228.7	5727.9	863.2
Jan-08	214.7	3490.2	592.6	228.7	5727.9	863.2
Feb-08	214.7	3490.2	564.9	228.7	5727.9	816.7
Mar-08	214.7	3490.2	564.9	228.7	5727.9	816.7
Apr-08	214.7	3490.2	560.6	228.7	5727.9	809.4
May-08	214.7	3490.2	556.3	228.7	5727.9	802.2
Jun-08	214.7	3490.2	564.9	228.7	5727.9	816.7
Jul-08	214.7	3490.2	548.1	228.7	5727.9	788.5
Aug-08	214.7	3490.2	536.6	228.7	5727.9	769.1
Sep-08	214.7	3490.2	512.5	228.7	5727.9	728.6
Oct-08	214.7	3490.2	507.5	228.7	5727.9	720.2
Nov-08	214.7	3490.2	493.1	228.7	5727.9	696.1
Dec-08	214.7	3490.2	505.5	228.7	5727.9	716.9
Jan-09	214.7	3490.2	488.9	228.7	5727.9	689.1
Feb-09	214.7	3490.2	490.2	228.7	5727.9	691.2
Mar-09	214.7	3490.2	488.9	228.7	5727.9	689.1
Apr-09	214.7	3490.2	506.9	228.7	5727.9	719.2
May-09	214.7	3490.2	505.5	228.7	5727.9	716.9
Jun-09	214.7	3490.2	490.2	228.7	5727.9	691.2
Jul-09	214.7	3490.2	516.6	228.7	5727.9	735.5
Aug-09	214.7	3490.2	511.1	228.7	5727.9	726.2
Sep-09	214.7	3490.2	515.3	228.7	5727.9	733.5
Oct-09	214.7	3490.2	545.4	228.7	5727.9	783.9
Nov-09	214.7	3490.2	543.8	228.7	5727.9	781.3
Dec-09	214.7	3490.2	554.6	228.7	5727.9	799.4
Jan-10	214.7	3490.2	556.5	228.7	5727.9	802.5
Feb-10	214.7	3490.2	572.3	228.7	5727.9	829.0
Mar-10	214.7	3490.2	589.9	228.7	5727.9	858.6
Apr-10	214.7	3490.2	569.2	228.7	5727.9	823.9
May-10	214.7	3490.2	543.6	228.7	5727.9	780.9
Jun-10	214.7	3490.2	550.6	228.7	5727.9	792.7
Jul-10	214.7	3490.2	563.2	228.7	5727.9	813.7
Aug-10	214.7	3490.2	524.2	228.7	5727.9	748.3
Sep-10	214.7	3490.2	521.4	228.7	5727.9	743.6
Oct-10	214.7	3490.2	523.7	228.7	5727.9	747.5
Nov-10	214.7	3490.2	521.4	228.7	5727.9	743.6
Dec-10	214.7	3490.2	512.5	228.7	5727.9	728.6

TABLE 6

Predicted TDS Concentrations of the Mine Water Discharge - Sensitivity Simulation 4
(Page 3 of 8)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
Jan-11	214.7	3490.2	524.4	228.7	5727.9	748.6
Feb-11	214.7	3490.2	526.7	228.7	5727.9	752.4
Mar-11	214.7	3490.2	553.9	228.7	5727.9	798.3
Apr-11	214.7	3490.2	548.0	228.7	5727.9	788.3
May-11	214.7	3490.2	581.2	228.7	5727.9	844.0
Jun-11	214.7	3490.2	584.9	228.7	5727.9	850.2
Jul-11	214.7	3490.2	594.8	228.7	5727.9	866.8
Aug-11	214.7	3490.2	599.4	228.7	5727.9	874.6
Sep-11	214.7	3490.2	578.6	230.5	5727.9	839.7
Oct-11	214.7	3490.2	579.8	233.5	5727.9	843.3
Nov-11	214.7	3490.2	591.4	236.8	5727.9	865.4
Dec-11	214.7	3490.2	568.2	239.7	5727.9	829.5
Jan-12	214.7	3490.2	577.5	242.8	5727.9	847.6
Feb-12	214.7	3490.2	579.8	246.0	5727.9	854.2
Mar-12	214.7	3490.2	588.8	249.3	5727.9	872.0
Apr-12	214.7	3490.2	572.0	252.5	5727.9	847.0
May-12	214.7	3490.2	586.5	255.7	5727.9	873.9
Jun-12	214.7	3490.2	584.2	259.0	5727.9	873.0
Jul-12	214.7	3490.2	590.7	262.3	5727.9	886.8
Aug-12	214.7	3490.2	627.8	266.2	5727.9	951.6
Sep-12	214.7	3490.2	599.0	270.3	5727.9	907.0
Oct-12	214.7	3490.2	603.6	274.6	5727.9	918.3
Nov-12	214.7	3490.2	637.3	279.2	5727.9	978.2
Dec-12	214.7	3490.2	617.7	283.6	5727.9	949.6
Jan-13	214.7	3490.2	606.4	288.0	5727.9	934.7
Feb-13	214.7	3490.2	610.7	292.6	5727.9	945.8
Mar-13	214.7	3490.2	601.4	297.2	5727.9	934.3
Apr-13	214.7	3490.2	631.1	302.1	5727.9	987.6
May-13	214.7	3490.2	638.1	307.2	5727.9	1003.5
Jun-13	216.8	3490.2	588.2	312.1	5727.9	925.4
Jul-13	219.4	3490.2	566.1	316.8	5727.9	890.0
Aug-13	222.1	3490.2	576.0	321.6	5727.9	906.7
Sep-13	224.8	3490.2	580.0	326.5	5727.9	913.6
Oct-13	227.5	3490.2	585.4	331.4	5727.9	922.9
Nov-13	229.9	3490.2	549.9	335.6	5727.9	864.5
Dec-13	232.2	3490.2	552.0	339.8	5727.9	868.3
Jan-14	234.4	3490.2	546.2	343.8	5727.9	859.1
Feb-14	236.3	3490.2	507.2	347.4	5727.9	795.0
Mar-14	238.1	3490.2	494.7	350.7	5727.9	774.7
Apr-14	239.9	3490.2	503.6	354.1	5727.9	789.7
May-14	241.9	3490.2	519.4	357.7	5727.9	816.1
Jun-14	243.7	3490.2	508.6	361.1	5727.9	798.6

TABLE 6

Predicted TDS Concentrations of the Mine Water Discharge - Sensitivity Simulation 4
(Page 4 of 8)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
Jul-14	246.9	3490.2	584.9	366.6	5727.9	925.0
Aug-14	250.3	3490.2	614.9	372.6	5727.9	974.9
Sep-14	254.3	3490.2	654.6	379.5	5727.9	1040.8
Oct-14	257.9	3490.2	575.5	385.9	5727.9	910.4
Nov-14	261.4	3490.2	547.0	392.0	5727.9	863.6
Dec-14	266.0	3490.2	599.2	399.9	5727.9	950.3
Jan-15	270.5	3490.2	616.3	407.7	5727.9	978.8
Feb-15	276.1	3490.2	676.8	417.2	5727.9	1079.1
Mar-15	281.3	3490.2	662.6	426.2	5727.9	1055.9
Apr-15	286.4	3490.2	668.1	435.0	5727.9	1065.3
May-15	291.9	3490.2	696.8	444.4	5727.9	1113.0
Jun-15	297.5	3490.2	679.5	454.0	5727.9	1084.6
Jul-15	303.0	3490.2	692.4	463.3	5727.9	1106.3
Aug-15	307.7	3490.2	631.3	471.4	5727.9	1005.5
Sep-15	311.8	3490.2	614.0	478.5	5727.9	977.2
Oct-15	316.3	3490.2	649.3	486.2	5727.9	1035.9
Nov-15	320.8	3490.2	665.3	493.9	5727.9	1062.5
Dec-15	325.6	3490.2	641.0	502.1	5727.9	1022.6
Jan-16	329.7	3490.2	628.4	509.2	5727.9	1002.1
Feb-16	333.7	3490.2	638.9	516.2	5727.9	1019.8
Mar-16	338.2	3490.2	667.8	523.9	5727.9	1067.8
Apr-16	343.5	3490.2	707.9	532.9	5727.9	1134.3
May-16	349.4	3490.2	748.8	543.0	5727.9	1202.0
Jun-16	355.1	3490.2	747.8	552.6	5727.9	1200.7
Jul-16	361.4	3490.2	767.7	563.3	5727.9	1233.7
Aug-16	367.7	3490.2	674.6	573.9	5727.9	1080.2
Sep-16	372.9	3490.2	646.2	582.8	5727.9	1033.7
Oct-16	378.8	3490.2	700.5	592.7	5727.9	1123.6
Nov-16	384.3	3490.2	708.6	602.2	5727.9	1137.1
Dec-16	388.4	3490.2	644.6	609.2	5727.9	1031.7
Jan-17	392.2	3490.2	650.0	615.7	5727.9	1040.9
Feb-17	395.3	3490.2	597.3	621.1	5727.9	954.2
Mar-17	398.1	3490.2	614.7	626.0	5727.9	983.1
Apr-17	403.2	3490.2	688.3	634.6	5727.9	1104.8
May-17	407.7	3490.2	690.5	642.4	5727.9	1108.7
Jun-17	410.8	3490.2	634.9	647.6	5727.9	1017.1
Jul-17	413.7	3490.2	640.0	652.7	5727.9	1025.8
Aug-17	417.5	3490.2	675.0	659.2	5727.9	1083.7
Sep-17	421.1	3490.2	675.3	665.4	5727.9	1084.5
Oct-17	426.7	3490.2	750.6	674.9	5727.9	1209.0
Nov-17	432.0	3490.2	752.9	683.9	5727.9	1212.9
Dec-17	439.0	3490.2	815.8	695.7	5727.9	1316.8

TABLE 6

Predicted TDS Concentrations of the Mine Water Discharge - Sensitivity Simulation 4
(Page 5 of 8)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
Jan-18	448.6	3490.2	901.5	711.7	5727.9	1458.4
Feb-18	459.2	3490.2	949.9	729.4	5727.9	1538.5
Mar-18	468.9	3490.2	934.3	745.7	5727.9	1513.0
Apr-18	477.8	3490.2	922.8	760.6	5727.9	1494.2
May-18	485.0	3490.2	870.3	772.7	5727.9	1407.9
Jun-18	491.9	3490.2	874.9	784.3	5727.9	1415.6
Jul-18	498.2	3490.2	863.5	794.9	5727.9	1397.0
Aug-18	504.2	3490.2	867.2	805.1	5727.9	1403.2
Sep-18	510.7	3490.2	889.2	815.9	5727.9	1439.8
Oct-18	516.7	3490.2	883.8	826.1	5727.9	1431.1
Nov-18	522.7	3490.2	889.1	836.1	5727.9	1440.0
Dec-18	528.4	3490.2	887.2	845.7	5727.9	1437.0
Jan-19	533.2	3490.2	860.3	853.9	5727.9	1392.8
Feb-19	537.9	3490.2	866.8	861.9	5727.9	1403.8
Mar-19	542.5	3490.2	869.4	869.6	5727.9	1408.3
Apr-19	546.9	3490.2	870.3	877.1	5727.9	1409.9
May-19	551.3	3490.2	875.9	884.6	5727.9	1419.3
Jun-19	555.6	3490.2	877.2	891.8	5727.9	1421.7
Jul-19	559.8	3490.2	882.3	899.0	5727.9	1430.2
Aug-19	563.9	3490.2	883.8	905.9	5727.9	1432.9
Sep-19	565.5	3490.2	791.1	908.8	5727.9	1280.3
Oct-19	566.9	3490.2	787.5	911.2	5727.9	1274.5
Nov-19	568.1	3490.2	785.8	913.4	5727.9	1272.0
Dec-19	569.4	3490.2	790.0	915.7	5727.9	1279.1
Jan-20	570.7	3490.2	791.4	918.0	5727.9	1281.6
Feb-20	572.1	3490.2	795.9	920.5	5727.9	1289.1
Mar-20	573.5	3490.2	799.4	923.0	5727.9	1295.0
Apr-20	574.9	3490.2	800.9	925.5	5727.9	1297.7
May-20	576.2	3490.2	800.2	927.8	5727.9	1296.7
Jun-20	577.5	3490.2	801.4	930.1	5727.9	1298.9
Jul-20	578.8	3490.2	802.4	932.4	5727.9	1300.6
Aug-20	579.9	3490.2	796.8	934.4	5727.9	1291.6
Sep-20	581.0	3490.2	799.3	936.4	5727.9	1295.9
Oct-20	582.0	3490.2	796.3	938.3	5727.9	1291.1
Nov-20	583.0	3490.2	797.9	940.2	5727.9	1293.8
Dec-20	584.0	3490.2	799.0	941.9	5727.9	1295.8
Jan-21	585.0	3490.2	800.3	943.7	5727.9	1298.2
Feb-21	585.9	3490.2	799.2	945.3	5727.9	1296.5
Mar-21	586.8	3490.2	799.6	946.9	5727.9	1297.3
Apr-21	587.6	3490.2	800.5	948.5	5727.9	1298.8
May-21	588.5	3490.2	801.9	950.1	5727.9	1301.3
Jun-21	589.4	3490.2	805.1	951.8	5727.9	1306.8

TABLE 6

Predicted TDS Concentrations of the Mine Water Discharge - Sensitivity Simulation 4
(Page 6 of 8)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
Jul-21	590.3	3490.2	803.6	953.3	5727.9	1304.4
Aug-21	591.1	3490.2	803.9	954.9	5727.9	1305.1
Sep-21	592.0	3490.2	806.3	956.5	5727.9	1309.1
Oct-21	592.7	3490.2	803.9	957.9	5727.9	1305.4
Nov-21	593.5	3490.2	804.2	959.2	5727.9	1306.0
Dec-21	594.3	3490.2	807.3	960.7	5727.9	1311.2
Jan-22	595.0	3490.2	805.8	962.0	5727.9	1308.9
Feb-22	595.7	3490.2	806.5	963.3	5727.9	1310.2
Mar-22	596.4	3490.2	807.1	964.6	5727.9	1311.4
Apr-22	597.1	3490.2	807.8	965.9	5727.9	1312.6
May-22	597.8	3490.2	808.6	967.2	5727.9	1314.1
Jun-22	598.5	3490.2	809.3	968.4	5727.9	1315.3
Jul-22	599.1	3490.2	809.9	969.7	5727.9	1316.5
Aug-22	599.8	3490.2	810.5	970.9	5727.9	1317.6
Sep-22	600.5	3490.2	811.1	972.1	5727.9	1318.8
Oct-22	601.1	3490.2	812.0	973.3	5727.9	1320.2
Nov-22	601.7	3490.2	812.6	974.5	5727.9	1321.4
Dec-22	602.4	3490.2	812.5	975.7	5727.9	1321.4
Jan-23	602.9	3490.2	811.1	976.8	5727.9	1319.2
Feb-23	603.5	3490.2	811.2	977.8	5727.9	1319.5
Mar-23	604.0	3490.2	812.1	978.8	5727.9	1321.1
Apr-23	604.6	3490.2	812.4	979.8	5727.9	1321.7
May-23	605.0	3490.2	810.5	980.7	5727.9	1318.6
Jun-23	605.5	3490.2	810.5	981.6	5727.9	1318.8
Jul-23	605.9	3490.2	811.1	982.4	5727.9	1319.9
Aug-23	606.4	3490.2	811.5	983.3	5727.9	1320.7
Sep-23	606.7	3490.2	806.4	983.9	5727.9	1312.4
Oct-23	607.0	3490.2	809.8	984.6	5727.9	1318.0
Nov-23	607.4	3490.2	810.1	985.3	5727.9	1318.7
Dec-23	607.7	3490.2	810.4	986.0	5727.9	1319.3
Jan-24	608.1	3490.2	810.8	986.7	5727.9	1320.0
Feb-24	608.4	3490.2	811.1	987.4	5727.9	1320.6
Mar-24	608.8	3490.2	811.6	988.0	5727.9	1321.6
Apr-24	609.1	3490.2	811.9	988.7	5727.9	1322.2
May-24	609.4	3490.2	812.2	989.4	5727.9	1322.8
Jun-24	609.8	3490.2	812.5	990.0	5727.9	1323.5
Jul-24	610.1	3490.2	812.9	990.7	5727.9	1324.1
Aug-24	610.4	3490.2	813.2	991.3	5727.9	1324.7
Sep-24	610.7	3490.2	813.5	991.9	5727.9	1325.3
Oct-24	611.1	3490.2	813.8	992.6	5727.9	1325.8
Nov-24	611.4	3490.2	814.1	993.2	5727.9	1326.4
Dec-24	611.7	3490.2	814.3	993.8	5727.9	1327.0

TABLE 6

Predicted TDS Concentrations of the Mine Water Discharge - Sensitivity Simulation 4
(Page 7 of 8)

Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
Jan-25	612.0	3490.2	814.8	994.4	5727.9	1327.9
Feb-25	612.3	3490.2	815.1	995.0	5727.9	1328.5
Mar-25	612.6	3490.2	815.4	995.6	5727.9	1329.0
Apr-25	612.9	3490.2	815.7	996.2	5727.9	1329.6
May-25	613.2	3490.2	816.0	996.8	5727.9	1330.1
Jun-25	613.5	3490.2	816.2	997.4	5727.9	1330.7
Jul-25	613.8	3490.2	816.5	997.9	5727.9	1331.2
Aug-25	614.1	3490.2	816.8	998.5	5727.9	1331.8
Sep-25	614.3	3490.2	817.1	999.1	5727.9	1332.3
Oct-25	614.6	3490.2	817.3	999.6	5727.9	1332.8
Nov-25	614.9	3490.2	817.6	1000.2	5727.9	1333.3
Dec-25	615.2	3490.2	817.8	1000.7	5727.9	1333.8
Jan-26	615.5	3490.2	817.5	1001.2	5727.9	1333.3
Feb-26	617.5	3490.2	880.6	1004.8	5727.9	1437.2
Mar-26	619.5	3490.2	876.9	1008.0	5727.9	1431.2
Apr-26	621.3	3490.2	876.9	1011.1	5727.9	1431.2
May-26	623.1	3490.2	877.5	1014.2	5727.9	1432.4
Jun-26	626.3	3490.2	927.1	1019.5	5727.9	1513.9
Jul-26	629.4	3490.2	923.3	1024.6	5727.9	1507.8
Aug-26	632.2	3490.2	922.0	1029.4	5727.9	1505.7
Sep-26	633.5	3490.2	836.0	1031.6	5727.9	1364.4
Oct-26	634.7	3490.2	853.5	1033.6	5727.9	1393.2
Nov-26	634.6	3490.2	813.1	1033.5	5727.9	1327.0
Dec-26	634.4	3490.2	811.3	1033.4	5727.9	1324.0
Jan-27	633.1	3490.2	772.2	1031.3	5727.9	1259.8
Feb-27	631.8	3490.2	769.1	1029.2	5727.9	1254.8
Mar-27	630.5	3490.2	767.8	1027.1	5727.9	1252.7
Apr-27	629.1	3490.2	766.9	1025.0	5727.9	1251.3
May-27	627.8	3490.2	766.0	1022.9	5727.9	1250.0
Jun-27	626.5	3490.2	764.6	1020.9	5727.9	1247.8
Jul-27	625.3	3490.2	763.9	1018.8	5727.9	1246.7
Aug-27	624.0	3490.2	762.8	1016.8	5727.9	1244.9
Sep-27	622.8	3490.2	763.4	1015.0	5727.9	1245.9
Oct-27	621.6	3490.2	762.5	1013.1	5727.9	1244.5
Nov-27	620.5	3490.2	761.6	1011.3	5727.9	1243.2
Dec-27	619.3	3490.2	758.0	1009.3	5727.9	1237.3
Jan-28	618.0	3490.2	756.6	1007.4	5727.9	1235.1
Feb-28	616.8	3490.2	756.1	1005.5	5727.9	1234.3
Mar-28	615.7	3490.2	754.9	1003.6	5727.9	1232.5
Apr-28	614.5	3490.2	753.8	1001.8	5727.9	1230.7
May-28	613.3	3490.2	752.8	999.9	5727.9	1229.1
Jun-28	612.2	3490.2	751.6	998.1	5727.9	1227.1

TABLE 6

Predicted TDS Concentrations of the Mine Water Discharge - Sensitivity Simulation 4
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Date	Using Geometric Mean Value of TDS			Using Arithmetic Mean Value of TDS		
	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)	HW TDS (mg/L)	FW TDS (mg/L)	Calculated TDS in the Mine Discharge (mg/L)
	Assigned from Snap Lake[1]	Constant[1]		Assigned from Snap Lake[1]	Constant[1]	
Jul-28	611.0	3490.2	750.2	996.3	5727.9	1225.0
Aug-28	609.9	3490.2	749.5	994.5	5727.9	1223.9
Sep-28	608.8	3490.2	748.7	992.7	5727.9	1222.6
Oct-28	607.7	3490.2	747.5	990.9	5727.9	1220.7
Nov-28	606.6	3490.2	746.4	989.2	5727.9	1219.0
Dec-28	605.5	3490.2	745.1	987.5	5727.9	1216.9

Final

Snap Lake Mine Water Treatment Plant Alternatives Evaluation

Prepared for

De Beers Canada Inc.

December 2012

Prepared by

CH2MHILL®

425332_WBG073112092156

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SECTION 1

Summary

This report presents an evaluation of treatment alternatives for the expansion of the Snap Lake Mine water treatment plant (WTP) from a capacity of less than 35 ML/d to a capacity of 45 ML/d. While the existing Snap Lake Mine WTP has a reported capacity of 35 ML/d, the actual capacities of some of the individual treatment processes, such as the thickener, are thought to be significantly lower. Expansion to 45 ML/d will require the addition of a secondary treatment train. Furthermore, future effluent licence limits have been set for nitrate, chloride, and fluoride which will come into effect in 2015 (on January 1st). To comply with these new limits, advanced treatment processes will be required, in addition to conventional treatment to remove suspended solids and metals.

Alternative treatment technologies were identified, reviewed, and compared for the removal of total suspended solids (TSS), nitrate, metals, chloride and fluoride from the mine and water management pond (WMP) water. Additionally, the scale-of-treatment required to comply with the 2015 licence limits for each contaminant was assessed.

High rate clarification processes were compared for the reduction of TSS and heavy metals in the secondary treatment train. The Densadeg® Integrated Reactor/Clarifier/Thickener was found to be more economical in terms of equipment costs compared to the Actiflo® Package Plant Clarifier. Although the current licence limits for all regulated metals are expected to be attainable with the inclusion of high rate clarification and filtration in the secondary treatment train, provisions for lime addition could be added to ensure continued compliance if limits should change in the future.

In terms of nitrate removal technologies, nitrate specific ion-exchange (IX) and reverse osmosis (RO) were identified as viable options to comply with the 2015 licence limits. Similarly for chloride removal, IX and RO were identified as viable treatment options. Electrodialysis reversal (EDR) was eliminated from consideration as it is typically more costly than RO, more complex, and can be difficult to operate and maintain. While distillation can achieve high removals of all three contaminants, it was deemed to be not economically viable, as it would require a large input of thermal energy and has a very low recovery ratio (~50 percent). For fluoride removal, RO, IX, and activated alumina were all identified as potentially viable options; however, the efficiency to which activated alumina or IX processes can remove fluoride from the mine water is uncertain; these options could potentially be explored further through bench/pilot-scale testing to ensure that licence limits can be consistently met.

As a worst case scenario, RO was selected in the absence of bench/pilot-scale testing to ensure compliance with the 2015 effluent licence requirements for fluoride, chloride, and nitrate. The RO process will require pretreatment with conventional or high-rate clarification and microfiltration/ultrafiltration (MF/UF) to remove potential membrane foulants, resulting in a total equipment cost of approximately $ 20 million to treat a flow of 45 ML/d. Additionally, concentrate from the RO system containing high levels of dissolved ions and nutrients will require a proper treatment/disposal strategy. This will increase the costs for the RO alternative significantly, as a brine concentrator/crystallizer system would total approximately $33 million in equipment costs alone. If permitted, deep well injection is expected to be a much more cost effective disposal option; however, it may still be in the order of several million dollars in capital costs.

Due to the significant costs associated with RO treatment and brine treatment/disposal, it is recommended that bench/pilot-scale studies be carried out to investigate the feasibility of nitrate, chloride, and fluoride removal from the Snap Lake Mine WTP effluent through a multi-stage IX/adsorption treatment, including contaminant specific resins for nitrate and chloride and activated alumina for fluoride removal. Furthermore, it is recommended that De Beers conduct further investigation into the source/s of fluoride which enters the mine water during production to determine if sources can be eliminated to reduce the overall costs associated with treatment.

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SECTION 2

Introduction

De Beers Canada Inc. (De Beers) currently operates a diamond mine, the Snap Lake Mine, located approximately 220 km northeast of Yellowknife, Northwest Territories. The diamond mine is completely underground with the majority of the mine being located beneath Snap Lake. Water from Snap Lake infiltrates the mine through cracks in the rocks below the lake. The Snap Lake Mine Water Treatment Plant (WTP) was designed to remove particulate matter from the mine water via flocculation, sedimentation, and filtration, prior to discharge into Snap Lake. The final treatment stage involves adjusting the pH of the water to match that of the lake. Some of the treated water is sent to the Process Plant; however, the majority is sent back to the lake and discharged via a diffuser. Sludge from the clarification process is pumped to the Process Plant and combined with processed Kimberlite, which is then sent to the North Pile for containment.

Mine water accounts for the majority of the influent flow entering the Snap Lake Mine WTP (20 to 25 ML/d). During the spring to fall, surface water mixed with North Pile leachate, stored in the Water Management Pond (WMP), is also sent through the WTP (typically ranges from 0 to 5 ML/d). The WMP water contains elevated levels of nutrients (such as ammonia, nitrite, and nitrate) and dissolved ions (such as chloride and fluoride) which are not removed during treatment, as the existing WTP is designed primarily for reducing total suspended solids (TSS) and not for nutrient or TDS removal.

The effluent from the Snap Lake Mine WTP is in compliance with the current operating licence requirements; however, future licence requirements will require upgrades to the existing WTP via the addition of advanced treatment processes to comply with limits set for nitrate, chloride, and fluoride. To compound existing treatment concerns, an increase in production capacity is expected in the near future, which will affect the demand placed upon the existing WTP. It is estimated that an increase in mining production or an increase in mine water, due to Snap Lake water infiltration, would require a WTP capable of treating 45 ML/d. The current Snap Lake Mine WTP has a reported capacity of 35 ML/d; however, a preliminary investigation has identified that the actual capacity of the plant may be much less than the reported capacity. Any mining expansion or increased flow to the WTP would impact the final effluent quality and/or would require diverting the additional water to the WMP. Increased flows at the existing WTP could potentially increase effluent nutrient levels beyond the current licence limits.

To allow for future increases in mining production/water infiltration, and to ensure compliance with the future licence requirements, alternative treatment technologies were investigated relating to upgrades to the existing treatment process and the expansion of the Snap Lake Mine WTP.

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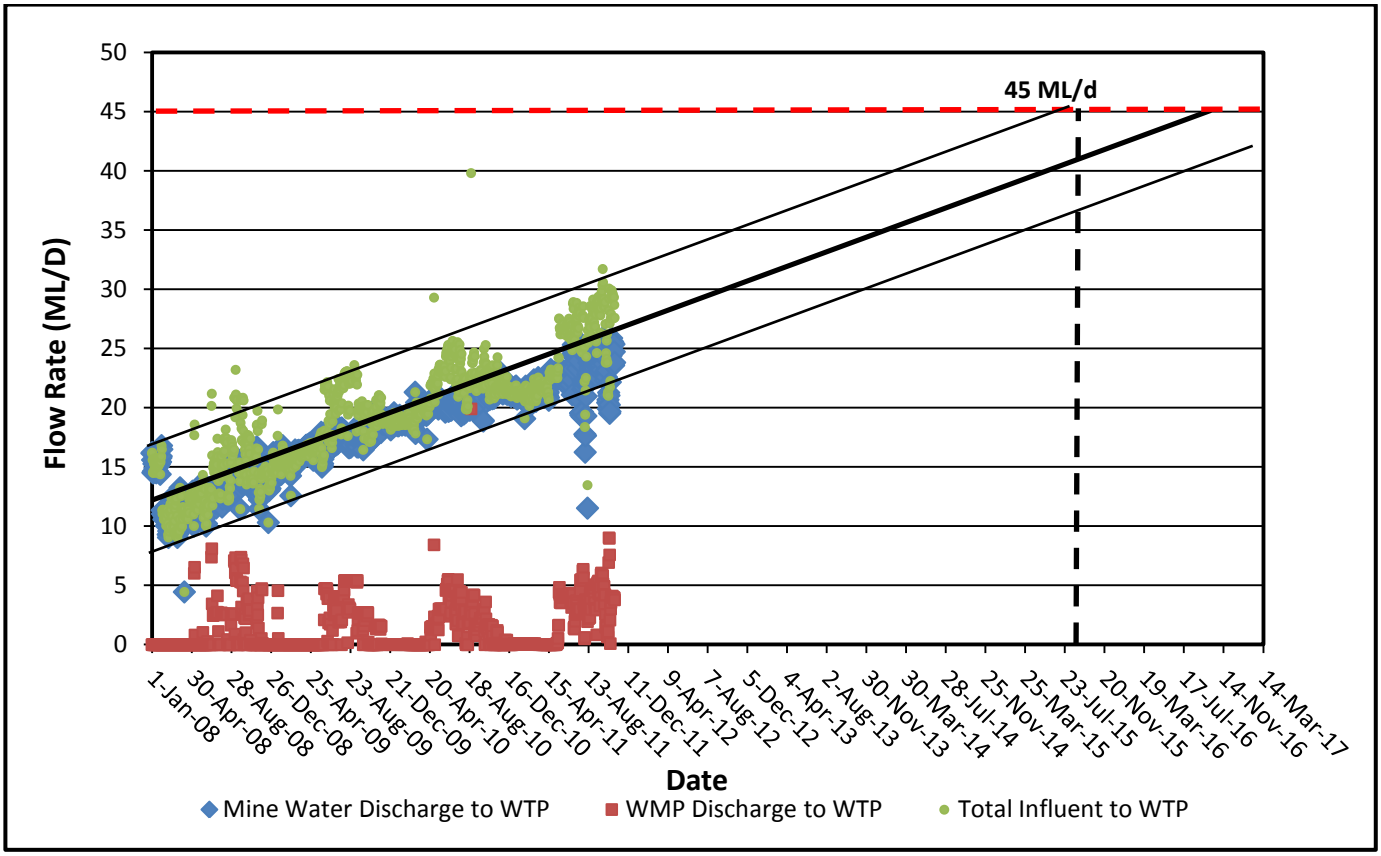
SECTION 3

Wastewater Quality Characterization

On November 9, 2011, De Beers provided CH2M HILL with influent flow data for the period of January 1, 2008 to October 31, 2011, including mine water and WMP discharges to the Snap Lake Mine WTP (Figure 1). Based on the flow data, it was determined that if mine production increases at the same rate observed over the last four years, the WTP will need to treat approximately 45 ML/d by mid-2015.

FIGURE 1
Discharge from the mine and WMP to the Snap Lake Mine WTP (2008-2011)



Water quality data was also provided for the period of January to October, 2011, for nine different monitoring points, including the final mine water collection sump, WMP water, and water treatment plant effluent. The water quality characteristics from these monitoring points are summarized in Tables 1, 2, and 3, respectively.

TABLE 1
Mine Water Quality in 2011 (January 1 to October 9, 2011)

Parameter	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)
Total Suspended Solids	63	636	3220
Total Dissolved Solids	360	517	810
Ammonia, NH_3-N	0.46	1.66	4.81
Nitrate, NO_3-N	2.01	4.14	30.7
Nitrite, NO_2-N	0.090	0.193	0.445
Aluminum	3.11	12.1	31.5
Arsenic	0.0011	0.0018	<0.0040[1]
Barium	0.099	0.367	1.01
Boron	0.092	0.121	0.190
Cadmium	0.000015	0.00021	<0.0008[2]
Chloride	120	237	310

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TABLE 1
Mine Water Quality in 2011 (January 1 to October 9, 2011)

Parameter	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)
Chromium	0.033	0.171	0.438
Copper	0.0029	0.014	0.040
Fluoride	0.278	0.351	0.420
Iron	4.08	21.0	56.6
Lead	0.00266	0.0162	0.0512
Manganese	0.126	0.437	0.997
Nickel	0.062	0.305	0.824
Strontium	1.55	1.76	2.20
Zinc	0.0133	0.0605	0.150

[1]The maximum concentration was <4 µg/L; not clear how much less
[2]The maximum concentration was <0.8 µg/L; not clear how much less

TABLE 2
WMP Water Quality in 2011 (January 1 to October 27, 2011)

Parameter	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)
Total Suspended Solids	1.0	9.4	209
Total Dissolved Solids	390	1359	4100
Ammonia, NH_3-N	0.987	6.15	14.7
Nitrate, NO_3-N	3.83	88	244
Nitrite, NO_2-N	0.094	0.367	1.09
Aluminum	0.010	0.144	1.08
Arsenic	0.00013	0.00022	<0.0040[1]
Barium	0.039	0.095	0.220
Boron	0.149	0.581	1.37
Cadmium	0.000007	0.00018	0.0008
Chloride	124	343	825
Chromium	0.001	0.0017	0.0078
Copper	0.00047	0.00126	0.0033
Fluoride	0.304	0.553	1.18
Iron	0.044	0.266	1.70
Lead	0.00004	0.00022	0.00138
Manganese	0.025	0.140	0.783
Nickel	0.015	0.068	0.248
Strontium	0.744	2.15	5.49
Zinc	0.002	0.031	0.268

[1]The maximum concentration was <4 µg/L; not clear how much less

TABLE 3
Summary of the Contaminant Concentrations in the Effluent (January 1st to October 29th, 2011) Compared with the Existing Licence Limits

Parameter	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Maximum Grab Limit (mg/L)	Average Monthly Limit (mg/L)	In Compliance?
Total Suspended Solids	4	5.5	9	14	7	Yes
Ammonia, NH_3-N	0.56	1.33	2.57	20	-	Yes
Nitrate, NO_3-N	3.9	8.1	18.1	56	28	Yes
Nitrite, NO_2-N	0.07	0.15	0.41	2	1	Yes
Aluminum	0.008	0.030	0.160	2	1	Yes
Arsenic	0.00003	0.0001	<0.004[1]	0.04	0.02	Yes
Cadmium	0.000006	0.000009	<0.0008[1]	0.002	0.001	Yes

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TABLE 3
Summary of the Contaminant Concentrations in the Effluent (January 1st to October 29th, 2011) Compared with the Existing Licence Limits

Parameter	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)	Maximum Grab Limit (mg/L)	Average Monthly Limit (mg/L)	In Compliance?
Chromium	0.00007	0.0005	<0.003[1]	0.04	0.02	Yes
Copper	0.0002	0.0005	<0.004[1]	0.02	0.01	Yes
Nickel	0.007	0.010	0.013	0.10	0.05	Yes
Lead	0.00004	0.00009	<0.0004[1]	0.009	0.005	Yes
Zinc	0.0016	0.0025	<0.016[1]	0.02	0.01	Yes

[1]The maximum concentration was listed as "<" µg/L; not clear how much less

Based on the review and analysis of the Snap Lake Mine WTP data, CH2M HILL prepared a memorandum (Appendix A) outlining the major findings. These findings are summarized below:

- The current influent flow rate into the WTP is approaching its rated capacity (35 ML/d). The total influent flow into the WTP has been increasing steadily over the past 4 years. If the discharge from the mine continues to increase at the same rate relative to production, the WTP will require a treatment capacity of 45 ML/d by mid-2015.
- Mine water constitutes the majority of the influent flow entering the WTP (typically >80 percent). During the spring to fall, the WMP discharge contributes approximately 0 to 20 percent of the total influent flow. The treated sewage effluent and process water contribute minimally (<5 percent) to the total influent flow into the WTP.
- The WMP water contains high concentrations of TDS, nutrients (such as ammonia, nitrate, and nitrite), boron, strontium, chloride, and fluoride, which exceed the concentrations measured in the mine water.
- Although the WMP only contributed to approximately 10 percent of the total flow (volume basis) entering the WTP in 2011, the nitrate mass loading from the WMP contributed to approximately 52 percent of the total mass entering the WTP; additionally, the WMP contributed to more than 10 percent of the total mass of ammonia, nitrite, and TDS entering the WTP.
- The existing WTP is in compliance with the current licence requirements; however, TSS and nitrate concentrations occasionally approach the licence limits. To further reduce TSS concentrations in the effluent, upgrades/modifications could be made to the existing treatment process (that is, tube settlers and coagulation optimization). To remove nitrate, a nutrient removal process could be added to the existing WTP (for example, ion-exchange, membrane filtration, or biological nutrient removal).
- Effluent limits proposed by the Mackenzie Valley Land and Water Board (MVLWB) are far more restrictive than the current licence limits in terms of nutrient and metal concentrations. Additionally, new effluent limits have been proposed for parameters which are currently not regulated (such as TDS, chloride, fluoride, strontium, manganese, etc.).
- If the proposed limits are adopted into the licence requirements, in addition to expanding the WTP capacity to 45 ML/d, advanced treatment processes will be required to treat the water.

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SECTION 4

Future Effluent Requirements

On April 17, 2012, De Beers provided CH2M HILL with the future licence limits for the Snap Lake Mine WTP effluent (Table 4). As of June 14, 2012, the maximum monthly average and maximum grab limits have been reduced for nutrients (ammonia, nitrite, and nitrate) and several metals (aluminum, arsenic, chromium, and copper). Additionally, new limits have been set for chloride and sulphate. On January 1, 2015, limits for nitrate and chloride will be further reduced and new limits will come into effect for fluoride.

TABLE 4
Comparison of Future Licence Requirements for the Snap Lake Mine WTP Effluent with the Current Requirements

Parameter	Previous Licence		June 14, 2012 (Current)		January 1, 2015	
	Max Average (mg/L)	Max Grab (mg/L)	Max Average (mg/L)	Max Grab (mg/L)	Max Average (mg/L)	Max Grab (mg/L)
Total Suspended Solids	7	14	7	14	NC	NC
Ammonia, NH_3-N	n/a	20	10	20	NC	NC
Nitrate , NO_3-N	28	56	22	44	4	8
Nitrite, NO_2-N	1	2	0.5	1.0	NC	NC
Chloride	n/a	n/a	310	640	160	320
Fluoride	n/a	n/a	n/a	n/a	0.15	0.3
Sulphate	n/a	n/a	75	150	NC	NC
Aluminum	1	2	0.1	0.2	NC	NC
Arsenic	0.04	0.02	0.007	0.014	NC	NC
Cadmium	0.001	0.002	n/a	n/a	NC	NC
Chromium	0.02	0.04	0.01	0.02	NC	NC
Copper	0.02	0.04	0.003	0.006	NC	NC
Lead	0.005	0.009	0.005	0.01	NC	NC
Nickel	0.05	0.1	0.05	0.1	NC	NC
Zinc	0.01	0.02	0.01	0.02	NC	NC
F1 Fractions		4.6		4.6	NC	NC
F2 Fractions		2.1		2.1	NC	NC

NC = No change currently planned

Table 5 compares the 2011 effluent data with the current 2012 limits and the future limits set for 2015. Based on the 2011 data, the 2012 limits should be achievable with conventional treatment. However, the 2015 limits for nitrate, chloride, and fluoride will require alternative treatment processes to ensure compliance.

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TABLE 5
Comparison of 2011 Effluent Data from the Snap Lake Mine WTP with the Current and Future Licence Limits

Parameter	SLM WTP Effluent Minimum (mg/L)	SLM WTP Effluent Average (mg/L)	SLM WTP Effluent Maximum (mg/L)	June 14, 2012 Average Monthly Limit (mg/L)	June 14, 2012 Maximum Grab Limit (mg/L)	Jan. 1, 2015 Average Monthly Limit (mg/L)	Jan. 1, 2015 Maximum Grab Limit (mg/L)	In Compliance?
Ammonia, NH_3-N	0.56	1.33	2.57	10	20	NC	NC	Yes
Nitrate, NO_3-N	3.9	8.1	18.1	22	44	4	8	Not with 2015
Nitrite, NO_2-N	0.07	0.15	0.41	0.5	1.0	NC	NC	Yes
Chloride	168	237	316	310	640	160	320	Not with 2015
Fluoride	0.292	0.359	0.432	n/a	n/a	0.15	0.3	Not with 2015
Sulphate	39.5	46.0	60.5	75	150	NC	NC	Yes
Aluminum	0.008	0.030	0.160	0.1	0.2	NC	NC	Yes
Arsenic	0.00003	0.0001	<0.004[1]	0.007	0.014	NC	NC	Yes
Chromium	0.00007	0.0005	<0.003[1]	0.01	0.02	NC	NC	Yes
Copper	0.0002	0.0005	<0.004[1]	0.003	0.006	NC	NC	Yes

[1]The maximum concentration was listed as "<" µg/L; not clear how much less
NC = No change currently planned

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SECTION 5

Alternative Treatment Technologies

Alternative treatment technologies were investigated to allow for the expansion of the Snap Lake Mine WTP to a capacity of 45 ML/d and to ensure compliance with the current and future licence requirements. A preliminary review of potential treatment approaches and technologies was presented to De Beers during the kick-off meeting held on December 15th, 2011. The meeting slides and minutes are included in Appendix B for reference. Treatment technologies considered for TSS removal include: high rate clarification processes, gravity media filtration or alternative filtration processes, and membrane filtration. Technologies for nitrate removal were also investigated as the 2015 limits will not be achievable with conventional treatment alone. These technologies include ion-exchange (IX), reverse osmosis (RO), electrodialysis reversal (EDR), and biological processes. Additionally, technologies were investigated for chloride and fluoride removal to comply with the future 2015 limits. These include lime precipitation, RO, EDR, IX, adsorption, and distillation.

5.1 Total Suspended Solids Removal

TSS are typically removed from water through conventional treatment with coagulation, flocculation, sedimentation, and filtration. The existing Snap Lake Mine WTP incorporates coagulation with the addition of ferric sulphate into a reactor tank. A flocculant is added to the water following the reactor tank as it flows into the thickener where the majority of solids settle out. Twelve pressure filters are used for further solids removal.

Preliminary calculations indicate that the thickener is currently operating beyond its intended capacity and WTP operators have noted that the plant is capable of producing high quality (turbidity <1 NTU) water when influent flows are less than 1000 m^3/h (24 ML/d). To increase the capacity of the thickener while maintaining high quality clarified water, tube or plate settlers could be added to the thickener.

The addition of tube/plate settlers to the thickener will only increase the capacity of the existing thickener by approximately 20 to 25 percent. To increase the capacity of the WTP to 45 ML/d, an additional treatment train will be required. Current licence limits for TSS will remain the same in 2015. Hence, the secondary treatment train will need to comply with the maximum monthly average limit of 7 mg/L and the maximum grab limit of 14 mg/L.TSS removal in the second treatment train could be provided by a high rate clarification process followed filtration, or microfiltration/ultrafiltration (MF/UF) membranes.

5.1.1 Treatment Options for TSS Removal

Tube and Plate Settlers

The addition of tube or plate settlers is an inexpensive approach to upgrading an existing WTP sedimentation basin or clarifier to improve performance. Tube and plate settlers allow the overflow rate in sedimentation basins and clarifiers to be increased, while maintaining or improving clarified water quality. While coagulation/flocculation processes increase the size of particles to accelerate settling, tube and plate settlers decrease the distance that particles must fall before they can settle out of a suspension; solids collect on the tube/plate surface and form a compact mass. Tube/plate surfaces are inclined to allow for the settled solids to slide down into the sludge collection zone where they can be removed.

Tube settlers are typically inclined at a 60 degree angle to optimize solids collection and mobility. The vertical height of tubes typically ranges from 0.5 to 2 m; longer tubes may be advantageous in high flow/high turbidity applications as they offer a longer residence time.

Tube settlers are typically made of lightweight PVC to minimize support structures. Circular clarifiers can use supports that span from the outside diameter to the centre well. Settler modules may be hung by an existing launder system, eliminating the need for an elaborate support system. The support system is typically constructed out of stainless steel, painted carbon steel, or aluminum.

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Parallel plates are also efficient at removing solids; however, it can be difficult to maintain even spacing and uniform flow, as wide plates in operation tend to be hydraulically unstable. Depending on the number of plates, plate size, and plate spacing, surface hydraulic loading rates will typically range from 9.5 to 17 m/h. The plates are typically spaced 50 mm (2 in) apart with an inclined length of 1 to 2 m. Plate settlers are typically more expensive than tube settlers as they are constructed out of stainless steel or aluminum; however, plate settlers will last longer than tube settlers and have fewer maintenance requirements. Composite plate settlers (PVC or FRP) are available but can degrade and distort over time due to water absorption and in the presence of UV light.

A comparison of the advantages and disadvantages of tube and plate settlers is shown in Table 6 below:

TABLE 6
Comparison of Advantages and Disadvantages of Tube Settlers Versus plate Settlers

Comparison	Tube Settlers	Plate Settlers
Advantages	• Lower initial cost than plate settlers • Tubes are lightweight; support structure can also be lightweight • Increases the rise rate of the existing clarifier; potentially decreases coagulant dosage and improves clarified water turbidity (rise rates from 1.0 gpm/ft^2 to 2.5 gpm/ft^2)	• Plate materials (stainless steel and aluminum) will not chip-off and damage pumps • Plate materials (stainless steel and aluminum) are resistant to corrosion, robust, and not subject to damage during cleaning • Provides a more effective surface area for settling (smaller footprint) • Increases the rise rate of the existing clarifier; potentially decreases coagulant dosage and improves clarified water turbidity • Contractors/operators can walk on the plates for installation and cleaning
Disadvantages	• Can be damaged during cleaning; large chips of plastic can clog drains and damage pumps • Must be replaced after 10 to 25 years • Effluent quality is better with plate settlers • Can degrade and distort due to water absorption and in the presence of UV light	• Higher initial cost than tube settlers • Composite plate settlers can warp overtime causing unbalances in the flow and short circuiting • Plate settlers require significant structural supports due to weight • Greater vertical height requirement for plates may impact solid collection system

Tanks equipped with high-rate settler modules must provide continuous sludge removal to keep up with the high sludge accumulation rate. The existing thickener at the Snap Lake Mine WTP is designed to remove sludge at a continuous rate but operators are currently practicing intermittent sludge disposal; the addition of tube/plate settlers may require the operators to switch back to continuous sludge disposal.

High Rate Clarification

To expand the capacity of the Snap Lake Mine WTP to 45 ML/d, while continuing to meet the existing/future licence requirements for TSS, an additional treatment train will be required that can remove suspended solids. This could be accomplished by adding a high rate clarification process followed by a filtration or MF/UF.

High rate clarification processes typically incorporate ballasted flocculation with fine sand or recirculated sludge and/or plate/tube settlers to promote settling at a faster rate than in a conventional clarification process. This leads to higher rise rates, higher treatment capacities, and a smaller plant footprint. High rate clarification processes are typically bundled into pre-engineered package plants that are easy to install and operate. Three examples of these packaged units include the DensaDeg® clarifier/thickener, the Actiflo™ high rate clarification unit, and the CONTRAFAST® high rate sludge thickening clarifier/softener.

DensaDeg® Clarifier/Thickener

The DensaDeg® Clarifier/Thickener is a high-rate solids contact unit manufactured by Infilco Degremont Inc. The DensaDeg® unit combines optimized flocculation, internal and external sludge recirculation, and lamella settling tubes in two conjoined vessels to maximize hydraulic loading and treatment efficiencies. It can be used for

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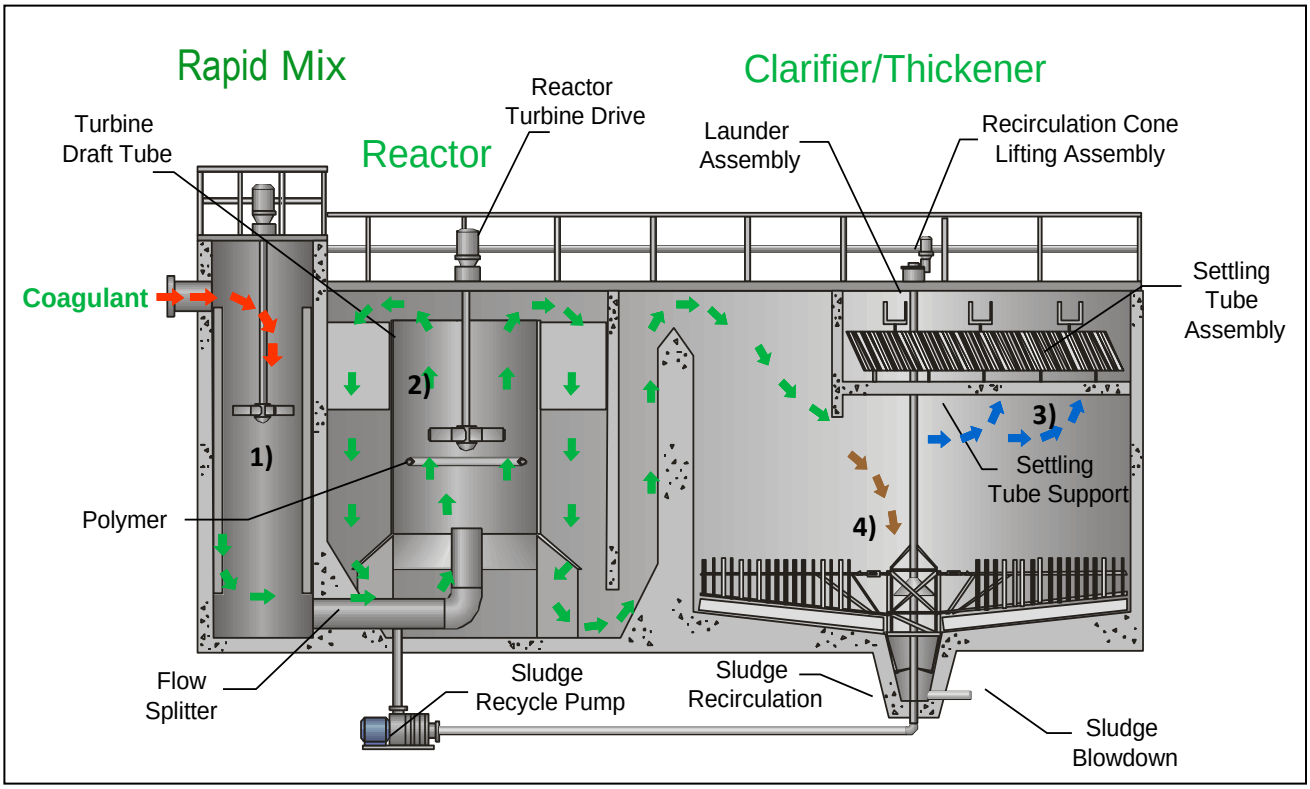
treating industrial wastewaters to remove TSS and heavy metals (precipitation). Figure 2 shows a side view of a typical DensaDeg® high rate solids contact unit.

FIGURE 2
DensaDeg® High Rate Solids Contact Unit Process Design (Courtesy of IDI)



The DensaDeg® unit incorporates an integrated process involving: 1) a rapid mix stage; 2) a reactor-zone; 3) settling and separation; and 4) and sludge collection and thickening. Water flows into the rapid mix area and a coagulant is added, along with sodium hydroxide or lime for pH adjustment. In the reactor-zone the water is mixed by an axial flow turbine and recirculated through a cylindrical draft tube to promote solids contact and floc formation. A polymer and thickened sludge (recycled from the clarifier) are injected into the reactor draft tube to accelerate the flocculation process and promote the formation of dense floc particles. Following flocculation, the water flows into the setting zone over a submerged weir wall where dense floc particles settle out to the sludge thickening zone. Tube settlers provide additional removal of lighter, low-density solids, as the clarified effluent exits the DensaDeg® unit. Sludge is thickened at the bottom of the clarifier via a rotating scraper mechanism and periodically removed. A small portion of the sludge is recycled back to the reactor zone to enhance flocculation.

A DensaDeg® unit can either be constructed out of concrete or steel. Concrete tanks can have capacities ranging from 4 to 83 ML/d (1.0 to 22 MG/D) and steel tanks can have capacities ranging from 0.6 to 57 ML/d (0.15 to 15 MG/D). Rise rates for the DensaDeg® unit range from 14 to 36 m/h (6 to 15 gpm/ft^2) and the unit can range from 4.6 to 6.7 m (15 to 22 ft) in height. For a unit that is capable of treating approximately 25 ML/d, the footprint required for coagulation, flocculation, and clarification (~300 m^2) is much smaller than the footprint of a conventional clarifier (>500 m^2). Thickened sludge produced by a DensaDeg® unit ranges from 2 to 10 percent solids. Compared to sand ballasted systems, the DensaDeg® unit produces an extremely low waste volume (10 times less).

Actiflo®

The Actiflo® high rate clarification unit, developed by Veolia Water Solutions & Technologies, is a compact process that includes coagulation, ballasted flocculation, and settling. The ballasted flocculation process uses microsand (Actisand®) as a seed for flocculate formation to promote rapid floc settlement and to allow for high overflow

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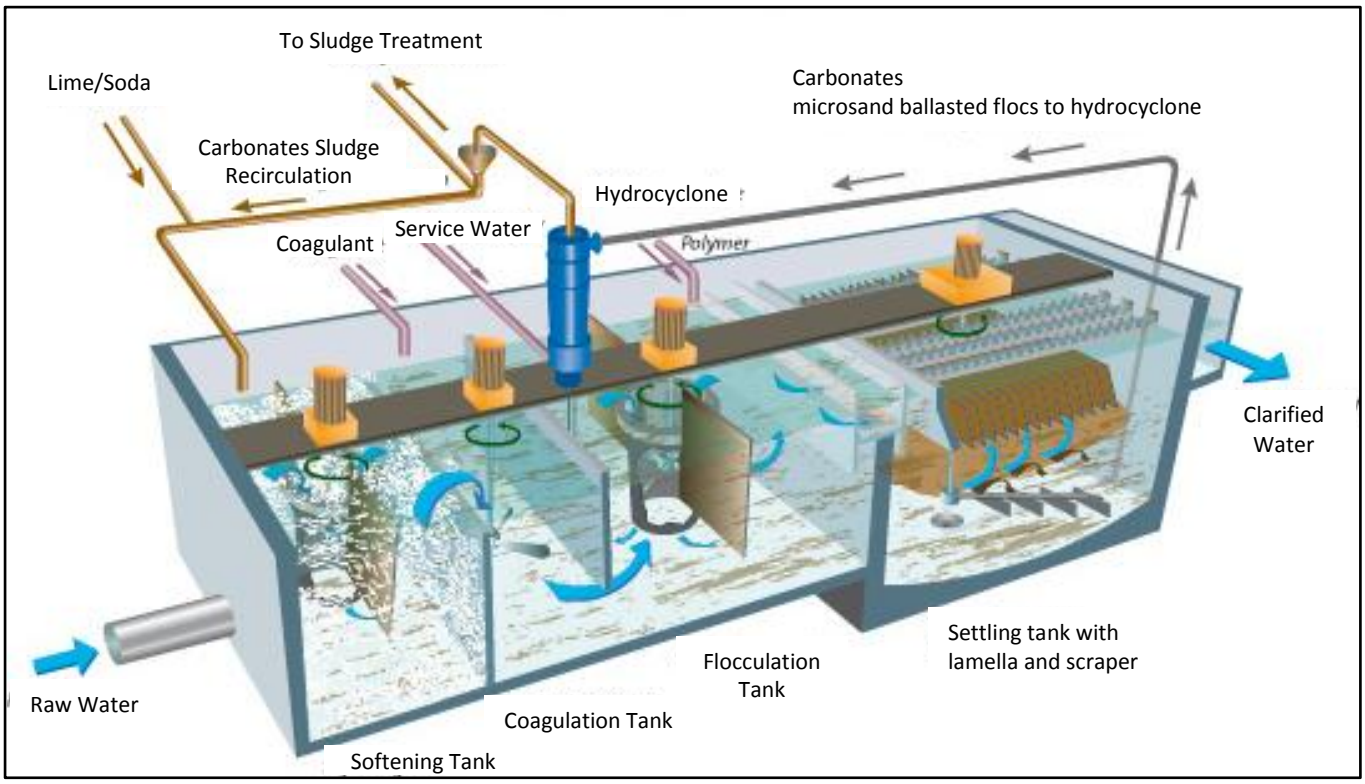
rates and shorter retention times. An Actiflo® unit, capable of treating approximately 25 ML/d (~144 m^2), has a smaller footprint than both a conventional clarifier (>500 m^2) and the DensaDeg®(~300 m^2).

The Actiflo® unit can be used to treat industrial process water and reduce concentrations of TSS (>90 percent), heavy metals, total organic carbon (TOC), phosphorus, and color; hence, it can serve as pretreatment process prior to membrane filtration or RO. For highly loaded industrial effluents, the Actiflo® unit can maintain rise rates of 50 to 100 m/h (21 to 41 gpm/ft^2).

To achieve higher reductions in heavy metal concentrations, the Actiflo® unit can come equipped with a softening tank (Figure 3).

FIGURE 3
Actiflo® High Rate Softening/Clarification Unit (Courtesy of Veolia)



Chemical inputs to the unit include lime/soda ash, coagulant, polymer, and microsand. After the sludge is removed from the settling tank it is sent through a hydrocyclone where the microsand is recovered and recycled in the flocculation process.

CONTRAFAST®

The CONTRAFAST® is a high rate sludge thickening clarifier/softener that combines clarification and sludge thickening in a single compact unit. Internal and external sludge recirculation and tube settling are included to optimize clarification. As shown in the flow diagram in Figure 4, raw water combined with recycled sludge and treatment chemicals enters the center draft tube (1). There they are mixed and recirculated within the reactor (2) by the variable speed impeller. The impeller aids in accelerating solids formation and densifying the sludge. A high-velocity upflow port prevents settling in the reactor and transfers the water to the settling chamber. The water passes under a baffle and continues upward through the settling tubes (3) and into the effluent collection launder (4). The dense sludge settles to the basin floor where it is continually scraped and further thickened, until it is removed from the unit (5).

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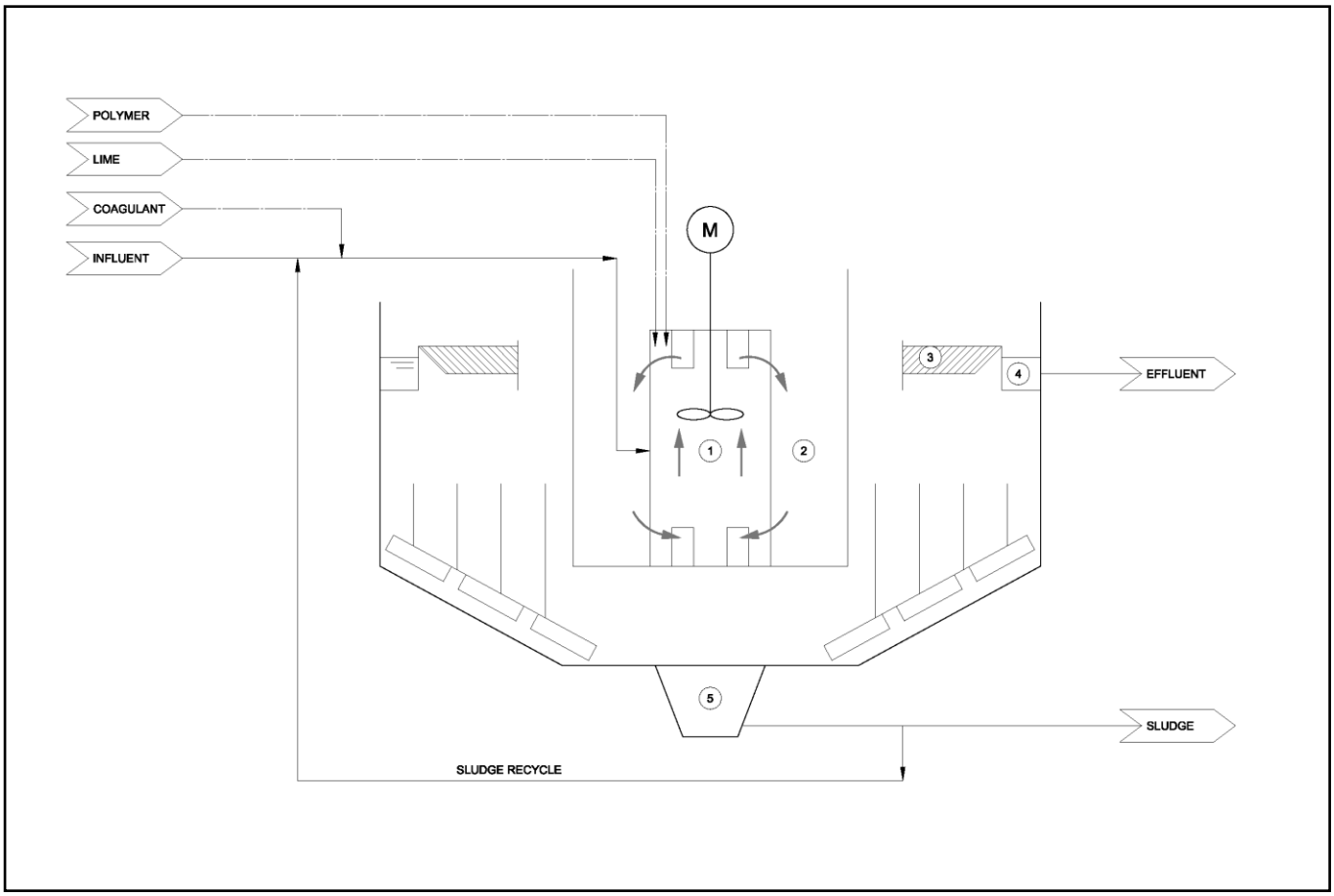
FIGURE 4
Contrafast Process Diagram



The CONTRAFAST® can be used for treating industrial wastewaters to remove TSS (>80 percent), iron and manganese (>90 percent), and hardness (50 to 60 percent). It has a similar rise rate (14 m/h) and footprint (~264 m^2) as the DensaDeg®. The main advantage of the CONTRAFAST® is that it is capable of producing sludge with more than 20 percent solids by weight, making additional sludge thickening unnecessary; hence, there is a low volume of waste to be disposed.

A comparison of the three different high rate clarification units is shown in Table 7.

TABLE 7
Comparison of High Rate Clarification/Softening Processes

Comparison Criteria	DensaDeg®	ActiFlo®	CONTRAFAST®
Ballast Material	Recirculated sludge; no maintenance concerns	Microsand; potential for abrasive wear	Recirculated sludge; no maintenance concerns
Waste volume and sludge solids content	Low waste volume (thickened sludge 2 to 10% solids by weight)	A hydrocyclone is used to separate sludge from microsand; final sludge concentration is 2,000 to 5,000 mg/L; up to 8% dry solids can be achieved with softening	Extremely low waste volume (thickened sludge more than 20% solids by weight)
Removes:	TSS, heavy metals, TOC (enhanced removal with softening), phosphorus, and color	TSS, heavy metals, TOC (enhanced removal with softening), phosphorus, and color	TSS, iron, manganese, and hardness
Clarified Water Quality	Treated water turbidity is normally less than 1 NTU	Turbidity removal greater than 90 percent; with lime softening clarified water turbidity is typically less than 1 NTU and TSS is less than 3 mg/L	Turbidity removal greater than 90 percent; TSS removal greater than 80 percent

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TABLE 7
Comparison of High Rate Clarification/Softening Processes

Comparison Criteria	DensaDeg®	ActiFlo®	CONTRAFAST®
Start-up Time	Rapid start-up due to internal/external sludge recirculation (~30 minutes)	Rapid start-up (less than 20 minutes)	
Adaptability	Can be operated over a wide range of flows and raw water characteristics	Reacts to changing water quality and provides consistent effluent quality	
Softening?	Yes	Yes	Yes
Filtration in a Combined Unit?	No	Possible	No
Chemical Addition	Coagulant and/or lime, and polymer	Coagulant and/or lime, polymer, and microsand	Lime and soda ash; may require a polymer
Chemical Consumption	Slightly less than ActiFlo® based on pilot studies (CDM, 2009)[1]	Slightly higher than DensaDeg® based on pilot studies (CDM, 2009)[1]	No comparative information available
Rise Rates (m/h)	High rise rates (14 to 36 m/h)	Very high rise rates (50 to 100 m/h)	High rise rate (~14 m/h)
Heights (m)	4.6 to 6.7	5	7
Footprint	For 25 MLD ~26.5 m x 11.5 m or 300 m^2	Smallest footprint; for 25 ML/d ~12 m x 12 m or 144 m^2	For 28 ML/d ~16.5 m x 16 m or 264 m^2
Tank Materials	External: steel or concrete Internal: Painted carbon steel, stainless steel, or special coating	Tanks available in epoxy coated steel, stainless steel or glass fibre armed polyester (GAP).	

[1]Camp, Dresser & McKee. 2009. City of Springfield, Ohio Comprehensive Facility Plan Technical Memorandum No. 3.

Filtration Technologies

To ensure compliance with the Snap Lake Mine WTP licence requirement for TSS, filtration processes can be applied to provide further polishing of the settled water (following high rate clarification) to remove fine flocs, which are carried over after the clarification process.

High rate, gravity media filtration is the most common technology for treating municipal drinking water over a wide range of water quality conditions. Filter beds are typically comprised of a layer of sand overlain by granulated anthracite coal. Filtration occurs as particles are trapped within the voids of the filter bed. Periodic (often daily or more frequently) cleaning of the filters is accomplished by backwashing (reverse flow with or without supplemental surface wash or air scour). Backwashed solids are thickened in a settling basin or pond prior to disposal. Thickened sludge (2 to 6 percent solids) can be further dewatered by mechanical or non-mechanical methods depending on the needs for ultimate disposal. Common disposal options include onsite storage, land-filling, discharge to sanitary sewer system, and land application.

Some alternatives to conventional gravity media filtration include pressure filters, continuous backwash upflow filters, and surface filtration. Pressure filters and continuous backwash upflow filters are both considered depth filtration processes. In pressure filters, water is pumped through a pressurized vessel containing filter media (sand or anthracite). Filtration rates in pressure filters are similar to gravity filters. In continuous backwash upflow filters, water is introduced at the bottom of the filter; as the water flows upwards through the sand media, particles are trapped. A small portion of sand is continuously cleaned and recycled to eliminate the need for a backwash cycle. Surface filtration involves the removal of particulate matter via mechanical sieving with a filter septum (cloths or synthetic materials). Pore size of the material dictates the degree of particle removal.

Micro/Ultra - Membrane Filtration

MF/UF processes can also be used as an alternative to granular media filtration to remove TSS following clarification. In MF/UF processes, water is sent through a semi-permeable membrane to remove TSS; dissolved

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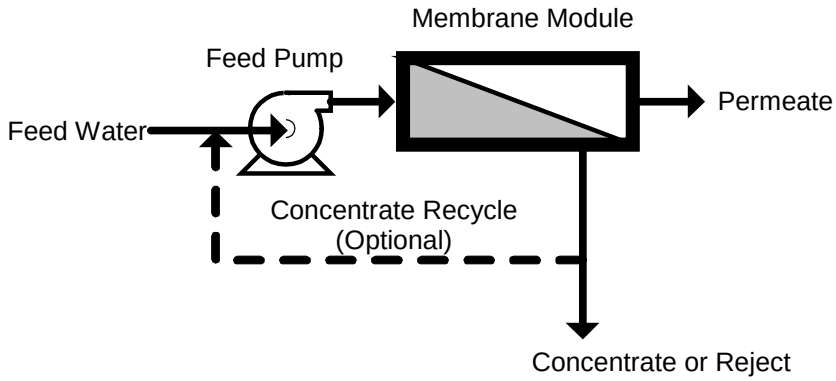
solids are not removed in MF/UF processes unless they are first adsorbed onto powder activated carbon or coagulated. Water passing through the membrane is referred to as the permeate stream and the water left behind is referred to as the concentrate stream. A simplified flow schematic for a typical pressure-driven membrane process is shown in Figure 5.

FIGURE 5
Simplified Flow Schematic for a Pressure-Driven Membrane Process



MF/UF processes can achieve a higher effluent quality compared to gravity media filters or alternative filtration processes. Effluent turbidity exiting an MF/UF membrane is typically lower than 0.1 mg/L and TSS is lower than 1 mg/L. Hence, MF/UF membranes are typically used as a pretreatment prior to advanced treatment processes, such as RO, that require a high quality feed water with low in turbidity and TSS.

A comparison of the operating characteristics of MF and UF membranes is shown in Table 8. MF membranes typically have pore sizes ranging from 0.08 to 2.0 µm and UF membranes have smaller pore sizes ranging from 0.005 to 0.2 µm; hence, UF membranes can remove smaller particles and achieve higher TSS removals. A MF membrane is typically operated at a lower pressure than an UF membrane (15 vs. 75 psi), consumes less energy, and has a higher product recovery ratio. Additionally, MF membranes can treat water at a higher rate of flux.

TABLE 8
Comparison of Microfiltration to Ultrafiltration Membranes

Characteristics	Microfiltration	Ultrafiltration
Pore size (µm)	0.08 – 2.0	0.005 to 0.2
Operating Pressure (psi)	1 - 15 (typically 15)	10 - 100 (typically 75)
Rate of Flux ($L/m^2/d$)	405 - 1600	405 - 815
Energy Consumption (kWh/m^3)	~0.4	~3.0
Product Recovery (%)	94 to 98	70 to 80

Commercially available MF/UF membranes can come in different geometries including spiral wound, tubular, hollow fiber, plate and frame, and cassette. In wastewater applications spiral, tubular and hollow fiber membranes are most commonly used; in industrial applications, plate and frames and cassette membranes are typically used. Tubular modules are used to treat wastewater with high suspended solids as they contain large diameters of channels which are easy to clean; however, these membranes are generally more expensive and provide a lower surface area to volume ratio. Hollow fiber membranes consist of bundles of tiny hollow fibers which provide a higher surface area to volume ratio; however, these membranes are more susceptible to plugging and require pretreatment to remove large particles.

MF/UF processes may require pretreatment in some applications to prevent or limit membrane fouling. Pretreatment can consist of prefiltration to remove large particles, pH adjustment (depends on optimal range for the membrane), adsorption (PAC addition) with coagulation to allow for the removal of dissolved solids, and preoxidation. Liquid and gas backwashing systems are routinely used with low-pressure membrane technologies to remove foulant materials from the membrane surface. Additionally, chemical cleaning is required on a less

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frequent basis (1 to 6 months) to remove constituents that are not removed during conventional backwashing and restore the transmembrane flux.

Compared to a conventional treatment process, MF/UF processes can reduce chemical consumption and save on space and labour requirements. However, MF/UF processes typically use more electricity (high energy costs), have lower recovery ratios, require disposal of concentrate streams, and may require pretreatment to prevent membrane fouling. A comparison of conventional gravity media filtration to MF/UF membranes processes is shown in Table 9.

TABLE 9
Comparison of Conventional Filtration to Microfiltration/Ultrafiltration Membranes Filtration for Effluent Polishing

Filtration Process	Typical Performance	Advantages	Disadvantages
Conventional Filtration	• TSS (<5 mg/L) • Turbidity (<1 NTU) • Can also remove iron, manganese, arsenic, and some organics,	• Low to moderate capital cost • Less waste to treat/dispose; single waste stream from backwashing (4 to 6%) • Low energy consumption compared to membranes • Low cost to replace granular media (~10 to 20% per year)	• Larger footprint • Requires pretreatment with coagulation and sedimentation • More labour required to operate • Typically, additional treatment is required prior to RO to reduce turbidity
MF/UF Membrane Filtration	• TSS (<1 mg/L) • Turbidity (<0.1 NTU) • Can also remove iron, manganese, arsenic, and some organics.	• Improved effluent quality; reduced cleaning costs and fouling associated with subsequent membrane processes (i.e., RO) • More space efficient; smaller footprint than conventional filtration • Can reduce the amount of treatment chemicals (if pretreatment isn't required) • Reduced labour requirement; automated easily	• High capital costs and high cost to replace membranes (every 3 to 5 years) • Higher O & M costs due to high energy consumption and membrane washing and cleaning • Waste streams can be large for UF (10 to 15%) • Can require pretreatment if the feed water contains high turbidity and organics, and other potential membrane foulants (i.e., coagulation and sedimentation) • Scaling formation

5.2 Nutrients Removal

The existing Snap Lake Mine WTP was not designed to remove nutrients; however, the 2011 effluent nutrient levels for ammonia, nitrate, and nitrite are all below the current licence limits. The 2010/2011 effluent concentrations of ammonia and nitrite are plotted in Figure 6, along with the current licence limits. The current maximum grab and maximum average monthly limits for nitrite in the effluent are 1 mg/L and 0.5 mg/L, respectively. Ammonia has a maximum grab limit of 20 mg/L and a maximum average monthly limit of 10 mg/L.

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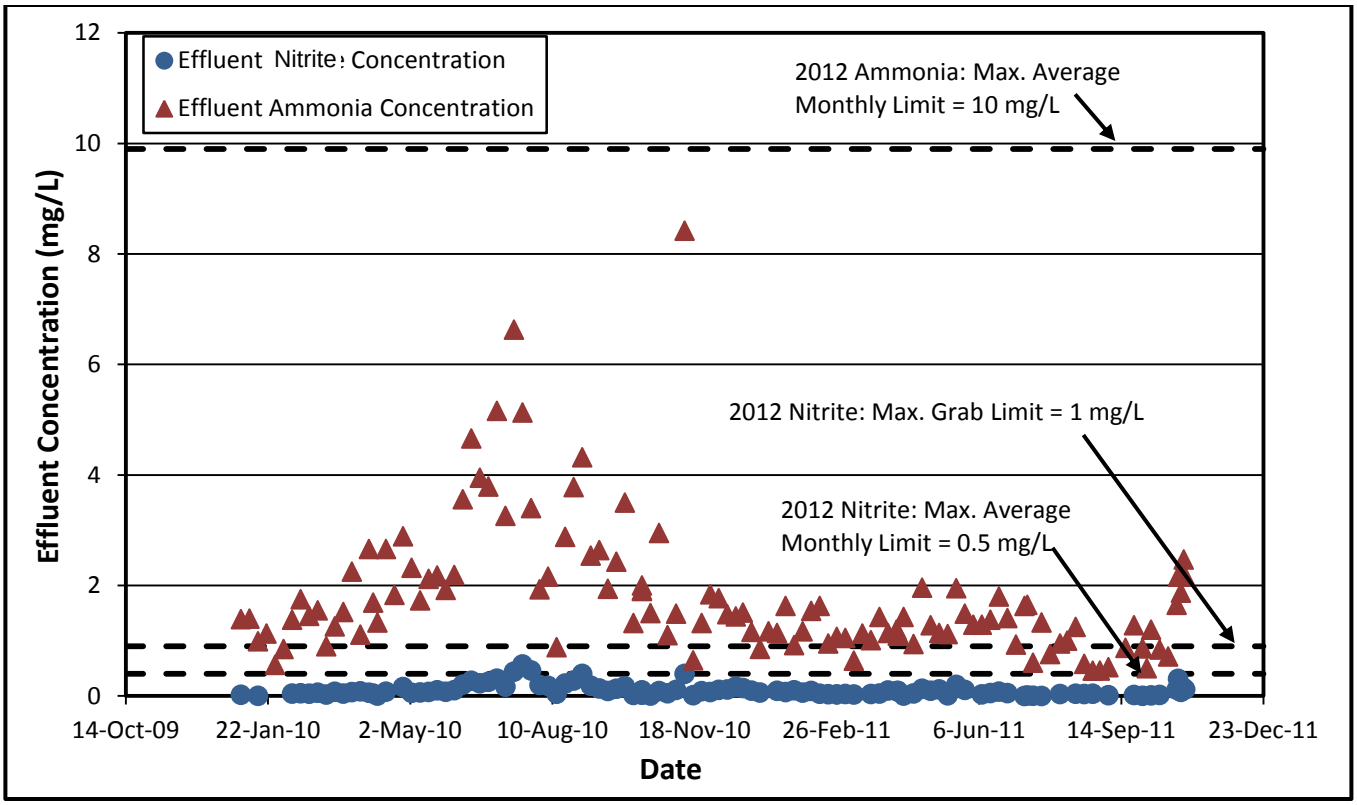
FIGURE 6
Nitrite and Ammonia Concentrations in the Snap Lake Mine WTP Effluent from 2010 to 2011 Compared with Current Licence Limits



On November 11, 2010, a maximum grab sample of 55.5 mg/L of nitrate was reported, which exceeds current maximum grab limit of 44 mg/L; however, at that time the licence limit was 56 mg/L. All other effluent samples tested in 2010 contained nitrate concentrations below the current maximum grab limit (44 mg/L). In 2015, the average monthly licence limit for nitrate will be reduced to 4 mg/L (maximum grab = 8 mg/L). Nitrate levels in the effluent will exceed these new limits if it is not removed during treatment (Figure 7). To ensure compliance with the future 2015 limits for nitrate, treatment technologies for nitrate removal must be incorporated into the Snap Lake Mine WTP as part of the expansion. Typical processes that will remove nitrates and nitrites include IX (anion), RO, EDR, and biological treatment.

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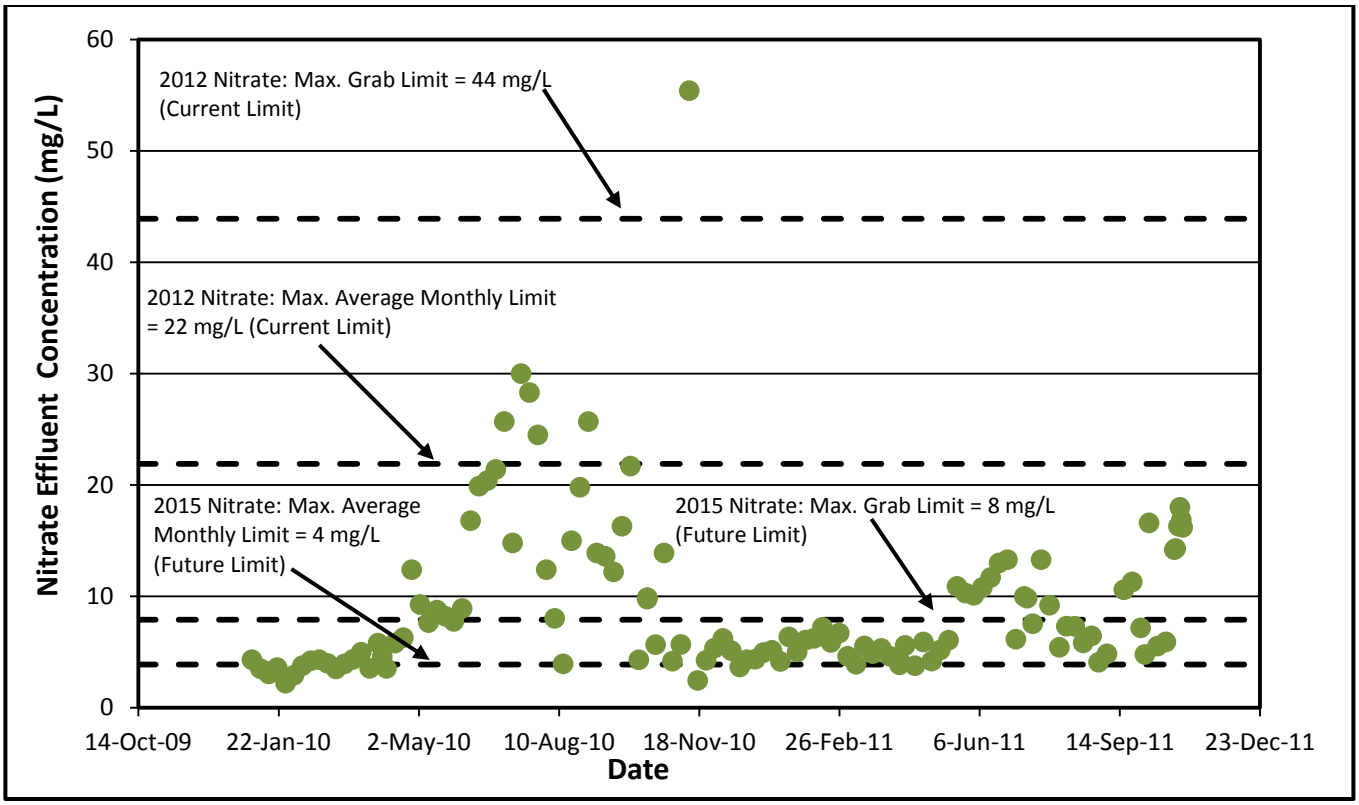
FIGURE 7
Nitrate Concentrations in the Snap Lake Mine WTP Effluent from 2010 to 2011 Compared with Current and Future Licence Limits



5.2.1 Scale of Treatment

During the water quality data review, a mass balance was conducted to estimate the percent mass contribution of the mine and WMP water on the total influent nutrient mass loading (see Data Review Findings TM in Appendix A). The WMP was found to contribute to more than 50 percent of the total nitrate mass loading in 2011. Additionally, the WMP contributed to more than 20 percent of the total ammonia mass loading and to more than 15 percent for nitrite. Side-stream treatment of the WMP water for nutrient removal, prior to blending with the mine water, could result in significant reductions in ammonia, nitrate, and nitrite, during the periods when the WMP discharge to the WTP is high.

Figure 8 shows the estimated concentration of nitrate in the Snap Lake Mine WTP effluent under a scenario where 90 percent of the influent nitrate is removed from the WMP prior to the WTP (note the scale is different for the WMP since nitrate concentrations are significantly higher). Although, effluent nitrate concentrations are reduced significantly during the periods of high nitrate loading from the WMP, effluent nitrate concentrations often exceed the 2015 maximum average monthly limit of 4 mg/L. Hence, a side-stream treatment approach for nitrate removal from the WMP will not be sufficient to comply with the 2015 effluent requirements; the mine water will also require at least partial treatment for nitrate removal.

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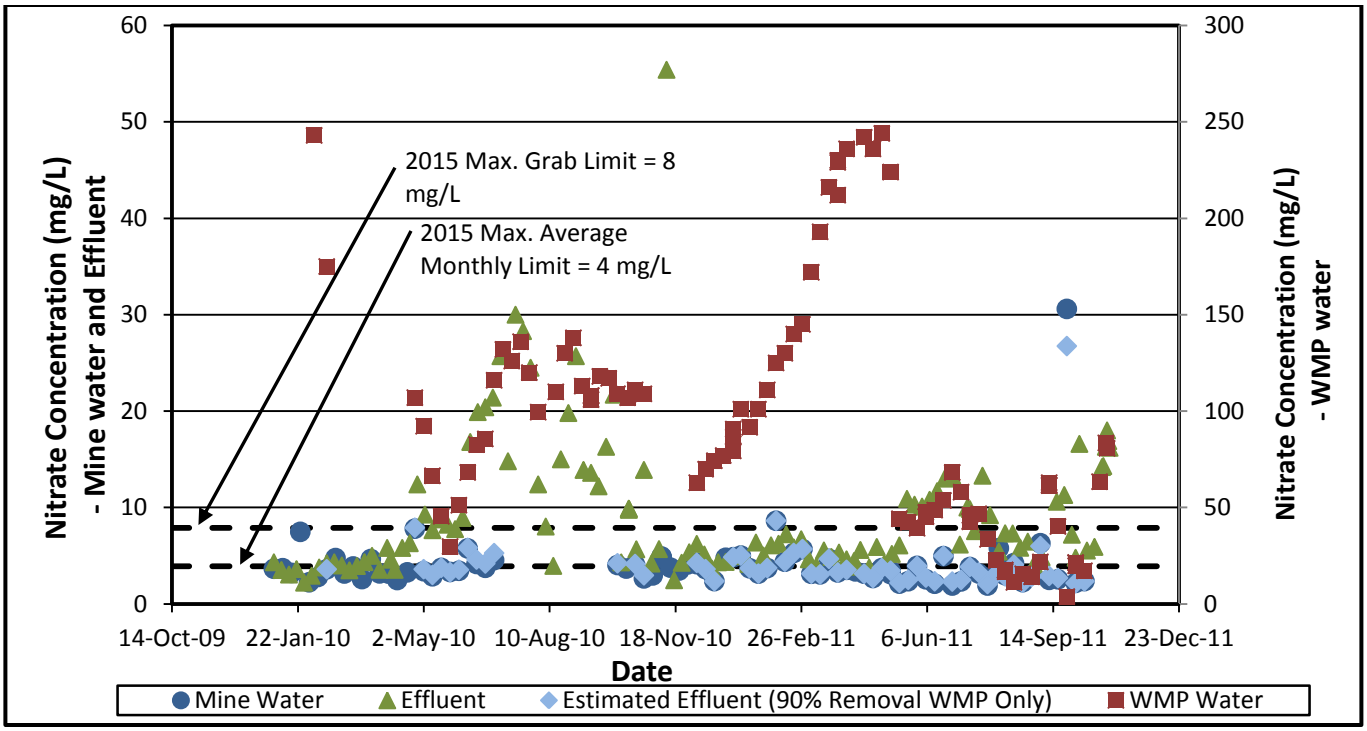
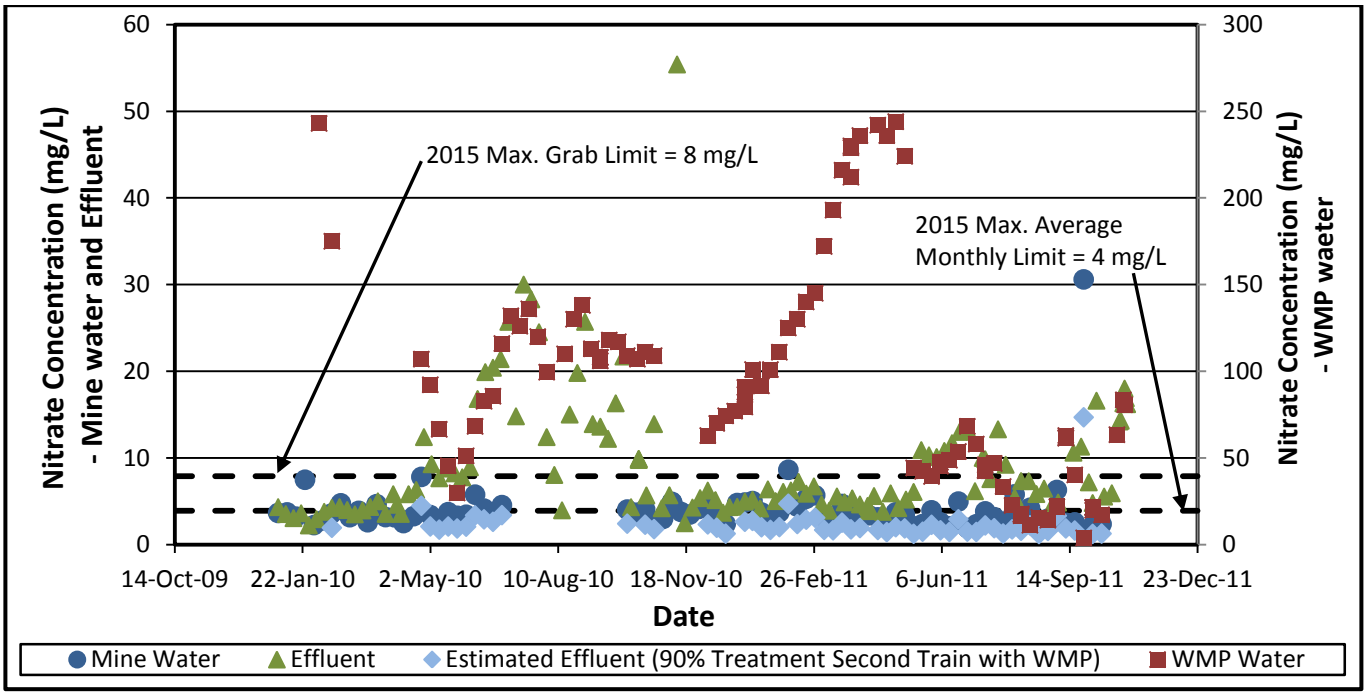
FIGURE 8
Estimated Nitrate Concentration in the Snap Lake Mine WTP Effluent if 90 percent of the Influent WMP Nitrate is Removed Prior to Blending with the Mine Water (note the scale is different for the WMP)



Alternatively, nitrate removal could be incorporated into a secondary treatment train. In this option the WMP water would be directed into the second treatment train (expansion), along with a portion of the mine water (~50 percent). The remaining mine water would be treated by the existing WTP train. Then, the two treatment trains would be blended prior to discharge into Snap Lake. Figure 9 shows the estimated concentration of nitrate in the blended effluent under a scenario where 90 percent of the influent nitrate is removed from the secondary treatment train (including the WMP water).

FIGURE 9
Estimated Nitrate Concentration in the Snap Lake Mine WTP Effluent if 90 Percent of the Nitrate is Removed from the Secondary Treatment Train and WMP Water (note the scale is different for the WMP)



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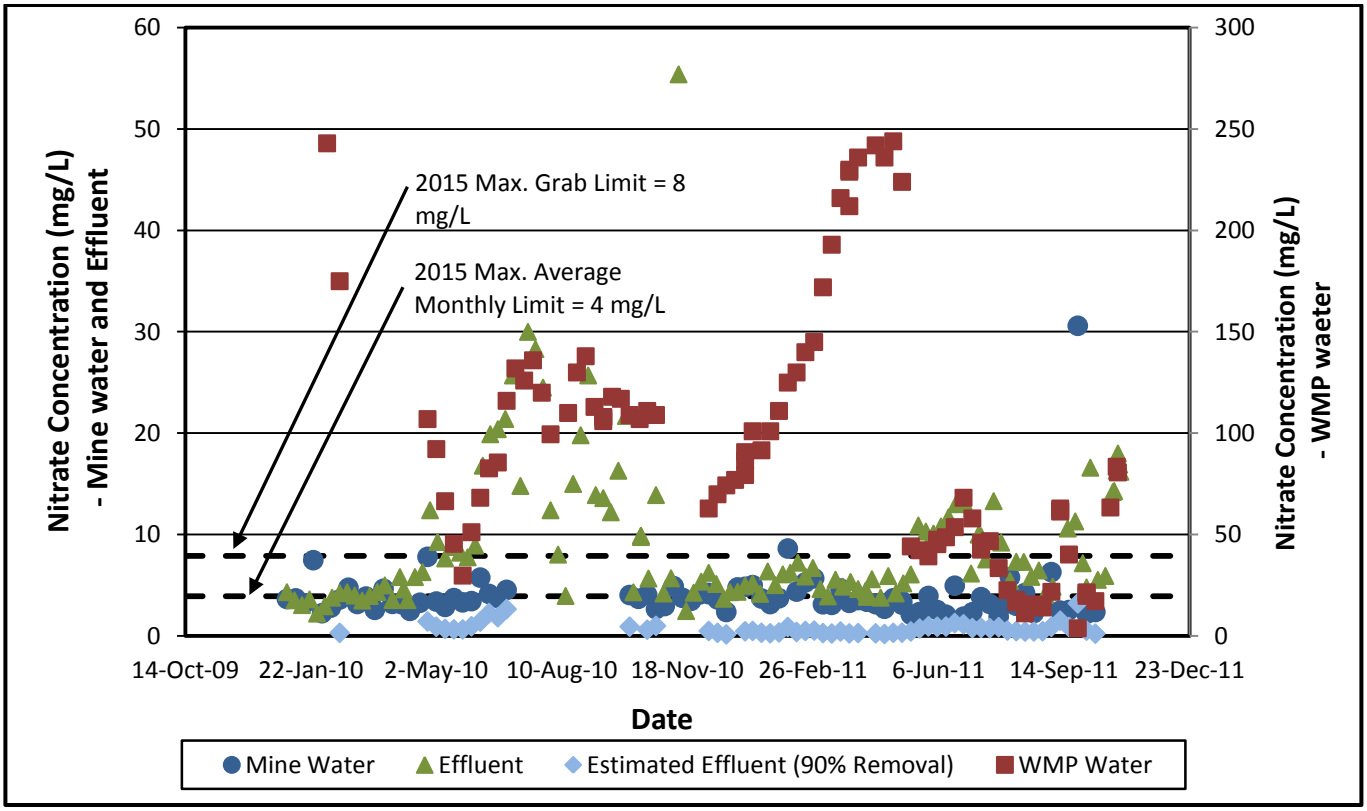
By directing approximately half of the influent flow (that is, ~50 percent of the mine water influent flow plus 100 percent of the WMP water) through a secondary treatment train that includes a nutrient removal process, the blended effluent nitrate concentration will be approximately one half of the influent mine water concentration, assuming nitrate removal is high (> 90 percent). As shown in Figure 9, under this scenario the estimated blended effluent nitrate concentration is typically lower than the 2015 maximum average monthly limit of 4 mg/L (except on a few occasions where nitrate levels in the mine water were elevated). This analysis does not take into consideration the effect of water recovery on the nitrate concentration in the blended effluent. If nutrient removal processes with low water recovery are selected, such as RO or EDR, the effluent concentrations of nitrate in the blended effluent stream would be greater, likely exceeding the 2015 monthly licence limit.

Full treatment of the mine and WMP water to remove nitrates would ensure that nitrate concentrations in the effluent are in compliance with the 2015 licence requirements. Estimated effluent nitrate concentrations under the full treatment scenario are shown in Figure 10.

FIGURE 10
Estimated Nitrate Concentration in the Snap Lake Mine WTP Effluent if 90 Percent of the Nitrate is Removed from the Full Influent Flow (note the scale is different for the WMP)



5.2.2 Treatment Options for Nitrate Removal

Ion Exchange

IX processes involve the passage of water over an insoluble IX resin. IX resins can either be placed as a fixed bed or in a reactor as slurry; fixed bed is similar to a filtration system. Ions present in the water matrix are exchanged with ions that are bound to the surface of the resin. Strong base anion (SBA) exchange resins can be used to remove nitrate from water. Nitrate ions are typically exchanged with chloride ions; however, they can also be exchanged with hydroxide or bicarbonate ions. The relative affinity of anions for exchange on standard SBA resins (Type 1 and 2 resins) follows the order of: sulphate > nitrate > bicarbonate > chloride > hydroxide. Hence, high levels of sulphate could reduce the exchange capacity of the resin available for nitrate. There are also specially designed nitrate-specific resins that prefer nitrate over sulphate (for example, tributylamine and triethylamine resins). These resins are designed such that they prefer monovalent anions over divalent anions due to the

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spacing of binding sites. Pretreatment for nitrate specific IX resins may include de-chlorination (if chlorine is present) and pre-filtration to prevent oxidation and physical fouling from occurring.

High TDS levels can also significantly reduce nitrate removal efficiencies. In general, an IX process is not economically attractive if source water contains greater than 500 mg/L of TDS and greater than 150 mg/L of sulphate. The Snap Lake mine water and effluent often contains over 500 mg/L of TDS; however, sulphate concentration is typically less than 50 mg/L.

If IX was implemented at the Snap Lake Mine WTP to treat nitrate, preference would be for an IX resin that exchanges hydroxide ions rather than chloride ions, as a new licence limit for chloride will be introduced in 2015 that will require additional treatment to remove chloride ions from the mine water. For an SBA resin, a sodium hydroxide (NaOH) solution or sodium bicarbonate solution ($NaHCO_3^-$) can used as a regenerant to replenish the exchange sites. One disadvantage of using NaOH or $NaHCO_3^-$ solutions for regeneration instead of sodium chloride is the cost, as NaOH or $NaHCO_3^-$ solutions are more expensive per tonne. During regeneration, a concentrated brine stream is produced that must be disposed of; the brine is typically 1 to 2 percent of the total treated water flow.

Reverse Osmosis

RO is a non-ion-specific technology which involves the use of high-pressure membranes capable of generating a high-purity treated effluent. By applying a pressure to water that is greater than the natural osmotic pressure, the water is forced to flow across a semi-permeable membrane towards a more dilute solution. RO membranes are primarily used to reduce high TDS concentrations (>90 percent reduction) but they can also be used to remove nitrates (>90 percent reduction possible). Additionally, RO can remove ions, including chloride and fluoride, and heavy metals. Although RO membranes will remove heavy metals from the feed water, some metals compounds should be removed during pretreatment to prevent scaling (for example, iron and manganese).

Compared to MF/UF membranes, RO membranes have smaller pores (0.1 to 1 nm), they operate at higher pressures (125 to 1000 psi), and they consume more energy (10 to 20 kWh/m^3); hence, they are more expensive to operate. Additionally, RO membranes have lower product recovery ratios than MF/UF membranes (65 to 85 percent); as such, they produce a larger amount of concentrate that must be treated and disposed of. As with MF/UF membranes, RO membranes require regular chemical cleaning (once per month) to remove foulants and to restore the membrane flux. Residuals are generated during chemical cleaning which also require treatment and disposal.

Pretreatment for an RO membrane is typically more stringent than for MF/UF membranes. Chemical oxidants such as chlorine and potassium permanganate can damage an RO membrane and must be removed if pre-oxidation is practiced. To prevent fouling/scaling of the membrane, the feed water pH is adjusted to modify the solubility of precipitates; at a pH of 5.5 to 6.0, carbonate is in the form of carbon dioxide and will pass through the membrane. An antiscalent can be added to interfere with or slow down the rate of precipitate formation. Additionally, pretreatment with MF/UF is typically required to prevent fouling of the RO membrane with larger particles. RO is a continuous separation process without a periodic backwash cycle; thus, if it is not removed, particulate matter can clog the feed channels and accumulate on the membrane surface. RO feed water requires turbidity less than 1 NTU and a salt density index (SDI) less than 4. Compared to conventional filtration processes, MF/UF pretreatment will result in a consistently higher feed water quality (SDI of 2 to 3), reducing the rate of RO fouling thereby extending membrane life.

Based on review of available water quality data from the Snap Lake Mine WTP, pretreatment for metal /mineral removal and/or the addition of an antiscalent will be required to minimize scale formation if RO is selected to remove nitrate. Compounds present in feed water with a low solubility that tend scale include calcium carbonate, calcium fluoride, calcium orthophosphate, calcium sulphate, strontium sulphate, barium sulphate, iron, manganese, aluminum, and silica dioxide. The Snap Lake WTP effluent contains elevated levels of strontium (1 to 2 mg/L), and moderate level of iron (average = 0.05 mg/L) and manganese (average = 0.06 mg/L). Reactive soluble silica concentrations were measured in drift water at the Snap Lake Mine in 2008 and reported to range from 9.6

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to 15.4 mg/L; hence, silica is not expected to cause major scaling problems if an antiscalent is applied to the feed water.

Another factor to consider is the temperature of the feed water entering the RO membrane. The optimum water temperature for most RO membranes is 25°C. As the temperature drops to 5°C, the capacity of the RO unit will be reduced to less than one half. The water temperature at of the Snap Lake Mine water is typically ranges from 6 to 11°C; hence, unless the water temperature is increased, the capacity of the membrane will be reduced from what is specified under optimal conditions.

Electrodialysis Reversal

Electrodialysis (ED) is an electrochemical process that involves passing an electric current through a series of ion-selective semipermeable membranes to mobilize and remove dissolved ions from a solution. The membranes are composed of ion-exchange material, with alternating cation and anion membranes assembled into stacks. As cations move towards the anode, they become trapped behind an anion-selective membrane and are disposed of into a brine solution; the opposite occurs for anions. In the EDR system, the polarity of the electric field is periodically reversed, which aids in flushing scale-forming ions off the membrane surface and further concentrating the brine solution.

Similar to RO, EDR removes TDS, chloride, fluoride, nitrate, and nitrite. Nitrate removals have been reported to range from 50 to 85 percent, typically lower than the removals achieved with RO membranes. However, EDR systems can achieve higher product recovery ratios than RO membranes; recoveries of greater than 90 percent are possible, as such a smaller volume of concentrated water waste is generated. Additionally, less pretreatment is typically required with EDR compared to RO, as EDR membranes are more durable, can operate over a wide range of pH values, can withstand high cleaning temperatures, are more resistant to organics, and are chlorine tolerant. In EDR, antiscalents are not required to prevent membrane fouling, as with RO.

Compared to RO, EDR systems are more complex, can be difficult to operate and maintain, and require close full-time monitoring. Costs for EDR systems are high (typically more costly than RO), as the process requires a large amount of energy, high operating costs, and waste treatment and disposal. For a TDS concentration greater than 3,000 mg/L, an EDR system can become more economically viable than RO due to the high scaling potential of the feedwater. However, this is not the case at the Snap Lake Mine WTP as the effluent TDS concentration is typically less than 600 mg/L.

Membrane Bioreactor

Membrane bioreactors (MBRs) combine microfiltration with a suspended growth bioreactor into a single unit process. In a typical MBR system, MF modules are immersed directly into an activated-sludge reactor. A vacuum is applied to the membranes on the effluent-side, drawing water through the modules, while solids remain in the reactor. An air blower forces compressed air into a distribution manifold at the base of the reactors to clean the exterior of the membranes, maintain TSS, and provide oxygen to promote anaerobic conditions. A schematic diagram of a MBR is shown in Figure 11.

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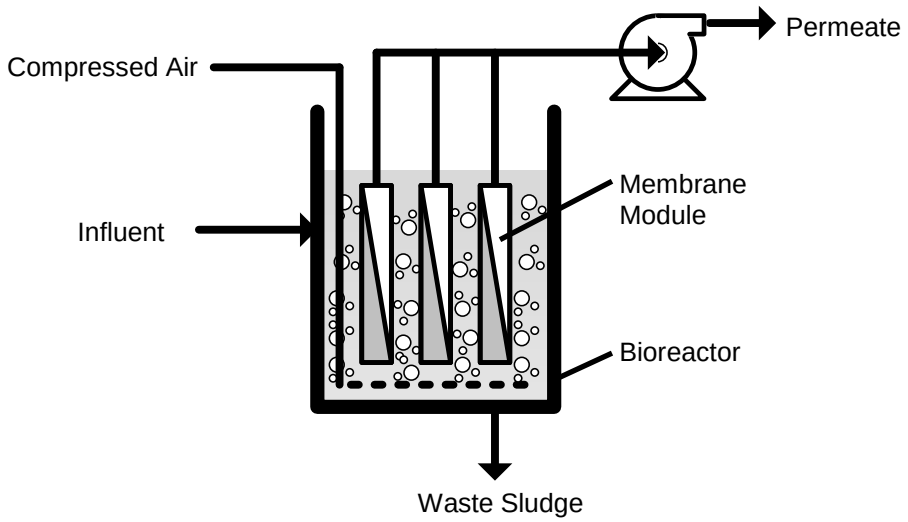
FIGURE 11
Simplified Schematic a Membrane Bioreactor



At low dissolved oxygen concentrations, MBRs are capable of simultaneous nitrification and denitrification. Denitrification requires an external carbon source, which can be added to the water in the form of methanol or ethanol. Denitrification rates also depend on water temperature, with rates doubling for every 4°C increase in temperature. The temperature of the mine water entering the Snap Lake Mine WTP typically ranges from 6 to 11°C during the year; hence, denitrification via MBRs may not be as efficient as reported for WWTPs located in warmer climates.

Typical MBR configurations include hollow fiber grouped into bundles (for example, GE/Zenon ZeeWeed and Siemens MemPulse™ MBR) or flat plates (Kubota, Enviroquip). Membranes are constructed out of cellulose or polymer material with pore sizes ranging from 0.1 to 0.4 µm. High removal efficiencies can be achieved with an MBR for nutrients and TSS. Greater than 95 percent removal of ammonia-nitrogen (effluent ammonia-nitrogen <0.5 mg/L) and TSS (TSS <1 mg/L) has been achieved, as well as greater than 90 percent of total kjeldahl nitrogen (TKN <3 mg/L) and greater than 80 percent of total phosphorus (TP <1 mg/L). Dissolved solids are not removed with MBRs; hence, additional processes would be required to remove chloride and fluoride ions from the mine water. Compared to conventional biological treatment processes, MBRs can be operated with longer solids residence times (SRTs), resulting in lower sludge production.

Depending on the wastewater quality, pretreatment may be required to protect the membranes from physical damage. This may consist of primary settling and fine screens (1 to 3 mm cut-off) before the membranes. To prevent fouling and extend membrane life, continuous and intermittent cleaning is typically employed. Continuous air scouring prevents solids build-up on the surface of the membranes. If an anaerobic environment is desired for denitrification, scouring can be achieved by flushing the membrane with water. Intermittent treatments can include back-pulsing of permeate to keep the pores cleared, chemical cleaning with a strong sodium hypochlorite or citric acid solution (weekly), and periodic chemical bath cleaning (3 to 6 months).

In contrast to separation processes, such as RO or EDR, MBRs can achieve a high recovery of water and they do not produce waste brine or concentrate (reduction of nitrate rather than removal to a waste stream). A small volume of sludge waste (biological solids and organic matter) is produced that must be stored and disposed.

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Summary of Treatment Technologies for Nitrate Removal

A summary of the different treatment process for removing nitrate are shown in Table 10.

TABLE 10
Treatment Technology Comparison for Nitrate Removal

Treatment Technologies	Removal Efficiency of Nitrate (%)	Water Loss (%)	Optimal Conditions	Advantages	Disadvantages
Ion Exchange (Anion)	Up to 90% possible under optimal conditions	1 to 2% (depends on influent water quality and operating conditions)	Low turbidity, low TDS and low concentration of competing ions (e.g., sulphate) in feed water	• High removals of nitrate may be possible • Smaller waste stream that RO or EDR	• Moderate capital cost • Moderate to high O & M costs • Low capacity for fluoride; water will require additional treatment • Capacity affected by competing ions (e.g., sulphate) • Capacity for nitrate may be reduced due to high TDS in mine water • Requires disposal of brine solution produced during regeneration • Pretreatment will be required to reduce suspended solids • NaOH or $NaCO_3$ will be required for regeneration; theses chemicals are more expensive than NaCl.
Reverse Osmosis	>90% possible under optimal conditions	20 to 40%	<30 mg/L of silica; no particulates Slightly acidic pH (5.5 to 6.0)	• High removals of nitrate are possible • Also removes chloride, fluoride, TDS and heavy metals • Will ensure compliance if future limits are set for TDS	• High capital and O & M costs • High energy consumption • High water loss • Inference by turbidity and silica • May require addition of antiscalent • Requires pretreatment and may require post-treatment (pH and/or alkalinity adjustment) • Brine stream and chemical cleaning residuals must be treated and disposed of
EDR	50 to 85%	10 to 30%	Treats most waters without preference; most economical for TDS of 3000 to 5000 mg/L; maximum turbidity = 0.5 NTU	• Higher water recovery than RO • Also removes chloride, fluoride, TDS and heavy metals • Not affected by silica concentrations in feed water	• Multiple desalting stages required to achieve high removals of nitrate • High capital and O & M costs • Complex operation (close monitoring) • High energy consumption • High water loss • Brine stream must be must be treated and disposed of
MBR	>90%	Very low	May require pH adjustment. Will require the addition of a substrate (carbon source)	• High removals of nitrate, ammonia, and TSS • No waste brine or concentrate • High water	• Will not remove chloride and fluoride ions; additional treatment required • High capital costs • High O & M costs associated with membrane cleaning, fouling control, and potential membrane

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TABLE 10
Treatment Technology Comparison for Nitrate Removal

Treatment Technologies	Removal Efficiency of Nitrate (%)	Water Loss (%)	Optimal Conditions	Advantages	Disadvantages
				recovery • Footprint can be comparable to RO or EDR systems	replacement • Complex, close monitoring required • High energy consumption • Will require an external source of carbon to allow for denitrification (e.g. methanol) • Chemicals are required to produce biosolids acceptable for disposal

5.3 Metal Removal

The existing Snap Lake Mine WTP can achieve high reductions in total metal concentrations using a conventional treatment process (coagulation, clarification, and filtration). The mine water typically has low metal concentrations (refer to Table 1, Section 3) with the exception of aluminum (average = 12.1 mg/L), iron (average = 21.0 mg/L), and strontium (average = 1.76 mg/L); these metals can exist at concentrations above 1 mg/L. Metal concentrations are even lower in the WMP water (refer to Table 2, Section 3), with the exception of strontium (average = 2.15 mg/L). Although the existing train includes the option for lime addition to the reactor tank (to induce the chemical precipitation of dissolved metals), lime is currently not added to the water and coagulation is controlled at a pH close to 8; hence, low removals of some dissolved metals is expected.

The current treatment process is achieving high removals of total metals (Table 11) through the removal of the particulate fraction and low to moderate removals of the dissolved metals. The 2010 and 2011 effluent concentrations of regulated metals are in compliance with the current licence limits (Table 12). Table 13 compares the 2011 dissolved metal concentrations in the mine water to the current licence limits. All regulated metals, except for copper, had maximum dissolved metal concentrations which were less than or equal to the monthly average limits (Table 13). As such, the Snap Lake Mine WTP can meet the current effluent licence limits for most metals, even when the dissolved fraction is not removed during treatment (no precipitation). It should be noted that there was uncertainty regarding a few of the lab measurements of total and dissolved concentrations of metals; hence, the average dissolved concentrations reported in Tables 11 and 13 are likely higher than the actual average concentrations found in the mine water.

TABLE 11
Average percentage of total and dissolved metals removed at the Snap Lake Mine WTP - 2011

Metal	Average Mine Water Influent Concentration (mg/L)		Average WTP Effluent Concentration (mg/L)		Average Percent Removed (%)	
	Total	Dissolved	Total	Dissolved	Total	Dissolved
Aluminum[1]	12.13	0.015	0.030	0.017	99.8	-17.5
Arsenic[1,2]	0.0018	0.0004	0.0001	0.00009	94.4	77.1
Cadmium[1,2]	0.00021	<0.0001	0.00003	0.00004	86.8	59.9
Chromium[1,2]	0.171	0.0004	0.0004	0.0005	99.8	-9.9
Copper[1,2]	0.014	0.004	0.0006	0.002	96.2	50.4
Lead[1,2]	0.016	0.0001	0.00009	0.00007	99.5	40.3
Nickel	0.305	0.009	0.010	0.010	96.8	-8.3
Zinc[1]	0.061	0.004	0.002	0.004	95.9	7.5

[1]Uncertainty regarding a few of the dissolved metal concentrations. Actual average concentrations may be lower than those reported.
[2]Uncertainty regarding a few of the total metal concentrations. Actual average concentrations may be lower than those reported.

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TABLE 12
Comparison of 2010 and 2011 effluent data from the Snap Lake Mine WTP with current licence limits (total metals)

Parameter	2010 SLM WTP Effluent Average (mg/L)	2010 SLM WTP Effluent Maximum (mg/L)	2011 SLM WTP Effluent Average (mg/L)	2011 SLM WTP Effluent Maximum (mg/L)	June 14, 2012 Average Monthly Limit (mg/L)	June 14, 2012 Maximum Grab Limit (mg/L)	In Compliance?
Aluminum	0.059	0.124	0.030	0.160	0.1	0.2	Yes
Arsenic	0.0005	<0.004[1]	0.0001	<0.004[1]	0.007	0.014	Yes
Chromium	0.002	0.01	0.0005	<0.003[1]	0.01	0.02	Yes
Copper	0.001	<0.004[1]	0.0005	<0.004[1]	0.003	0.006	Yes
Lead	0.0003	0.0011	0.00009	<0.0004[1]	0.005	0.010	Yes
Nickel	0.013	0.040	0.010	0.013	0.05	0.10	Yes
Zinc	0.004	<0.016[1]	0.0025	<0.016[1]	0.01	0.02	Yes

[1]The maximum concentration was listed as "<" µg/L; not clear how much less

TABLE 13
Comparison of dissolved metal concentrations in the mine water with current effluent licence limits

Metal	Dissolved Metal Concentration in Mine Water (mg/L)			2012 Effluent Average Monthly Limit (mg/L)	2012 Effluent Max Grab Limit (mg/L)	Dissolved Metals below limit?
	Minimum	Average	Maximum			
Aluminum	0.005	0.015[1]	0.054	0.1	0.2	Yes
Arsenic	0.0001	0.0004[1]	<0.0016[2]	0.007	0.014	Yes
Chromium	0.0001	0.0004[1]	<0.008[2]	0.01	0.02	Yes
Copper	0.0008	0.0039	0.0127	0.003	0.006	No
Lead	0.00005	0.00012[1]	<0.0004[2]	0.005	0.010	Yes
Nickel	0.0075	0.0088	0.0111	0.05	0.10	Yes
Zinc	0.0012	0.0043[1]	0.0101	0.01	0.02	Yes

[1]Uncertainty regarding a few of the dissolved metal concentrations. Actual average concentrations may be lower than those reported.
[2]The maximum concentration was listed as "<" µg/L; not clear how much less

Expansion of the Snap Lake Mine WTP to 45 ML/d will require a secondary treatment train. Compliance with current limits for aluminum, arsenic, chromium, and copper should be attainable as long as the secondary treatment train incorporates conventional treatment, including optimized coagulation, clarification, and filtration processes. The existing WTP includes the option for lime addition to the reactor tank to induce the precipitation of dissolved metals. Likewise, provisions for lime addition could be integrated in the secondary treatment train to ensure continued compliance in the future if licence requirements become more stringent and the removal of dissolved metals is necessary.

If RO membranes are incorporated into the Snap Lake Mine WTP to remove nitrate, chloride, and fluoride, they will also remove dissolved metals. However, lime softening may be required as a pretreatment step to remove potential membrane foulants. Some minerals/metals present in the mine water can cause scale formation on the surface of RO membranes. These minerals/metals include aluminum, iron, manganese, barium (barium sulphate), strontium (strontium sulphate), and calcium (calcium carbonate and calcium sulphate).

To minimize scale formation, RO manufacturers typically recommend that combined iron levels in the feed water are less than 0.05 mg/L. Total iron concentrations in the effluent at the existing Snap Lake Mine WTP have exceeded 0.05 mg/L in the past, reaching up to 0.35 mg/L on July 14, 2010. The majority of this iron is insoluble and can foul the front end of an RO system; hence, pretreatment with lime softening is required to prevent fouling. Similarly, potential RO fouling can occur if the aluminum or manganese concentration reaches 0.05 mg/L. Effluent levels of manganese at the Snap Lake Mine WTP are typically higher than 0.05 mg/L and the majority of manganese is present in the dissolved form (soluble). Aluminum levels are typically lower than 0.05 mg/L but can

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exceed on occasion. Lime softening is very effective at removing dissolved iron and manganese from water and moderately effective at removing dissolved aluminum.

Due to their low solubility, very low levels of barium or strontium in the feed water can cause membrane fouling. Barium levels in the effluent at the Snap Lake Mine WTP are typically less than 0.05 mg/L. On the other hand, strontium is present in very high concentrations (1 to 3 mg/L) in the Snap Lake Mine WTP influent and it is not reduced significantly through conventional treatment; the effluent concentration is typically greater than 1 mg/L and present in the dissolved form. These contaminants may not be reduced significantly during lime softening and will require the addition of an antiscalent prior to the RO membrane to limit scale formation.

5.4 Major Ion Removal

The existing Snap Lake Mine WTP is not designed to remove dissolved ions during treatment. On June 14, 2012, new licence limits came into effect for chloride and sulphate. The 2011 effluent concentrations of chloride and sulphate were found to comply with these new limits (Table 14). However, the licence limits for chloride will be further reduced in 2015 (on January 1) and a new limit will come into effect for fluoride. Mine water and WMP concentrations of chloride and fluoride measured in 2011 exceed the 2015 limits; hence, the water will need to be treated to remove these ions.

TABLE 14
Comparison of 2011 Chloride, Fluoride, Sulphate Data with 2012 and 2015 Licence Limits

Parameter	SLM WTP Effluent Minimum (mg/L)	SLM WTP Effluent Average (mg/L)	SLM WTP Effluent Maximum (mg/L)	June 14, 2012 Average Monthly Limit (mg/L)	June 14, 2012 Maximum Grab Limit (mg/L)	Jan. 1, 2015 Average Monthly Limit (mg/L)	Jan. 1, 2015 Maximum Grab Limit (mg/L)	In Compliance?
Chloride	168	237	316	310	640	160	320	Not with 2015
Fluoride	0.292	0.359	0.432	n/a	n/a	0.15	0.3	Not with 2015
Sulphate	39.5	46.0	60.5	75	150			Yes

Treatment technologies that will remove chloride from water, as well as sulphates and fluoride, include ion-exchange, RO, EDR, and distillation. Fluoride can also be removed using adsorption processes (activated alumina) or with lime softening.

5.4.1 Scale of Treatment

To comply with the 2015 limits for chloride and fluoride, both the mine water and WMP water will need to be treated for the removal of these ions, as the 2011 chloride and fluoride concentrations in the mine water and WMP exceed the future 2015 limits (Figure 12 and 13).

As shown in Figure 12, current effluent concentrations of fluoride approach 0.4 mg/L and can be higher on occasion. The fluoride concentration in the effluent is similar to that of the mine water. In 2010, the fluoride concentrations measured at the Snap Lake water intake were all less than 0.1 mg/L; hence, the fluoride concentrations in the mine water exceed background levels. Fluoride is likely entering the mine water during the mining process, as it can occur naturally in groundwater due to weathering of rocks containing fluoride bearing minerals (such as apatite, fluorite, and biotite). The WMP water can contain even higher concentrations of fluoride than present in the mine water; however, this does not appear to significantly increase the effluent concentration above that of the mine water. To ensure compliance with the 2015 effluent limits, at least 65 percent of the fluoride in the mine water will need to be removed (this could increase depending on the recovery of the treatment process selected). Hence, the best strategy for fluoride removal at the Snap Lake Mine WTP is to treat the full influent flow. This includes treating the existing train and any additional treatment trains required to expand capacity to 45 ML/d.

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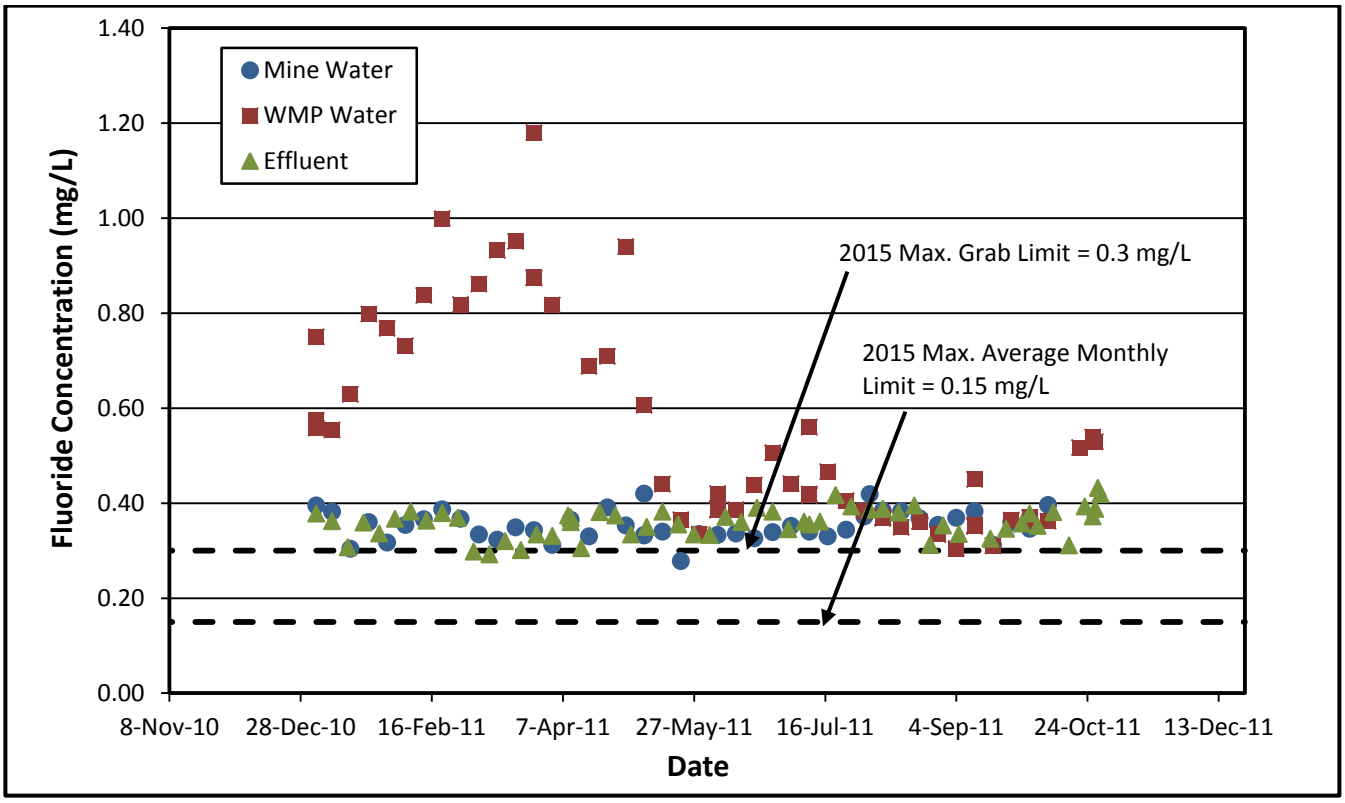
FIGURE 12
2011 Fluoride Concentrations in the Mine Water and WMP Compared with the 2015 Limits



Effluent chloride concentrations typically range between 200 and 300 mg/L (Figure 13). The mine water concentrations of chloride are similar to the effluent concentrations exiting the Snap Lake Mine WTP, suggesting that the WMP water has a negligible effect on the resulting effluent concentration. To comply with the 2015 maximum average monthly limit of 160 mg/L, approximately 50 percent of the chloride in the mine water must be removed during treatment. One option would be to treat the WMP water (100 percent) and approximately half of the mine water (~20 ML/d) with a secondary treatment train that removes a high percentage of chloride (≥90 percent). Under this scenario, chloride concentrations in the effluent would fall below 160 mg/L most of the time (Figure 14). Under the full treatment scenario, effluent chloride concentrations would fall below 30 mg/L most of the time (Figure 15).

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FIGURE 13
2011 Chloride Concentrations in the Mine Water and WMP Compared with the 2015 Limits

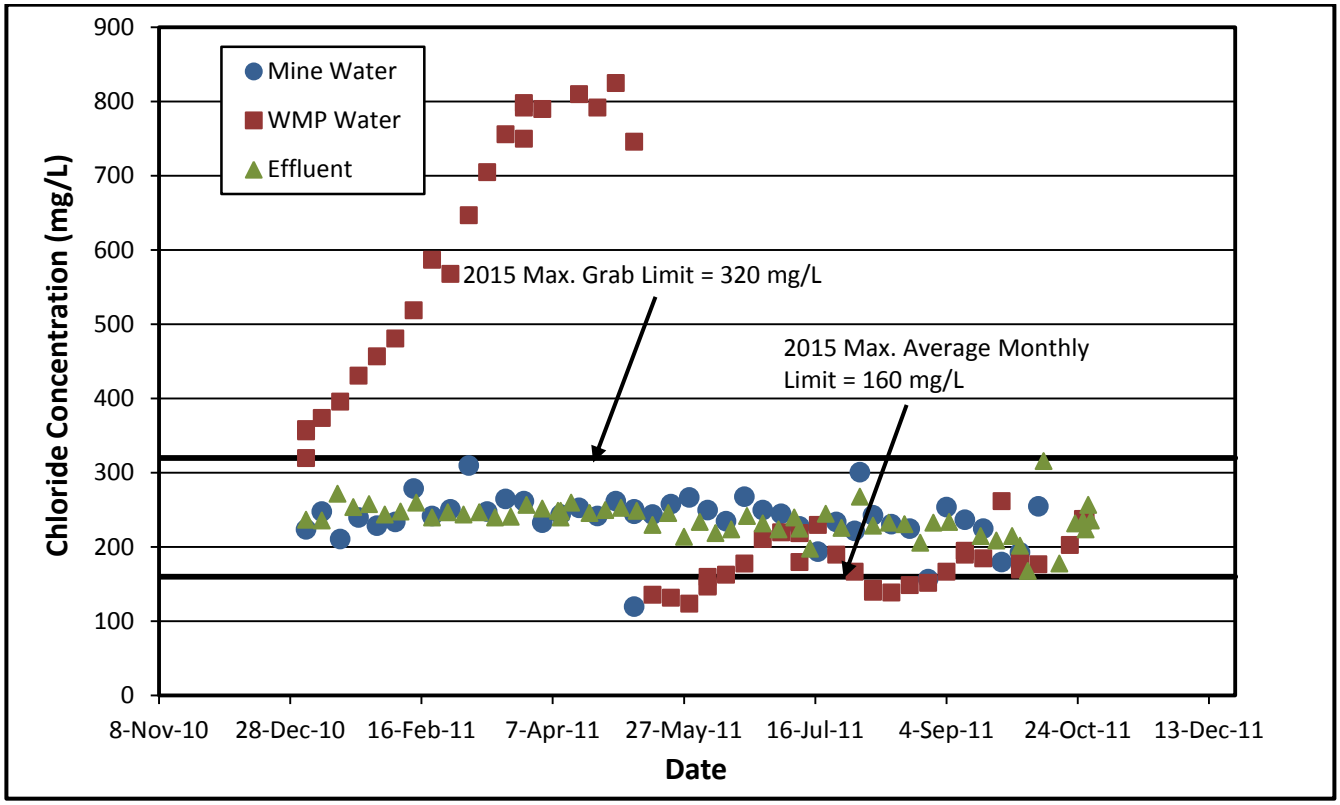

FIGURE 14
Estimated Chloride Concentration in the Snap Lake Mine WTP Effluent if 50 percent of Influent Mine Water and 100 percent of the WMP Water is Treated for Chloride Removal (≥90 percent). Estimates are Based on 2010-2011 Data

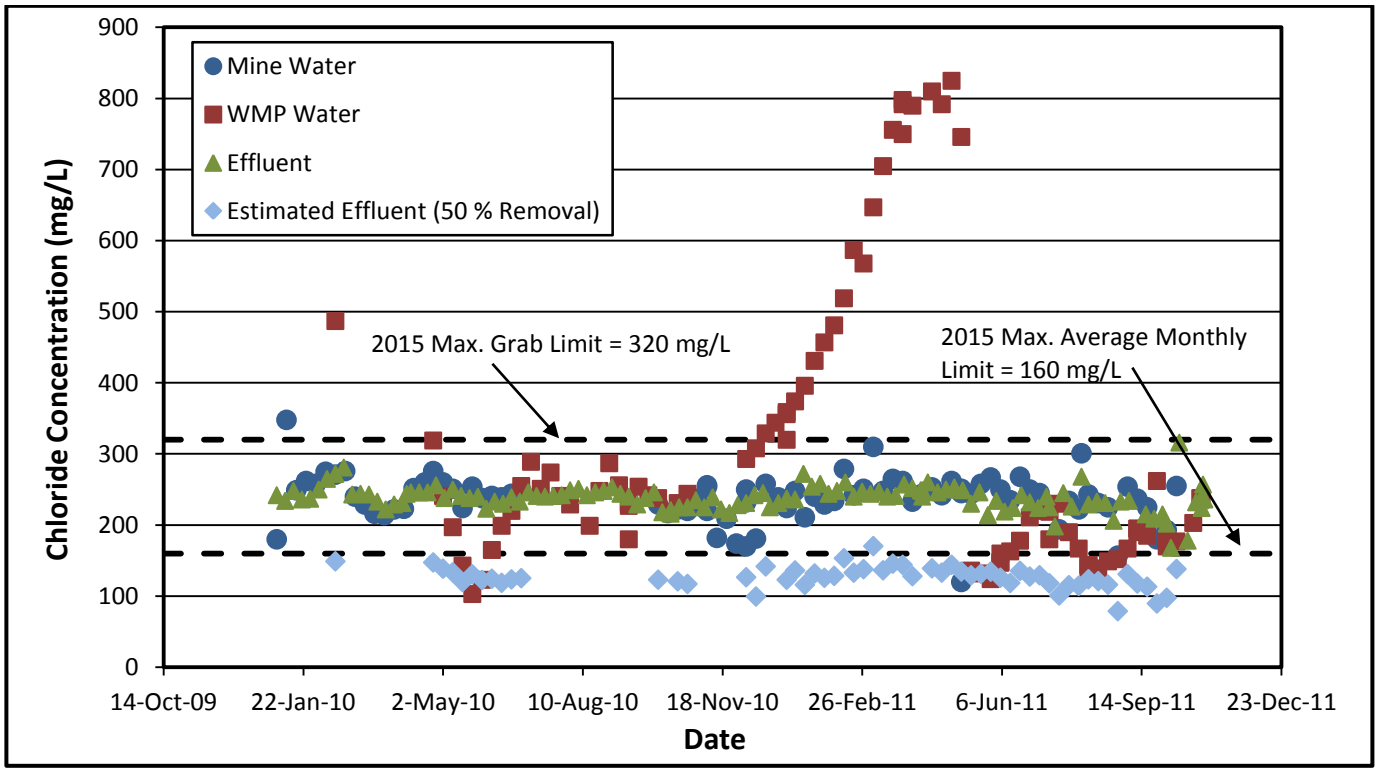

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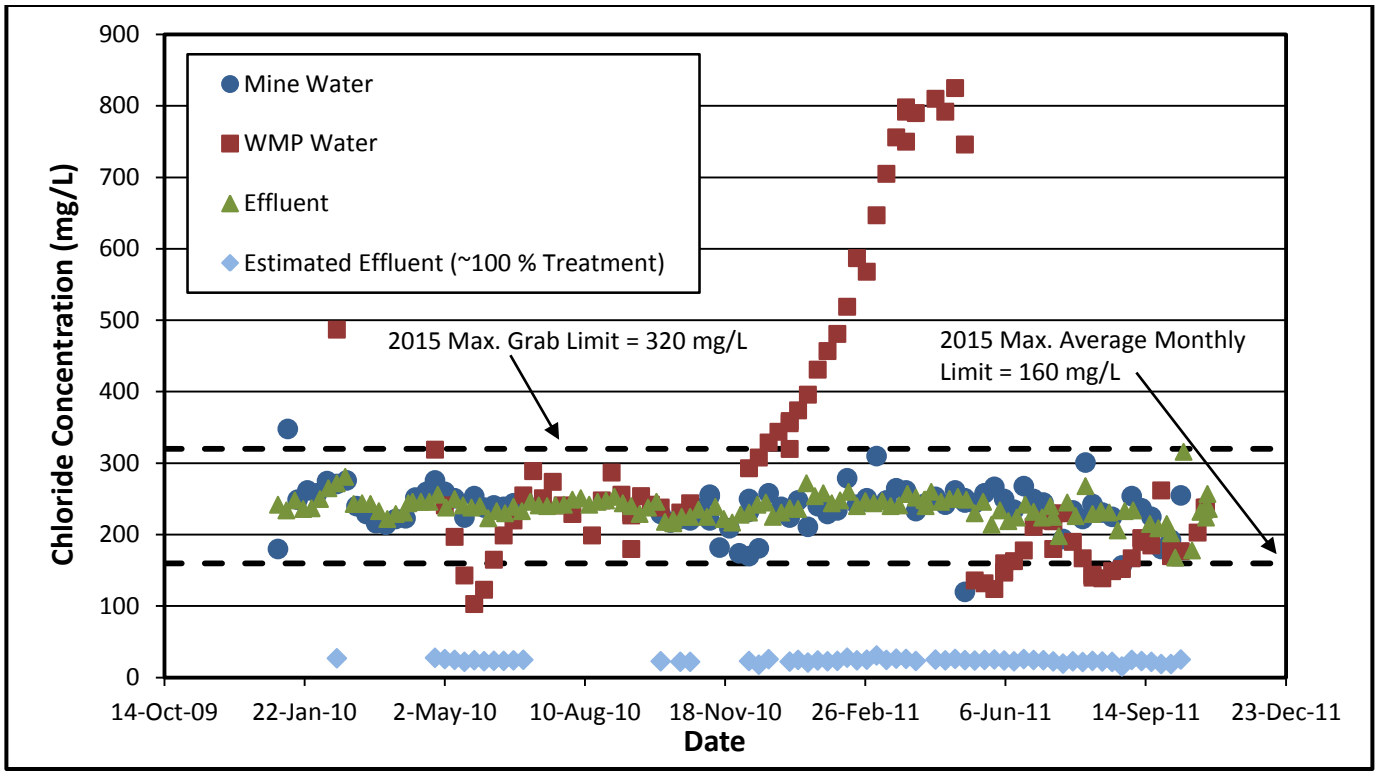
FIGURE 15
Estimated Chloride Concentration in the Snap Lake Mine WTP Effluent if 100 percent of Influent Mine Water and 100 Percent of the WMP Water is Treated for Chloride Removal (≥90 percent). Estimates are based on 2010-2011 data.



5.4.2 Treatment Options for Chloride and/or Fluoride Removal

Ion-Exchange

Strong base anion (SBA) or weak base anion (WBA) exchange resins can be used to remove chloride and other ions from water. SBA resins will remove all anions (bicarbonate, alkalinity, chloride, sulphate, nitrate, silica, etc.); while WBA resins preferentially remove strong acid anions (for example, chloride, sulphate and nitrate); WBA resin are used if the anions in a feed water are essentially all chlorides, sulphates, and nitrates. Chloride is removed when hydroxide ions on the resin are replaced with chloride ions. Hydroxide ions are released into the solution. Other anions, such as sulphate and nitrate, have a greater affinity for the anionic resins and will be removed to a greater degree than chloride. Once the resin has been exhausted it can be regenerated using a NaOH solution. Suspended solids and organics must be removed from the wastewater prior to treatment by ion exchange to prevent fouling of the resin.

A demineralization process is typically applied to remove chloride ions, rather than SBA or WBA resins on their own. This is to prevent the precipitation of calcium and magnesium onto the anion resin exchange sites (due to hydroxide ions). In demineralization, water is first sent through a strong base cation (SAC) exchange resin where cations (for example, calcium, magnesium, and sodium) are removed via exchange with hydrogen ions. Next the water is sent through the SBA or WBA where chloride and other anions are removed via exchange with hydroxide ions. The hydrogen and hydroxide ions combine to form water; hence, pH is not affected significantly. The SAC resin is regenerated using an acid solution (for example, sulphuric acid). Demineralization plants are typically limited by the anion exchange resins as service life is shorter for the anion resins and regeneration costs are higher.

Strong base anion exchange resins can be used to remove low concentrations of fluoride; however, they are typically not selected for treatment since the fluoride ion is weakly held and not well removed. The relative quantity of fluoride compared to other competing anions (such as chloride, sulphate, and nitrate) is very small; as such, the effective capacity of anion exchange resins for fluoride is quite low. Additionally, since fluoride is weakly

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held by SBA resins, if the process is over-run, it can be dumped into the effluent at concentrations greater than the influent loading. In anion exchange, fluoride is removed when chloride ions on the resin are replaced with fluoride ions. Hence, the chloride concentration in the effluent will increase, which is not desirable at the Snap Lake Mine WTP. Furthermore, high TDS levels (> 500 mg/L) can decrease IX capacity and hinder the IX reaction. The Snap Lake mine water and effluent often contains over 500 mg/L of TDS.

Reverse Osmosis

RO is an effective process for removing chloride from drinking water. Removals greater than 95 percent can be achieved. Additionally, the US EPA has identified RO as a Best Available Technology (BAT) for the control of fluoride in drinking water; 85 to 95 percent of fluoride can be removed with RO. Removal efficiency depends upon pH, membrane characteristics, flow rate, feed water composition, and the initial feed water fluoride concentration. Pretreatment of the feed water is required to prevent membrane fouling and scaling. Disadvantages of RO include its high capital cost, high operational costs, high energy consumption, and high water loss (20 to 40 percent).

Electrodialysis Reversal

For high initial feed water concentrations (>100 mg/L), removals of chloride by EDR can range from 70 to greater than 90 percent depending on the number of desalting stages. Additionally, EDR is can achieved 85 to 95 percent removal of fluoride.

Less pretreatment is typically required with EDR compared to RO, as EDR membranes are more durable, can operate over a wide range of pH values, can withstand high cleaning temperatures, are more resistant to organics, and are chlorine tolerant. Process efficiency is not affect by silica, as with RO, and membranes are tolerant to the turbidity values typically achieved following clarification and media filtration processes. The guideline for maximum feed water turbidity is 0.5 NTU. Additionally, antiscalents are not required to prevent membrane fouling.

Similar to RO, the disadvantages of EDR include its high capital cost, high operational costs, high energy consumption, and high water loss (10 to 30 percent). The product recovery ratio can sometimes be higher than with RO.

Distillation

Treatment by distillation involves the separation of ions from water by vaporization and then condensation to turn the vapour back to water. Chloride salts and fluoride are left behind when the water vaporizes; additionally, distillation will remove nitrate from the water. Distillation is an expensive process (high capital costs and high energy consumption) and it’s typically limited to applications were a high degree of treatment is required for contaminants that cannot be removed by any other means. Since thermal energy makes up the majority of operating costs, distillation can become more economically feasible if a source of waste heat is available from another process (for example, power production). As with RO, distillation processes produce a concentrated waste stream that must be disposed of. Recovery ratios for distillation plants are low (~50 percent), typically less than those observed for membrane processes.

The boiling chamber in a distillation process requires periodic cleaning to remove the accumulated minerals and prevent scaling. Calcium sulfate, magnesium hydroxide, and calcium carbonate can cause scaling on heat exchanger tube surfaces; scaling is typically controlled using an antiscalent or by operating at a lower temperature. Pretreatment with nanofiltration can also be used to reduce the potential of calcium sulfate scaling. Corrosion can be controlled by adjusting the operating temperature and pH, and/or by limiting the concentration of corrosive gases and chloride ions in the feed water. Sand must be removed before the evaporator with sedimentation to prevent erosion of tubing surfaces and the plugging of spray nozzles.

Adsorption

Adsorption processes, such as activated alumina and powdered activated carbon (PAC) have been used to remove fluoride from water. The US EPA has identified activated alumina as another BAT for the control of fluoride in drinking water.

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Activated alumina is primarily composed of aluminum oxide that is ground into the granular form and has been exposed to high temperature and caustic soda. As fluoride accumulates on the surface of the alumina media, adsorption capacity decreases and less fluoride is removed. Hence, alumina must be periodically replaced or regenerated to continue removing fluoride. Spent regenerant can be treated with lime or dried in evaporation ponds. Activated alumina can be advantageous compared to other fluoride removal techniques (such as ion-exchange) as it is not affected significantly by competing anions such as sulphate, nitrate, or chloride and it will adsorb fluoride without releasing aluminum ions into the water. Additionally, compared with RO, treatment with activated alumina is more economical, as a smaller waste stream is generated (typically 3 percent), lower costs are associated with equipment and operation, and the activated alumina process consumes less energy.

Adsorption with activated alumina is generally is most effective at a slightly acidic pH (5.5 to 6.5). At the Snap Lake Mine WTP, the influent pH of the mine water is typically close to 8; hence, sulphuric acid would need to be added prior to treatment with activated alumina to maximize effectiveness. Additionally, the pH would need to be raised to between 7 and 8 following treatment, prior to discharge into Snap Lake. Treatment is less effective in waters containing a high concentration of compounds that can interfere with the adsorption process. Compounds such as metal hydroxides, suspended solids, carbonates, and adsorbed silicates can reduce the adsorption capacity of activated alumina (Health Canada, 2010). Treatment with activated alumina would need to follow coagulation, sedimentation and filtration to reduce the feed water TSS and prevent clogging.

Fluoride removals with activated alumina have been reported to range from less than 50 percent, to 100 percent, in bench- and pilot-scale experiments (US EPA, 2012). Most of these studies have focused on reducing elevated concentrations of fluoride (>4.0 mg/L) to achieve an effluent concentration less than 1 mg/L; however, few studies have been completed to assess fluoride reduction in waters with low influent concentrations (< 1 mg/L), such as in case of the Snap Lake Mine WTP influent (0.3 to 0.43 mg/L). In the majority of studies, the effluent concentrations reported typically exceeded 0.2 mg/L, which is greater than the maximum average monthly effluent limit for 2015. Furthermore, the capacity of activated alumina for fluoride has been found to be reduced with a decrease in influent fluoride concentration (Health Canada, 2010). Without bench or pilot-scale testing on the mine water, it is uncertain whether activated alumina can be used to consistently reduce fluoride concentrations below the 2015 effluent limits.

PAC has been found to be effective at removing fluoride from drinking water at a pH of 3.0 or less (up to 100 percent removal); however, at a pH of 8, removals less than 5 percent have been observed (US EPA, 2012).Due to the low pH required for effective removal, the use of PAC for fluoride removal is limited.

Lime Precipitation

Fluoride can be precipitated as calcium fluoride at an alkaline pH (10 to 11) through the addition of lime. Calcium fluoride has a minimum solubility of 7.7 mg/L. Theoretically, the lowest fluoride concentration achievable by lime precipitation is 8 mg/L; however, lower fluoride concentrations (≤ 1 mg/L) have been observed following treatment. Removals up to 80 percent have been reported (US EPA, 2012). Source water quality can influence fluoride removal through lime precipitation. Higher removal of fluoride can occur in waters with higher magnesium concentrations as precipitation of fluoride can also occur as a coprecipitation process with magnesium hydroxide.

Since the influent concentration of fluoride entering the Snap Lake Mine WTP is already less than 1 mg/L, lime softening will not be an effective treatment to remove additional fluoride to comply with the 2015 licence limits. However, lime softening may still be necessary as a pretreatment, if RO is selected to remove chloride and fluoride, to precipitate silica and dissolved metals (such as iron and manganese) that can cause scaling/fouling problems.

5.4.3 Summary of Treatment Technologies for Fluoride and Chloride Removal

A summary of the different treatment process for removing chloride and fluoride are shown in Table 15.

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TABLE 15
Treatment Technology Comparison (References: Pickard, 2004; Feenstra et al., 2007)

Treatment Technologies	Removal Efficiency		Water Loss	Optimal Conditions	Advantages	Disadvantages
	Fluoride	Chloride				
Ion Exchange	Low	65 to >90%	1 to 2%	pH 6.5 to 9 (decreased efficiency at high pH) <50 mg/L SO_4 <5 mg/L NO_3 Low turbidity (<0.3 NTU) <500 mg/L TDS	• Can also remove some nitrate • Smaller waste stream that RO or EDR	• Moderate capital cost • Moderate to high O & M costs • Low capacity for fluoride • Can impart chloride into the water • Demineralization IX may be required to remove chloride • Capacity affected by competing ions, turbidity, and TDS
Reverse Osmosis	85 to 95%	>95%	20 to 40%	<30 mg/L of silica; no particulates Slightly acidic pH (5.5 to 6.0)	• Treats for both chloride and fluoride • Can also remove nitrate	• High capital and O & M costs • High energy consumption • High water loss • Inference by turbidity and silica • Requires pretreatment and may require post-treatment (pH alkalinity adjustment) • Brine stream must be disposed of
EDR	85 to 95%	70 to >90%	10 to 30%	Treats most waters without preference; most economical for TDS of 3000 to 5000 mg/L; maximum turbidity = 0.5 NTU	• Treats for both chloride and fluoride • Can also remove nitrate • Not affected by silica concentrations in the feed water	• High capital and O & M costs • High energy consumption • High water loss • Brine stream must be disposed of
Distillation	>99%	>99%	50%		• Can be more economic is waste heat is available • Removes chloride fluoride, and nitrate	• Higher capital costs and energy requirements compared with membrane processes • Large footprint

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TABLE 15
Treatment Technology Comparison (References: Pickard, 2004; Feenstra et al., 2007)

Treatment Technologies	Removal Efficiency		Water Loss	Optimal Conditions	Advantages	Disadvantages
	Fluoride	Chloride				
					• High quality water produced • Less monitoring than for membrane processes • No membrane replacement	• Lower recovery ratios than membrane processes • Pretreatment required to prevent scaling and corrosion of plant components
Activated Alumina	<50 to 100% (most removals have been reported for influent conc. > 1 mg/L)	-	1 to 2%	pH of 5.5 to 6.5 <30 mg/L Silica low turbidity	• Smaller waste stream • Low energy consumption • Low water loss (3 to 5%) • Sludge typically non-hazardous	• Requires pH adjustment before and after treatment • Periodic regeneration • Chemical and sludge handling required • Will not remove chloride and nitrate
Lime Precipitation	Up to 80 % removal at high fluoride conc.; not very effective at lower fluoride conc.	-	1 to 2%	Precipitation occurs at an alkaline pH (10 to 11)	• Easy to operate • Provisions for lime softening already at the Snap Lake WTP	• Not very effective at low fluoride concentrations (< 1 mg/L) • Will not remove chloride or nitrate • Requires sludge handling and disposal • Requires post-pH adjustment

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SECTION 6

Treatment Technology Screening

Potential technologies for treating mine water at the Snap Lake Mine WTP to comply with the current and future licence requirements were screened to determine the suitable alternatives for a secondary treatment train and additional treatment on the existing train. A summary of the selection process for each contaminant is shown in Table 16.

TABLE 16
Treatment Technology Screening

Contaminant	Scale of Treatment	Potential Treatment Options	Compliance with Future Licence Requirements?	Alternatives Selection
TSS	Full Influent Flow (remove >90%)	• High Rate Clarification • Media Filtration • MF/UF Membrane Filtration	• High Rate Clarification • Media Filtration • MF/UF Membrane Filtration	• High Rate Clarification • Media Filtration • MF/UF Membrane Filtration
Nitrate	Partial (remove >50% of mine water nitrate; with >90 removal of WMP nitrate)	• Nitrate Selective IX • Reverse Osmosis • Distillation • Electrodialysis Reversal • Membrane Bioreactor	• Nitrate Selective IX • Reverse Osmosis • Distillation • Membrane Bioreactor	• Reverse Osmosis
Metals	Full Influent Flow (remove >90% for some metals)	• Particulate: Conventional Treatment (clarification /sedimentation/filtration) • Dissolved: Lime Softening	• Conventional Treatment (clarification/sedimentation/ filtration)	• High Rate Clarification • Media Filtration or MF/UF • Lime Softening[1]
Chloride	Partial (remove >50% chloride)	• IX/Demineralization • Reverse Osmosis • Distillation • Electrodialysis Reversal	• IX/Demineralization • Reverse Osmosis • Distillation • Electrodialysis Reversal	• Reverse Osmosis
Fluoride	Full Influent Flow (remove ~65% fluoride)	• IX • Reverse Osmosis • Distillation • Electrodialysis Reversal • Activated Alumina • Lime Precipitation	• Reverse Osmosis • Electrodialysis Reversal • Distillation • Activated Alumina[2]	• Reverse Osmosis

[1]Not required to achieve current and future licence limits for metals but may be required as a pretreatment for RO
[2]Uncertain whether activated alumina can be used to consistently reduce fluoride concentrations below the 2015 effluent limits; bench/pilot-scale studies could be carried out to confirm.

The secondary treatment train will require a high rate clarification process, followed by gravity media filtration or an alternative filtration process (for example, MF/UF membrane filtration) to comply with the current and future licence limits for TSS and heavy metals. Precipitation of dissolved metals with lime softening is not required at the Snap Lake Mine WTP to meet the current effluent licence requirements, as the dissolved fraction of regulated metals in the WTP influent are low and conventional treatment can achieve high removals of the particulate metals. However, incorporating provisions for lime softening into the secondary treatment train will ensure continued compliance in the future if licence requirements become more stringent and the removal of dissolved metals is necessary. Additionally, if RO membranes are incorporated into the Snap Lake Mine WTP to remove

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nitrate, chloride, and fluoride, lime softening will likely be required as a pretreatment step to remove potential membrane foulants.

The secondary treatment train and the existing WTP plant will require additional treatment to comply with the future licence limits for nitrate, chloride, and fluoride. For nitrate removal, EDR was eliminated as a treatment option since it has a lower rejection rate of nitrate than the other technologies. Additionally, EDR systems are typically more costly than RO, more complex, and can be difficult to operate and maintain. Treatment with an MBR was deemed non-viable due to its high costs and complex biological requirements (i.e. temperature, external carbon source, dissolved oxygen, etc.). For fluoride removal, lime precipitation was eliminated as a treatment option since it is not be capable of achieving high enough removals of fluoride to comply with the future licence requirements. The efficiency to which activated alumina or IX processes can remove fluoride from an industrial mine water with a low influent fluoride concentration and high TDS is uncertain. These options could potentially be explored further through bench/pilot-scale testing. While distillation can achieve high removals of all three contaminants, it was deemed to be not economically viable, as it would require a large input of thermal energy and has a very low recovery ratio (~50 percent). As a worst case scenario, RO was selected over other potential treatment options in the absence of bench/pilot-scale testing to ensure compliance with the 2015 effluent licence requirements for fluoride, chloride, and nitrate.

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SECTION 7

Treatment Train Alternatives

Alternative treatment trains were investigated under two different treatment scenarios to allow for cost comparisons to be made regarding treatment options to comply with the current and future licence limits. Under Scenario No. 1, alternative treatment trains were considered to expand the plant capacity to 45 ML/d, while continuing to comply with the current licence requirements. Under Scenario No. 2, alternative treatment trains, including additions to the existing treatment train, were considered to comply with the 2015 licence requirements and to expand treatment capacity to 45 ML/d.

7.1 Scenario 1: Current Licence Requirements

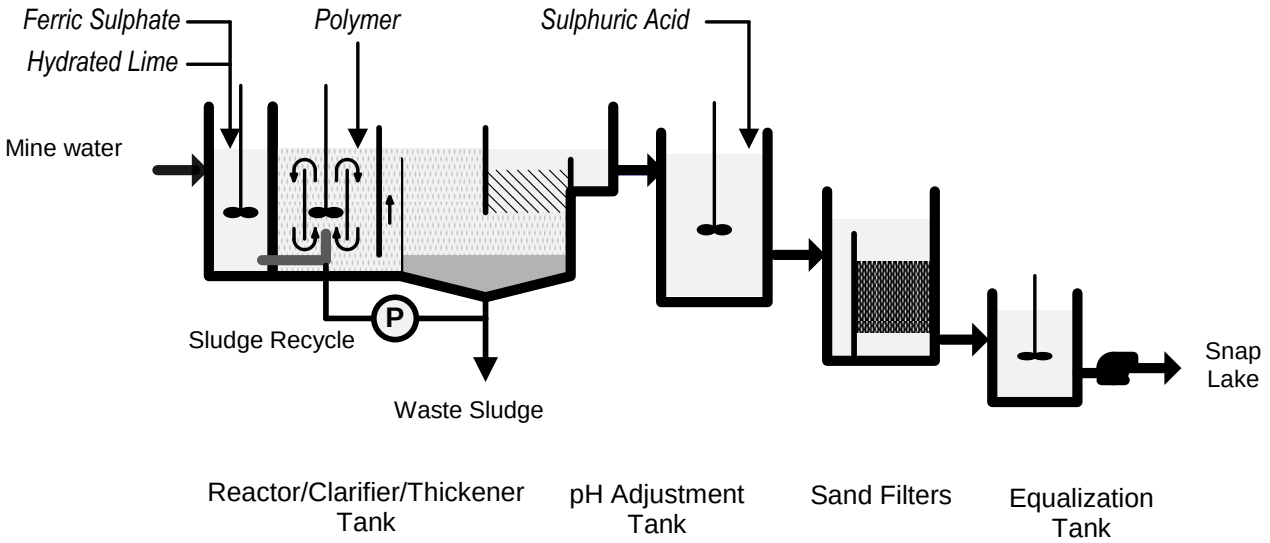
Based on the treatment technologies selected through the screening process, secondary treatment trains were investigated for the Snap Lake Mine WTP to expand capacity to 45 ML/d and to ensure compliance with the current licence requirements. Each alternative includes a high rate clarification process to remove TSS and metals, followed by polishing filters to further reduce TSS:

- Alternative 1: Densadeg® with Continuous Backwash Filters
- Alternative 2: Actiflo® Package Plant Clarifier and Polishing Filter

7.1.1 Alternative 1: Densadeg® Integrated Reactor/Clarifier/Thickener with Continuous Backwash Filters

The secondary train will be able to treat an average flow of 20 ML/d and a maximum flow of 25 ML/d. Treatment will consist of coagulation (with optional lime precipitation), flocculation, clarification and thickening, and filtration. All processes prior to filtration will be provided for with the Densadeg® Integrated Reactor/Clarifier/Thickener. Chemical feed systems will be required for coagulation, flocculation, and pH adjustment prior to filtration. A process schematic of the secondary treatment train is shown in Figure 16.

FIGURE 16
Process Schematic of the Secondary Treatment Train Equipped with Densadeg® and Continuous Backwash Sand Filters



Process Description

Coagulation

Coagulation will occur in a single rapid mix tank (RMT) with the addition of ferric sulphate and hydrated lime at a pH of 9 to 10. Ferric sulphate serves as a co-precipitating agent to enhance heavy metal removal. Hydrated lime is added to the RMT to adjust and maintain the pH between 9 and 10 and provide alkalinity. The coagulant will react

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with the alkalinity in the water to create pin flocs of ferric hydroxide that can settle rapidly in the clarification tank.

Flocculation

Flocculation will occur in a single Densadeg® Reactor Tank with the addition of an anionic polyelectrolyte (polymer). The polymer is added to bridge between the pin flocs and create larger floc which will settle faster during clarification. Additionally, a portion of the thickened sludge (recycled from the clarifier) is injected into the Reactor Tank to promote the formation of dense floc particles.

Clarification

Clarification and thickening will occur in a single Densadeg® Clarifier Tank. Flocs will settle to the bottom as the clarifier and collect as sludge, which is compacted by gravity and further thickened by a rotating scraping mechanism. A portion of the sludge is recycled back to the Reactor Tank to promote the densification of the floc particles. The sludge densification that is achieve through internal and external sludge recirculation, leads to a thick sludge, ranging from 2 to 5 percent solids by weight. The upper portion of the Clarifier Tank contains lamella settling modules to catch light particles that would otherwise carry-over into the settled water. The TSS in the settled water is typically less than 5 mg/L (less than the current/future licence effluent limit of 7 mg/L).

pH Adjustment Tank

Prior to the filtration process, sulphuric acid will be added to the settled water in a pH Adjustment Tank to bring the pH back down, between 7 and 7.5.

Filtration

Following treatment with the Densadeg®, the settled water will require further polishing to remove suspended solids and turbidity. This will be accomplished by conventional gravity media filtration or continuous backwash sand filters. Continuous backwash filters can efficiently filter out heavy metal flocs that carry over from the clarification process at a high flow rate.

Parkson Corporation manufactures the Dynasand® filter, an upflow, deep bed, granular media filter with continuous backwash. The deep media bed allows the filters to handle a higher loading of suspended solids. For an influent TSS concentration of 15 mg/L, the Dynasand® filter can achieve an effluent TSS concentration of 5 mg/L, which would comply with the current max grab licence limit at the Snap Lake Mine WTP (7 mg/L). The Dynasand® filter media is cleaned by a simple internal washing system and does not require backwashing pumps or storage tanks; hence, the filters have low energy consumption.

Equalization Tank

Filtered water will flow by gravity to an equalization tank. Finished water in the equalization tank will be pumped for discharge into Snap Lake, with the option to divert a portion of the flow to the process plant.

Preliminary Equipment List

The Densadeg® Integrated Reactor/Clarifier/Thickener comes equipped with:

- Rapid Mix Tank (1)
- Densadeg® Reactor Tank (1)
- Densadeg® Clarifier/Thickener Tank with sludge scraper (1)
- Sludge Recycle/Blowdown Pumps contained on one skid (3 pumps)
  - One pump for recycle stream,
  - One pump for the sludge blowdown
  - One standby pump to serve as a backup for both the recycle stream pump and sludge blowdown pump
- Instrumentation and PLC control system

The specifications for tank size are presented in Table 17 below.

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TABLE 17
Specifications for the Components of the Densadeg® Integrated Reactor/Clarifier/Thickener

Component	Specification
Rapid Mix Tank	
Diameter (m)	4.4
Cylindrical Height (m)	6.9 SS
Reactor Tank	
Diameter (m)	7.6
Cylindrical Height (m)	6.4 SS
Clarifier/Thickener Tank	
Diameter (m)	11.6
Cylindrical Height (m)	6.4 SS

SS = seam-to-seam

The chemical feed systems and storage tanks required include:

- Hydrated lime chemical feed and storage
  - Lime hopper (1)
  - Screw feeder (1)
  - Lime slurry holding tank (1)
  - Lime dosing system skid with duty/standby metering pumps (2)
- Coagulant (ferric sulphate) chemical feed and storage
  - Coagulant mixing tank (1)
  - Coagulant holding tank (1)
  - Coagulant dosing system skid complete with three metering pumps (3)
- Polymer Dosing Package
  - Polymer preparation system (1)
  - Polymer dosing system skids (2) with duty/standby metering pumps (2)
- Sulphuric acid chemical feed
  - Sulphuric acid dosing system skid with duty/standby metering pumps (2)

Based on the assumption that approximately 50 mg/L of sulphuric acid would be required to adjust the pH of the mine water prior to filtration, 40,000 L of storage would be required for 30 days storage at 45 ML/d. The existing sulphuric acid storage at the Snap Lake WTP consists of three tanks, each with a capacity of approximately 90,000 L (Ø = 3.5 m, h = 9.76 m), and 270,000 L in total. Hence, there is already sufficient storage available onsite for sulphuric acid. Additional metering pumps would be required to dose sulphuric acid into the pH adjustment tank in the secondary treatment train.

To treat 25 ML/d, 20 continuous backwash filter modules would be required, installed within two common filter cells (10 modules per cell) in a concrete tank. The specifications for the continuous backwash filters are provided in Table 18.

TABLE 18
Specifications for the Dynasand® Continuous Backwash Filters

Component	Specification
Type	Continuous backwash filters
Number of filter cells	2
Number of modules per cell	10
Filtration area per module (m^2)	4.65
Filtration depth (m)	1.02
Design loading rate (m/h)	11,221 (all cells in service)
Design headloss across filter (m)	0.91

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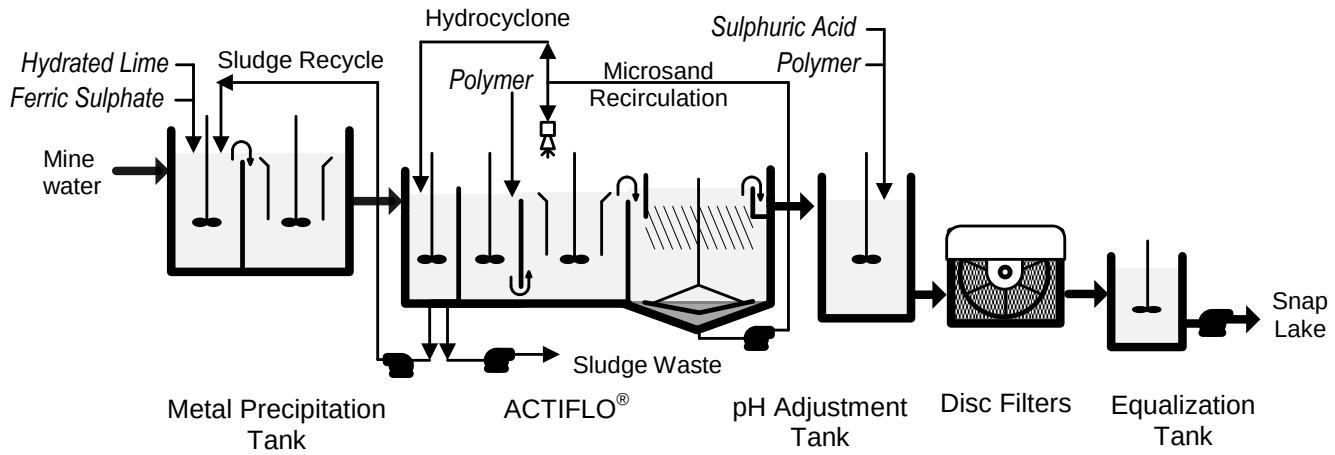
Component	Specification
Plant Dimensions, L x W x D (m)	23.7 x 4.9 x 5.9

7.1.2 Alternative 2: Actiflo® Package Plant Clarifier with Metal Precipitation and Polishing Filters

The second alternative combines high rate clarification via ballasted flocculation and lamella settling with filtration to treat a maximum flow of 25 ML/d. Treatment will consist of metal precipitation, coagulation, flocculation, sedimentation, and pH adjustment in two parallel trains and further polishing with disc filters (or conventional gravity media filtration). Chemical feed systems will be required for metal precipitation, coagulation, flocculation, and pH adjustment. A process schematic of the secondary treatment train is shown in Figure 17.

FIGURE 17
Process Schematic of the Secondary Treatment Train Equipped with Actiflo® Package Plant Clarifier and Filtration



Process Description

Metal Precipitation

The mine water flows through a Metal Precipitation Reactor to precipitate dissolved metals and remove TSS. Hydrated lime is added to the reactor to raise the pH between 9 and 10, so that the majority of metals will precipitate as hydroxides (pH can be optimized for metal removal). Ferric sulphate is added as the coagulant, which will form a ferric hydroxide floc that can adsorb a portion of the dissolved metals by coprecipitation and capture fine solids. Additionally, a large portion of the sludge recycled from the Actiflo® clarifier is sent back to the Metal Precipitation Reactor to act as a seed and aid in precipitation.

Coagulation/Flocculation

Next, the Metal Precipitation Reactor effluent flows into the coagulation chamber of the Actiflo® Package Plant Clarifier where the reaction is completed. In the flocculation chamber of the Actiflo®, an anionic polymer is added is added and microsand to initiate floc formation. Microsand provides a surface area to enhance flocculation and acts as a ballast or weight during sedimentation. The TURBOMIX™ draft tube in the flocculation chamber provides ideal conditions for bridging between the microsand and destabilized suspended solids.

Sedimentation

Ballasted flocs enter the clarification chamber in the Actiflo® and settle rapidly with the aid of lamella settling tubes. Sludge mixed with microsand is collected at the bottom of the clarifier and continuously pumped to a hydrocyclone, where the sand is separated from the sludge. The recovered microsand is recycled back into the flocculation chamber and the light density sludge is split; the majority of the sludge is recycled back into the Metal Precipitation Reactor to act as a seed for precipitation and the remaining sludge is sent to waste. Clarified water exits the Actiflo® and is sent to the filters for further polishing.

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pH Adjustment Tank

Clarified water from the Actiflo® flows into the pH Adjustment Tank where the pH is adjusted to between 7 and 7.5 with sulphuric acid. Polymer can also be added, prior to the filters, to agglomerate any residual suspended solids.

Polishing Filters

Settled water could be treated with conventional gravity media filtration or cloth-media disc filters to further reduce the suspended solids and turbidity. In disc filtration, solids are separated from the water via cloth filter media mounted on the two sides of the discs, which are partially submerged in the water. Filtered water flows into the collection tank, while solids are retained inside the media disc. Backwashing is automatically initiated when the water level in the inlet channel increases to a specific height. Solids from the filter media are washed into the collection trough as the discs are rotated.

Equalization Tank

Filtered water flows by gravity to an equalization tank. Finished water in the equalization tank will be pumped for discharge into Snap Lake, with the option to divert a portion of the flow to the process plant.

Preliminary Equipment List

The Actiflo® high rate clarification process comes equipped with:

- Metal Precipitation Reactor (2)
- Actiflo® Package Plant Clarifier (2), each includes:
  - Microsand recirculation line equipped with pumps (2) and hydrocyclone
  - Sludge pumps (2)
- pH Correction Reactor (2)
- Control Panel for All Equipment (1)

The chemical feed systems and storage tanks required include:

- Hydrated lime chemical feed and storage
  - Lime hopper (1)
  - Screw feeder (1)
  - Lime slurry holding tank (1)
  - Lime dosing system skid with duty/standby metering pumps (2)
- Coagulant (ferric sulphate) chemical feed and storage
  - Coagulant mixing tank (1)
  - Coagulant holding tank (1)
  - Coagulant dosing system skid complete with three metering pumps (3)
- Polymer dosing package, skid mounted
  - Automatic polymer preparation system (1)
  - Polymer dosing system skid (1) with three metering pumps (3)
- Sulphuric acid chemical feed and storage
  - Sulphuric acid dosing system skid with duty/standby metering pumps (2)
- Microsand for startup

Based on the assumption that approximately 50 mg/L of sulphuric acid would be required to adjust the pH of the mine water prior to filtration, 40,000 L of storage would be required for 30 days storage at 45 ML/d. The existing sulphuric acid storage at the Snap Lake WTP consists of three tanks, each with a capacity of approximately 90,000 L (Ø = 3.5 m, h = 9.76 m), and 270,000 L in total. Hence, there is already sufficient storage available onsite for sulphuric acid. Additional metering pumps would be required to dose sulphuric acid into the pH adjustment tank in the secondary treatment train.

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The equipment required for filtration includes:

- Hydrotech Discfilter (2), each includes:
  - Tank (1)
  - Drum (1)
  - Backwash pump (1)
  - Woven polyester filter media discs (12)

7.2 Scenario 2: Future Licence Requirements

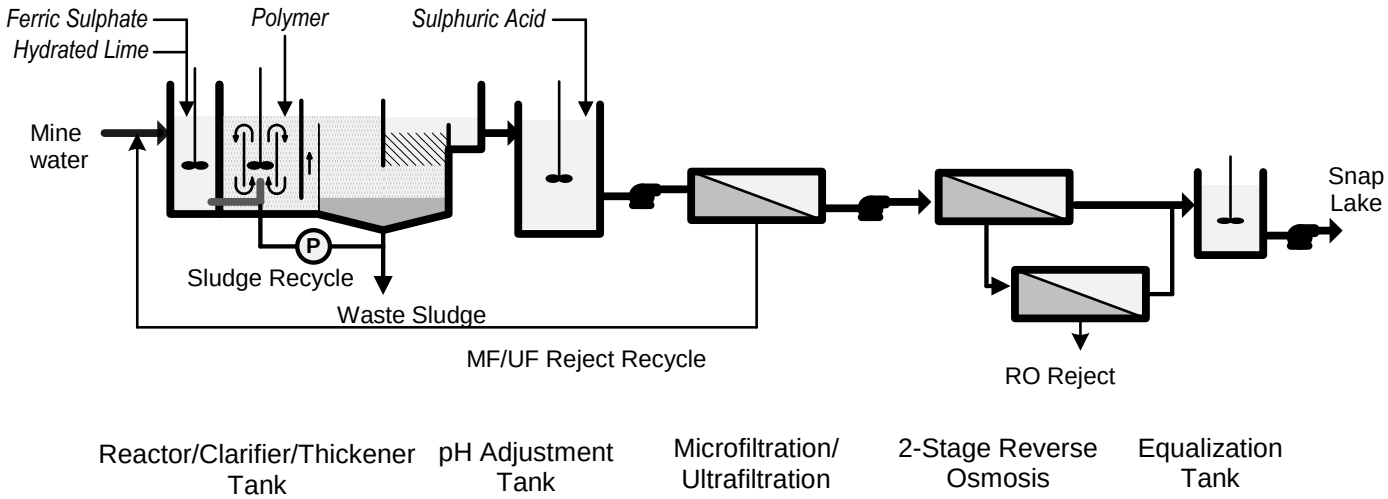
Based on the treatment technologies selected through the screening process, secondary treatment trains were investigated for the Snap Lake Mine WTP to expand capacity to 45 ML/d and to ensure compliance with the future 2015 licence requirements. Each alternative includes a high rate clarification process to remove TSS and metals, followed by MF/UF to further reduce TSS, and RO membranes to remove nitrate, chloride, and fluoride from the mine water. Options for the secondary treatment train include:

- Alternative 3: Densadeg® with MF/UF and RO
- Alternative 4: Actiflo® Package Plant Clarifier with MF/UF and RO

7.2.1 Alternative 3: Densadeg® Integrated Reactor/Clarifier/Thickener with Microfiltration/Ultrafiltration and Reverse Osmosis

The secondary train will be able to treat an average flow of 20 ML/d and a maximum flow of 25 ML/d. Treatment will consist of coagulation (with optional lime precipitation), flocculation, clarification and thickening, MF/UF, and RO. All processes prior to pH adjustment will be provided for with the Densadeg® Reactor/Clarifier/Thickener. Chemical feed systems will be required for coagulation, flocculation, and pH adjustment prior to the RO process. A process schematic of the secondary treatment train is shown in Figure 18.

FIGURE 18
Process Schematic of the Secondary Treatment Train Equipped with Densadeg®, Microfiltration/Ultrafiltration, and Reverse Osmosis



Process Description

Coagulation/Flocculation/Clarification

Coagulation will occur in a single rapid mix tank (RMT) with the addition of ferric sulphate and hydrated lime at a pH of 9 to 10 followed by flocculation will occur in a single Densadeg® Reactor Tank with the addition of an anionic polyelectrolyte (polymer). Additionally, a portion of the thickened sludge (recycled from the clarifier) is injected into the Reactor Tank to promote the formation of dense floc particles. Clarification and thickening will occur in a single Densadeg® Clarifier Tank. Flocs will settle to the bottom as the clarifier and collect as sludge, which is compacted by gravity and further thickened by a rotating scraping mechanism. The upper portion of the

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Clarifier Tank contains lamella settling modules to catch light particles that would otherwise carry-over into the settled water. The TSS in the settled water is typically less than 5 mg/L.

pH Adjustment Tank

Prior to the filtration process, sulphuric acid will be added to the settled water in a pH Adjustment Tank to bring the pH back down, between 7 and 7.5.

Microfiltration/Ultrafiltration and Reverse Osmosis Systems

The settled water will require further polishing to remove suspended solids and turbidity prior to the RO membrane. This will be accomplished by an MF/UF system. Reject water from the MF/UF system will be recycled to the front of the WTP, as it contains mostly solids which can be removed in the Densadeg®. Following MF/UF, the permeate is pumped through two stages of RO to remove nitrate, chloride, and fluoride from the filtered water to comply with the future 2015 effluent licence requirements. The addition of an antiscalent may be required prior to the RO process to minimize membrane fouling/scaling. Reject from the second stage RO will need to be managed. Options for treatment and disposal of RO brine are discussed following the description of the alternative treatment options.

Equalization Tank

Permeate from the RO system will flow by gravity to an equalization tank. Finished water in the equalization tank will be pumped for discharge into Snap Lake, with the option to divert a portion of the flow to the process plant.

Preliminary Equipment List

The preliminary equipment list and specifications for the Densadeg® Integrated Reactor/Clarifier/Thickener and chemical feed systems are listed under Alternative No. 1 in Section 7.1.1

The MF/UF system will include:

- MF/UF membranes, skid mounted (8 skids)
- MF/UF membrane feed pumps (8)
- MF/UF permeate tank (1)
- Low pressure permeate transfer pumps, skid mounted (2)
- Chemical enhanced backwash (CEB) skids, shared with RO system (5)
  - CEB tank (1 per CEB skid)
  - CEB pumps (2 per CEB skid)
- Controls

The RO system will include:

- Two stages of RO membranes, skid-mounted (12 skids)
- RO membrane feed pumps (12)
- RO permeate tank (1)
- Low pressure permeate transfer pumps, skid mounted (2)
- Chemical enhanced backwash (CEB) skids, shared with UF system (5)
  - CEB tank (1 per CEB skid)
  - CEB pumps (2 per CEB skid)
- Controls

7.2.2 Alternative 4: Actiflo® Package Plant Clarifier with Microfiltration/ Ultrafiltration and Reverse Osmosis

The second alternative combines high rate clarification via ballasted flocculation and lamella settling with MF/UF and RO to treat a maximum flow of 25 ML/d. Treatment will consist of metal precipitation, coagulation, flocculation, sedimentation, and pH adjustment, in two parallel trains, prior to the MF/UF and RO systems.

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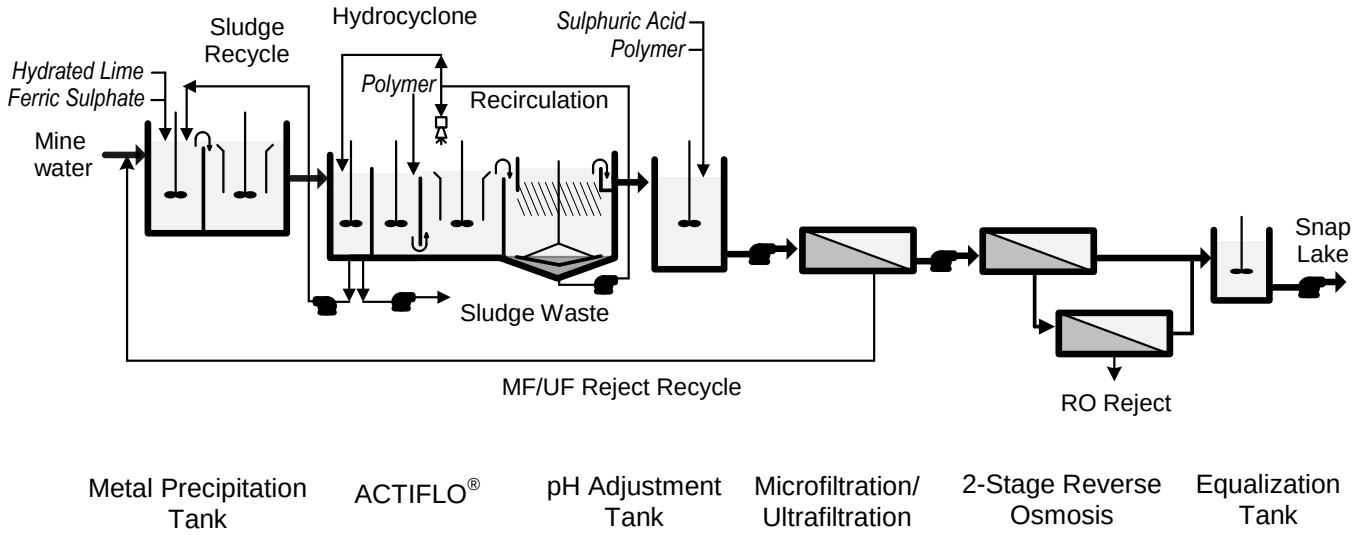
Chemical feed systems will be required for metal precipitation, coagulation, flocculation, and pH adjustment. A process schematic of the secondary treatment train is shown in Figure 19.

FIGURE 19
Process Schematic of the Secondary Treatment Train Equipped with Actiflo® Package Plant Clarifier, Microfiltration/Ultrafiltration, and Reverse Osmosis



Process Description

Metal Precipitation

The mine water flows through a Metal Precipitation Reactor to precipitate dissolved metals and remove TSS. Hydrated lime is added to the reactor to raise the pH between 9 and 10, so that the majority of metals will precipitate as hydroxides (pH can be optimized for metal removal). Ferric sulphate is added as the coagulant, which will form a ferric hydroxide floc that can adsorb a portion of the dissolved metals by coprecipitation and capture fine solids. Additionally, a large portion of the sludge recycled from the Actiflo® clarifier is sent back to the Metal Precipitation Reactor to act as a seed and aid in precipitation.

Coagulation/Flocculation

Next, the Metal Precipitation Reactor effluent flows into the coagulation chamber of the Actiflo® Package Plant Clarifier where the reaction is completed. In the flocculation chamber of the Actiflo®, an anionic polymer is added is added and microsand to initiate floc formation. Microsand provides a surface area to enhance flocculation and acts as a ballast or weight during sedimentation.

Sedimentation

Ballasted flocs enter the clarification chamber in the Actiflo® and settle rapidly with the aid of lamella settling tubes. Sludge mixed with microsand is collected at the bottom of the clarifier and continuously pumped to a hydrocyclone, where the sand is separated from the sludge. The recovered microsand is recycled back into the flocculation chamber and the light density sludge is split; the majority of the sludge is recycled back into the Metal Precipitation Reactor to act as a seed for precipitation and the remaining sludge is sent to waste. Clarified water exits the Actiflo® and is sent to the filters for further polishing.

pH Adjustment Tank

Clarified water from the Actiflo® flows into the pH Adjustment Tank where the pH is adjusted to between 7 and 7.5 with sulphuric acid.

Microfiltration/Ultrafiltration and Reverse Osmosis

The settled water will require further polishing to remove suspended solids and turbidity prior to the RO membrane. This will be accomplished by an MF/UF system. Reject water from the MF/UF system will be recycled

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to the front of the WTP, as it contains mostly solids which can be removed in the Densadeg®. Following MF/UF, the permeate is pumped through two stages of RO to remove nitrate, chloride, and fluoride from the filtered water to comply with the future 2015 effluent licence requirements. The addition of an antiscalent may be required prior to the RO process to minimize membrane fouling/scaling. Reject from the second stage RO will need to be managed. Options for treatment and disposal of RO brine are discussed following the description of the alternative treatment options.

Equalization Tank

Permeate from the RO system flows by gravity to an equalization tank. Finished water in the equalization tank will be pumped for discharge into Snap Lake, with the option to divert a portion of the flow to the process plant.

Preliminary Equipment List

The preliminary equipment list and specifications for the Actiflo® high rate clarification process and chemical feed systems are listed under Alternative No. 2 in Section 7.1.2

The MF/UF system will include:

- MF/UF membranes, skid mounted (8 skids)
- MF/UF membrane feed pumps (8)
- MF/UF permeate tank (1)
- Low pressure permeate transfer pumps, skid mounted (2)
- Chemical enhanced backwash (CEB) skids, shared with RO system (5)
  - CEB tank (1 per CEB skid)
  - CEB pumps (2 per CEB skid)
- Controls

The RO system will include:

- Two stages of RO membranes, skid-mounted (12 skids)
- RO membrane feed pumps (12)
- RO permeate tank (1)
- Low pressure permeate transfer pumps, skid mounted (2)
- Chemical enhanced backwash (CEB) skids, shared with UF system (5)
  - CEB tank (1 per CEB skid)
  - CEB pumps (2 per CEB skid)
- Controls

7.2.3 Upgrades to Existing Treatment Train at the Snap Lake Mine WTP

In addition to providing MF/UF and RO treatment at the end of the secondary treatment train, the existing treatment train at the Snap Lake Mine WTP will need to be upgraded to include MF/UF and RO treatment to ensure compliance with the 2015 licence requirements for chloride, fluoride, and nitrate. Construction of the secondary treatment train and upgrades to the existing treatment train can be phased to allow for continued operation of the WTP. In the first phase, the existing WTP will continue to treat the mine water while the secondary treatment train is under construction. Following commissioning of the secondary treatment train, the existing treatment train will be shut down for upgrades. The pressure filters in the existing treatment train will not provide sufficient pretreatment for the RO system; hence the pressure filters will be decommissioned and an RO system with MF/UF pretreatment will be installed (similar to the secondary treatment train). Additionally plate/tube settling modules could be added to the existing thickener to increase its capacity. At this point the full WTP will be capable of treating 45 ML/d. A process schematic of the full WTP, following construction and upgrades is shown in Figure 20.

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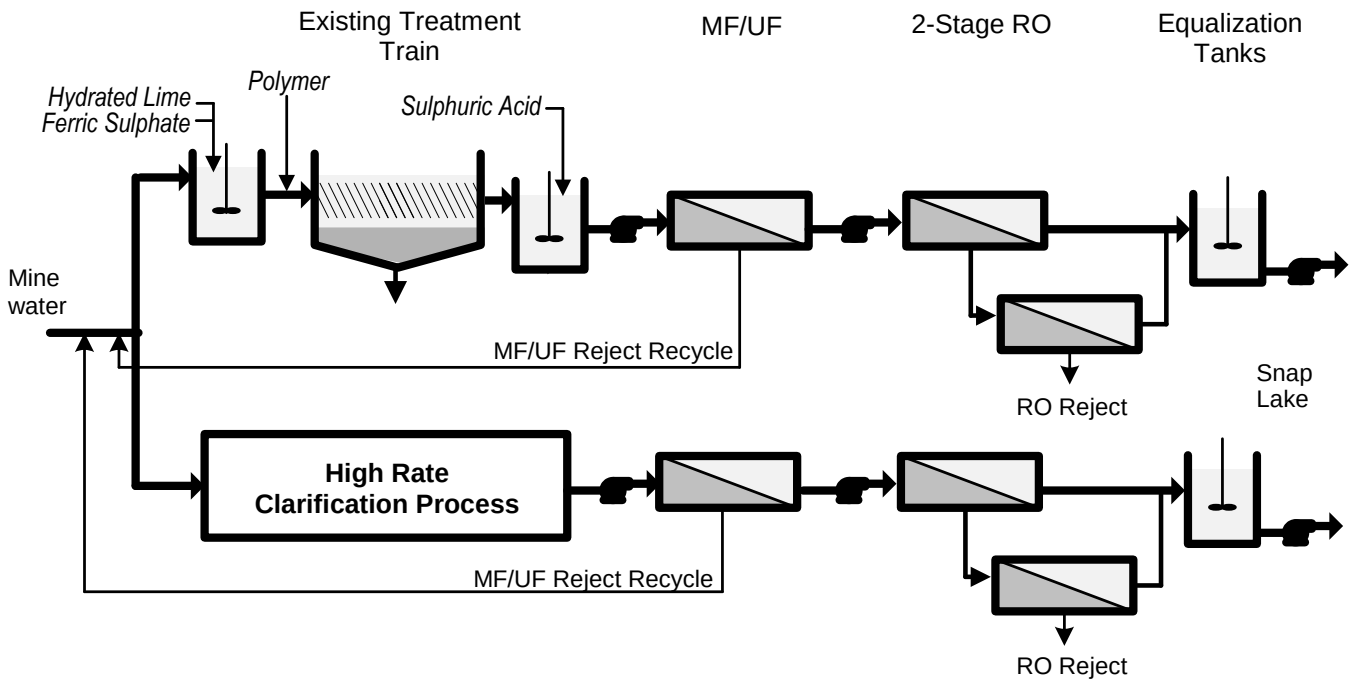
FIGURE 20
Process Schematic of Snap Lake Mine WTP Following Expansion and Upgrades to the Existing Treatment Train



Reverse Osmosis Mass Balance

The finished water concentrations of nitrate, chloride, fluoride, and TDS were calculated for a two-stage RO system assuming 60 percent product recovery for each stage and 90 percent or greater rejection of each contaminant (Table 19). Maximum effluent concentrations from 2011 were used in this analysis, as MF/UF will not remove the dissolved soluble ions. Finished water concentrations of all contaminants are below the 2015 average monthly limits.

TABLE 19
Mass Balance of Contaminants throughout the Reverse Osmosis 2 Stage System

Location/Recovery	Flow Rate (ML/d)	Nitrate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	TDS (mg/L)
Influent	45 ML/d	18.1[1]	316[1]	0.432[1]	937[1]
Recovery or Rejection Ratio per Stage (%)	60%	90%[2]	95%	90%	90%
Permeate – Stage 1	27 ML/d	1.81	15.8	0.043	93.7
Brine Stage - 1	18 ML/d	42.5	766	1.015	2202
Permeate Stage 2	10.8 ML/d	4.3	38.3	0.102	220
Brine Stage 2	7.2 ML/d	100	1858	2.386	5175
Finished Water – Equalization Tanks	37.8 ML/d	2.5	22.2	0.060	130
Overall Recovery (%)	84%[3]	-	-	-	-

[1]Maxmimum concentration reported in effluent in 2011
[2]Assumed 90% rejection of nitrate, however this may be less depending on the membrane selected
[3]80 to 90% overall recovery is anticipated as the concentrate will become supersaturated with $BaSO_4^-$ limiting further recovery

7.2.4 Waste Treatment/Disposal Options

The RO system will generate a large amount of reject water, highly concentrated with contaminants; hence a treatment/disposal plan is required for this waste. The waste could either be disposed of as a liquid or salt cake. A brine concentrator/crystallizer system could be employed to recover most of the reject water (>99 percent) and

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produce a salt cake suitable for landfill disposal. Alternatively, the reject water could be disposed through deep well injection.

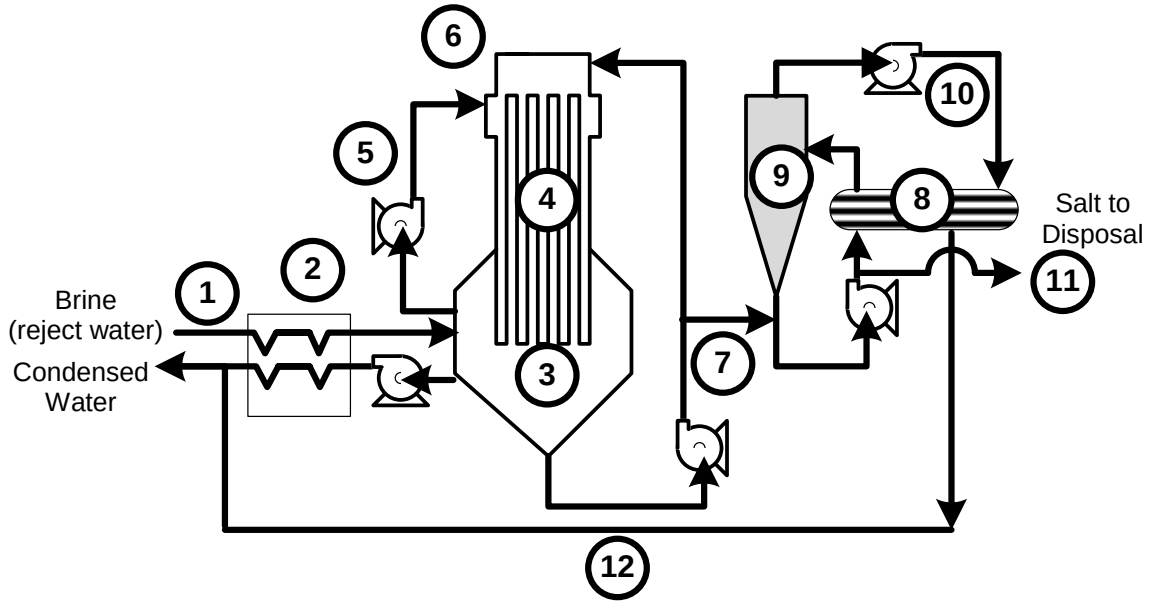
Brine Concentrator/Crystallizer System

Mechanical evaporation involving a brine concentrator followed by a forced-circulation crystallizer can be used to process concentrate and separate salt from the water. Prior to entering the brine concentrator, the reject water may require pre-treatment to limit scaling, including pH adjustment and de-aeration to remove non-condensable gases (for example, oxygen, carbon dioxide, etc.). The reject water is pumped through a heat exchanger to raise its boiling point and then sent to the evaporator sump where it combines with brine slurry. The brine slurry is constantly circulated from the sump to the top of the heat transfer tubes. As the brine flows down the vertical heat transfer tubes back to the sump, some of it evaporates. This vapour passes through a vapour compressor and then flows on the outside of the heat transfer tubes, transferring heat to the cooler brine falling inside the tubes. As the heat is transferred to the brine, some of the vapour condenses into water and is sent to the heat exchanger to warm the incoming reject water. A portion of the brine concentrate is passed onto the forced-circulation crystallizer where it is further concentrated.

Brine concentrate from the mechanical evaporator joins the recirculated concentrate in the crystallizer and is pumped through the forced-circulation heat exchanger. The concentrate is heated above its normal boiling temperature with steam. The heated concentrate then enters the flash evaporation tank, which is operated at a slightly lower pressure and this causes the evaporation of water. As the water evaporates, crystals form in the brine. The vapour passes through a compressor and a heat exchanger, where it condenses as it heats the recirculated concentrate. Condensed water is cooled further as it passes through another heat exchanger and provides heat to the incoming reject water. The treated water (condensed water) can be disposed of or reused as process water; however, it may need further cooling prior to discharge into Snap Lake. A small stream of the recirculated brine is sent to a centrifuge or a belt-filter and dewatered. The liquid portion is returned to the crystallizer for further concentration, while the salt cake is collected for disposal.

A schematic of a brine concentrator in combination with a forced-circulation crystallizer is presented in Figure 21.

FIGURE 21
Schematic of a Brine Concentrator followed by a Crystallizer



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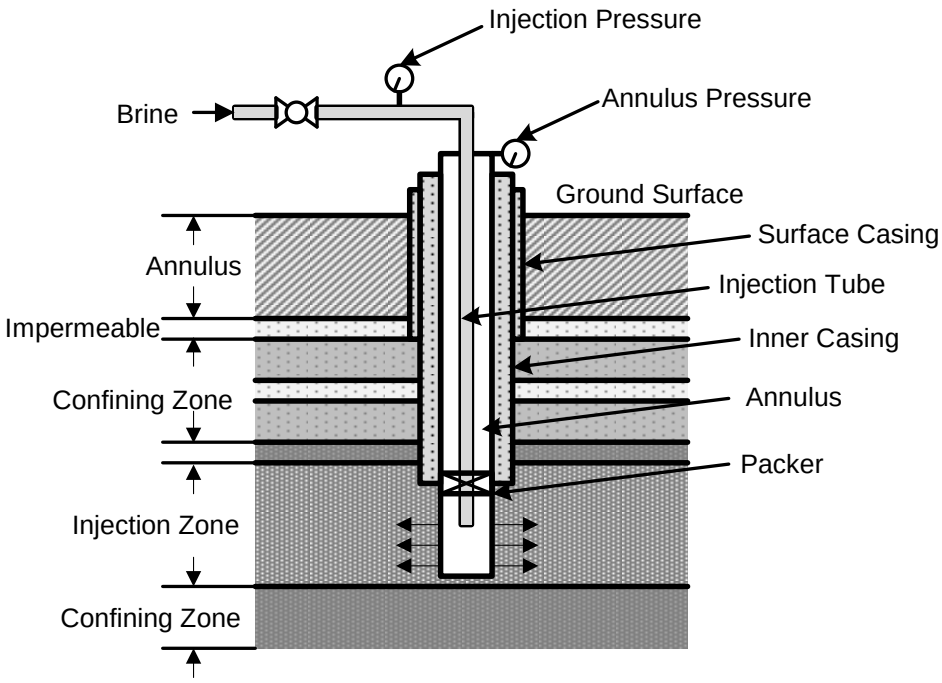
LEGEND

1 MEMBRANE REJECT	5 VAPOR COMPRESSOR	9 FLASH EVAPORATION TANK
2 HEAT EXCHANGER	6 HEATED COMPRESSED VAPOUR	10 VAPOR COMPRESSOR
3 EVAPORATOR SUMP	7 BRINE CONCENTRATE	11 SALT TO DISPOSAL
4 VERTICAL HEAT TRANSFER TUBES	8 FORCED CIRCULATION HEAT EXCHANGER	12 CONDENSED WATER

Deep-Well Injection

Deep well injection is a technique used to dispose of liquid wastes via injection beneath the lowermost geologic formations (confining zone) to prevent contaminants from migrating into potable water aquifers and surface waters. An injection well will typically extend several thousand feet below the ground level. Brine is injected into the well through injection tubing surrounded by an intermediate casing (inner casing) and a surface casing on the exterior (Figure 22). The space between the injection tubing and intermediate casing, referred to as the annulus, is filled with a pressurized fluid that isolates the casing from the injected wastewater. The pressure inside the annulus can be monitored to detect leaks and verify the integrity of the well.

FIGURE 22
Typical Deep Well injection System



When properly sited and constructed, deep well injection can be a safe means of waste disposal; however, extensive contamination of the ground or surface water can occur if the wastewater migrates towards the surface. A site assessment and aquifer characterization are required to determine the suitability of the site for disposal; the underlying geology of the site is a main factor influencing the decision. The geological formation should be highly impermeable to act as a hydraulically confining barrier. Additionally, extensive assessments must be completed to obtain approval for injection from the regulatory authority.

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7.3 Preliminary Layouts for Alternative Treatment Options

Preliminary layout drawings were prepared for each alternative secondary treatment train, including the RO system for the entire WTP. These layouts are shown in Figures 23 to 26.

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FIGURE 23
Preliminary Layout for Alternative 1 – Densadeg® Integrated Reactor/Clarifier/Thickener with Continuous Backwash Filters

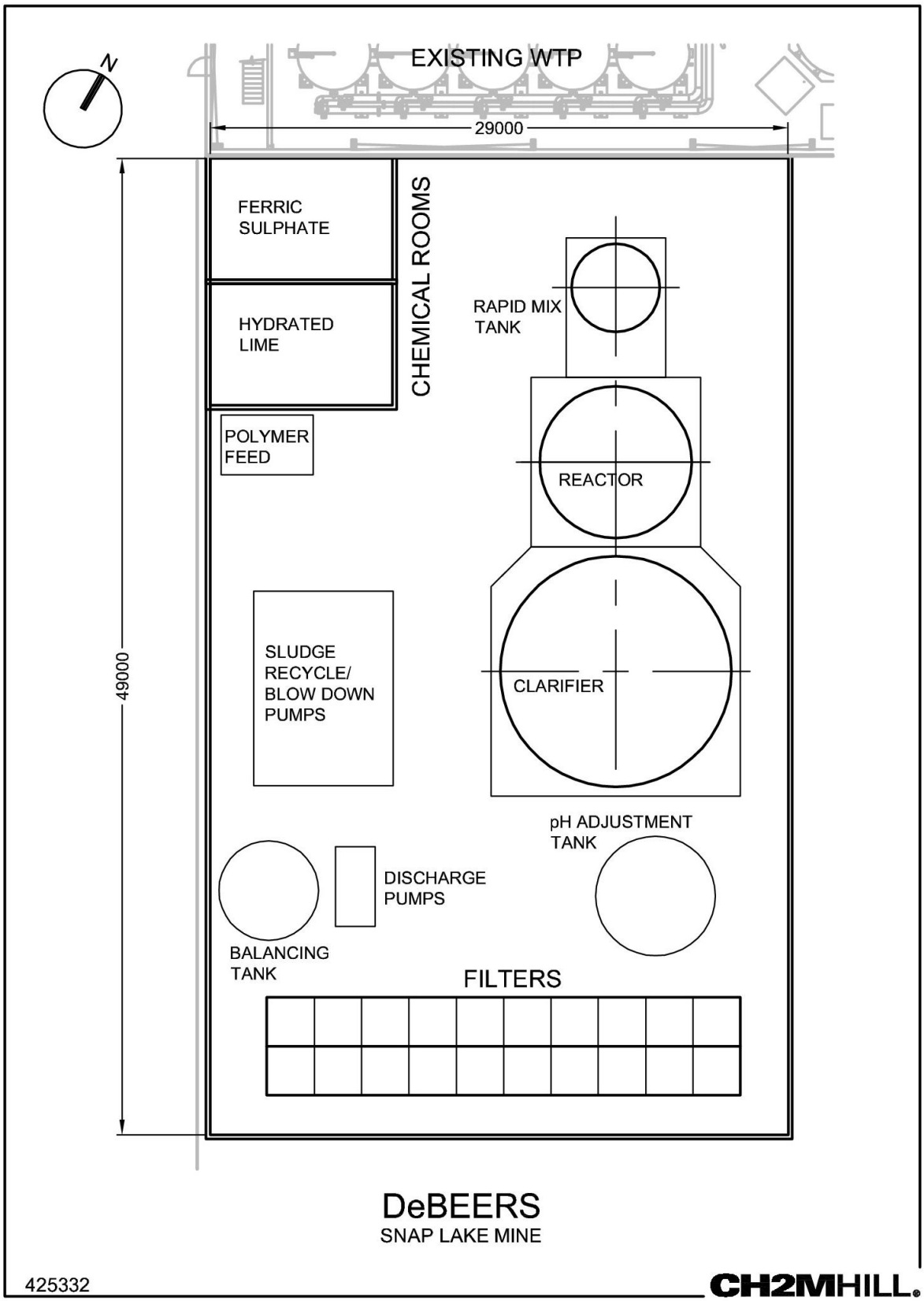

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FIGURE 24
Preliminary Layout for Alternative 2 – Actiflo® Package Plant Clarifier with Metal Precipitation and Cloth Media Filtration

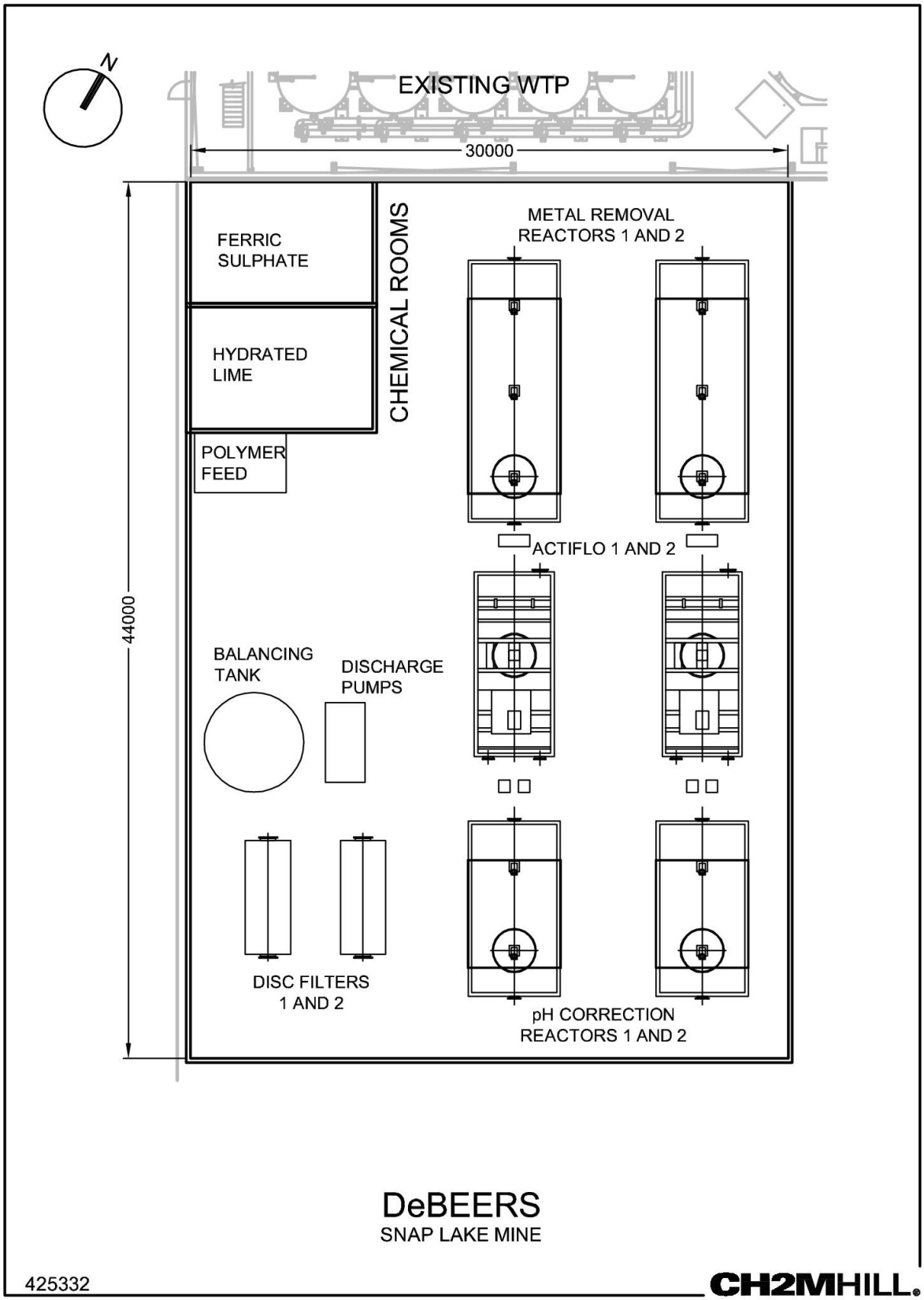

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FIGURE 25
Preliminary Layout for Alternative 3 – Densadeg® Integrated Reactor/Clarifier/Thickener with MF/UF and RO

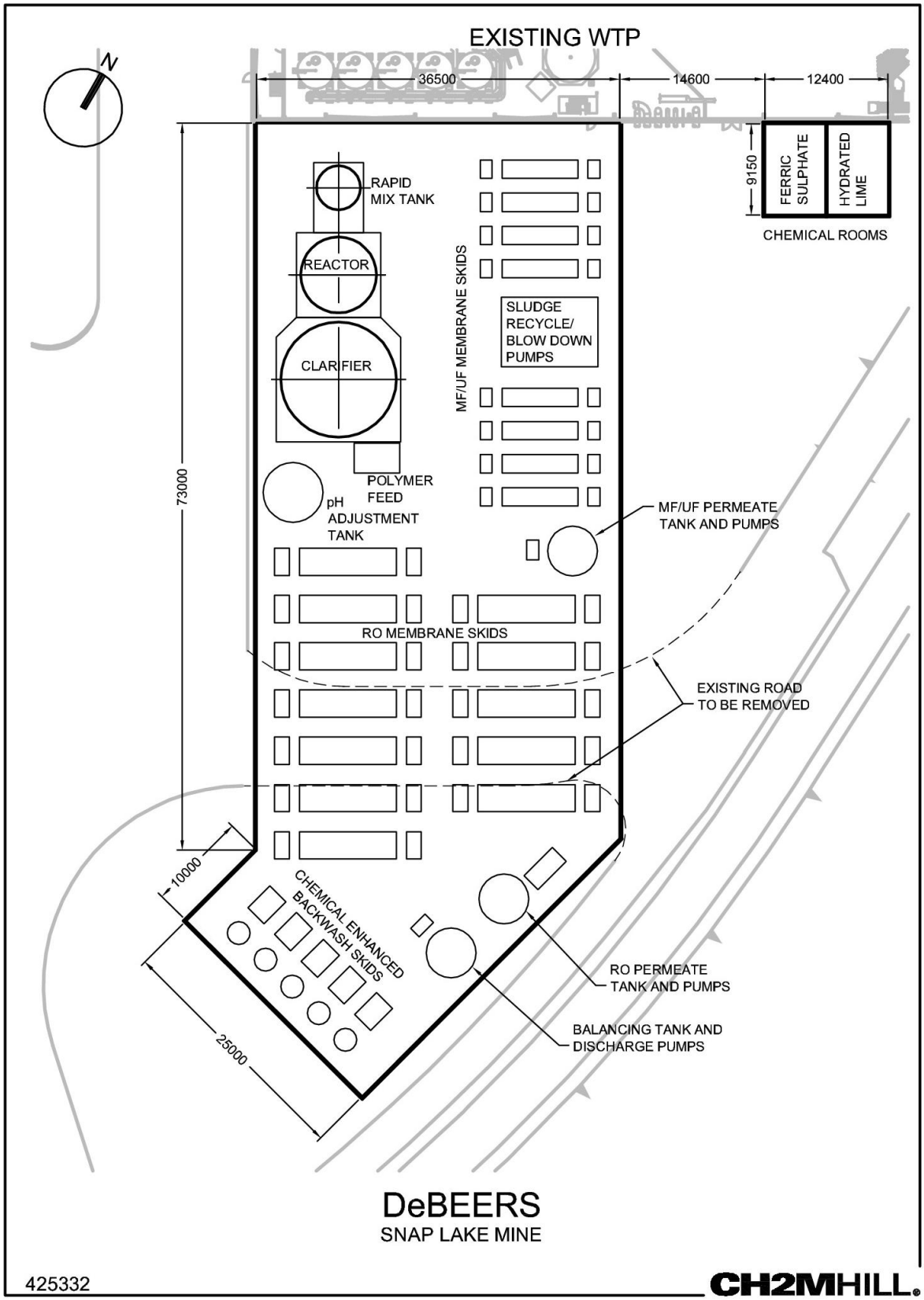

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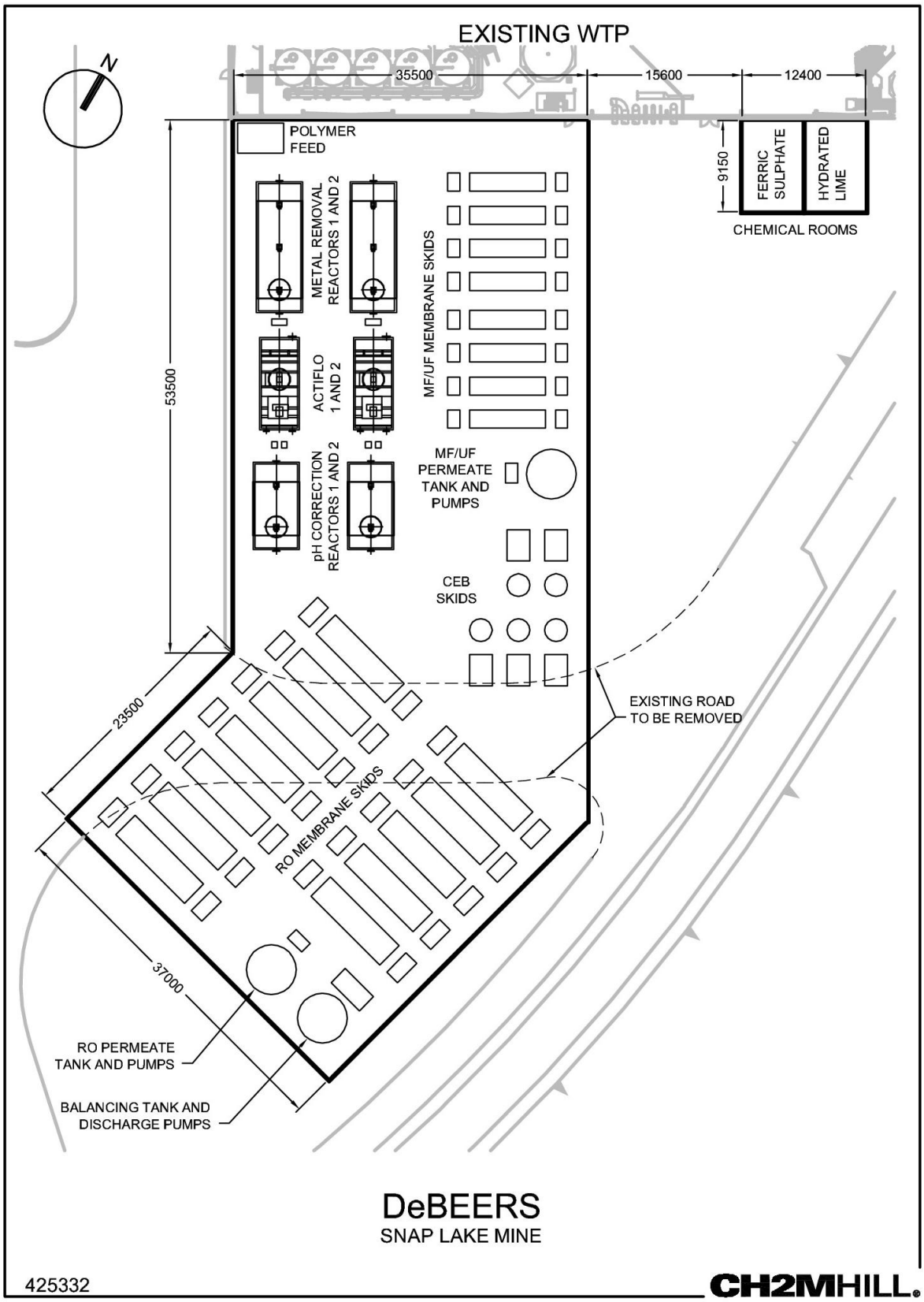
FIGURE 26: Preliminary Layout for Alternative 4 – Actiflo® Package Plant Clarifier with MF/UF and RO



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7.4 Equipment Costs

Four different treatment alternatives were developed for the Snap Lake Mine WTP upgrades/expansion. The first two alternatives were developed to expand capacity to 45 ML/d, while continuing to comply with the current licence requirements (Scenario 1). The second two alternatives were developed to ensure compliance with the more stringent 2015 licence requirements for nitrate, chloride, and fluoride (Scenario 2).

- Scenario 1, Alternative 1: Densadeg® Integrated Reactor/Clarifier/Thickener with Continuous Backwash Filters
- Scenario 1, Alternative 2: Actiflo® Package Plant Clarifier with Metal Precipitation and Cloth-Media Filtration
- Scenario 2, Alternative 3: Densadeg® Integrated Reactor/Clarifier/Thickener with MF/UF and RO
- Scenario 2, Alternative 4: Actiflo® Package Plant Clarifier with MF/UF and RO

Table 20 presents the estimated equipment costs for the four treatment train alternatives. In terms of high rate clarification, the equipment costs for the Densadeg® System are approximately half of the costs for the Actiflo® system. In terms of overall equipment costs for Scenario 1, Alternative No. 1 will cost approximately 36 percent less than Alternative No. 2. In Scenario 2, the equipment cost increase significantly by approximately $17 million with the addition of an MF/UF system and a two-stage RO system to treat the future flow of 45 ML/D (existing WTP flow plus expansion). The total equipment costs for Alternative 3 and 4 will be approximately $20 million and $ 22 million, respectively.

TABLE 20
Equipment Costs for Alternative Treatment Train Options for the Snap Lake Mine WTP

Component	Scenario 1, Alternative 1: DensaDeg + Filtration	Scenario 1, Alternative 2: Actiflo + Filtration	Scenario 2, Alternative 3: Densadeg + MF/UF + RO	Scenario 2, Alternative 4: Actiflo + MF/UF + RO
High Rate Clarification[1]				
Densadeg® System	$2,609,037	-	$2,609,037	-
ACTIFLO® System	-	$4,664,532	-	$4,664,532
Polishing Filter/s				
Dynasand Filters	$723,985	-	-	-
Disc Filter	-	$600,000.00	-	-
MF/UF + RO System[2]	-	-	$17,000,000	$17,000,000
Equalization	$120,000	$120,000	$120,000	$120,000
Total Equipment Cost	$3,453,000	$5,385,000	$19,730,000	$21,785,000

[1] Includes chemical dosing systems and pH adjustment tank
[2] Total capital costs for MF/UF and RO system to treat 45 ML/d (existing WTP flow plus expansion)

Under Scenario 2, the RO process will generate a large amount of highly concentrated wastewater (~7 ML/d). A brine concentrator/crystallizer system with a centrifuge, capable of producing a salt cake suitable for landfill disposal, would cost approximately $33 million in equipment costs. This would increase the total equipment costs for Alternative 3 and 4 to $ 53 million and $55 million, respectively. The costs associated with the disposal of the RO reject via deep well injection have not been tabulated as this approach is subject to many site-specific factors (i.e. terrain, geology, proximity to WTP, regulatory issues etc.); however, we are confident that the overall costs associated with deep well injection will be substantially less than the costs associated with the brine concentrator/crystallizer system.

A Class 4 Opinion of Cost for Alternative 3, the Densadeg® Integrated Reactor/Clarifier/Thickener with MF/UF and RO, are shown in Table 21.

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TABLE 21
Class 4 Opinion of Capital Cost for Preferred Treatment Alternative

Cost Category	Densadeg + MF/UF + RO (Alternative 3)
Process Mechanical Allowance	$ 19,730,000
Mechanical Allowance	$ 4,000,000
Electrical Allowance	$ 4,000,000
I & C Allowance	$ 3,000,000
Structural, Pre-Eng Building Allowance	$ 10,000,000
Civil / Site Work Allowance	$ 3,000,000
Subtotal	$ 43,730,000
Total Opinion of Capital Cost Range (-10% to +50%)	$ 39,357,000 to $ 65,595,000

The opinion of capital cost estimates have been developed to a Class 4 estimate as defined by the American Association of Cost Engineers (AACE). Rough order-of-magnitude cost estimates are generally performed when the design is approximately 1 to 15 percent complete and normally are expected to have an accuracy level between -30 percent and +50 percent. Cost information from major equipment suppliers, published unit costs for labor and commodities, and historical cost information from CH2M HILL's previous projects have been used to develop the cost estimates. For the above opinion of capital cost, we have reduced the lower accuracy level to -10% as process equipment costs were provided by the vendors, while the remaining costs were developed from historical information.

The opinion of cost does not include the cost to dispose of the RO brine as it depends on the selected / approved disposal option (concentrator/crystallizer versus deep well injection). Consultation with the regulatory authorities is recommended to determine if deep well injection is a viable option.

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SECTION 8

Conclusions and Recommendations

Alternative treatment technologies were identified, reviewed, and compared to allow for the expansion of the Snap Lake Mine WTP to a capacity of 45 ML/d, while ensuring compliance with the current/future licence requirements for TSS, metals, nitrate, chloride and fluoride.

To continue to meet the current licence limits for TSS and heavy metals, while increasing mining production, it is recommended that De Beers proceed with the design and construction of a secondary treatment train which incorporates a high-rate clarification process. In terms of equipment costs, the Densadeg® Integrated Reactor/Clarifier/Thickener was found to be more economical than the Actiflo® Package Plant Clarifier. Although the current licence limits for all regulated metals are anticipated to be attainable with the inclusion of high rate clarification and filtration in the secondary treatment train, provisions for lime addition could be added to ensure continued compliance if metal limits are reduced in the future.

To comply with the 2015 licence limits for nitrate, chloride and fluoride, it is recommended that De Beers incorporate advanced treatment processes to treat both the mine and WMP waters. The WMP water should be treated in full, as it typically contains greater concentrations of nitrate, chloride and fluoride compared to the mine water. While partial treatment to remove approximately 50 percent (or greater depending on recovery of the treatment process) of nitrate and chloride from the mine water may be sufficient to meet the 2015 limits, at least 65 percent of the mine water (possibly more depending on recovery of the treatment process) will need to be treated to ensure that fluoride levels do not exceed the 2015 limits.

As a worst case scenario, RO was selected over other potential treatment options in the absence of bench/pilot-scale testing to ensure compliance with the 2015 effluent licence requirements for fluoride, chloride, and nitrate. The RO process will require pretreatment with conventional or high-rate clarification and MF/UF to remove suspended solids, turbidity, and other potential membrane foulants. The equipment costs associated with an MF/UF and RO treatment system, capable of treating 45 ML/D will be approximately $ 17 million; this is in addition to the cost of adding a secondary treatment train with high-rate clarification (~ $ 3 million). Additionally, concentrate from the RO system containing high levels of dissolved ions and nutrients will require a proper treatment/disposal strategy. This will increase the costs for the RO alternatives significantly, as a brine concentrator/crystallizer system to treat 7 ML/d of concentrate would total approximately $33 million in equipment costs alone. If permitted, deep well injection is expected to be a much more cost effective disposal option; however, it may still be in the order of several million dollars in capital costs.

Due to the significant costs associated with RO treatment and brine treatment/disposal, we recommend that bench/pilot-scale studies be carried out to investigate the feasibility of nitrate, chloride, and fluoride removal from the Snap Lake Mine WTP effluent through a multi-stage IX/adsorption treatment, including contaminant specific resins for nitrate and chloride and activated alumina for fluoride removal. Bench-scale testing can be conducted to evaluate the adsorption capacity of each resin, determine the efficiency of removal for each contaminant, examine the effects of competitive exchange (e.g. chloride, sulfate, etc.) and high TDS, and monitor the fouling potential of TSS and metals/minerals. Additionally, this will allow for the identification of operating parameters such as run-length, service flow rate, backwash flow rate, and the dose and concentration of regenerant required. Pilot-scale studies would be required to monitor resin stability under cyclic operation over longer-periods of time.

We also recommend further investigation into the source/s of fluoride that is entering the mine water during production. Removing fluoride to comply with the 2015 licence requirements complicates treatment by requiring additional fluoride-specific treatment technologies or by increasing the scale-of-treatment required for technologies such as RO that can be used to remove multiple dissolved ions. If fluoride can be prevented from entering the mine water, this will reduce the overall costs associated with treatment.

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SECTION 9

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MACKENZIE VALLEY
ENVIRONMENTAL IMPACT
REVIEW BOARD

13 February 2003

Mackenzie Valley Environmental Impact Review Board (MVEIRB)
Box 938, 5102 – 50th Avenue
Yellowknife, NT X1A 2N7

Attention: Glenda Fratton, Environmental Assessment Coordinator

Dear: Glenda

SUBJECT: Summary of Water Treatment Process Development, Selection and Comparison of Alternatives

Please accept the attached technical memorandum titled "Summary of Water Treatment Process Development, Selection and Comparison of Alternatives" for submission to the Public Registry. This memo was compiled in response to issues raised by Environment Canada during the MVEIRB Technical Sessions.

Additionally, information contained within this memo should address outstanding concerns identified by Indian and Northern Affairs Canada in their Request for Ruling to the Board dated 22 January 2003.

Should you have any questions, please feel free to contact the undersigned.

Sincerely,
SNAP LAKE DIAMOND PROJECT

Robin Johnstone
Senior Environmental Manager

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Fax #0902

SNAP LAKE DIAMOND PROJECT
De Beers

amec

SNAP LAKE DIAMOND PROJECT

MEMO

To:	Robin Johnstone, Senior Environmental Manager, De Beers Canada Mining Inc.	Date:	13 February 2003
From:	Tom Higgs, Senior Process Engineer, Water Treatment	File No.	4.9.3/1020
Tel:	604 664-4542 (fax: 604 664-3057)	Project No.	U638A
CC:			
Subject:	***Summary of Water Treatment Process Development, Selection and Comparison of Alternatives***		

This memo has been prepared to provide a summary of the process development and selection work that lead to the current proposed mine water treatment system (WTP).

Goldsim Modelling and Water Quality Sampling

Initial Goldsim modelling predicted that sedimentation in a settling pond would not be sufficient to remove fine suspended sediment to a level that would approach CCME guidelines for a number of metals, mainly Cr and Cu, which are present in untreated mine water in finely dispersed colloidal form. This conclusion was supported by water quality data collected during the water management pond (WMP) discharge in May 2001. The water quality data indicated that the mine water had a neutral to alkaline pH with dissolved metal concentrations close to the initial draft Ambient Water Quality Guidelines (summarized below) established by the EA team for the Snap Lake project at the start of the water treatment process selection and design program. The final guidelines and benchmark values used for discharge screening during the environmental impact assessment are provided in the EAR in Table 9.4-18.

Draft Ambient Water Quality Guidelines for Total Metals (ug/L)

Aluminum	100
Arsenic	5
Cadmium	0.08
Chromium	8.9
Copper	2
Iron	1000
Lead	1
Mercury	0.1
Molybdenum	73
Nickel	25
Selenium	5
Silver	0.1
Zinc	30

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To:	Robin Johnstone	Date	13 February 2003
From:	Tom Higgs	File No.	U638A

Process Screening

The initial process selection and screening work was guided by three factors:
(1) an examination of maximum predicted mine water flows
(2) the expected waste characteristics
(3) the potential discharge permit limits.

Process option methods that were screened can be broken down into:
- physical methods to remove particulate matter
- conventional chemical precipitation methods for reduction of dissolved metals
- advanced treatment alternatives for removal of ammonia and chloride.

The physical methods and technology evaluated for removal of suspended solids included:
(1) sediment removal in sumps underground
(2) clarification in the WMP
(3) use of a mine water thickener
(4) filtration.

The conventional precipitation methods evaluated included;
(1) coagulant addition using alum, ferric sulphate or lime in combination with organic flocculants to treat either
   a. mine water directly in a thickener, or
   b. WMP overflow
(2) ferric co-precipitation in combination with lime, organic flocculant and sulphide addition in a high density sludge recycle system.

The advanced water treatment alternatives evaluated included;
(1) ion exchange for removal of residual metals, ammonia, nitrate or total dissolved solids (TDS)
(2) reverse osmosis (RO) for removal of residual metals, ammonia or TDS.

Process Screening Conclusions

Based on an initial review of expected mine water flows and chemistry the following conclusions were reached at the process screening stage
- Primary solids removal would be required with the alternatives being to use either (1) underground (U/G) sumps, (2) the WMP or a (3) above ground thickener.
- Final effluent filtration and discharge of an effluent with a low TSS would be required to approach the specific Snap Lake ambient water quality objectives, due to the elevated concentration of metals in the particulate form.
- The use of advanced alternatives using either membrane technology, such as RO or ion exchange (IX) was deemed impractical due to the large expected mine water flowrates and the resultant reject brine streams that would have required additional processing to produce a dry solids waste for disposal. The energy consumption, chemicals required

and solids waste generated to implement advanced treatment alternatives were deemed unacceptably high. The potential environmental benefits did not appear to warrant further consideration. This is discussed further in the De Beers submission on TDS removal provided to the MVEIRB on February 10, 2003.

- Although the expected dissolved metal concentrations in the untreated mine water met most of the objectives, it was recognized that further reduction for specific dissolved metals such as copper and chromium could still be required to meet the Ambient Water Quality Guidelines. It was concluded that testwork would therefore be required to evaluate the removal efficiency of the proposed alternatives and to select and design the water treatment system. Finally it was recognized that continuous pilot testing of the selected key alternatives would be required to demonstrate the process and complete toxicity assessments.

Water Treatment Testing Program

The treatability testwork was performed in the following phases;

- **Phase 1**. Head characterization followed by settling and flocculant screening tests conducted using simulated mine water generated from samples of rock (granite, metavolcanic and kimberlite) collected underground by Golder Associates to refine source terms for Goldsim modeling (June/July 2001).
- **Phase 2**. Head characterization, flocculant screening, column settling tests and jar tests conducted on mine water and WMP samples collected during the Advanced Exploration Program (AEP)(July/August 2001). This work focused on basic screening and evaluation of different water treatment process configurations involving alternative coagulants (alum, ferric sulphate, and lime), different dosages and different pH set points.
- **Phase 3**. Head characterization followed by batch and continuous pilot plant studies using a bulk mine water sample consisting of 33 - 200 L barrels collected in August 2001 prior to shut-down of the AEP. This work carried out between September and December 2001 focused on evaluating alternative process configurations on a continuous basis. The flowsheets tested on a continuous basis are attached. These flowsheets can be described as follows:
  - **Flowsheet 1.** Flocculant addition to raw mine water, sedimentation in a thickener and direct filtration;
  - **Flowsheet 2.** Ferric sulphide addition to raw mine water, pH adjustment with lime, flocculant addition, sedimentation and direct filtration;
  - **Flowsheet 3.** Flocculant addition to raw mine water, sedimentation in a thickener with overflow reporting to a high density sludge (HDS) circuit. HDS circuit included ferric sulphide, lime and flocculant addition followed by direct filtration of clarifier overflow; and,
  - **Flowsheet 4.** Flowsheet 3 but with the addition of sodium hydrosulphide (NaHS) addition to the HDS circuit and hydrogen peroxide (H_2O_2) upstream of sand filter.

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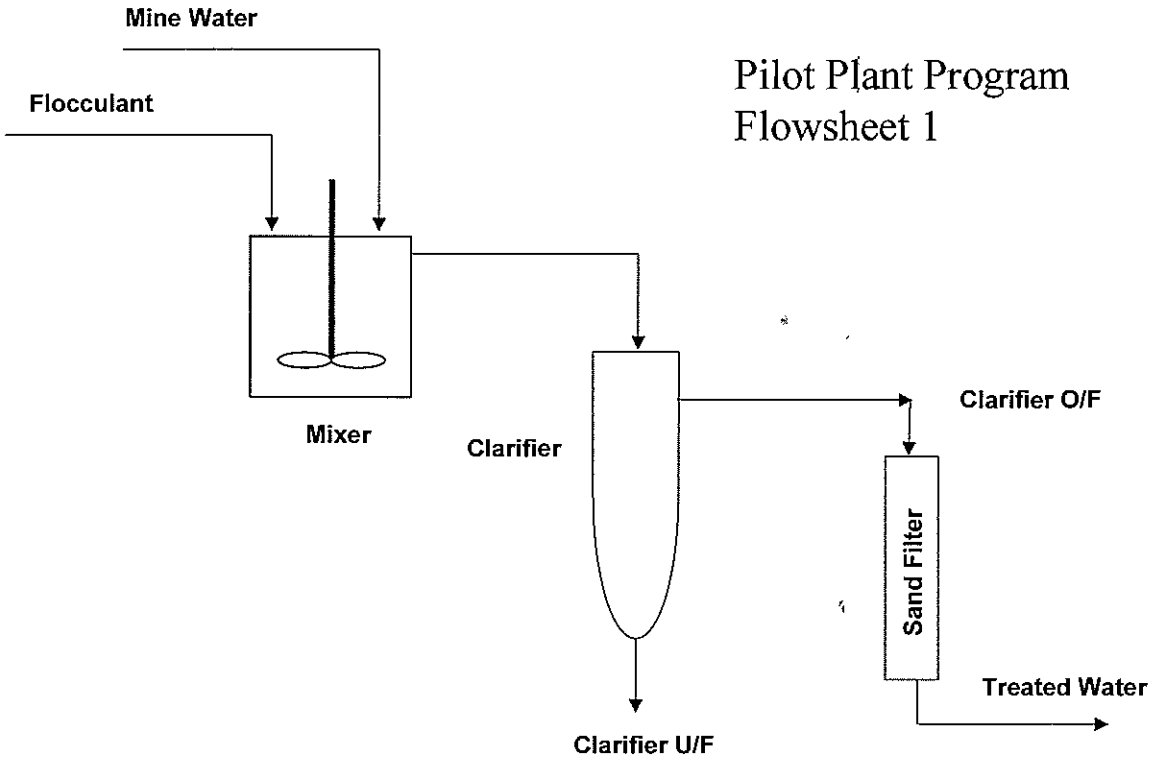

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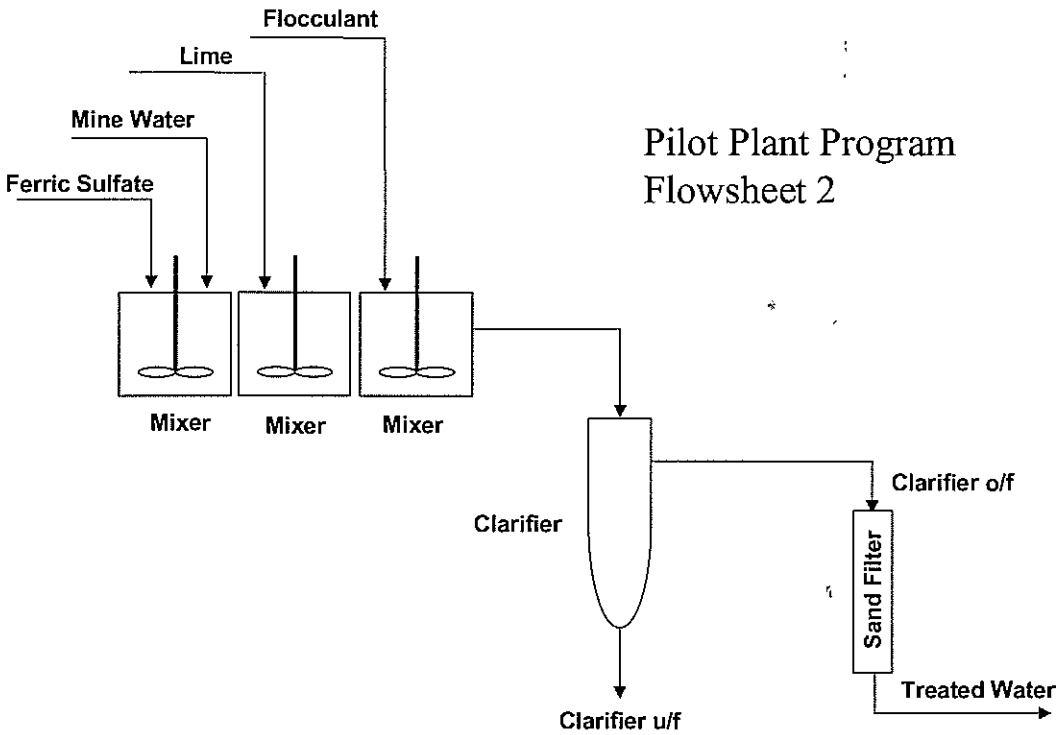

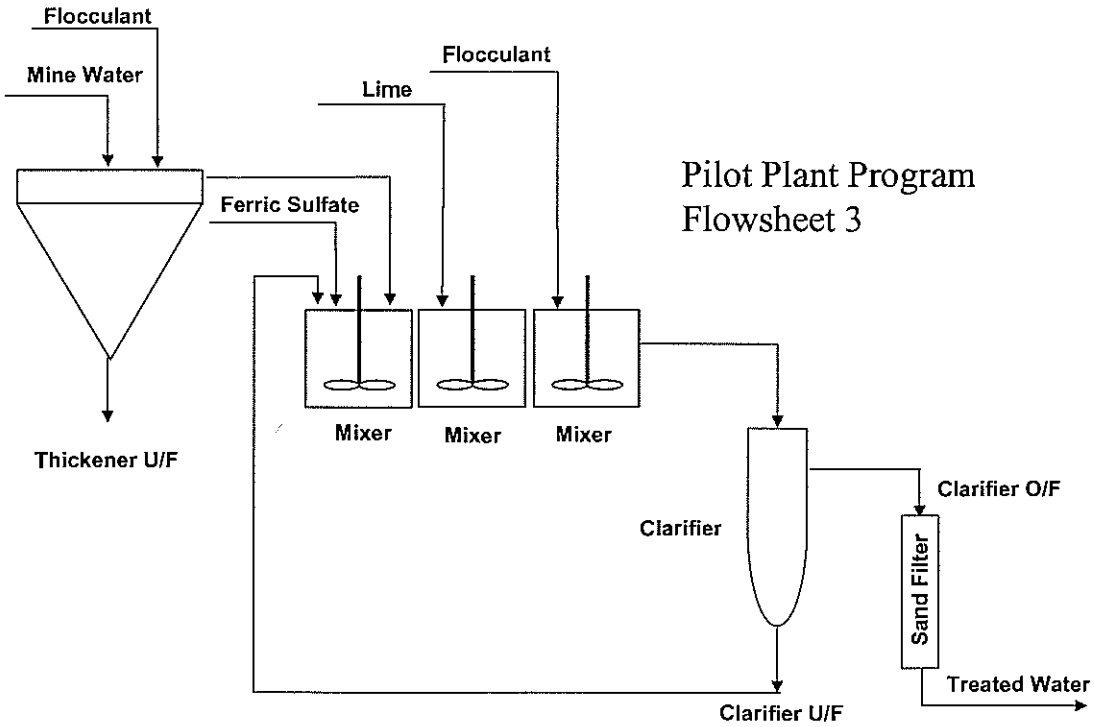

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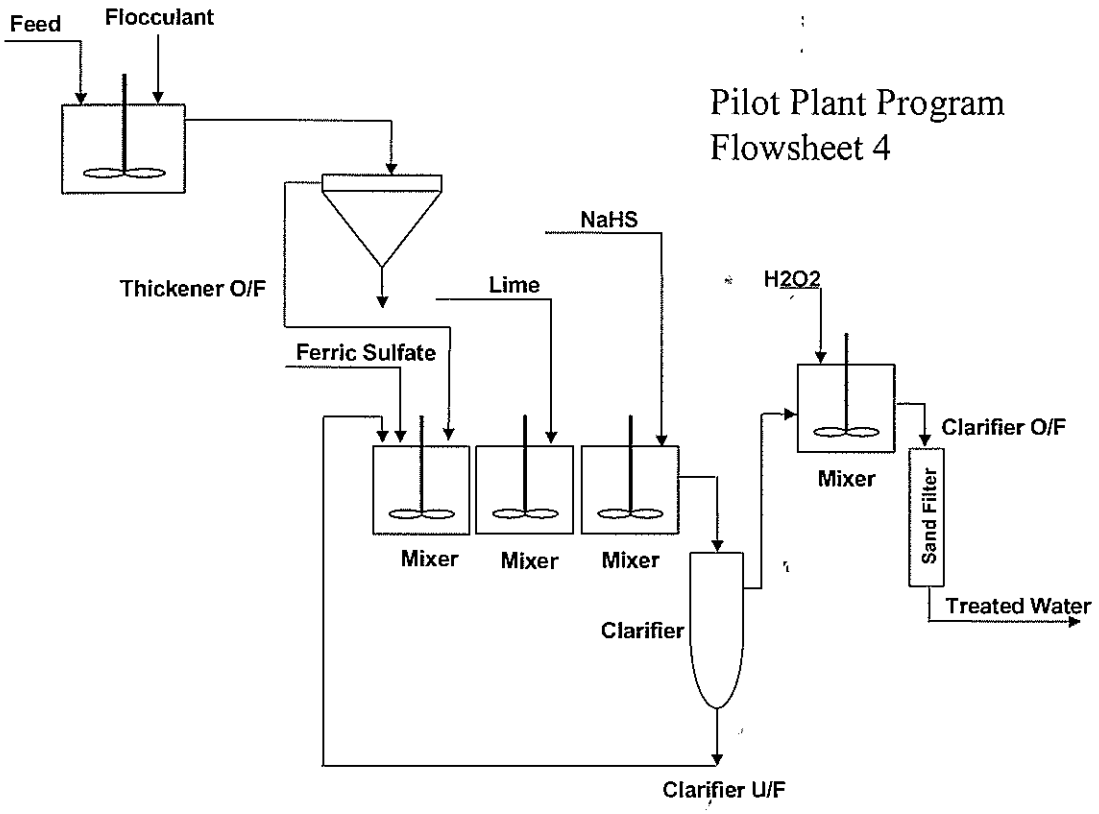

The Ambient Water Quality Objectives were used as targets to guide the testwork. Prior to the completion of Phase 2, preliminary modelling and prediction of final effluent quality based solely on TSS removal indicated that an effluent TSS target of 5 mg/L would generate an effluent that met the objectives. The Phase 2 tests confirmed this prediction and demonstrated that regardless of the combinations of reagents used, sedimentation plus filtration would be required to meet the 5 mg/L target. In addition, the Phase 2 tests demonstrated coagulation and filtration could reduce metals to comply with the objectives, with the exception of copper, which marginally exceed the objective of 2 ug/L.

Selection of Option for Primary Solids Handling

Based on the nature of sludge generated during the bench tests in Phase 2 and estimates of sludge quantities that could be generated underground, a decision was reached at this stage that primary solids and handling would be carried out a thickener. The use of sumps underground was negated by the complications associated cleaning of the sumps and transporting this material to surface for incorporation into the paste backfill. The use of the WMP

pond for primary solids removal was evaluated and rejected due to projected short-term requirements for cleaning the WMP and the additional handling required to dispose of this accumulated sludge in either the North Pile or underground as paste backfill.
Therefore, the Phase 3 test work assumed that primary solids removal would be provided by a thickener c/w flocculant addition. Addition of ferric sulphate and lime as coagulants to further optimize suspended solids removal could be retained as a contingency.

The pilot testing conducted as part of Phase 3 focused primarily on evaluating the performance of alternative flowsheets in terms of both suspended solids reductions to meet the 5 mg/L target and potential further reductions in copper to meet the 2 ug/L guideline.

Conclusions from Pilot Testing (Phase 3) and Final Flowsheet Selection

Based on both the bench tests and the continuous pilot testing, the thickener/filter option with the use of flocculant only (Flowsheet 1) appeared to represent the most practical option for treatment. The addition of ferric sulphide and lime in the thickener/filter option with Flowsheet 2 did not appear to provide a clear demonstrated benefit over Flowsheet 1, considering the inherent variability in the assay results which occurs when testing is conducted near detection limits. The HDS options (Flowsheets 3 and 4) appeared to produce some reductions, however variability in the assays results was also high. The addition of an HDS circuit between the thickener and the filter did not appear to provide a clear benefit. Differences in total and dissolved copper, the primary target for the Phase 3 program, were marginal in all the flowsheets tested, supporting the selection of the simplest flowsheet – Flowsheet 1.
The selection of Flowsheet 1 was further supported by the toxicity testwork results, reported in Appendix IX.8, that demonstrated that all the flowsheets were able to produce non-toxic effluents as defined by standard fish bioassays. Based on the Phase 2 and 3 testwork, it was recognized that the availability of ferric sulphate and lime for coagulation might still be retained as a contingency for use in either the thickener or the filtration system. The use of a coagulant would apply in cases where the feed contained elevated levels of colloidal aluminum, phosphorous or chromium that may not respond to conventional flocculation using organic polyelectrolytes. However the base case would be to not use chemicals unless required.
An important point to recognize in the analyses of the alternative flowsheets is that Flowsheets 3 and 4 both require the addition of ferric sulphate and lime on continuous basis in order to operate the HDS portion of the system. Whereas, based on the testwork, the thickener/filter flowsheets will operate successfully without ferric sulphate and lime, relying solely on the use of flocculant at very low relative concentrations. The lower level of reagent consumption in Flowsheet 1 is environmentally preferable due the inherent reductions in chemical transportation and storage requirements, and subsequent reductions in environment risk.

Cost Evaluations

Further analyses to support the process flowsheet selection is provided from the capital and operating cost comparisons provided below. The capital cost estimates for the basic systems were factored from the Snap Lake feasibility study to reflect the maximum expected flow of

35,000 m^3/d. Flowsheet 1 has a capital cost advantage of $3.6 million and operating cost advantage of $1.6 million/yr. Flowsheet 1 could also result in significant reductions in the use chemicals that would need to be transported to site as well requiring less power.

Capital Cost Estimate	Flowsheet 3 c/w High Density Sludge Plant and Thickener/Filtration System	Flowsheet1 Thickener/Filtration System only
Direct Cost	$15,132,500	$12,376,000
Indirect Costs		
Start-up	302,600	247,500
Freight	286,900	263,800
Spares	256,500	227,000
EPCM	2,269,900	1,856,400
Contingency	1,513,200	1,237,600
Total Indirect	$4,629,100	$3,832,300
Total Capital Cost	$19,761,600	$16,208,300

Operating Cost Estimate (per year)		
Chemicals	$1,500,000	$200,000r
Power	600,000	400,000
Labour	500,000	400,000
Total Operating Cost	$2,600,000	$1,000,000

Proposed Treatment System Process Description

The schematic flowsheet for proposed system is provided below and can be described as follows.

- There are two major sources of feed to the WTP; mine water is the major source to the WTP and North pile run-off, which is a relatively small flow.
- Mine water containing major amounts of solids will report directly to the thickener where flocculant will be added to assist with solids removal.
- The thickener overflow containing minor amounts of suspended solids will report to the filter feed tank.
- The thickener U/F will report to the process plant to combine with the paste backfill.

- As illustrated on the schematic, if the thickener is out of service mine water can be sent to the WMP for solids removal. - also, if the mine water is clean enough it may be possible to bypass the thickener and go directly to the filter feed tank.
- North Pile run-off (which will have low suspended solids) will be sent directly to the filter feed tank or alternatively to the WMP if short-term inflows are too high or the filtration portion of the plant is out-of-service.
- The filter feed tank is also a flocculation tank where ferric sulphate and lime can be added, if necessary, to assist with solids removal.
- An organic flocculant will be added upstream of the filter and finally the filter removes the remaining particles.
- Filter backwash will report back to the thickener.
- The system will also have the capability of adding ferric sulphate and lime to the thickener feed if required to deal with high levels of suspended solids.

Water Treatment By-Products

All solids by-product, which would include any reagents used in the treatment process, will leave the WTP with the sludge generated by the thickener. Solids in the filter feed, which originate from thickener overflow, will be discharged from the filters during backwash. These solids would then report to the thickener and ultimately be incorporated into the sludge, which is sent to the process plant and added to the paste.

WTP Optimization and Operating Strategy

Commissioning and start-up will involve a series of typical activities aimed at developing a detail operating strategy for the WTP plant. These activities will be:

- ensure full compliance with the discharge regulations
- set-up a control system that can rapidly respond to and correct mechanical problems and process upset conditions,
- minimize operating costs, and
- assemble a manual for plant personnel that can be used for both operation and training of new personnel.

Typical activities would include;

- A short-term monitoring program to demonstrate compliance, assist with short-term optimization and select key operating set-points.
- Programming to set-up interlocks and communication between the PLC/HMI (Programmable Logic Controller/Human Machine Interface), the on-line instrumentation and the mechanical equipment controllers.
- Development of a long-term monitoring program and optimization plan that will ensure continuing successful operation at minimum operating costs.

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The development of a sound operating strategy for the Snap Lake project will be important since the mine water flows and solids loading will increase steadily during the first few years of operation. The operating strategy will have to be flexible to accommodate the expected changes in operating conditions. Therefore, process optimization will be an on-going activity to ensure compliance and minimize costs.

Flocculant Screening and Optimization

The initial testwork was conducted with using a common water treatment flocculant, Percol 351, which is classified as a non-ionic polyacrylamide. Toxicity testing results for this flocculant were provided in Appendix IX.8 of the EA Report. Start-up of the WTP will take place using either this flocculant or a very similar formulation. Plant operation would likely continue with this flocculant unless bench testing demonstrates that improved performance could be achieved with an alternative flocculant. Based on past experience, some changes in the flocculant being used by a particular process can occur during the first few years of operation. However the alternative flocculants are typically only slightly different from the original. A decision to change flocculants would require confirmation, based on published chemical supplier data, that the toxicity of the alternate new flocculant was similar or less than the original.

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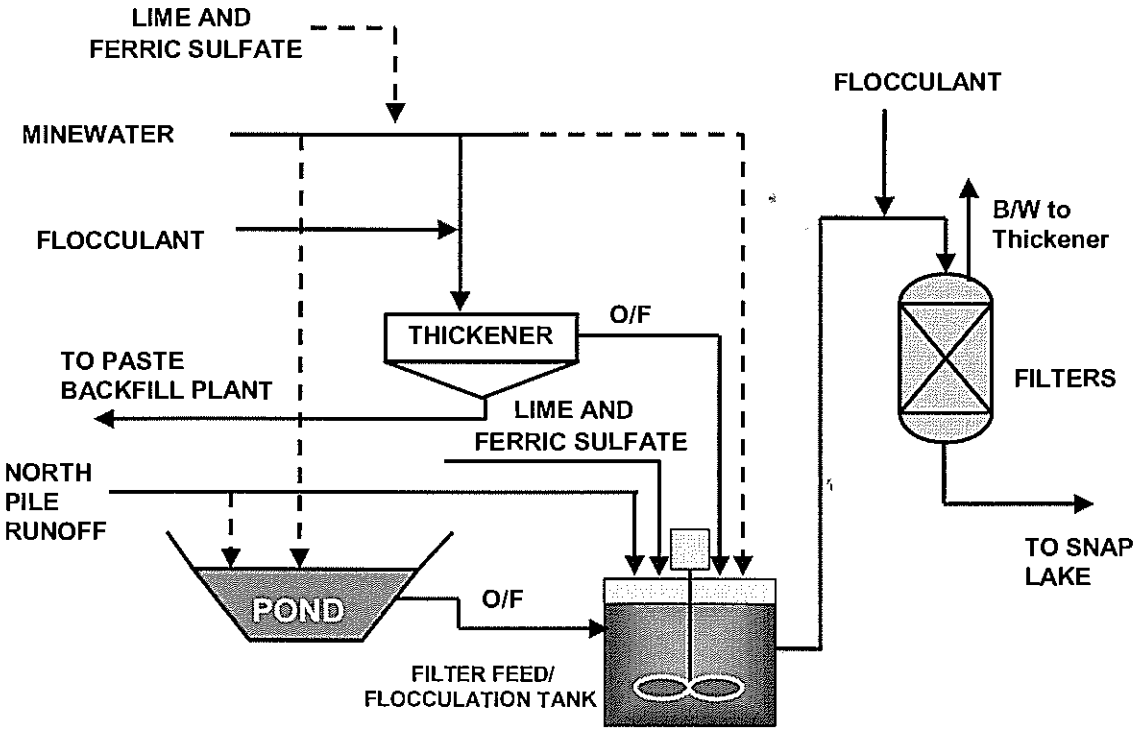
Water Treatment Process Schematic



Summary of Options Rejected During Process Selection

A number of options and alternatives were evaluated and rejected during the course of process selection. The options that were rejected and the bases used for rejecting them are summarized in the table below.

Summary of Process Alternatives Rejected

Option	Description	Advantages	Disadvantages	Reason for Rejection
Use of Mine Sumps for Primary Solids Removal	Primary removal of solids in sumps underground, that would be cleaned mechanically. The solids/ sludge would either be disposed of underground (if possible) or hauled (or pumped) to surface to be added to the paste backfill. Flocculant could be added to the sumps to increase solids removal.	Simple proven system, low capital and operating costs, provides for sludge removal. Provides equalization of flows and loadings.	Limitations in the removal of colloidal material. Sludge handling would require hauling or pumping to surface to allow for disposal in backfill. Solids not removed in the sumps would still require removal by either a thickener or pond.	Complicated method for solids handling. Not attractive for incorporating solids in backfill
Mine water Thickener plus WMP for polishing	Sumps underground would be sized to remove coarse material only from the mine water prior to forwarding to the thickener. Sumps would be cleaned out using mine equipment with the coarse materials deposited underground and fines pumped with the mine water to the thickener. Thickener O/F would report to the WMP for polishing	Conventional technology for treating mine water with high sediment loads. Allows for addition of reagents to improve solids removal and final clarification. Produces sludge for incorporation into backfill. Can produce higher quality effluent than the use of pond only. Potential lower operating costs than use of sumps.	Higher capital cost. Lack of equalization could negatively impact operation of thickener. Higher operating complexity than pond system. Some dissolved metals removed thru use of inorganic coagulants but typically not expected to reduce total metals concentrations to meet Objectives.	Use of WMP as Polishing Pond would eliminate its use for equalization. Water quality from polishing pond would not meet the Objectives without additional treatment (such as filtration)
WMP for Settling Pond plus Filter Plant	WMP used for primary solids removal with the addition of a filter plant to remove fine suspended solids prior to discharge. Coagulants such as alum or ferric sulphate and/or polyelectrolytes can be added to filter feed to optimize performance compared to straight filtration. Backwash to pond.	All the advantages of pond with the ability to reduce total metals and solids to lower concentrations than simple pond systems. Better able to deal with increases in feed contaminant concentrations. Able to remove some dissolved metals thru use of coagulants.	Does not produce a sludge that can be easily incorporated into backfill. More difficult to operate than thickener/filter option due variability in filter feed suspended solid's	Complicated requirements to clean pond and dispose of accumulated sludge during operation
Use of alum for coagulation versus ferric sulphate	Alum could replace ferric sulphate in either the thickener feed or the filter feed.	Conventional reagent for water treatment, less corrosive and reactive than ferric sulphate	Testwork demonstrated that feed already contained elevated levels of aluminium. Alum did not produce as low dissolved aluminium or copper levels as ferric sulphate. Alum requires lower operating pH range than ferric sulphate to avoid high	Inability to meet objectives for Al and reduced capability to depress copper.

Option	Description	Advantages	Disadvantages	Reason for Rejection
			dissolved aluminium residuals – reduces flexibility.	
Use of HDS system instead of thickener before filter	Mine water would report directly to HDS system where reagents would be added to generate a dense sludge for recycle. Solids in mine water would be incorporated in sludge. Flocculants would be added to enhance solids separation prior to filtration	HDS systems able to produce high effluent quality. Proven technology.	Performance would be negatively impact by presence of large amount of solids in feed. Consumption of chemicals to achieve acceptable overflow water quality could be high to overcome impact of mine solids. Complex operating and control requirements	Combining primary solids removal and ferric co-precipitate HDS in one system complicates operation. Could have significant operating costs disadvantage compared to separate systems to warrant capital cost savings. Could require significant consumption of chemicals.
Use of HDS system after thickener and before filtration	Mine water would report first to thickener and then to HDS system where reagents would be added to generate a dense sludge for recycling. Primary solids in mine water would be incorporated in sludge. Flocculant would be added to enhance solids separation prior to filtration	HDS systems able to produce high effluent quality. Proven technology.	Higher capital and operating costs than proposed system. Higher level of reagent consumption resulting in increased hazards associated with transportation and storage of chemicals. Higher operating complexity than proposed system increased risk of process upset.	Pilot testing did not demonstrate clear process advantage, especially with copper, to warrant additional cost, operating complexities and chemical handling increased requirements for ferric sulphate and lime.
Use of sulphide for metal precipitation either in HDS circuit or filter	Sulphide could be as an additional reagent to achieved enhanced metals removal	Sulphide addition can produce lower dissolved metal than hydroxide i.e. for Cd, Pb, Hg, and Ag.	Sulphide precipitates are added to sludge and present some disposal concern in terms of acid generation. Sulphide residual in water would require removal using oxidant such as hydrogen peroxide. Increase risk in handling of reactive chemicals. Higher operating cost.	Bench and pilot plant tests did not demonstrate process advantage especially in terms of copper. Other metals already met objectives. Would have required handling and storage of hydrogen peroxide as well as sulphide.

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Summary of Process Alternatives Rejected

Option	Description	Advantages	Disadvantages	Reason for Rejection
Use of Mine Sumps for Primary Solids Removal	Primary removal of solids in sumps underground, that would be cleaned mechanically. The solids/ sludge would either be disposed of underground (if possible) or hauled (or pumped) to surface to be added to the paste backfill. Flocculant could be added to the sumps to increase solids removal.	Simple proven system, low capital and operating costs, provides for sludge removal. Provides equalization of flows and loadings.	Limitations in the removal of colloidal material. Sludge handling would require hauling or pumping to surface to allow for disposal in backfill. Solids not removed in the sumps would still require removal by either a thickener or pond.	Complicated method for solids handling. Not attractive for incorporating solids in backfill
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Snap Lake Mine

Water Management Plan

October 1, 2013

De Beers

Group of Companies

De Beers Snap Lake Mine

Water Management Plan

(Water License MV2011L2-0004)

1 October 2013

Rev 1.0

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UNITS

M	metre
m^3/d	cubic metres per day
mg/L	milligrams per litre
Mt	mega tonne
T	tonne

ACRONYMS

EAR	environmental assessment report
non-PAG	not potentially acid-generating
PAG	potentially acid-generating
PK	processed kimberlite
PKC	processed kimberlite containment
PWCS	perimeter water control structures
PWTP	potable water treatment plant
PS	perimeter sump
SBR	sequencing batch reactor
SNP	surveillance network program
STP	sewage treatment plant
TWTP	temporary water treatment plant
TSS	total suspended solids
WMP	water management pond
WTP	water treatment plant

1 INTRODUCTION

1.1 PURPOSE

The purpose of the Snap Lake Mine Water Management Plan (the Plan) is to provide a description of the design and management of water systems at the Snap Lake mine site. The plan describes water management activities during the operational phase, which commenced in 2007 and will continue through to closure. The Plan applies to all operations.

The Plan updates prior water management information presented in the Environmental Assessment Report (EAR) for the Project (De Beers 2002) in accordance with the previously approved 2009 Water Management Plan. The update of the Plan will incorporate changes to the water management facilities and will take into account the most recent information available, along with criteria contained in Schedule 5 of Water License MV2011L2-0004. The Plan is intended to complement other related documents, including the Aquatic Effects Monitoring Plan, North Pile Management Plan, and future Plans such as the Waste Management Plan, Strontium Response Plan, TDS Response Plan, and Nitrogen Response Plan.

1.2 OVERVIEW

Mine activities during the operational phase include camp operation and underground mining and processing. There are for distinct sources of water on the mine site: underground water divided between upper bench (lake infiltration), lower bench (connate) water, water from the North Pile and precipitation. These activities and related water sources require management of water quantity and quality to prevent adverse environmental effects throughout the Life of Mine. De Beers is committed to managing this water, and the Plan has been developed to meet the requirement of Water License MV2011L2-0004.

Specifically Part F, Item 5:

The Licensee shall submit to the Board for approval an update of the Water Management Plan on October 1, 2013 and at the following times:

a) If the Licensee seeks changes to the plan;
b) Every three (3) years following approval of the plan; or
c) Upon the request of the Board.

Updates to the Water Management Plan shall describe how the Licensee is meeting the objectives listed in Part F, Item 4 of this License and satisfy the requirements of Schedule 5, Item 1.

For the purposes of the Plan, water management is defined as the collection, storage, treatment, and recycling of water at the mine site, in a safe, efficient, and compliant manner.

The water management system comprises of the infrastructure and practices that are designed to manage water quantity and quality. It is a requirement of the water license to include a Response Framework for the Water Management Pond. This will be included in future submissions as a means to link monitoring results to the corrective actions necessary to ensure the objective of minimizing the impacts of the Project on the quantity and quality of Water in the Receiving Environment. The water management system can be divided into two parts:

- The water and wastewater facilities system contains infrastructure for water supply, potable water treatment and distribution, sewage collection and treatment, and return of treated effluent to Snap Lake; and
- The mine water system contains facilities for collection and conveyance of surface water runoff and of groundwater seepage into the underground mine workings, for storage and treatment of this water and for the return of treated effluent to Snap Lake.

The Plan for the operational phase will describe process water management.

<u>The Plan contains three sections:</u>

Water and Wastewater Management

- a presentation of a water balance to describe inflows, outflows and internal water transfers related to project activities;
- a description of the management of core facilities water systems, including raw water and fire suppression water supply, potable water treatment, and sewage treatment and discharge; and
- a description of the management of mine water systems, including North Pile Starter Cell and East Cell drainage, core and outlying facilities drainage, Water Management Pond, and Water Treatment Plant and discharge.

Monitoring

- monitoring details, including a rationale for the components of the Water management system;
- linkages to other monitoring programs

Responses to Monitoring results-Framework

This section describes the Response Framework for the Snap Lake Water Management Pond. The Response Framework links monitoring results to actions with the purpose of maintaining the Assessment Endpoints.

This section is provided to comply with the following specific Water License conditions [Schedule 5, Item 1(c) of MVLWB (2012)]:

> *i. A description of the Response Framework that will be implemented by the Licensee to link the results of monitoring to those corrective actions necessary to ensure that the objectives listed in Part F, Item 5 are met including:*
>
> a. *definitions, with rationale for Action Levels applicable to the performance of the Water Management Pond with respect to geotechnical stability;*
>
> b. *for each Action Level, a description of how exceedances of the Action Level will be assessed and generally which types of actions may be taken if the Action Level is exceeded.*

2 INFORMATION REGARDING WATER AND WASTEWATER MANAGEMENT

The goal of water management is to minimize the impact of the Mine on the aquatic ecosystems including Snap Lake. Based on this, the two primary objectives of the water management plan are:

1. to minimize the impacts from the Mine on the quantity of surface water; and
2. to minimize the impacts from the Mine on the quality of surface and groundwater.

2.1 COMPONENTS OF THE WATER MANAGEMENT SYSTEM AND ALL THE WATER AND WASTE WATER STREAMS THAT REPORT TO IT

The site water balance provides a basis for design of the water management plan. The water balance describes the quantity of inflow [gains] to the site, outflow [losses] from the site, and the quantity of water conveyed internally within the mine site. A summary describing the site water balance is provided in Table 2-3, and a corresponding schematic showing the locations of water management facilities is provided in Figure 2-1. Major water management facilities considered in the water balance include:

- Site water systems, including:
  - Raw water intake;
  - Potable Water Treatment Plant (PWTP);
  - Domestic water supply to camp;
  - Sewage collection system;
  - Sewage Treatment Plant (STP);
  - Water Treatment Plant and Portable Water Treatment Plant(s) (WTP) and;
  - Treated domestic effluent discharge.
- Mine water systems, including:
  - Core and outlying facilities runoff collection system;
  - Underground mine workings;

- North Pile drainage system;
- Water Management Pond (WMP);
- Water Treatment Plant; and
- Treated mine water discharge via the diffuser assembly.

2.1.1 Water Inflows

Water inflows considered in the mine water balance for the operational phase program include:

- Raw water withdrawn from Snap Lake for domestic and industrial water supply;
- Seepage into the underground mine workings;
- Direct precipitation to mine facilities; and
- Runoff to mine facilities from adjacent catchments.

The approximate amount of fresh water to be drawn from Snap Lake during the operational phase program is expected to be 100-400 m^3/d. Precipitation and runoff managed by the mine water management facilities will vary seasonally and are expected to be small, relative to North Pile seepage volumes.

2.1.2 Water Outflows

Water outflows considered in the mine water balance for the operational phase program include:

- Treated minewater, discharged to Snap Lake;
- Treated minewater used for dust suppression;
- Losses to groundwater seepage from water management facilities; and
- Losses to evaporation from water management facilities.

The approximate amount of water used for dust suppression is estimated to be 30-350 m^3/d, during months when road surfaces are dry and unfrozen, which is usually June to September. The approximate amount of treated domestic water to be discharged to Snap Lake during the operational phase program is estimated to be 200 m^3/d. The amount of

treated mine water to be discharged to Snap Lake during the operational phase program is estimated to increase with inflows into the underground workings. Seepage from the North Pile will vary seasonally and is expected to be small, relative the mine waste discharge volumes.

2.1.3 Raw Water Supply System

Raw water and fire suppression water supply is withdrawn from Snap Lake. Fresh water is withdrawn from the west arm of Snap Lake via the submerged intake. The planned water withdrawal from Snap Lake is expected to be approximately 100-200 m^3/d. Fresh water will be used for:

- potable water supply; and
- fire suppression and dust suppression

Water used in the Process Plant is recycled, however, water for fire suppression and dust suppression will be drawn directly from Snap Lake and distributed through a pressured system to the Process Plant, Service Complex, accommodations, fuel storage area, power and water treatment plants, and utilidors.

A single intake pipe is used for domestic potable water use (daily use) and for fire suppression (rare event). The peak domestic water withdrawal rate will be 200 m^3/d (2.3 L/s) and the peak fire suppression withdrawal rate will be 12,960 m^3/d (150 L/s) for a maximum total as per Water License MV2011L2-0004 of 188,000 m^3/yr.

2.1.4 Potable Water

Raw water is pumped from Snap Lake by overland pipeline to the Potable Water Treatment Plant. Water is treated with Ultra-Violet light for disinfection, chlorinated and stored in a storage tank in the Potable Water Treatment Plant. Treated water is piped to areas in the Process Plant requiring potable water and to the Accommodations and Service Complex. Insulated and heat-traced pipes are used to distribute water through utilidors between the plants, service complex and camp. Potable water is trucked to the underground mine and remote buildings as required.

2.1.5 Sewage Treatment

Sewage will be treated in Membrane Bioreactors (MBR) once the new sewage treatment plant is online in December 2013. This technology utilizes a biological process (bacteria and aeration) to break down sewage influent. At the final stage of the process, liquid that meets discharge criteria set out in the De Beers Water License MV2011L2-0004 is decanted as effluent and pumped to the Water Management Pond. The effluent is treated through the TWTP and WTP prior to release to Snap Lake.

This plant is an Activated Sludge Treatment plant with one C_x9 external membrane designed for a maximum capacity of 135 cubic meters per day. The plant with one membrane required the installation of automatic pre-filters, one membrane feed pump, one membrane circulation pump. The modular design allows the plant to be relocated as necessary.

The sewage treatment plants includes phosphorus removal as part of an overall water management strategy to meet the total phosphorus loading limit set out in the Water License. Alum and caustic soda will be added to control total phosphorus (TP) level and pH adjustment in the effluent. Existing chemical storage and metering pump system will be used. Alum dosage will be manually set to minimum chemical usage while keeping TP under 1 ppm. Caustic soda dosage will be manually set to minimum chemical usage while keeping pH above 6.5. Management of sewage treatment is linked with the Aquatic Effects Monitoring Plan, as one component of the monitoring is to evaluate the effects of nutrients from the mine on productivity within Snap Lake.

Solids produced during sewage treatment are caked and pressed in the filter press to remove additional water. Dewatered solids are bagged and usually land filled, however, on some occasions they may be incinerated.

2.1.6 North Pile Water Control Structures

The design objective of the North Pile Water Control Structures (PWCS), comprising ditches and sumps, is to collect surface water runoff and internal seepage from the North Pile (Appendix I) for pumping to the WTP via the WMP. The runoff and seepage from the North Pile is controlled to prevent it from reporting to the downstream environment.

In addition to the existing PWCS of the Starter Cell and the East Cell, an additional ditch was constructed to intercept the December 2011 overtopping flows from TS4, direct them to Inland Lake 6 (IL6), and provide redundancy for flow containment at the area west of the Starter

and East cells. The IL6 Ditch will become redundant upon the construction of the PWCS.

The North Pile PWCS are inspected annually by an independent geotechnical engineer to assess performance.

The PWCS ditches intercept and route surface water runoff and internal seepage from the North Pile to the sumps. The sumps provide for collection prior to pumping to the WMP. The ditch flow direction is based on ground surface topography to provide gravity flow to the sumps. The sumps are dewatered to maintain the water levels at the minimum practicable levels at all times.

The sequencing of any pump is reliant upon the level within the sump it receives, but is ultimately reliant upon the level and nitrate concentration within the WMP. As nitrate concentration relates to mass per litre, regulating the volume of high nitrates reporting to the WMP is the most effective means of dilution control. Selecting the sump to pump is observational and must be directed by the person designated to manage the pumping of the North Pile PWCS.

An independent geotechnical engineer visually inspected the water control structures during construction and operations to identify the requirements for mineral soil and bedrock surface treatment types, locations, and extents such that the design intent of the structures is achieved. The inspections have not identified the requirement for mineral soil or bedrock surface treatment. A similar evaluation will be carried out during construction of the West Cell PWCS. A grout curtain was constructed as a method for limiting the flow of water from the lake into the PWCS (Golder 2008b). The grout curtain acts as a barrier to flows between the PWCS and Snap Lake. EBA Engineering Consultants Ltd. performed the necessary quality control activities while Golder Associates Ltd. provided quality assurance during construction.

Peak runoff occurs during the spring freshet. The ditches and sumps are inspected on a daily basis during spring freshet and during periods of prolonged rain. Current capacities for the temporary and perimeter sumps are presented in Table 2-1. Any water collected in the sumps is pumped as soon as practical to the WMP and then to the TWTP and WTP for treatment before discharge to the environment and to maintain the minimum possible water level at all times.

Table 2-1 Volume of Water Containment Structures

Location	Maximum Storage Capacity [m^3]
Perimeter Sump 1	3,161
Perimeter Sump 2	4,893
Perimeter Sump 3	65,000
Perimeter Sump 4	10,683
Perimeter Sump 5	18,905
Water Management Pond	92,762
Temporary Sump 4	4,053

m^3 = cubic metres.

All water from the North Pile is diverted to the WMP and then treated at the WTP before discharge. Ditches around the North Pile were constructed to direct and convey runoff from areas affected by operations of the Starter Cell, as well as from a limited area upstream of the Starter Cell that would otherwise drain through the affected area. Managed water will include runoff from granite quarries, as these areas are within the footprint of the North Pile. Snap Lake Mine operates with two points of discharge of treated effluent to Snap Lake; both of which split off of the main line from the Water Treatment plant where sampling station 02-17B is located.

Ditches and sumps in mineral soil with high hydraulic conductivity are lined using a geo-synthetic clay liner to prevent seepage to Snap Lake. Additional seepage control measures, such as grouting of previous fractured rock zones, was applied when such zones were encountered.

2.1.7 Core and Outlying Facilities Runoff Water

Surface water runoff is seasonal. It generally commences with snowmelt in May and continues with snowmelt and rainfall runoff through October. Surface water runoff from the core facilities is conveyed to the WMP (flow path Q19 on Figure 2-1). Surface runoff that is conveyed to natural receiving streams is not considered in the mine water balance.

2.1.8 Water Management Pond

During the Advanced Exploration Project (AEP), water from the underground workings and Processed Kimberlite (PK) were stored in the Processed Kimberlite Containment (PKC) facility. The PKC has been renamed the “Water Management Pond” (WMP as defined earlier) because of its revised function. The WMP receives water from the

catchment area, underground workings, Process Plant, North Pile, and can receive water from the Sewage Treatment Plant. The WMP was created by two dams that were constructed in 2000. The dams consist of a rock fill embankment supporting an 80-mil textured HDPE liner on the upstream side. The liner is keyed into the underlying intact bedrock (using a mixture of sand and powdered bentonite) and compacted into a key trench to minimize the seepage beneath the dams. Suitable granular bedding and cover layers were placed on either side of the liners. Small seepage losses from the WMP are expected and were scoped during the Environmental Assessment for the project.

2.1.9 Water Treatment Plant/Temporary Water Treatment Plant

The Water Treatment Plant (WTP) includes a pumping station to decant water from the WMP. The treatment facilities consist of a temporary, portable filtration plant that was constructed in 2004 on a granite pad near the WMP causeway. The temporary WTP is expected to operate as required to augment the permanent WTP. It was designed to treat the relatively low flows in the mine pre-production period and the water stored in the WMP, and has a nominal capacity of 5,000 m^3/d In the event that monitoring of underground water inflows shows potential for higher than predicted levels, the plant can be expanded via additional filters and higher flow pumps. The permanent plant was commissioned in 2006. The WTP is capable of treating approximately 75,000 m^3/day with the addition of a portable WTP that is connected in to the pH adjustment tank. Further capacity expansions are underway to offset the additional underground inflows.

The process includes a bank of filtration units. The filters in the Water Treatment Plant(s) are regularly cleaned by backwashing with treated water. Backwash water containing suspended solids are pumped to the Process Plant. Treated water is discharged to Snap Lake via two diffusers. These diffusers direct the discharge through multiple ports and increase mixing of effluent with Snap Lake water. Sulphuric acid is used for pH control/adjustment and to reduce potential ammonia toxicity.

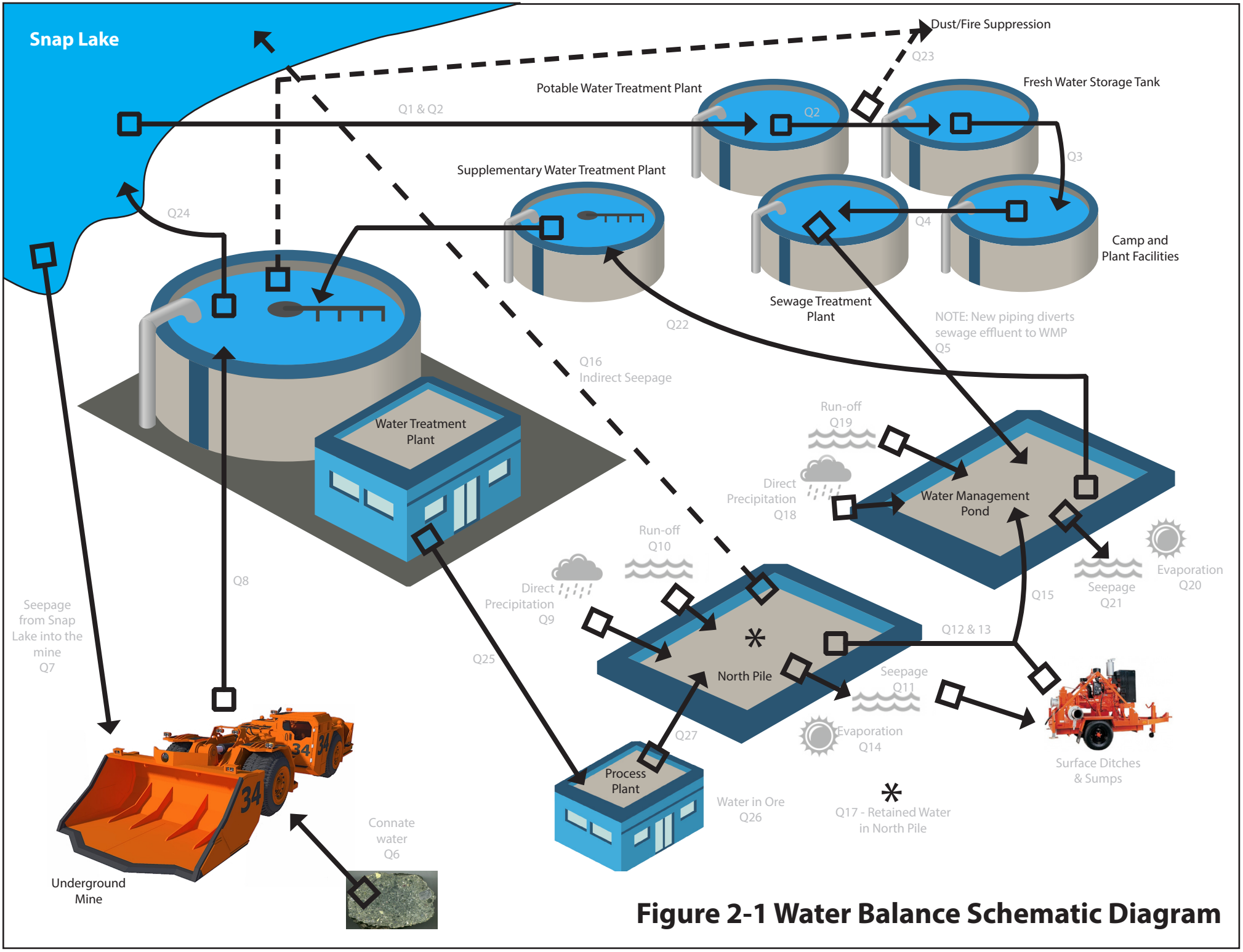


Figure 2-1 Water Balance Schematic Diagram

2.2 A DESCRIPTION OF THE PROCESS AND FACILITIES INTENDED FOR THE PURPOSES OF OBTAINING FRESH WATER FROM SNAP LAKE FOR USE AT THE SNAP LAKE DIAMOND MINE

The monthly quantities of freshwater removed from Snap Lake between January and December 2012 are listed in Table 2-3. The freshwater was used for domestic use, process use as well as dust suppression. The total amount of freshwater removed from Snap Lake during 2012 was 40,132 cubic metres (m^3). De Beers attempts to reduce freshwater intake by recycling water and encouraging environmental awareness. In 2012, De Beers recycled 353,954 m^3 of water from the Water Treatment Plant for use in the Processing Plant. Recycled water that meets effluent quality criteria is also used for dust suppression on the roads during the summer months.

Table 2-2 Snap Lake Freshwater Intake (m^3), 2012

Date	Volume [m^3]
Jan	3,464
Feb	2,950
Mar	3,574
Apr	3,414
May	3,862
Jun	3,221
Jul	3,125
Aug	3,013
Sep	2,878
Oct	3,308
Nov	4,176
Dec	3,149
Annual Total	**40,134**

m^3 = cubic metres.

2.2.1 Potable Water

Water will be supplied to the potable water treatment plant from the Snap Lake intake, as described by flow path Q1 on Figure 2-1. Potable water for domestic use is piped to users, as described by flow path Q3 on Figure 2-1.

The water intake pump well is housed within a rock-filled embankment on the north shore of the northwest peninsula of Snap Lake. The pump well, consisting of vertical pump wells fitted with vertical turbine pumps which receives water through the single pipe buried under the rock-filled granite embankment. The intake pipe will exit at the bottom of the embankment into Snap Lake and will be fitted with a stainless steel screen. The screen selected meets the Department of Fisheries and Oceans (DFO) 1995 criteria for the combined water withdrawal rate for fire suppression and domestic potable water use. As per the DFO policy intake screens are cleaned every 2 years. A habitat compensation plan was finalized with DFO Yellowknife for the habitat affected by the installation of the water intake embankment. This fisheries authorization is now closed.

2.3 THE PROCESS AND FACILITIES FOR THE COLLECTION AND MANAGEMENT OF SURFACE RUNOFF GENERATED ON SITE

External drainage around the North Pile includes the following components:

- Direct precipitation to the system (flow path Q9 and Q18 on Figure 2-1);
- Runoff from adjacent catchments (flow path Q10 and Q19 on Figure 2-1);
- Evaporation from the system (flow path Q14 and Q20 on Figure 2-1);
- Seepage from the system (flow path Q11, Q16, and Q21 on Figure 2-1); and
- Discharge from the system to the Water Management Pond (flow path Q12 and Q13 on Figure 2-1).

2.3.1 North Pile

The objectives of drainage facilities at the North Pile Starter Cell, East Cell and future West Cell are to collect water that is affected by mining activities and convey it to the Water Management Pond.

The Starter Cell initial embankments and perimeter water control structures were designed by Golder between 2004 and 2005. The water

control structures of the Starter Cell were constructed between 2005 and 2007. The majority of the construction for the Starter Cell initial embankments was performed by Nuna Logistics Limited (Nuna) under construction supervision of AMEC commencing in July of 2005. Thermistor and Piezometer instrumentation for the Starter Cell were installed in Q1/Q2 of 2006. Tli'Cho Logistics Inc. and Ke Te Whii/Ledcor continued Starter Cell embankment construction under the supervision by AMEC in November 2006 until completion in Q3 of 2007.

The perimeter water control structures of the East Cell were constructed between 2008 and 2010 by the De Beers. In 2010, as part of the construction works for the East Cell perimeter water control structures, a grout curtain was constructed from SP3 to SP5 along the access road, adjacent to Snap Lake, to reduce the flow of water from Snap Lake into SP4. Grouting works were performed by McCaw North Drilling under quality assurance supervision performed by Golder (Golder 2010b).

In late December 2011 a surge water flow event to Temporary Sump 4 (TS4) resulted in an overtopping event and the loss of water from containment. In March 2012, Golder provided De Beers the design report of the IL6 ditch to route the water to IL6 (Golder 2012a). The construction of the IL6 ditch was performed by Nuna with quality assurance supervision by Golder. The IL6 ditch provides redundancy flow containment for the western PWCS of the Starter Cell and East Cell. The IL6 ditch will be made redundant the development of the West Cell.

2.3.2 Runoff Water

The objectives of the core and outlying facilities runoff water management system are to:

- Collect runoff from the core facilities (camp and plant site) that may be contaminated by mine activities;
- Convey that runoff to the WMP for storage and subsequent treatment;
- Maintain the exploration pit water sump level at below capacity; and
- Convey uncontaminated surface runoff from outlying facilities to natural receiving streams after polishing to remove sediment.

A site plan showing existing material stockpiles and surface water runoff, as well as layout for perimeter drainage ditches and sumps, is provided in Appendix II. The design basis for core facility drainage was presented by Golder (2004c). In general, natural drainage for the plant site area flows from a local topographic high, east of the mine portal, and collects in the WMP to the west of the plant site area. Grading within the natural catchment area is designed to collect and promote positive drainage towards the WMP. Any core facility development located beyond the natural catchment area is contained within a perimeter drainage system to collect surface water runoff and active layer groundwater, and flow is conveyed back to the WMP from a terminal sump. Perimeter drainage measures include gravity flow ditches, sumps and pumps, and are protected for seasonal operating conditions.

In areas where the near-surface sub grade is in mineral soil with high hydraulic conductivity, or bedrock fractures are encountered, perimeter ditch and sump designs contain linings to limit seepage losses.

- Perimeter drainage, including drainage ditches and sumps, was established around the north, east and south sides of the plant site to collect surface water runoff and active layer groundwater for discharge to the WMP.
- The storage pads have positive drainage to promote surface water runoff.

2.4 THE PROCESS AND FACILITIES FOR THE COLLECTION, MANAGEMENT AND TREATMENT OF ANY WASTEWATER AND DISCHARGE OF EFFLUENT RESULTING FROM MINING ACTIVITIES

This section corresponds to Schedule 5, Part F of the Water Licence, items iv and v. Figure 2-2 provides an illustration of the facilities and pumping system for purposes of collection and management of wastewater and treated effluent. The Starter Cell and East Cell components of the North Pile are covered more thoroughly in sections 2.1.1 and 2.1.6 of the report.

The main components of the Mine with regard to process and facilities of wastewater collection and management pertain to the following:

- North Pile Facility Components
- Water Management Pond
- Water Treatment Plant/Temporary Water Treatment Plant
- Diffusers

2.4.1 North Pile Facility Components

The North Pile Waste Rock and Processed Kimberlite Storage Facility is the surface storage facility for waste rock and processed kimberlite (PK) produced during the operation of the Mine.

Starter Cell

The estimated storage capacity of the Starter Cell is approximately 3.2 million cubic metres. Deposition of slurry is expected to occur throughout the complete development of the Starter Cell.

East Cell

The estimated storage capacity of the East Cell is approximately 2.6 million cubic meters.

West Cell

The detailed design of the West Cell has not yet been completed. This section will be updated as and when appropriate.

Perimeter Water Control Structures

The ditches surrounding the North Pile are designed to capture seepage and surface runoff water and provide gravity flow of the water into the sumps. The northern portion of the ditch along the shoreline will be constructed to promote positive flow of water from Snap Lake towards the ditch to reduce the risk of seepage from the North Pile entering Snap Lake.

The sumps are collection points for flows from the ditches and the North Pile to enable pumping of water to the WMP before treatment at the WTP and discharge to the environment.

Inland Lake 6 Ditch

The IL6 ditch, located within the future development area of the West Cell on the western side of the East Cell, is to intercept surface water runoff and route it to IL6 for pumping to the WMP. The ditch provides redundancy to the western perimeter water control system of the Starter Cell and East Cell should flows bypass these structures.

Processed Kimberlite Distribution Systems

The PK distribution piping system for transporting paste and slurry from the Process Plant to the North Pile and for deposition into the Starter and East Cell are in place along the perimeter of the Starter Cell Northern perimeter embankment, centre pipe bench of the Starter Cell and will be installed along the North embankment of the Starter Cell for deposition into the East Cell.

Water Management System and Piping

Water collected from the perimeter ditches and sumps are pumped to the WMP prior to treatment at the WTP. Following treatment at the WTP, the water will be discharged to the environment.

Water reporting to and from the North Pile components is managed through a network of pipes and pumps.

2.4.2 Water Management Pond

The WMP is the collection point for all water pumped from the sumps around the north pile. The two main potential challenges are elevated nitrate and turbidity levels. Nitrate and turbidity levels can be controlled by understanding the sources of nitrate and turbidity, and then adjusting pumping rates from sumps into the WMP as well as water pumped out of the pond to the WTP. Therefore, having information such as nitrate and turbidity levels of each source before pumps are activated provides a valuable tool to managing surface water in an environmentally responsible manner. The water mixing spreadsheet model is useful for predicting the effect on the WMP and WTP discharge quality and the surface water balance, as a result of the flows from the sumps.

2.4.3 Water Treatment Plant/Temporary Water Treatment Plant

The objectives of the water treatment plant are to treat mine-affected waters to ensure that water quality guidelines are met, prior to release to Snap Lake.

Mine-affected water will be pumped to the WTP from the underground and WMP (flow path Q19 on Figure 2-1). Treated water will be discharged to Snap Lake (flow path Q21 on Figure 2-1). Small quantities of treated water will be used for dust suppression (flow path Q20 on Figure 2-1).

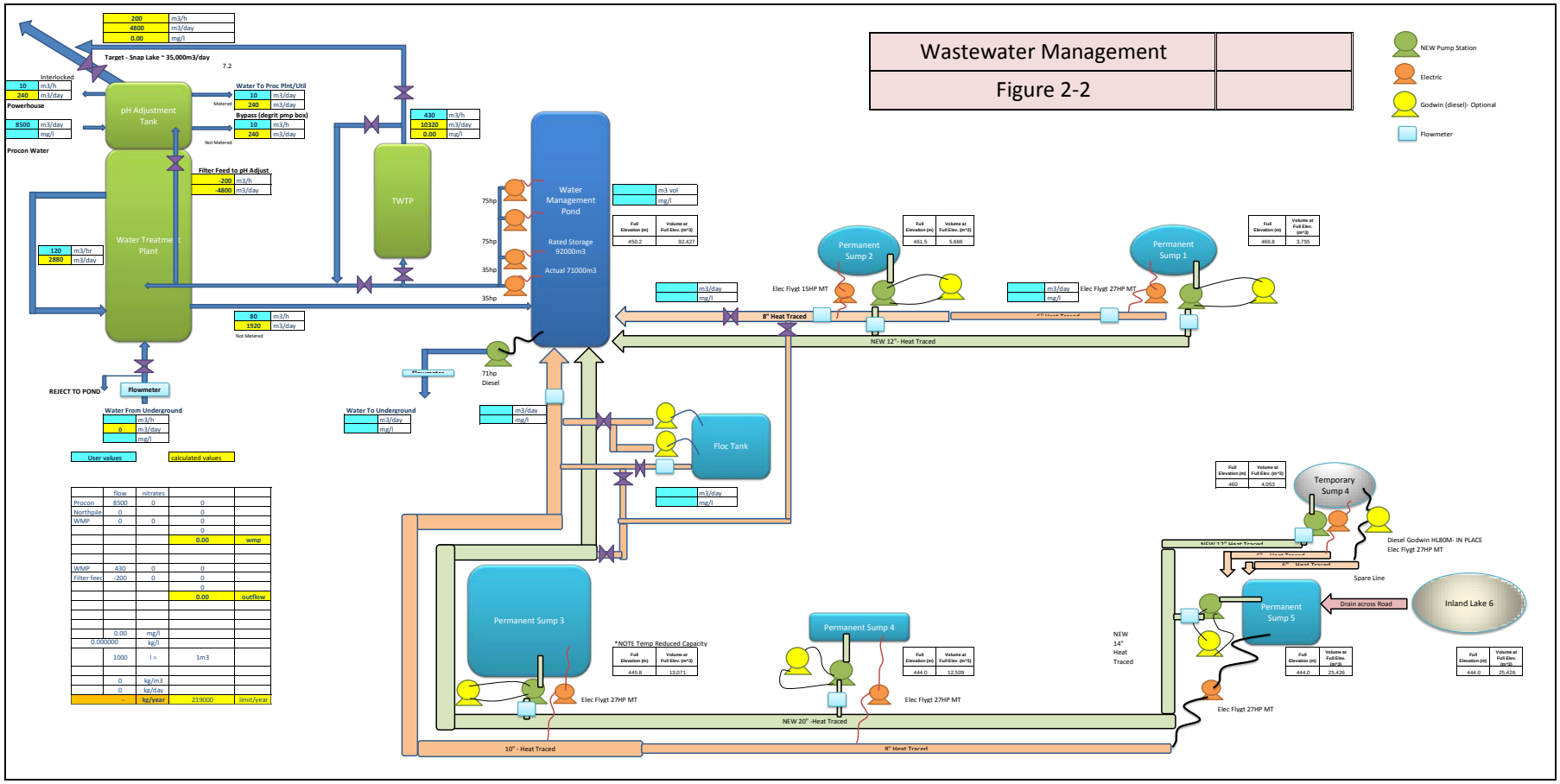
The temporary WTP is expected to operate as required to augment the permanent WTP. It was designed to treat the relatively low flows in the mine pre-production period and the water stored in the WMP, and has a nominal capacity of 7,500 m^3/d In the event that monitoring of underground water inflows shows potential for higher than predicted levels, the plant can be expanded via additional filters and higher flow pumps..

The process includes a bank of filtration units. Sulphuric acid is used for pH control/adjustment and to reduce potential ammonia toxicity.

Performance of the Water Treatment Plant will be optimized by comparison of the quality of water before and after treatment. The Water Treatment Plant(s) are equipped with instrumentation for continuous monitoring of effluent flow rate, ammonia, pH, temperature, conductivity and turbidity, in accordance with the requirements of the Water Licence. Measurements of these parameters will be used to adjust the addition rates of reagents in order to ensure discharge quality targets are met.

2.4.4 Diffuser

The minewater outfalls are located on the eastern shoreline of the northwest peninsula. The area affected by the outfalls includes part of a constructed shoreline embankment and a submerged area to approximately 24 m in water depth (2 locations at approximately 12m each). The submerged pipelines are weighted down near the lake bottom and cover an area of approximately 125 m out from the shore. At the end of the pipelines, there is a 60 m long diffuser structure with five evenly spaced outlet ports. Note that the pipelines do not lie on the substrate of the lake but rather are weighted to sit slightly above the substrate.



	flow	nitrates		
Procon	8500	0	0	
Northpile	0		0	
WMP	0	0	0	
			0	
			0.00	wmp
WMP	430	0	0	
Filter feed	-200	0	0	
			0	
			0.00	outflow
	0.00	mg/l		
0.0000000		kg/l		
	1000	l =	1m3	
	0	kg/m3		
	0	kg/day		
	-	kg/year	219000	tkmit/year

2.5 DETAILS OF THE HYDRAULIC DESIGN OF ALL WATER MANAGEMENT STRUCTURES AND WATER BALANCE ESTIMATES ON A MONTHLY BASIS FOR EACH YEAR OF THE PROPOSED LICENCE

Water balance estimates have been provided in table 2-3 below.

Table 2-3 Summary of Water Balance for Operational Phase (2011 to 2020)[(a)]

	Snap Lake	Core Facilities Water Systems				Underground			North Pile Sumps								
Stream Description	**Raw Water Withdrawal**	**Raw Water to WTP**	**Domestic Water to Camp**	**Sanitary Sewage to STP**	**Treated Effluent to Snap Lake**	**Seepage from Concatenate Water**	**Seepage from Snap Lake**	**Minewater to WTP**	**Direct Precipitation on Sumps**	**Runoff from Land Areas**	**Process Flows**	**Draindown**	**Infiltration**	**Evaporation**	**Drainage to WMP**	**Seepage to Snap Lake**	**Water Retained in the Pile Source of draindown flows)**
Stream Number	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**	**Q13**	**Q14**	**Q15**	**Q16**	**Q17**
Data Source	**Calculated =Q3**	**Calculated =Q1**		**Calculated =Q3**	**Calculated =Q4**			**Calculated =Q6**									**Calculated =Q28-Q11**
Sign Convention	**+ From Lake**	**+ To Site**	**+ To Site**	**+ To STP**	**+ From STP**	**+ To Mine**	**+ To Mine**	**+ From Mine**	**+ To North Pile**	**+ To North Pile**	**+ From North Pile To North Pile Sumps**	**+ From North Pile To North Pile Sumps**	**+ From North Pile To North Pile Sumps**	**+ From North Pile**	**+ From North Pile**	**+ From North Pile**	**+ To North Pile**
Month-Year	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**		**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**
Jan-11	64	64	64	64	64	2,246	21,344	23,590	0	0	1,034	0	117	0	1,621	1	407
Feb-11	76	76	76	76	76	2,371	21,379	23,751	0	0	890	0	117	0	1,288	1	402
Mar-11	69	69	69	69	69	2,506	21,806	24,312	0	1	865	0	117	0	1,148	1	373
Apr-11	66	66	66	66	66	2,631	21,993	24,624	4	28	837	0	117	0	866	1	271
May-11	68	68	68	68	68	2,807	22,068	24,875	165	1,345	891	0	133	38	2,554	1	385
Jun-11	66	66	66	66	66	2,893	22,291	25,184	40	299	907	0	183	161	1,353	1	359
Jul-11	60	60	60	60	60	2,979	22,375	25,354	64	471	893	0	217	241	1,270	1	397
Aug-11	62	62	62	62	62	2,982	22,924	25,906	72	534	778	0	192	182	1,046	1	406
Sep-11	71	71	71	71	71	2,938	23,456	26,394	50	373	801	0	144	65	1,576	1	407
Oct-11	65	65	65	65	65	3,021	23,668	26,689	24	178	643	0	117	0	324	1	366
Nov-11	73	73	73	73	73	3,027	23,930	26,957	1	8	581	0	117	0	1,121	1	545
Dec-11	66	66	66	66	66	2,979	24,061	27,040	0	1	685	0	117	0	798	1	426
Jan-12	80	80	80	80	80	3,066	24,315	27,380	0	0	569	684	442	0	1,308	1	389
Feb-12	81	81	81	81	81	3,152	24,579	27,731	0	0	594	418	316	0	1,240	1	471
Mar-12	81	81	81	81	81	3,155	24,917	28,072	0	0	1,070	297	258	0	1,603	1	543
Apr-12	78	78	78	78	78	3,152	24,978	28,130	0	0	1,090	224	223	0	1,301	1	235
May-12	81	81	81	81	81	3,197	24,752	27,949	524	4,300	1,464	175	217	40	6,879	1	15
Jun-12	75	75	75	75	75	3,239	25,006	28,244	125	922	1,937	140	251	164	3,030	1	68
Jul-12	78	78	78	78	78	3,450	25,062	28,512	38	280	1,317	114	269	237	1,594	1	274
Aug-12	78	78	78	78	78	3,712	26,430	30,142	99	732	1,162	94	240	189	1,603	1	302
Sep-12	76	76	76	76	76	3,802	28,080	31,882	50	367	1,194	79	195	98	2,235	1	343
Oct-12	77	77	77	77	77	3,927	27,746	31,673	14	105	824	67	158	22	804	1	470
Nov-12	77	77	77	77	77	4,019	27,973	31,992	0	0	881	57	144	0	1,181	1	575
Dec-12	73	73	73	73	73	3,974	29,058	33,033	0	0	830	49	140	0	934	1	608
Jan-13	74	74	74	74	74	4,016	29,674	33,690	0	0	1,223	42	137	0	1,638	1	444
Feb-13	89	89	89	89	89	4,144	30,350	34,494	0	0	1,163	37	134	0	1,322	1	422
Mar-13	78	78	78	78	78	4,317	30,430	34,747	0	1	943	32	132	0	1,127	1	343
Apr-13	79	79	79	79	79	4,406	29,894	34,300	4	28	1,066	28	130	0	1,321	1	387

Stream Description	Snap Lake	Core Facilities Water Systems				Underground			North Pile Sumps								
	Raw Water Withdrawal	Raw Water to WTP	Domestic Water to Camp	Sanitary Sewage to STP	Treated Effluent to Snap Lake	Seepage from Concatenate Water	Seepage from Snap Lake	Minewater to WTP	Direct Precipitation on Sumps	Runoff from Land Areas	Process Flows	Draindown	Infiltration	Evaporation	Drainage to WMP	Seepage to Snap Lake	Water Retained in the Pile Source of draindown flows)
Stream Number	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**	**Q13**	**Q14**	**Q15**	**Q16**	**Q17**
Data Source	**Calculated =Q3**	**Calculated =Q1**		**Calculated =Q3**	**Calculated =Q4**			**Calculated =Q6**									**Calculated =Q28-Q11**
Sign Convention	**+ From Lake**	**+ To Site**	**+ To Site**	**+ To STP**	**+ From STP**	**+ To Mine**	**+ To Mine**	**+ From Mine**	**+ To North Pile**	**+ To North Pile**	**+ From North Pile To North Pile Sumps**	**+ From North Pile To North Pile Sumps**	**+ From North Pile To North Pile Sumps**	**+ From North Pile**	**+ From North Pile**	**+ From North Pile**	**+ To North Pile**
Month-Year	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**		**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**
May-13	73	73	73	73	73	4,365	31,650	36,015	356	2,915	1,224	24	148	47	4,353	1	444
Jun-13	76	76	76	76	76	4,278	34,442	38,720	40	299	1,206	21	200	176	1,738	1	438
Jul-13	74	74	74	74	74	4,275	35,382	39,658	64	471	1,015	18	220	228	1,314	1	369
Aug-13	74	74	74	74	74	4,320	35,505	39,825	72	534	1,015	16	179	132	1,322	1	369
Sep-13	74	74	74	74	74	4,362	35,474	39,836	50	373	1,015	14	144	49	1,795	1	369
Oct-13	74	74	74	74	74	4,281	35,920	40,201	24	178	1,015	12	130	17	1,077	1	369
Nov-13	74	74	74	74	74	4,105	36,508	40,614	1	8	1,015	11	122	0	1,286	1	369
Dec-13	74	74	74	74	74	4,019	36,500	40,519	0	1	1,015	10	121	0	967	1	369
Jan-14	74	74	74	74	74	3,849	38,055	41,904	0	0	1,015	8	121	0	1,370	1	369
Feb-14	74	74	74	74	74	3,674	40,154	43,828	0	0	1,015	7	120	0	1,086	1	369
Mar-14	74	74	74	74	74	3,629	40,070	43,699	0	1	1,015	7	120	0	1,275	1	369
Apr-14	74	74	74	74	74	3,712	39,020	42,732	4	28	1,015	6	120	0	940	1	369
May-14	74	74	74	74	74	3,760	39,083	42,843	356	2,915	1,015	5	139	47	4,466	1	369
Jun-14	74	74	74	74	74	3,799	39,735	43,534	40	299	1,015	5	192	166	1,477	1	369
Jul-14	74	74	74	74	74	3,972	39,627	43,599	64	471	1,015	4	213	199	1,405	1	369
Aug-14	74	74	74	74	74	4,228	39,226	43,454	72	534	1,015	4	173	115	1,309	1	369
Sep-14	74	74	74	74	74	4,365	42,859	47,223	50	373	1,015	3	139	43	1,832	1	369
Oct-14	74	74	74	74	74	4,195	48,206	52,400	24	178	1,015	3	125	15	1,046	1	369
Nov-14	74	74	74	74	74	4,144	49,516	53,660	1	8	1,015	2	118	0	1,286	1	369
Dec-14	74	74	74	74	74	4,275	48,245	52,520	0	1	1,015	2	118	0	963	1	369
Jan-15	74	74	74	74	74	4,613	46,798	51,411	0	0	1,015	2	118	0	1,366	1	369
Feb-15	74	74	74	74	74	4,841	46,605	51,447	0	0	1,015	2	118	0	1,078	1	369
Mar-15	74	74	74	74	74	4,710	46,578	51,288	0	1	1,015	2	118	0	1,269	1	369
Apr-15	74	74	74	74	74	4,833	45,768	50,600	4	28	1,015	1	117	0	932	1	369
May-15	74	74	74	74	74	5,095	45,187	50,282	356	2,915	1,015	1	137	41	4,473	1	369
Jun-15	74	74	74	74	74	5,142	45,104	50,246	40	299	1,015	1	190	153	1,467	1	369
Jul-15	74	74	74	74	74	4,930	47,063	51,993	64	471	1,015	1	212	199	1,399	1	369
Aug-15	74	74	74	74	74	4,668	48,788	53,456	72	534	1,015	1	172	115	1,306	1	369
Sep-15	74	74	74	74	74	4,746	48,047	52,793	50	373	1,015	1	138	43	1,829	1	369
Oct-15	74	74	74	74	74	4,925	47,194	52,119	24	178	1,015	1	124	15	1,044	1	369
Nov-15	74	74	74	74	74	5,008	49,910	54,919	1	8	1,015	1	117	0	1,289	1	369
Dec-15	74	74	74	74	74	4,847	52,771	57,618	0	1	1,015	1	117	0	966	1	369
Jan-16	74	74	74	74	74	4,496	50,759	55,254	0	0	1,015	0	117	0	1,365	1	369
Feb-16	74	74	74	74	74	4,698	48,920	53,619	0	0	1,015	0	117	0	1,080	1	369
Mar-16	74	74	74	74	74	5,053	48,300	53,353	0	1	1,015	0	117	0	1,230	1	369
Apr-16	74	74	74	74	74	5,515	47,627	53,142	32	262	1,015	0	117	0	973	1	369
May-16	74	74	74	74	74	5,878	46,751	52,629	328	2,688	1,015	0	136	41	4,533	1	369
Jun-16	74	74	74	74	74	6,123	46,943	53,065	40	299	1,015	0	190	153	1,410	1	369
Jul-16	74	74	74	74	74	6,689	47,893	54,582	64	471	1,015	0	211	199	1,393	1	369
Aug-16	74	74	74	74	74	6,536	52,899	59,435	72	534	1,015	0	172	115	1,298	1	369

Stream Description	Snap Lake	Core Facilities Water Systems				Underground			North Pile Sumps								
	Raw Water Withdrawal	Raw Water to WTP	Domestic Water to Camp	Sanitary Sewage to STP	Treated Effluent to Snap Lake	Seepage from Concatenate Water	Seepage from Snap Lake	Minewater to WTP	Direct Precipitation on Sumps	Runoff from Land Areas	Process Flows	Draindown	Infiltration	Evaporation	Drainage to WMP	Seepage to Snap Lake	Water Retained in the Pile Source of draindown flows)
Stream Number	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**	**Q13**	**Q14**	**Q15**	**Q16**	**Q17**
Data Source	**Calculated =Q3**	**Calculated =Q1**		**Calculated =Q3**	**Calculated =Q4**			**Calculated =Q6**									**Calculated =Q28-Q11**
Sign Convention	**+ From Lake**	**+ To Site**	**+ To Site**	**+ To STP**	**+ From STP**	**+ To Mine**	**+ To Mine**	**+ From Mine**	**+ To North Pile**	**+ To North Pile**	**+ From North Pile To North Pile Sumps**	**+ From North Pile To North Pile Sumps**	**+ From North Pile To North Pile Sumps**	**+ From North Pile**	**+ From North Pile**	**+ From North Pile**	**+ To North Pile**
Month-Year	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**		**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**
Sep-16	74	74	74	74	74	6,677	54,625	61,302	50	373	1,015	0	137	43	1,879	1	369
Oct-16	74	74	74	74	74	7,090	50,402	57,492	24	178	1,015	0	124	15	1,008	1	369
Nov-16	74	74	74	74	74	6,286	52,595	58,880	1	8	1,015	0	117	0	1,287	1	369
Dec-16	74	74	74	74	74	5,449	53,813	59,262	0	1	1,015	0	117	0	939	1	369
Jan-17	74	74	74	74	74	5,187	51,996	57,183	0	0	1,015	0	117	0	1,425	1	369
Feb-17	74	74	74	74	74	5,056	51,656	56,712	0	0	1,015	0	117	0	1,051	1	369
Mar-17	74	74	74	74	74	5,304	50,759	56,062	0	1	1,015	0	117	0	1,230	1	369
Apr-17	74	74	74	74	74	5,574	50,093	55,667	4	28	1,015	0	117	0	972	1	369
May-17	74	74	74	74	74	5,321	50,003	55,324	356	2,915	1,015	0	136	41	4,366	1	369
Jun-17	74	74	74	74	74	5,056	50,299	55,355	40	299	1,015	0	190	153	1,379	1	369
Jul-17	74	74	74	74	74	5,346	49,769	55,115	93	770	983	686	610	227	1,951	1	401
Aug-17	74	74	74	74	74	5,619	49,596	55,215	106	884	1,016	393	430	132	2,045	1	368
Sep-17	74	74	74	74	74	5,864	49,090	54,953	74	618	1,016	278	342	49	2,474	1	368
Oct-17	74	74	74	74	74	6,137	48,601	54,739	35	294	1,016	210	296	17	1,428	1	368
Nov-17	74	74	74	74	74	6,340	48,264	54,605	2	14	1,016	164	267	0	1,529	1	368
Dec-17	74	74	74	74	74	6,862	49,206	56,068	0	2	1,016	131	252	0	1,297	1	368
Jan-18	74	74	74	74	74	7,377	49,750	57,127	0	0	1,016	107	240	0	1,406	1	368
Feb-18	74	74	74	74	74	7,523	49,152	56,675	0	0	1,016	89	232	0	1,274	1	368
Mar-18	74	74	74	74	74	7,260	49,128	56,389	0	2	1,016	76	225	0	1,422	1	368
Apr-18	74	74	74	74	74	6,754	50,111	56,864	6	46	1,016	64	220	0	1,072	1	368
May-18	74	74	74	74	74	6,182	50,491	56,673	523	4,880	1,016	55	235	47	6,524	1	368
Jun-18	74	74	74	74	74	5,839	49,671	55,511	59	495	1,016	47	284	176	1,780	1	368
Jul-18	74	74	74	74	74	5,574	49,605	55,179	94	630	1,016	40	303	228	1,695	1	368
Aug-18	74	74	74	74	74	5,864	48,997	54,861	106	708	1,016	35	260	132	1,646	1	368
Sep-18	74	74	74	74	74	6,221	48,646	54,867	74	495	1,016	30	224	49	2,017	1	368
Oct-18	74	74	74	74	74	6,179	48,390	54,569	35	236	1,016	26	208	17	1,225	1	368
Nov-18	74	74	74	74	74	6,134	48,420	54,554	2	11	1,016	23	200	0	1,392	1	368
Dec-18	74	74	74	74	74	5,758	49,647	55,405	0	2	1,016	20	198	0	1,039	1	368
Jan-19	74	74	74	74	74	5,315	49,839	55,154	0	0	1,016	17	197	0	1,486	1	368
Feb-19	74	74	74	74	74	5,270	48,902	54,172	0	0	1,016	15	196	0	1,187	1	368
Mar-19	74	74	74	74	74	5,270	48,986	54,256	0	2	1,016	13	195	0	1,347	1	368
Apr-19	74	74	74	74	74	5,270	48,908	54,179	6	37	1,016	12	195	0	1,021	1	368
May-19	74	74	74	74	74	5,270	48,813	54,084	523	4,292	1,016	10	213	47	5,918	1	368
Jun-19	74	74	74	74	74	5,270	48,777	54,048	59	397	1,016	9	266	176	1,659	1	368
Jul-19	74	74	74	74	74	5,229	48,643	53,872	94	625	1,016	8	287	228	1,647	1	368
Aug-19	74	74	74	74	74	4,933	49,605	54,538	106	708	1,016	7	247	132	1,619	1	368
Sep-19	74	74	74	74	74	4,582	50,171	54,753	74	495	1,016	6	212	49	1,992	1	368
Oct-19	74	74	74	74	74	4,493	49,680	54,173	35	236	1,016	5	199	17	1,205	1	368
Nov-19	74	74	74	74	74	4,535	49,638	54,173	2	11	1,016	5	191	0	1,377	1	368
Dec-19	74	74	74	74	74	4,579	49,719	54,298	0	2	1,016	4	191	0	1,022	1	368

Stream Description	Snap Lake	Core Facilities Water Systems				Underground			North Pile Sumps								
	Raw Water Withdrawal	Raw Water to WTP	Domestic Water to Camp	Sanitary Sewage to STP	Treated Effluent to Snap Lake	Seepage from Concatenate Water	Seepage from Snap Lake	Minewater to WTP	Direct Precipitation on Sumps	Runoff from Land Areas	Process Flows	Draindown	Infiltration	Evaporation	Drainage to WMP	Seepage to Snap Lake	Water Retained in the Pile Source of draindown flows)
Stream Number	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**	**Q13**	**Q14**	**Q15**	**Q16**	**Q17**
Data Source	**Calculated =Q3**	**Calculated =Q1**		**Calculated =Q3**	**Calculated =Q4**			**Calculated =Q6**									**Calculated =Q28-Q11**
Sign Convention	**+ From Lake**	**+ To Site**	**+ To Site**	**+ To STP**	**+ From STP**	**+ To Mine**	**+ To Mine**	**+ From Mine**	**+ To North Pile**	**+ To North Pile**	**+ From North Pile To North Pile Sumps**	**+ From North Pile To North Pile Sumps**	**+ From North Pile To North Pile Sumps**	**+ From North Pile**	**+ From North Pile**	**+ From North Pile**	**+ To North Pile**
Month-Year	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**		**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**
Jan-20	74	74	74	74	74	4,663	50,062	54,725	0	0	1,016	4	191	0	1,476	1	368
Feb-20	74	74	74	74	74	4,752	49,868	54,620	0	0	1,016	3	191	0	1,177	1	368
Mar-20	74	74	74	74	74	4,752	49,421	54,173	0	2	1,016	3	190	0	1,294	1	368
Apr-20	74	74	74	74	74	4,752	49,379	54,131	47	383	1,016	3	190	0	1,067	1	368
May-20	74	74	74	74	74	4,752	49,376	54,128	483	3,956	1,016	2	210	47	5,965	1	368

Stream Description	Water Management Pond (WMP)					Water Treatment Plant (WTP)			Process Plant	
	Direct Precipitation	Runoff from Land Areas	Evaporation	Seepage	Net Flow Pumped to TWTP/WTP	Dust Suppression	Discharge to Snap Lake	Pumped to Process	Water in Ore	Pumped to North Pile
Stream Number	**Q18**	**Q19**	**Q20**	**Q21**	**Q22**	**Q23**	**Q24**	**Q25**	**Q26**	**Q27**
Data Source										
Sign Convention	**+ To WMP**	**+ To WMP**	**+ From WMP**	**+ From WMP**	**+ From WMP**	**+ From WTP**	**+ From WTP**	**+ From WTP**	**+ To Process Plant**	**+ From Process Plant**
Month-Year	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**
Jan-11	0	0	0	32	-629	0	21,723	1,388	19	1,442
Feb-11	0	0	0	36	915	0	23,591	1,279	19	1,292
Mar-11	0	0	0	32	1,021	0	24,277	1,213	19	1,238
Apr-11	3	10	0	33	845	0	24,505	1,072	19	1,107
May-11	126	476	26	32	4,609	0	28,374	1,265	19	1,276
Jun-11	31	103	107	33	2,744	300	26,533	1,248	19	1,266
Jul-11	49	162	161	32	1,681	300	25,699	1,266	19	1,290
Aug-11	55	184	122	32	1,043	300	25,729	1,159	19	1,184
Sep-11	39	129	44	33	1,954	300	26,929	1,193	19	1,208
Oct-11	18	61	0	32	294	300	25,737	1,008	19	1,010
Nov-11	1	3	0	33	815	0	26,890	1,124	19	1,126
Dec-11	0	0	0	32	787	0	27,047	1,063	19	1,112
Jan-12	0	0	0	32	-124	0	26,582	968	19	958
Feb-12	0	0	0	36	1,320	0	28,350	1,000	19	1,066
Mar-12	0	0	0	32	415	0	27,145	1,596	19	1,612
Apr-12	0	0	0	33	3,879	0	30,906	1,395	19	1,325
May-12	401	1,525	27	32	9,284	0	36,123	1,493	19	1,480
Jun-12	95	318	109	33	3,503	300	29,750	1,992	19	2,005
Jul-12	29	96	159	32	1,411	300	28,340	1,531	19	1,591
Aug-12	76	252	126	32	2,008	300	30,881	1,431	19	1,465
Sep-12	38	127	66	33	1,893	300	32,750	1,487	19	1,536
Oct-12	11	36	15	32	689	300	31,655	1,264	19	1,293
Nov-12	0	0	0	33	-352	0	30,853	1,431	19	1,455
Dec-12	0	0	0	32	288	0	32,414	1,411	19	1,438
Jan-13	0	0	0	32	1,282	0	33,850	1,628	19	1,667

Stream Description	Water Management Pond (WMP)					Water Treatment Plant (WTP)			Process Plant	
	Direct Precipitation	Runoff from Land Areas	Evaporation	Seepage	Net Flow Pumped to TWTP/WTP	Dust Suppression	Discharge to Snap Lake	Pumped to Process	Water in Ore	Pumped to North Pile
Stream Number	**Q18**	**Q19**	**Q20**	**Q21**	**Q22**	**Q23**	**Q24**	**Q25**	**Q26**	**Q27**
Data Source										
Sign Convention	**+ To WMP**	**+ To WMP**	**+ From WMP**	**+ From WMP**	**+ From WMP**	**+ From WTP**	**+ From WTP**	**+ From WTP**	**+ To Process Plant**	**+ From Process Plant**
Month-Year	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**
Feb-13	0	0	0	36	2,697	0	36,274	1,562	19	1,585
Mar-13	0	0	0	32	2,619	0	36,995	1,308	19	1,286
Apr-13	3	10	0	33	1,356	0	35,387	1,428	19	1,453
May-13	273	1,033	31	32	6,358	0	42,143	1,636	19	1,668
Jun-13	31	103	117	33	1,832	300	40,273	1,653	19	1,644
Jul-13	49	162	152	32	1,372	300	41,040	1,363	19	1,384
Aug-13	55	184	88	32	1,372	300	41,288	1,363	19	1,384
Sep-13	39	129	33	33	1,539	300	41,599	1,363	19	1,384
Oct-13	18	61	11	32	1,372	300	41,924	1,363	19	1,384
Nov-13	1	3	0	33	1,144	0	42,710	1,363	19	1,384
Dec-13	0	0	0	32	817	0	42,465	1,363	19	1,384
Jan-14	0	0	0	32	1,327	0	44,695	1,363	19	1,384
Feb-14	0	0	0	36	1,136	0	46,951	1,363	19	1,384
Mar-14	0	0	0	32	1,149	0	47,099	1,363	19	1,384
Apr-14	3	10	0	33	1,084	0	46,197	1,363	19	1,384
May-14	273	1,033	31	32	3,626	0	49,104	1,363	19	1,384
Jun-14	31	103	117	33	3,368	300	50,086	1,363	19	1,384
Jul-14	49	162	152	32	1,372	300	48,825	1,363	19	1,384
Aug-14	55	184	88	32	1,533	300	48,882	1,363	19	1,384
Sep-14	39	129	33	33	1,788	300	53,786	1,363	19	1,384
Oct-14	18	61	11	32	1,372	300	60,736	1,363	19	1,384
Nov-14	1	3	0	33	1,197	0	64,381	1,363	19	1,384
Dec-14	0	0	0	32	813	0	63,584	1,363	19	1,384
Jan-15	0	0	0	32	1,327	0	62,934	1,363	19	1,384
Feb-15	0	0	0	36	1,134	0	63,289	1,363	19	1,384
Mar-15	0	0	0	32	1,147	0	63,375	1,363	19	1,384
Apr-15	3	10	0	33	1,078	0	62,694	1,363	19	1,384
May-15	273	1,033	31	32	3,626	0	67,488	1,363	19	1,384
Jun-15	31	103	117	33	3,368	300	68,514	1,363	19	1,384
Jul-15	49	162	152	32	1,372	300	68,582	1,363	19	1,384
Aug-15	55	184	88	32	1,533	300	71,503	1,363	19	1,384
Sep-15	39	129	33	33	1,788	300	69,881	1,363	19	1,384
Oct-15	18	61	11	32	1,372	300	67,373	1,363	19	1,384
Nov-15	1	3	0	33	1,202	0	71,209	1,363	19	1,384
Dec-15	0	0	0	32	812	0	74,638	1,363	19	1,384
Jan-16	0	0	0	32	1,327	0	72,870	1,363	19	1,384
Feb-16	0	0	0	36	1,134	0	71,133	1,363	19	1,384
Mar-16	0	0	0	32	1,154	0	71,095	1,363	19	1,384
Apr-16	25	93	0	33	1,076	0	71,072	1,363	19	1,384
May-16	252	953	31	32	3,706	0	73,064	1,363	19	1,384
Jun-16	31	103	117	33	3,285	300	73,481	1,363	19	1,384
Jul-16	49	162	152	32	1,372	300	84,514	1,363	19	1,384
Aug-16	55	184	88	32	1,533	300	96,709	1,363	19	1,384
Sep-16	39	129	33	33	1,788	300	93,545	1,363	19	1,384
Oct-16	18	61	11	32	1,372	300	87,833	1,363	19	1,384

Stream Description	Water Management Pond (WMP)					Water Treatment Plant (WTP)			Process Plant	
	Direct Precipitation	Runoff from Land Areas	Evaporation	Seepage	Net Flow Pumped to TWTP/WTP	Dust Suppression	Discharge to Snap Lake	Pumped to Process	Water in Ore	Pumped to North Pile
Stream Number	**Q18**	**Q19**	**Q20**	**Q21**	**Q22**	**Q23**	**Q24**	**Q25**	**Q26**	**Q27**
Data Source										
Sign Convention	**+ To WMP**	**+ To WMP**	**+ From WMP**	**+ From WMP**	**+ From WMP**	**+ From WTP**	**+ From WTP**	**+ From WTP**	**+ To Process Plant**	**+ From Process Plant**
Month-Year	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**	**m^3/day**
Nov-16	1	3	0	33	1,172	0	88,871	1,363	19	1,384
Dec-16	0	0	0	32	840	0	89,050	1,363	19	1,384
Jan-17	0	0	0	32	1,327	0	94,236	1,363	19	1,384
Feb-17	0	0	0	36	1,126	0	96,616	1,363	19	1,384
Mar-17	0	0	0	32	1,154	0	92,488	1,363	19	1,384
Apr-17	3	10	0	33	1,073	0	91,822	1,363	19	1,384
May-17	273	1,033	31	32	3,774	0	93,768	1,363	19	1,384
Jun-17	31	103	117	33	3,036	300	93,065	1,363	19	1,384
Jul-17	49	162	152	32	1,855	300	90,813	1,363	19	1,384
Aug-17	55	184	88	32	2,177	300	90,675	1,363	19	1,384
Sep-17	39	129	33	33	2,537	300	90,795	1,363	19	1,384
Oct-17	18	61	11	32	1,533	300	89,641	1,363	19	1,384
Nov-17	1	3	0	33	1,372	0	89,793	1,363	19	1,384
Dec-17	0	0	0	32	1,372	0	91,873	1,363	19	1,384
Jan-18	0	0	0	32	1,372	0	93,484	1,363	19	1,384
Feb-18	0	0	0	36	1,372	0	93,312	1,363	19	1,384
Mar-18	0	0	0	32	1,272	0	92,579	1,363	19	1,384
Apr-18	3	10	0	33	1,303	0	92,739	1,363	19	1,384
May-18	273	1,033	31	32	5,711	0	96,819	1,363	19	1,384
Jun-18	31	103	117	33	3,618	300	93,308	1,363	19	1,384
Jul-18	49	162	152	32	1,775	300	91,050	1,363	19	1,384
Aug-18	55	184	88	32	1,855	300	90,682	1,363	19	1,384
Sep-18	39	129	33	33	2,038	300	90,867	1,363	19	1,384
Oct-18	18	61	11	32	1,372	300	89,822	1,363	19	1,384
Nov-18	1	3	0	33	1,372	0	89,933	1,363	19	1,384
Dec-18	0	0	0	32	989	0	90,189	1,363	19	1,384
Jan-19	0	0	0	32	1,327	0	90,348	1,363	19	1,384
Feb-19	0	0	0	36	1,347	0	89,488	1,363	19	1,384
Mar-19	0	0	0	32	1,181	0	89,185	1,363	19	1,384
Apr-19	3	10	0	33	1,242	0	89,082	1,363	19	1,384
May-19	273	1,033	31	32	5,035	0	92,609	1,363	19	1,384
Jun-19	31	103	117	33	3,535	300	90,598	1,363	19	1,384
Jul-19	49	162	152	32	1,694	300	88,495	1,363	19	1,384
Aug-19	55	184	88	32	1,775	300	89,908	1,363	19	1,384
Sep-19	39	129	33	33	2,038	300	90,517	1,363	19	1,384
Oct-19	18	61	11	32	1,372	300	88,602	1,363	19	1,384
Nov-19	1	3	0	33	1,372	0	88,860	1,363	19	1,384
Dec-19	0	0	0	32	960	0	88,361	1,363	19	1,384
Jan-20	0	0	0	32	1,327	0	89,144	1,363	19	1,384
Feb-20	0	0	0	36	1,324	0	89,214	1,363	19	1,384
Mar-20	0	0	0	32	1,183	0	88,584	1,363	19	1,384
Apr-20	25	93	0	33	1,209	0	88,399	1,363	19	1,384
May-20	252	953	31	32	5,113	0	92,124	1,363	19	1,384

2.6 ANY OTHER INFORMATION REQUIRED TO DESCRIBE HOW WATER AND WASTEWATER WILL BE MANAGED

This section corresponds to Schedule 5, Part 1a, item vii of Water License MV2011L2-0004.

2.6.1 Surface Water Management Protocols

Effective management of surface water at Snap Lake Mine is critical to adhere to water license agreements by preventing spills from occurring. Surface water management is comprised primarily of the North Pile Sumps, WMP, TWTP, WTP, as well as influent from underground that becomes part of the surface system en route to the WTP or WMP. There are a large number of personnel that contribute to the overall success of effective surface water management.

2.6.1.1 Freshet Management

The purpose of freshet management is to provide a clear description of the steps that must be followed daily as well as during an emergency event, for consistency between personnel and for the understanding of new employees to the team. It is up to every individual to ensure a clear understanding of every aspect of his/her role and how it fits into water management.

2.6.1.2 North Pile Perimeter Water Control Structures

Water captured by the north pile sumps is pumped to the WMP. There are five permanent sumps (PS1, PS2, PS3, PS4 and PS5), one temporary sump (TS4), three water collection/diversion ditches (IL6 Ditch, West Ditch, PS3-PS4 Ditch) and the WMP. The purpose of the sumps is to capture water draining off the north pile, and then pump to the WMP. During precipitation events such as the annual freshet (it is often necessary to have storage in the sumps, however this is only on a temporary basis. During freshet, due to increased inflows, there is a requirement for a close watch on the system for the duration of freshet to prevent spillage events. Outside of the freshet period, even though water volumes may be lower, water management is no less important as a spill can occur at anytime. The sump water levels are monitored by means of:

- Daily survey report
- Remote instrumentation network
- Field/visual checks (level poles, marker pylons/rocks, etc.)

2.6.1.3 Freshet Flocculation Tank

De Beers installed a 400 cubic meter settling tank structure in 2013 which has been erected for operation during Freshet to aid in turbidity control by pre-treating and settling high turbidity water before allowing it to enter the WMP. The main objective of this flocculation tank is to ensure that there is no hindrance to pumping from the WMP to the WTP due to turbidity issues.

The flocculation tank has been set up adjacent to PS3 on a gravel pad which has been leveled within grader tolerance during construction. The location was set to allow for mixing of chemicals in pipelines prior to discharge into the flocculation tank and also for the proximity to a perimeter sump in the event of very high flows or malfunction which will require draining of the flocculation tank into an existing sump structure. Piping in and out of the flocculation tank has been developed to accommodate both temporary and permanent perimeter sump piping system lines; there should be no changes required in piping infrastructure going forward.

2.6.1.4 Ice Management

During winter, sumps need to be maintained at a level where pumps can remain in recirculation, to prevent lines and suction wells from freezing, control the surface ice formation, and ensure there is always adequate pumping capacity available. De- icing is a regular practice to ensure that ice buildup is prevented and/or kept to a minimum. This requires continual monitoring and job planning to ensure that manpower and equipment are available to maintain all sump ice levels. Diligent maintenance of infrastructure such as pumps, lines, and generators, is especially critical during winter to manage the water amidst challenging conditions.

Ice accumulation in sumps requires action, as ice reduces the available storage volume and puts upstream water management at risk. In other words, water and ice must both be managed in sumps, whether by pumping or excavating. Sump icing is to be monitored during daily field checks, with the de-icing schedule for the following days formed accordingly, as different sumps are subject to ice formation at varying rates.

When water is not visible, survey will report ice levels instead. The absence of water or an ice survey reading does not indicate that a sump does not need maintenance, but rather may indicate that it is time to de-ice the sump to recover its storage capacity.

Ice formation must also be monitored and removed in the critical flow ditches which need to remain clear for water management, i.e. West Ditch.

2.6.1.5 IL6 Ditch

The primary purpose of IL6 Ditch is to capture runoff flow from the tundra between TS4 and IL6 Ditch during freshet. This area was impacted by the TS4 overtopping in December 2011, which contaminated the ground with elevated nitrate levels. The IL6 Ditch is only a mitigation tool to minimize a potential spill event from TS4. It is not a water control structure to be used in managing TS4.

The IL6 Ditch directs any captured flow into IL6 and this area is monitored, pumped, and de-iced. Environmental/Permitting permission has been granted to de-ice IL6 similar to all other sumps as of December 2012.

2.6.1.6 Water Management Pond

The WMP is the collection point for all water pumped from the sumps around the north pile. The two main potential challenges are heightened nitrate and turbidity levels. Nitrate and turbidity levels can be controlled by understanding the sources of nitrate and turbidity, and then adjusting pumping rates from sumps into the WMP as well as water pumped out of the pond to the WTP. Therefore, having information such as nitrate and turbidity levels of each source before pumps are activated provides a valuable tool to managing surface water in an environmentally responsible manner. The water mixing spreadsheet model is useful for predicting the effect on the WMP and WTP discharge quality and the surface water balance, as a result of the flows from the sumps.

2.6.1.7 Temporary Sump 4

TS4 is a critical sump as it is a receiving area for elevated flows of water from the North Pile, which in extreme cases can result in a spill, as occurred in December 2011. It is unacceptable to have a repeat spill, therefore, additional monitoring and manpower, additional pumping capacity, and increased communication between site personnel is provided at this location when required.

2.6.1.8 Conclusion

Successful surface water management is a team effort. Responsibilities, accountability, and diligent following of procedures are essential. This planning serves as the minimum baseline guide to surface water management at Snap Lake Mine.

2.7 INFORMATION REGARDING MONITORING

2.7.1 Details of Monitoring, Including a Rationale for Each Component of the Water Management System

The Water Management Plan will incorporate all necessary measures and procedures to comply with the requirements of Water License MV2011L2-0004. A Surveillance Network Program (SNP) has been established to satisfy water License requirements, and locations of mine site SNP stations are shown on in Appendix III. Specific requirements and standards for water monitoring and compliance, as per Part F of the Water Licence, include the following:

- *The total quantity of fresh Water drawn from Snap Lake and used by the Snap Lake Diamond Project shall not exceed one hundred and eighty-eight thousand (188,000) cubic metres annually.*

- *The Licensee shall install meters for all structures used to withdraw Water or Discharge Waters or Waste to the satisfaction of an Inspector.*

- *The Licensee shall construct and maintain the Water intake in accordance with the Department of Fisheries and Ocean's (DFO's) requirements to prevent entrainment of fish. Dimensions should follow DFO's Freshwater Intake End-of-Pipe Fish Screen Guidelines.*

- *The Licensee shall manage Water and Wastewater with the objective of minimizing the impacts of the Project on the quantity and quality of Water in the Receiving Environment through the use of appropriate mitigation measures, monitoring, and follow-up actions.*

- *The Licensee shall submit to the Board for approval an update of the Water Management Plan on October 1, 2013 and at the following times:*

  a) If the Licensee seeks changes to the plan;

  b) Every three (3) years following approval of the plan; or

  c) Upon the request of the Board.

  Updates to the Water Management Plan shall describe how the Licensee is meeting the objectives listed in Part F, Item 4 of this License and satisfy the requirements of Schedule 5, Item 1.

The Licensee shall operate in accordance with the plan referred to Part F, Item 5 as and when approved by the Board.

- *The Licensee shall operate in accordance with the plan referred to Part F, Item 5 as and when approved by the Board.*

- *The results of any monitoring performed in a calendar year under the approved Water Management Plan described shall be reported in the Annual Water License Report as per Part B, Item 7 and Schedule 1, Item 1.s.*

- *Effluent from the Sewage Treatment Plant shall be tested prior to mixing with the effluent from the Water Treatment Plant at Surveillance Network Program StationNumber 02-16i and will meet the following effluent quality requirements:*

Parameter	Maximum Concentration of any Grab Sample	Average Monthly Limit
BOD_5	25.0 mg/L	15.0 mg/L
Oil and Grease	5.0 mg/L	3.0 mg/L
Faecal Coliforms	20 CFU/100mL	10 CFU/100mL

- *Effluent quality criteria requirements:*

  All Water or Waste from the Project that enters the Receiving Environment, including all Discharges from Surveillance Network Program Station 02-17b (permanent Water treatment plant) and 02-17 (temporary Water treatment plant), shall meet the following effluent quality criteria:

Parameter	Effluent Quality Criteria in mg/L	
	Maximum Average	**Maximum Grab**
Total Suspended Sediments	7	14
Ammonia as N	10	20
Nitrite as N	0.5	1.0
Nitrate as N (up to December 31, 2014)	22	44
Nitrate as N (from January 1, 2015)	4	8
Chloride (up to December 31, 2014)	310	620
Chloride (from January 1, 2015)	160	320
Fluoride (from January 1, 2015)	0.15	0.3
Sulphate	75	150
Aluminum	0.1	0.2
Arsenic	0.007	0.014
Chromium	0.01	0.02
Copper	0.003	0.006
Lead	0.005	0.01
Nickel	0.05	0.1
Zinc	0.01	0.02

N = nitrogen; mg/L = milligrams per litre.

- *Any Water or Waste from the Project that enters the Receiving Environment shall have a pH between 6.0 and 9.0, except surface runoff which shall have a pH between 5.0 and 9.0.*

- *The monthly average limit for Extractable Petroleum Hydrocarbons shall be 4.6 mg/L for F1 (C6-C10) and 2.1 mg/L for F2 (C11-C16) and the Discharge shall be managed to prevent the appearance of any visible film from the Discharge on the surface of Snap Lake in the vicinity of the outfall.*

- *The Licensee shall ensure that the effluent discharged to Snap Lake shall not be acutely toxic to aquatic life, using protocols described in the Surveillance Network Program annexed to this Licence.*

- *The pH of the final effluent discharged to Snap lake at SNP station 02-17 and 02-17b shall be managed as necessary by the Licensee to prevent acute toxicity of ammonia in the final effluent discharged. Adjustment of the pH shall be made only when*

necessary to prevent acute ammonia toxicity and shall not result in a pH in the final effluent below the ambient pH of Snap lake at any time.

- *Total phosphorus loads from the Water and Sewage Treatment Plants discharging to Snap Lake must be controlled, as per approved operations plans, such that loads of total phosphorus do not exceed an annual loading of 256 (two hundred and fifty-six) kg per year in any calendar year during the life of the Project.*

- *The Licensee shall direct all Water or Waste from the Project that does not meet the effluent quality criteria specified under Part F, Item 9 to the Water Treatment Plant or Water Management Pond. The Inspector may authorize the divergence of Water to an alternate location if necessary. The Licensee shall notify the Board in writing within twenty-four (24) hours of this authorization being granted.*

- *The calculated whole lake average of total dissolved solids (TDS), (as described in the Surveillance Network Program) at sampling locations comprising Surveillance Network Program Station Number 02-18 shall remain below 350 mg/L at all times.*

- *The Licensee shall submit to the Board for approval a Plume Characterization Study to assess the performance of the outfall diffuser installed in 2011 and the distribution of the diffuser plume in Snap Lake under a variety of conditions (including under ice in late winter) by January 31, 2013.*

- *The Licensee shall submit for approval by December 31, 2013 a Strontium Response Plan that satisfies the requirements of Schedule 5, Item 2.*

- *The Licensee shall submit for approval by December 31, 2013 a TDS Response Plan that satisfies the requirements of Schedule 5, Item 3.*

- *The Licensee shall submit for approval by December 31, 2013 a Nitrogen Response Plan that satisfies the requirements of Schedule 5, Item 4.*

- *If not approved by the Board, the plans referred to in Part F, Items 5, 15, 16, and 17 shall be revised and resubmitted in accordance with directives from the Board.*

- *The Licensee shall implement the plans referred to in Part F, Items 15, 16, and 17 as and when approved by the Board.*

- *The Licensee will re-evaluate the Best Available Technology for treatment of the effluent discharged to Snap Lake and submit their findings at the request of the Board.*

The SNP includes a number of sampling stations on the mine site that are not explicitly referenced in the Water Licence. The locations of mine site SNP stations are shown in Appendix III, and are discussed in Table 2-4.

Table 2-4 Summary of SNP Sampling Stations

SNAP LAKE SNP SAMPLING REQUIREMENTS						
Water License (MV2011L2-004)						
Station Number	**Area Description**	**Frequency of Sample**	**Lab Analyzing Sample**	**# of Bottles**	**Bottles Used**	**Tests Performed**
SNP 02-01	Final Minewater Collection Sump	Continuous	Internal	0	None	Flow, Conductivity, Temperature, Turbidity, pH
		Weekly	ALS Global	3	Routine, Nutrients	pH, Turbidity, TDS/TSS, Total Ammonia, Calcium, Chloride
		Monthly	ALS Global	11	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC, Oil and Grease	Turbidity, TDS/TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX, Oil and Grease.
SNP 02-02	North Pile Drainage Collection Ditch	Continuous	Internal	0	None	Flow, Conductivity, Temperature, Turbidity, pH
		Weekly during spring freshet and heavy rainfall events	ALS Global	1	Routine	TSS and turbidity
		Monthly	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
SNP 02-03	Core Facilities Area Collection Ditch Near Water Management Pond	Continuous	Internal	1	None	Flow, Conductivity, Temperature, Turbidity, pH
		Weekly during spring freshet and heavy rainfall events	ALS Global	1	Routine	TSS and turbidity
		Monthly	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
SNP 02-04	Uncontrolled Surface Runoff at Culvert by Airstrip	Twice per week during spring freshet	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX

		Daily during heavy heavy rain if measurable flow is present	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
SNP 02-05	Uncontrolled Surface Runoff at Bulk Sample Mine Rock Pad	Twice per week during spring freshet	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
		Daily during heavy heavy rain if measurable flow is present	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
SNP 02-06	Uncontrolled Surface Runoff at Quarry Site	Twice per week during spring freshet	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
		Daily during heavy heavy rain if measurable flow is present	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
SNP 02-07	Uncontrolled Runoff at Road to Bulk Emulsion Plant	Twice per week during spring freshet	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
		Daily during heavy heavy rain if measurable flow is present	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
SNP 02-08	Uncontrolled Surface Runoff at Winter Access Road	Twice per week during spring freshet	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
		Daily during heavy heavy rain if measurable flow is present	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX-TEH, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX

SNP 02-09	Uncontrolled Surface Runoff at Emulsion Plant Road	Twice per week during spring freshet	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX-TEH, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
		Daily during heavy heavy rain if measurable flow is present	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
SNP 02-10	Any Other Point Where Observable Flow to Snap Lake of IL5 is Oberserved	Twice per week during spring freshet	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TDS/TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, Extractable Petroleum Hydrocarbons, (F1 & F2), BTEX
		Daily during heavy heavy rain if measurable flow is present	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
SNP 02-11	Seepage Well Down Gradient From Dam 1 Near Snap Lake Shoreline	Monthly	Internal	0	None	Water Level
		Quarterly when water is present	ALS Global	10	Routine, Nutients, Total and Dissolved Metals, BTEX, F1/F2, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
SNP 02-12	Seepage Well Down Gradient From Dam 1 at Water Management Pond	Monthly	Internal	0	None	Water Level
		Quarterly when water is present	ALS Global	10	Routine, Nutrients, Total and Dissolved Metals, BTEX, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
SNP 02-13	Seepage Well Down Gradient from Dam 2 at Water Management Pond	Monthly	Internal	0	None	Water Level
		Quarterly when water is present	ALS Global	10	Routine, Nutrients, Total and Dissolved Metals, BTEX, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX
SNP 02-14	Water Mangement Pond	Continuous	Internal	0	None	Flow
		Weekly when pumping to the WMP	ALS Global	10	Routine, Nutrients, Total and Dissolved Metals, BTEX-THE, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, TEH, F1/F2, BTEX

		Quarterly (when not pumping to the WTP)	ALS Global	10	Routine, Nutrients, Total and Dissolved Metals, BTEX, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury,TEH, F1/F2, BTEX
SNP 02-15	Water Intake from Snap Lake	Monthly	ALS Global	3	Routine, Nutrients, Feacal Coliform	E. Coli, Major Ions, Nitrate, TDS (calc)
		Quarterly	ALS Global	3	1x20L, 2x Faecal Coliform	Microbial Pathogens (Giardia, Cryptosporidium and total heterotrophic plate count)
		Annually	ALS Global	5	Routine, Nutrients, Total and Dissovled Metals, TOC	Colour, Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, ICP-MS Metal Scan, Total Mercury, Cyanide
SNP 02-16 i	Sewage discharge from Sewage Treatment Plant, Prior to Mixing with Water treatment Plant Effluent	Continuous	Internal	0	None	Flow, Conductivity, Temperature, Turbidity, pH
		Every 6 Days	ALS Global	5	Routine, Nutrients, Oil & Grease, BacT, BOD	BOD, Nutrients, Total Oil and Grease, TSS, E. Coli & Faecal Coliform
		Annually	ALS Global	2	Total and Dissolved Metals	ICP-MS Metals scan, colour, cyanide
SNP 02-17	Final Combined Water Treatment Plant and Sewage Treatment Plant Effluent	Continuous	Internal	0	None	Flow, Conductivity, Temperature, Turbidity, pH
		Every 6 Days	ALS Global	4	Routine, Nutrients, TOC, Total Metals	Nutrients, TSS/TDS, Turbidity, Conductivity, Chloride, Calcium, Total metals, TOC
		Monthly	ALS Global	13	Routine, Nutrients, Total and Dissolved Metals, BOD, BTEX, F1, F2, Fecal Coliform, Oil and Grease, TOC	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, BOD, ICP-MS Metal Scan, Total Mercury, F1/F2, BTEX, E. Coli, Total Oil and Grease, Dissolved Oxygen, TOC
		Quarterly	HydroQual	4-20L	80 Liters	Acute lethality to*Oncorhyncus mykiss*, Acute lethality to *Daphnia magna*, Chronic toxicity to the *Ceriodaphnia dubia*, Chronic toxicity to the algea *Pseudokirchneriella subcapitata*
SNP 02-20	Snap lake on the edge of the mixing zone around the diffuser (SNP 02-20d, e, f, and g)	Monthly (during safe ice conditions and during open water) at maximum conductivity	ALS Global	13	Routine, Nutrients, Total and Dissolved Metals, BOD, BTEX, F1, F2, Fecal Coliform, Oil and Grease, TOC, E.coli	Turbidity, TSS, pH, Conductivity, Major Ions, Nutrients, BOD, ICP-MS Metal Scan, Total Mercury, F1/F2, BTEX, E. Coli, Total Oil and Grease, Dissolved Oxygen, TOC

		Annually	HydroQual	4	40 liters	Chronic Toxicity (Ceriodaphnia dubia, Pseudokirchneriella subcapitata)
		Annually	HydroQual	4	60 liters	7-Day Early Life Stage (ELS) egg/alevin Toxicity test with rainbow trout
		Annually	HydroQual	4	60 liters / week for a total of 300 liters	30-Day Early Life Stage (ELS) egg/alevin Toxicity test with rainbow trout

3 INFORMATION ABOUT RESPONSES TO MONITORING RESULTS

3.1 REGULATORY REQUIREMENTS

This section describes the Response Framework for the Snap Lake Water Management Pond. The Response Framework links monitoring results to actions with the purpose of maintaining the Assessment Endpoints within an acceptable range. The framework provides a systematic approach to responding to the results of monitoring activities.

This section is provided to comply with the following specific Water License conditions [Schedule 5, Item 1(c) of MVLWB (2012)]:

> *ii. A description of the Response Framework that will be implemented by the Licensee to link the results of monitoring to those corrective actions necessary to ensure that the objectives listed in Part F, Item 5 are met including:*
>
> c. *definitions, with rationale for Action Levels applicable to the performance of the Water Management Pond with respect to geotechnical stability;*
>
> *d. for each Action Level, a description of how exceedances of the Action Level will be assessed and generally which types of actions may be taken if the Action Level is exceeded.*

3.2 DEFINITIONS AND APPROACH

An “effect” is a change that follows an event or cause. An effect is not inherently negative or positive. A linkage must be established between a measured change and a cause (e.g., mining activity) before appropriate management actions can be determined. Should an effect be detected during monitoring activities, a corresponding “action” will occur. The type of action taken depends on the magnitude or severity of an effect relative to an assessment endpoint. This is termed the *Action Level*.

The goal of the Response Framework is to systematically respond to monitoring results such that the potential for significant adverse effects is identified and any necessary mitigation actions are undertaken. This is accomplished by implementing appropriate mitigation at predefined Action Levels, which are triggered before a significant adverse effect

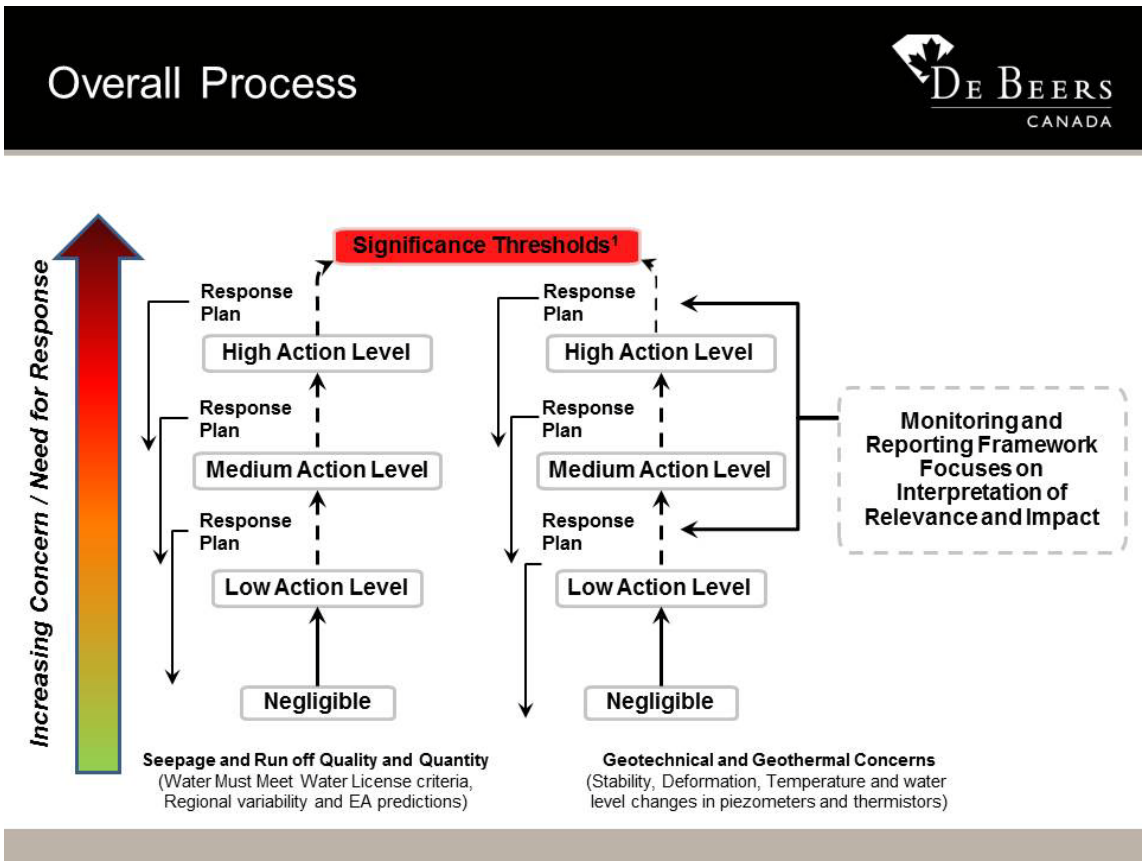
could occur. A level of change that, if exceeded, would result in a significant adverse effect is termed a *Significance Threshold*.

The magnitude of an effect is determined by comparing reference areas, background values, or benchmark values for Water Quality and Quantity. For geotechnical thresholds magnitude of effect is based on deformation. For geothermal thresholds it is more discrete dependent on the normal range of variability, however the dams do not rely on freezing to remain stable so thermal characteristics are not a useful measurement of dam stability. Piezometric and stability monitoring are performed. However, the monitoring to date shows that the piezometric conditions are not adversely affecting the stability of the dams. Geotechnical monitoring is performed through regular inspections by De Beers (on a biweekly basis) and Golder (the annual inspection).

A magnitude of effect that falls within the normal range of variability for the Snap Lake region for Water quality and quantity or is well below an applicable benchmark value would not lead to action and is termed a *Negligible Action Level*. A magnitude of effect that falls outside the range of normal variability for the region but is considered to be of low ecological consequence would be classified as a *Low Action Level* and constitutes a “red flag” for careful scrutiny and possible proactive management actions.

Effects at the *Medium Action Level* are either of ecological or stability concern. For example, for water quality, results that are above regional variability or water license criteria or for geotechnical signs of sloughing or deformation that could indicate concern for long term stability Any effect that falls within the *Medium Action Level* poses a potential threat to the Snap Lake ecosystem and must be dealt with by management actions that begin with further investigation to determine both significance and causation, and thus allow effective management intervention if such is required. Should the initial management intervention not be sufficient to remove the potential threat to the Snap Lake ecosystem, then the magnitude of the effect is classified as a *High Action Level* and further, timely management intervention to reverse the effect will be required.

Figure 3-1 Overview of Monitoring Response Framework



- Action Levels related to Geotechnical Stability are not set for each hypothesis because they are based on monitored changes and discussed in consultation with the geotechnical engineer.

- Action levels related to thermal characteristics are not set. In the environmental Assessment Report it noted that water management pond's retention dikes and dams are founded on prepared bedrock, so that they are to be stable even if the pile material remains unfrozen. However, monitoring data is reviewed and reported on should thermal conditions cause concern.

- Action levels related seepage and run off quality and quantity are not set for each hypothesis because they are based on measured chemical concentrations. Therefore, where a linkage exists, it is relatively simple to link chemical concentrations to Mine effluent and activities and develop response plans accordingly (i.e., metals, ions, nutrients come directly from Mine, so whatever substance reaches an Action Level, must be managed). It was acknowledged in the EA Decision Report that small volumes of water will seep into Snap Lake from the Water Management Pond, therefore the low action level is set above this threshold.

Note that the Monitoring framework does not prevent an Action Level from being triggered. A role of the monitoring is to determine whether to trigger the Action Levels for geotechnical/geothermal concern or seepage/run off quality and quantity. As well action Levels were not developed for every substance and monitoring scenario measured in the SNP. The Response Framework thus consists of Action Levels and Significance Thresholds for key indicators as well as types of action that may be taken. The specific action to be taken will depend on the type and severity of effect detected. Specifics on the Significance Thresholds, Action Levels, and types of actions that may be taken are outlined below. This is the first Response Framework that has been developed for the Snap Lake Water Management Plan; it is anticipated that future development and consultation will result in refinement of this Response Framework.

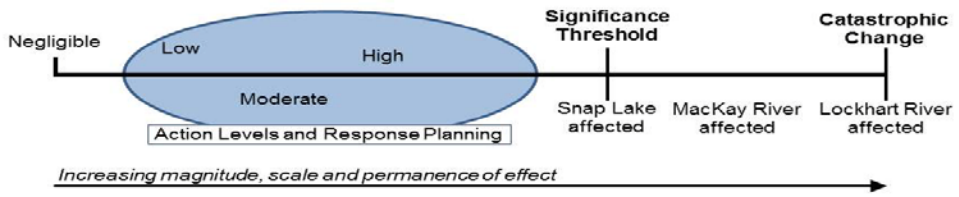
3.2.1 Identification of Significance Thresholds

Significance Thresholds were not explicitly defined in the EAR for the Snap Lake Project and as such had to be developed for this framework. They were developed based on project level risk assessments carried out for the water management pond. Bow ties from this activity are located in Appendix IV.

It was discussed during the EA process that seepage would occur to Snap Lake from the WMP at a rate of approximately 17m³/day and as per the Water License Annual report, some loadings to the lake due to water quality was acknowledged (Appendix 4). However, these loadings are not significant in terms of mass loading as reported on in the WLAR. However it was noted that geotechnical issues with the WMP dams or seepage resulting in changes to the Lockhart River and to the East arm of Great Slave Lake were also deemed unacceptable, if not “catastrophic”

(Figure 3-2.) The Significance Threshold and Action Levels were therefore designed around changes in Snap Lake only, since such changes would precede possible downstream changes.

Figure 3-2 Conceptual Overview of Action Levels relative to Significance Thresholds



In the Environmental Assessment, the WMP was designed to be located next to the water treatment plant. This pond will store excess water in case inflows exceed the water treatment facility's capacity or the treatment facility shuts down. It was also acknowledged that Drainage from the North Pile, Water conveyance and storage structures and the air Strip will be intercepted and diverted to the Water Management Pond, treated and discharged to Snap Lake during all phases of the mine until post-closure water quality is considered to be acceptable and the original overland runoff to Snap Lake can be restored. As such MVEIRB directed De Beers to monitor inflows to the Water Management pond. This is detailed in Q16, Q17, and Q20 of Table 2-3. It was also acknowledged in the MVEIRB EAR that small portions (0.1%) of water will seep into Snap Lake from the WMP.

3.3 SIGNIFICANCE THRESHOLDS

The significant thresholds for the WMP are provided in Table 3-1. These thresholds encompass the conditions representing a significant adverse effect to the WMP due to seepage quality/quantity or geotechnical stability and, in turn, the monitoring endpoint being evaluated.

Table 3-1 Water Management Pond Action/Significance Thresholds

Concern	Component
Water Management Pond Dam Failure	Geotechnical Stability
Uncontrolled release of water	Seepage/Run off Water Quality and Quantity
Water License Non compliance	Seepage/Run off Water Quality and Quantity

3.3.1 Proposed Action Levels and Response Framework

3.3.1.1 Geotechnical Stability

	Cause/Action threshold	Controls
Key Information	1) Inadequate design: -Seismic event -Extreme Storm or freshet event -Inadequate construction 2) –Dam overtopping -Rise in groundwater below structure - Erosion of embankment	1) Design by Experienced geotechnical professional 2) –Dedicated water management team -Biweekly dam inspections -Third party geotechnical inspections -Safe water levels established -Water Management Plan - Geotechnical monitoring -Armoring on Dam face
Negligible	• Dam performing as per design • No concerns raised during • inspections or visible sloughing, heaving, changes	
Low	• Visible heaving or erosion	• Monitoring as per design • Consultation with Geotechnical Engineer
Medium	TBD	
High	TBD	
Consequences	1) Property damage 2) Water Quality Impacts 3) Terrestrial impacts 4) Reputation 5) Clean-up and Reclamation 6) Legal Investigations 7) Production Interruption	

3.3.1.2 Thermal Characteristics

As per section 2.8.2 action levels related to thermal characteristics are not set. In the environmental Assessment Report it noted that water management pond's retention dikes and dams are founded on prepared bedrock, so that they are to be stable even if the pile material remains unfrozen. However, monitoring data is reviewed and reported on in the WLAR should thermal conditions cause concern.

3.3.1.3 Seepage/Run off Quality and Quantity

Primary concerns of seepage quality and quantity are related to compliance with the Water License, specifically Section, item 9(a) of MVLWB (2012):

All Water or Waste from the Project that enters the Receiving Environment, including all Discharges from Surveillance Network Program Station 02-17b (permanent Water treatment plant) and 02-17 (temporary Water treatment plant), shall meet the following effluent quality criteria:

Parameter	Max Average (mg/L) June 14, 2912	Max Grab (mg/L) June 14, 2012	Max Average (mg/L) January 1, 2015	Max Grab (mg/L) January 1, 2015
Total suspended solids	7	14		
Ammonium as N	10	20		
Nitrate as N	0.5	1.0		
Nitrate as N	22	44	4	8
Chloride	310	640	160	320
Flouride	n/a	n/a	0.15	0.3
Sulphate	75	150		
Aluminum	0.1	0.2		
Arsenic	0.007	0.014		
Cadmium	n/a	n/a		
Chromium	0.01	0.02		
Copper	0.003	0.006		
Lead	0.005	0.01		
Nickel	0.05	0.1		
Zinc	0.01	0.02		
F1 Fractions		4.6		
F2 Fractions		2.1		

Figure 3-3: Uncontrolled Release of Water

Tiered Action Level	Cause/Action Threshold	Controls
Key Information	1) Climate variability beyond design assumptions 2) Sequential / frequent major precipitation events 3) Excess precipitation 4) Poor understanding of natural/hydrogeological flows 5) Artificial infiltration 6) Unforeseen water accumulation 7) Poor design 8) Change in mine structure or flows 9) Human error 10) Inadequate resourcing 11) Infrastructure failure	1) -Modelling & forecasting of weather pattern -Including historical dataset in design 2) Water balance management 3) -Adequate infrastructure design -Storm water management (clean/dirty water separation and minimization of surface/catchment area 4) -Circulation System 5) Decommissioning of boreholes 6) -Unforeseen underground inrushes -Geological drilling and modeling 7) -Mine Design -Design regulations -Water level surveys -Audits and Inspections 8) Change of management 9) –Training -Coaching -Emergency Drills 10) Proper communication 11) –Preventative maintenance –Inspections and monitoring
Negligable	• WMP maintained below acceptable freeboard level; no concern with levels	• Monitoring program for water control structures, dams and SNP
Low	• Water within 1 meter of free board level • Concern over underground or surface storage due to inundation	• Pre-authorization for controlled release • Sufficient dam capacity design • Monitoring mine water storage capacity • Emergency response procedure • Mine water balance
Medium	TBD	
High	TBD	
Consequence		

Figure 3-4: Nonconformance of Water License

Tiered Action Level	Cause/Action Threshold	Controls
Key Information	1) Training 2) Criteria Awareness and appropriate QA/QC 3) Monitoring discrepancies 4) Equipment breakdown	1) Training programs in place for operators/ sampling technicians 2) Adherence to QA/QC and sampling procedures as approved -Posting of license in Laboratory 3) Duplicate sampling procedures, lab and field blanks 4) -Secondary Monitoring -Calibration
Negligable	All Water license samples meet license criteria	
Low	Trend of samples below Water Management Pond dams exceeding EQC criteria for Maximum average.	
Medium	TBD	
High	TBD	
Consequence	1) Environmental Contamination 2) Legal nonconformance 3) Reputational Damage	

The AEMP is designed to specifically monitor concerns due to Nutrient Enrichment and Toxicological Impairment, as well as impacts to drinking water and aesthetics. For specific Action Thresholds in lake please see Chapter 6 of the AEMP design plan.

3.3.2 Suggested Responses

Table 3-2 provides a summary of suggested responses to be taken (Actions) when an Action Level is reached. For any Action Level, the following Water Management “Best Practices” will be followed monthly if appropriate and at a minimum each year when interpreting Monitoring results:

- Assess cause/linkage to Mine;
- Examine trends;
- Predict trends, where appropriate;
- Examine ecological or geotechnical significance; and,
- Confirm that existing monitoring is appropriate, and revise if warranted.

Additional responses detailed in the Response Plan will depend on the component affected (e.g., geotechnical, geothermal, run off and/or water quality or quanitity), the likely cause of the effect as determined by the internal review and in consultation with relevant personnel, and the type and magnitude of effect.

Table 3-2 Suggested Types of Actions to be taken if an Action Level is Exceeded

Action Level	Types of Actions
Negligible	**Response Actions that would be taken:** • Monitoring best-practices
Low	**Response Actions that would be taken:** • Monitoring best-practices • Confirm Low Action level • Set Medium and High Action Levels • Develop Response Plan **Potential additional Response Actions:** • Revise Low Action level, if warranted and scientifically/technically defensible • Set site-specific benchmarks if appropriate • If trending towards Medium, identify potential mitigation options • Increase monitoring frequency • Desk-top or field special study to examine significance, causation, and/or linkage to Mine
Medium	**Response Actions that would be taken:** • Monitoring best-practices • Develop Response Plan • Confirm Medium Action Level • If Medium Action Level confirmed, implement mitigation(s) to stop or slow trend **Potential additional Response Actions:** • Desk-top or field special study(ies) to examine significance, causation, and/or linkage to Mine • Maintain increased monitoring frequency for plankton, benthos, and/or fish to confirm that mitigation is working • Refine Medium and High Action Levels if warranted and scientifically/technically defensible
High	**Response Actions that would be taken:** • Monitoring best-practices • Develop Response Plan • Confirm HighAction Level • If High Action Level confirmed, implement mitigation(s) to stop or slow trend **Potential additional Response Actions:** • Special study to examine effectiveness of mitigation, and long-term monitoring of mitigation effectiveness • Special study to examine significance and reversibility, causation, and/or linkage to Mine

3.3.3 Water Management Response Plan

If an Action Level of the Water Management Response Framework is triggered, a Monitoring Response Plan will be submitted to the Board. Additional consultation with regulators and communities may be required prior to completion and approval of a Response Plan, depending on the severity of the monitoring result.

4 STRONTIUM RESPONSE PLAN

Information regarding the Strontium Response Plan will be submitted to the Board under a separate cover on December 31, 2013.

5 TDS RESPONSE PLAN

Information regarding the TDS Response Plan will be submitted to the Board under a separate cover on December 31, 2013.

6 NITROGEN RESPONSE PLAN

Information regarding the Nitrogen Response Plan will be submitted to the Board under a separate cover on December 31, 2013.

7 REFERENCES

De Beers. 2002. Environmental Assessment Report – Snap Lake Diamond Project. Submitted to the Mackenzie Valley Land and Water Board. February 2002.

De Beers. 2006 . Aquatic Effects Monitoring Plan – Snap Lake Diamond Project. Prepared by Golder Associates Ltd. Submitted to the Mackenzie Valley Land and Water Board

De Beers. 2006. Ore Storage, Waste Rock – Snap Lake Mine, Processed Kimberlite Management Plan. Prepared by De Beers. Submitted to the Mackenzie Valley Land and Water Board.

De Beers. 2008. Spill Contingency Plan – Snap Lake Mine. Submitted to the Mackenzie Valley Land and Water Board

De Beers. 2006. Domestic Waste and Sewage Management Plan – Snap Lake Mine. Submitted to the Mackenzie Valley Land and Water Board.

Golder. 2004a. Technical Memorandum Re: Water Level Projections, Water Management Pond, Snap Lake Diamond Project, Northwest Territories. Golder Associates Ltd. Project Number 04-1328-003/6300, prepared for De Beers Canada Mining Inc., dated 15 June 2004.

Golder. 2004b. Snap Lake Diamond Project Site Capture Program – Detailed Design Report, North Pile Drainage Ditch. Golder Associates Ltd. Project Number 04-1413-436/5100, prepared for De Beers Canada Mining Inc., 38 p. + appendices.

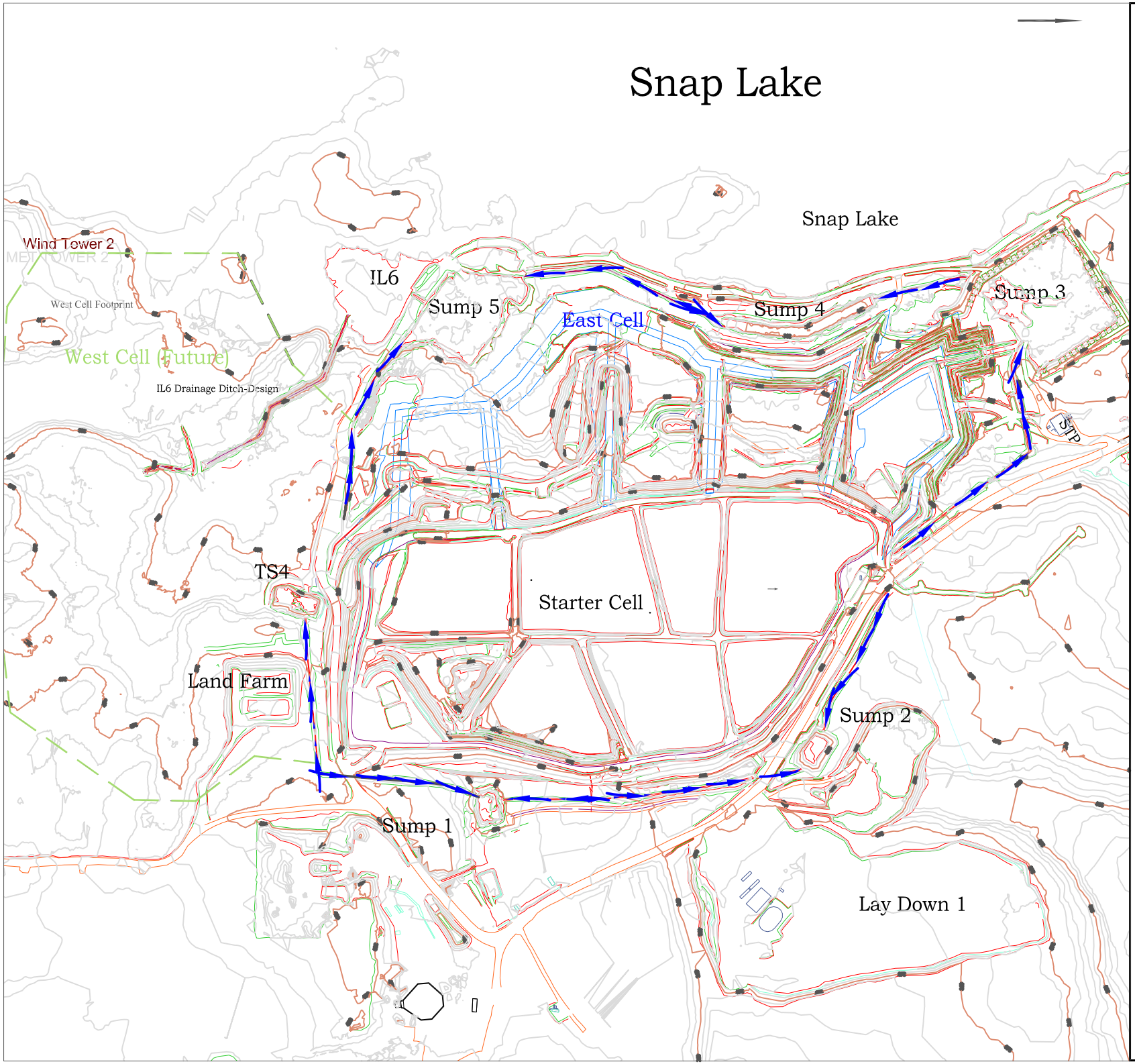
Golder. 2004c. Snap Lake Diamond Project Site Capture Program – Plant Site Infrastructure, Geotechnical Site Preparation. Golder Associates Ltd. Project Number 04-1413-436/5200, prepared for De Beers Canada Mining Inc., 50 p. + appendices.

Roster of Drawings related to Mine Water Management Plan

Drawing No.	Title
Appendix I	Surface Plan – Drainage Direction
Appendix II	Stockpiles
Appendix III	SNP Stations
Appendix IV	WMP – Major Ion Concentration Trends, WMP – Metals Concentration Trends

APPENDIX A

SURFACE PLAN – DRAINAGE DIRECTION



DeBeers Snap Lake Diamond Mine

General Surface Plan

Scale: 1:10,0000(metric)

N

Grid North- Local

UTM Surface Control

Surface Control Stations

Point #	Northing	Easting	Elevation	Description
100001AEL	7,052,975.023	506,400.678	453.539	AEL Original Control
100003AEL	7,053,163.881	506,675.305	461.737	AEL Original Control
100006CLS	7,052,959.094	506,743.269	466.003	By Comm Modules
1030SAS	7,052,364.711	506,395.999	458.330	On Hill West Dam1
Nmpc001	7,052,639.132	506,714.268	461.004	On Transformer base by Pump
1031SAS			452.549	On Dam1
SAS-AEL-1061	7,052,114.187	504,660.607	477.531	10m off road heading to Exist Plant
DB03	7,052,592.386	506,121.495	468.675	South Cell Control
DB10	7,052,509.736	506,891.655	469.295	South Cell Control
DB04	7,052,219.401	505,191.645	480.728	South Cell Control
DB05	7,052,406.889	504,962.632	478.554	South Cell Control
DB07	7,052,692.858	505,175.793	460.494	South Cell Control
DB08	7,052,639.586	505,395.647	469.543	South Cell Control
DB09	7,052,749.138	505,636.679	455.725	South Cell Control
DB02	7,052,685.454	505,994.510	458.521	South Cell Control
DB01	7,052,859.008	506,543.102	458.611	South Cell Control

Surface Parameters WGS84

Calibration Horizontal Adjustment

Translation North: 13.132m	Origin North: 7052597.750m
Translation East: 1.134m	Origin East: 505790.415m
Rotation: 00° 00' 02.08232"	Scale Factor: 0.99999013

Calibration Vertical Adjustment

Constant Adjustment: 10.756m	Origin North: 7052959.087
Slope North: -13.314ppm	Origin East: 506743.275
Slope East: 0.397ppm	

Geoid Model: GSD95

Underground Co-ordinates

Surface Co-ords

Point	Northing	Easting	Elev.	Description
100001AEL	7,052,975.023	506,400.678	453.549	AEL Original Control
100003AEL	7,053,163.867	506,675.311	461.727	AEL Original Control
TP2	7,052,972.970	506,713.361	467.155	Temp nail in ground
TP1B	7,053,163.641	506,514.950	453.120	Temp nail in ground
UG-1 (S-1)	7,052,997.974	506,645.102	461.047	Hilti Nail in Conc
UG-2 (S-2)	7,052,988.516	506,582.567	459.384	Hilti Nail in Conc

Under Ground Co-ords

Point	Northing	Easting	Elev.	Description
100001AEL	7,052,975.101	506,400.513	453.560	AEL Original Control
100003AEL	7,053,163.939	506,675.316	461.763	AEL Original Control
TP2	7,052,972.936	506,713.323	467.197	Temp nail in ground
TP1B	7,053,163.753	506,514.897	453.152	Temp nail in ground
UG-1 (S-1)	7,052,997.971	506,645.049	461.058	Hilti Nail in Conc
UG-2 (S-2)	7,052,988.531	506,582.479	459.384	Hilti Nail in Conc

Underground Parameters

Translate Underground to Surface

Calibration Horizontal Adjustment

Translation North: 0.040m	Origin North: 7,052,988.516
Translation East:-0.065m	Origin East: 506,582.567
Rotation:00°- 01'- 08"	Scale Factor: 1.00042101

Calibration Vertical Adjustment

Constant Adjustment: 0.017m	Origin North:7,052,988.516
Slope North: 85.164ppm	Origin East:506,582.567
Slope East: 63.532pp	

Geoid Model: GSD95

Surface Asbuilt Plan

Legend

Asbuilt Toe	Asbuilt Pag Toe
Asbuilt Crest	Asbuilt Pag Crest
Asbuilt Point Elevations	Asbuilt Berm
Asbuilt Grubbing Elevations	
Contour Interval = 0.2m	
2000-2012 Permafrost Thermistors	
Test Pits	
Bore Hole	
Top Surface Asbuilt Elevations	
Golder Design Phase II After Revised AK Corner and Value House Areas	Ditch Flow

Date: May 26-2012

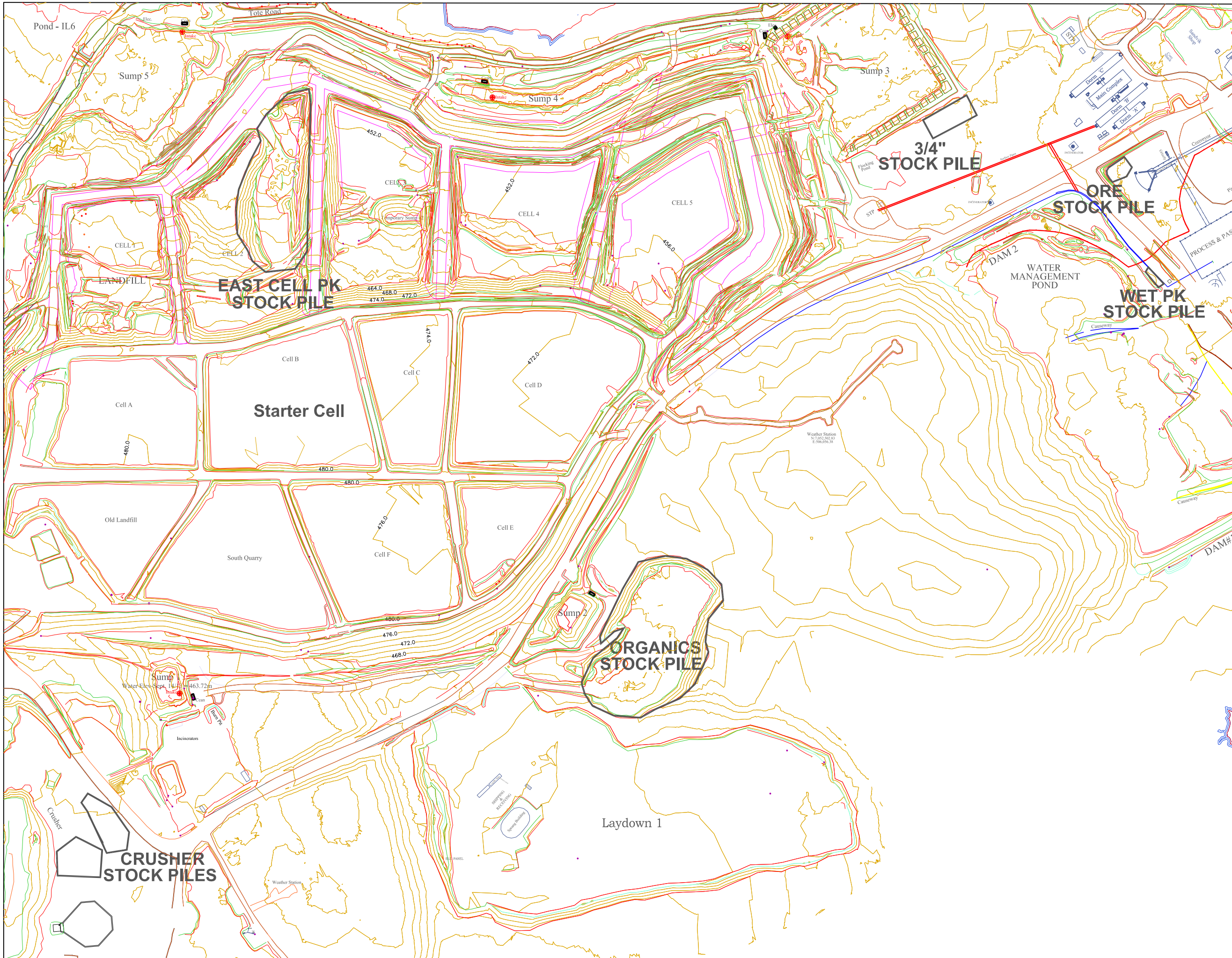
Dwg File: Dwg By: Nampcy Solutions Ltd.

APPENDIX B

MATERIAL STOCKPILES

DeBeers Snap Lake
Diamond Mine

EXISTING STOCK PILES



Not to Scale

N

Grid North- Local

Date: September 24 - 2013

Dwg File:

APPENDIX C

SURVEILLANCE NETWORK STATIONS

SURVEILLANCE NETWORK PROGRAMME SAMPLING STATIONS

http://dbcm-dca-fs-244/dep/she/EnvironMonitor/Shared Documents/Daily Entry Files/Maps and Drawings/Site

SURVEILLANCE NETWORK PROGRAMME SAMPLING STATIONS

http://dbcm-dca-fs-244/dep/she/EnvironMonitor/Shared Documents/Daily Entry Files/Maps and Drawings/Site

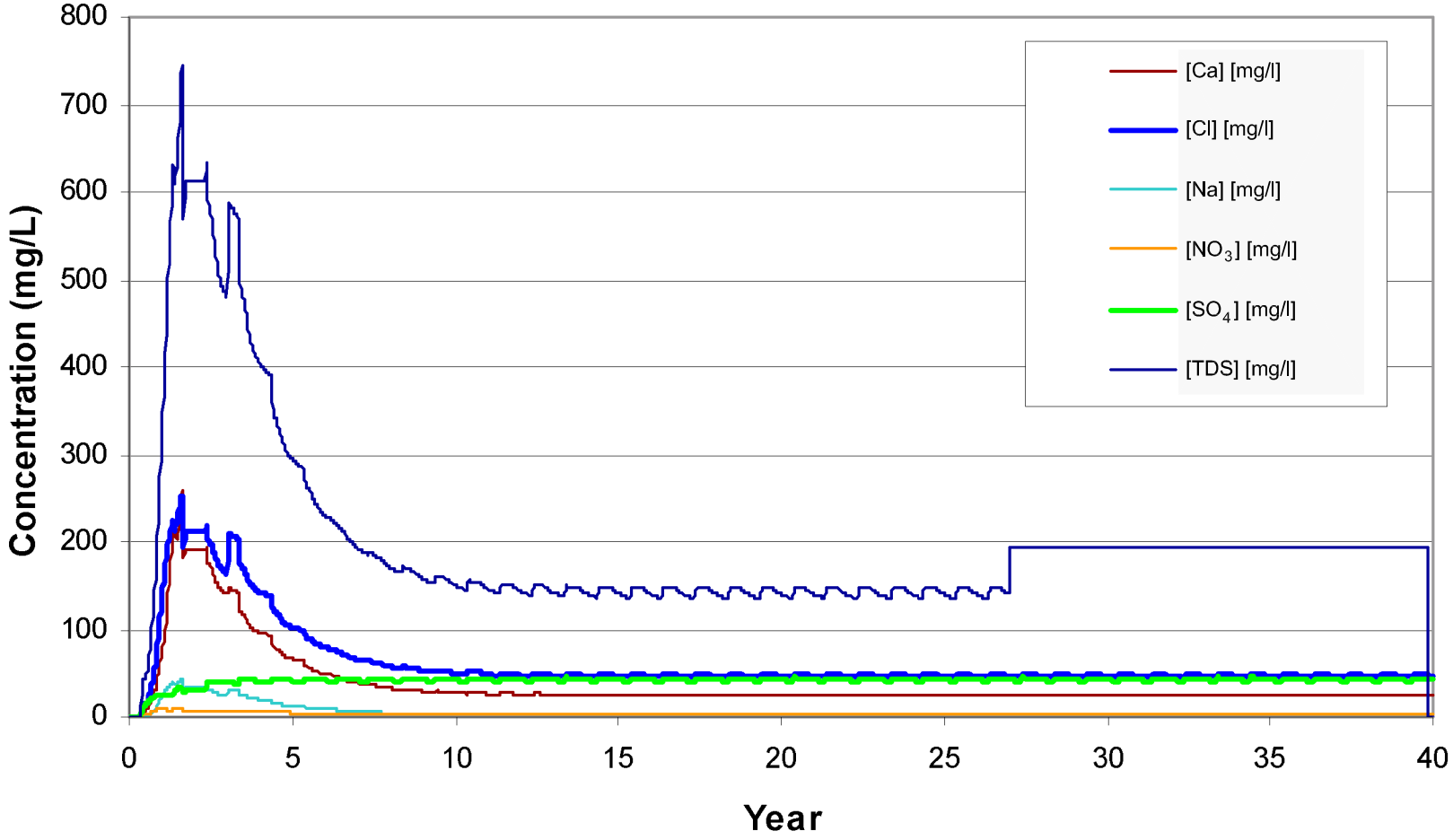
APPENDIX D

WMP – MAJOR ION CONCENTRATION TRENDS

AND

WMP – METALS CONCENTRSTION TRENDS

N:\Active\6400\012-6492\CAD\SECTION 9.2 HYDROGEOLOGY\ Drawing file: 6492-FIG9.2-16-MAJOR ION WMP.dwg Feb 19, 2002 - 6:13pm



Ca = calcium; Cl = chloride; Na = sodium; NO_3 = nitrate; SO_4 = sulfate; TDS = total dissolved solids

PROJECT

DE BEERS

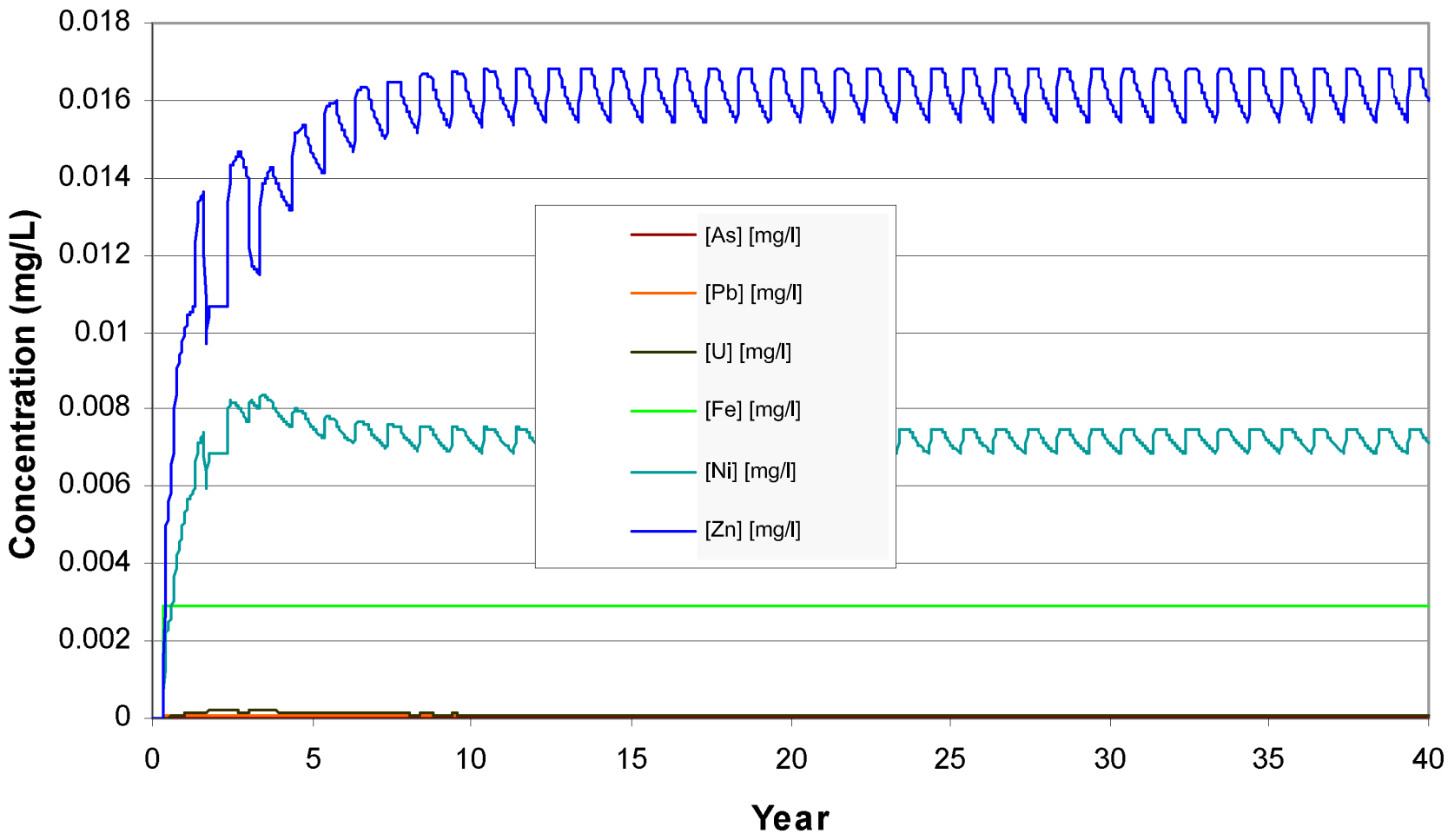
TITLE

SELECTED MAJOR ION CONCENTRATIONS TRENDS FOR WATER MANAGEMENT POND SEEPAGE ESTIMATES

Golder Associates
Saskatoon, Saskatchewan

PROJECT No.		012-6492	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
CADD	GNS	18/02/02	FIGURE: 9.2-16	
CHECK				
REVIEW				

N:\Active\6400\012-6492\CAD\SECTION 9.2 HYDROGEOLOGY\ Drawing file: 6492-FIG9.2-17-metals WMP.dwg Feb 19, 2002 - 6:08pm



As = arsenic; Pb = lead; U = uranium; Fe = iron; Ni = nickel; Zn = zinc

PROJECT

DE BEERS

TITLE

SELECTED METAL CONCENTRATION TRENDS FOR WATER MANAGEMENT POND SEEPAGE ESTIMATES

Golder Associates
Saskatoon, Saskatchewan

PROJECT No.		012-6492	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
CADD	GNS	18/02/02	FIGURE: 9.2-17	
CHECK				
REVIEW				

13 ACCIDENTS AND MALFUNCTIONS

13.1 SCOPE OF ASSESSMENT

13.1.1 Terms of Reference

This is the accidents and malfunctions component

This section consists of the accidents and malfunctions component of the environmental assessment (EA) of the De Beers Canada Mining Inc. (De Beers) Snap Lake Diamond Project.

Accidents and malfunctions are included in the Terms of Reference

The accidents and malfunctions component provides the information required by the Snap Lake Diamond Project EA Terms of Reference issued by the Mackenzie Valley Environmental Impact Review Board (MVEIRB). Section 2.4.2 of the Terms of Reference requires that De Beers "Clearly explain the probability and potential magnitude of an accident and/or malfunction occurring, and the resulting impacts on the proposed development, including the underground workings. Link the outcome of the accident and malfunction probability analysis to consequential impacts to the environment."

To meet the Terms of Reference, this component has to be different

In order to fulfill the Terms of Reference by determining probability and potential magnitude, this component of the EA follows a risk assessment approach, which is slightly different than other components. In addition, terms used in this component may have different definitions than used elsewhere.

The objective is to assess the high severity risks from accidents and malfunctions

The objective of this section is to assess the risks from accidents and malfunctions for both the proposed development (including underground mine workings) and the environment. Risks were estimated according to their associated frequencies and environmental consequences. Only risks that have the potential to result in impacts of high severity are evaluated in this section.

13.1.2 Component Description and Organization

The assessment scope included all mining activities and transportation

The assessment of accident and malfunction risks includes the construction and operation of all mining facilities on the Snap Lake site, including the airstrip and access roads, and transportation to the site via both aircraft and the winter access roads (the Tibbitt-Contwoyto winter road and the winter access road to the site).

Policies, procedures, and management systems are integral to managing risk

Standard policies, procedures, practices, and operating systems are integral to managing risks associated with potential accidents and malfunctions. Accidents and malfunctions are unlikely to adversely impact the development or the environment due to management systems or mitigation that:

- prevent accidents and malfunctions though proper training, awareness, education, and equipment maintenance;
- assess accidents and malfunction risks during the design of the proposed project;
- continue to assess these risks through all project life cycles including detailed engineering design, construction, operation, and closure;
- incorporate inherently safe designs and effective contingency plans; and,
- implement a site environmental management plan including effective and efficient emergency response plans.

Risks will be reduced through implementation of the loss control policy, the environmental policy, an environmental management plan, and an emergency response plan

As described in the Project Description (Section 3.9.2), De Beers has a loss control policy and an environmental policy that are specific to the Snap Lake Diamond Project. In the loss control policy, De Beers commits to a program of risk reduction that will provide protection from accidental losses for all personnel and physical assets under its control. Accidental losses will be controlled through best management practices and systems, combined with the active participation of the workforce. In the environmental policy, De Beers will assess, plan, construct, and operate its facilities in a manner that complies with or exceeds all applicable legislation providing for the protection of the environment, employees, and the public. A site environmental management plan will comply with International Organization for Standardization (ISO) 14001 requirements including the emergency response plan to mitigate potential environmental impact. These management systems will mitigate most environmental risks and limit the consequences.

Risks were screened according to frequency and environmental consequences

Therefore, the focus of this assessment is only on those risks with the potential to impact the off-site environment or the long-term viability of the Snap Lake Diamond Project. Risks were estimated according to their associated frequencies and environmental consequences. Frequency is an expression of the estimated number of accident or malfunction occurrences per unit time.

Section 13 includes the approach and methods, the risk assessment, and conclusions

Section 13.1 describes the Terms of Reference, the component description and organization, the assessment approach, the study area, and the assessment methods. Section 13.2 defines the baseline for accidents and malfunctions, and Section 13.3 presents the risk assessment. Conclusions are provided in Section 13.4. References, units, acronyms, and the glossary are summarized for easy reference in Sections 13.5 and 13.6.

13.1.3 Assessment Approach

13.1.3.1 Key Issues and Key Questions

The key issues are related to the effects of accidents and malfunctions on both the proposed development and the environment

The key issues related to accidents and malfunctions are the effects on the proposed development, and the effects on the environment around the mine site and the winter roads to the mine site. Concerns regarding spills and accidents at the mine site and on the winter roads were expressed during traditional knowledge consultation and community consultation. People are worried about the effects of spills on water quality and wildlife, and are concerned for human life.

> *I worked on the winter roads before. I am concerned about oil spills, especially when trucks are parking for the night….. (Madeline Drybones 11 07 01)* (Lutsel K'e Dene First Nation 2001).

> *It is important that fuel from the tank farm does not leak into the ground* (Lutsel K'e site visit, May 9, 2000).

> *Does the company have an emergency response team for spills and environmental stuff?* (Dogrib Treaty 11 community members site visit, May 11, 2000).

> *They have spills every year. Sometimes a tanker tips over ….. The summer would be the worse case scenario because spills go directly into the earth. Whereas in winter it's frozen and you can remove it, it will still be there in puddles …. Deal with it right away. Quick response. And I think everything will go fine* (D'Arcy Mercredi, NSMA, no date).

> *…Fish … could potentially (be damaged) from any spills resulting from trucks going through the winter road* (Weledeh Yellowknives Dene 1997).

> *Mining companies must take responsibility to secure their fuel storage from spills, explosions and other disasters. Fuel storage must be far from shorelines and creeks to reduce seepage. Fuel tanks should be placed in retainers with cement bottoms and walls so that, if tanks leak, any leaks can be contained. Fuel storage should be located a safe distance from camp facilities to reduce impacts (and lives) from potential fires resulting from lightning strikes* (Weledeh Yellowknives Dene 1997).

There are two key questions

The accident and malfunction issues have been consolidated in the following two key questions:

Key Question AM-1: What impacts will potential accidents and malfunctions at the Snap Lake Diamond Project site have on the development and the environment?

Key Question AM-2: What impacts will potential accidents and malfunctions on the winter road have on the environment?

13.1.3.2 Assessment Cases

The risk assessment was completed for two cases: the mine site and the winter road

In order to achieve the assessment objectives, a high level systems risk assessment was done. The risk assessment was carried out for the following two cases corresponding to each of the two key questions:

- the mine site case representing potential impacts from constructing, operating, and closing all mining facilities on site; and,
- the winter road case representing potential impacts from transporting hazardous materials to the mine site on both the Tibbitt-Contwoyto winter road and the winter access road.

13.1.3.3 Temporal Considerations

Construction will last three years beginning in 2003 and the project will continue until closure in 2028

The accidents and malfunctions section assesses the impacts for the construction, operation, closure, and post-closure phases of the project. Assuming that permits for construction and operation have been received during the first quarter of 2003, a limited pre-construction work program will begin in 2003. Full construction will begin in early 2004 and be completed by the end of 2005. The production phase will be approximately 22 years from 2005 to 2026, although pre-production mining from underground development will occur from 2003 to 2005. The site closure activities will be carried out primarily in 2027, with limited final clean-up and the continuation of effectiveness monitoring in 2028. The total elapsed duration of the project is 26 years. The proposed schedule for the Snap Lake Diamond Project is provided in more detail in Section 3.2.

13.1.4 Study Areas

Two study areas were selected

The study areas for the De Beers Snap Lake Diamond Project were selected by evaluating the regions around the mine site and winter road that are expected to be affected by potential accidents and malfunctions.

The local study area includes the mine site and a buffer

There are two study areas for accidents and malfunctions. The local study area (LSA) includes the mine site and the area immediately surrounding the mine site facilities. This LSA is principally on the northwest peninsula of Snap Lake but also includes the two vent raises on the north shore. The LSA for accidents and malfunctions is the same as the LSA for other components (*e.g.*, terrestrial resources). It consists of the project footprint plus a 500 metre (m) buffer as shown in Figure 13.1-1.

The regional study area includes the winter roads and a buffer

The regional study area (RSA) includes the area adjacent to the Tibbitt-Contwoyto winter road from Tibbitt Lake to MacKay Lake and the winter access road to the mine site. A 5 kilometre (km) buffer on either side of the road is included to encompass the lakes traversed by the winter roads. Spill consequences from truck transportation along this road were assessed to estimate risks to aquatic life in the RSA. The RSA is shown in Figure 13.1-2.

13.1.5 Assessment Methods

The residual impacts are assessed by using frequency and environmental consequence

The Terms of Reference identified in Section 13.1.1 require that probability and potential magnitude of accidents and malfunctions be assessed. Therefore, risk criteria were used to evaluate residual impacts based on the frequency with which the impact could occur and the environmental consequence. This method is different from that presented in other sections of the EA but is consistent with the Terms of Reference (MVEIRB 2001). In other sections of the EA, impact criteria were not defined as risks but were ranked according to a list of criteria.

Frequency terms are defined as negligible, low, moderate, and high

The frequency of accidents and malfunctions was defined according to four levels as follows:

negligible: extremely unlikely to occur during the life of the mine (1/10,000 events per year);

low: unlikely to occur during the life of the mine (1/1,000 events per year);

moderate: may occur during the life of the mine (1/100 events per year); and,

high: likely to occur repeatedly during the life of the mine (1/10 events/year).

Figure 13.1-1 Local Study Area for Accidents and Malfunctions

Figure 13.1-2 Regional Study Area for Accidents and Malfunctions

Environmental consequence terms are defined as negligible, low, moderate, and high in Table 13.1-1

Environmental consequence used in this section is ranked according to four levels (Table 13.1-1). These levels are defined according to a combination of magnitude of the toxic effect, spatial extent, duration, and reversibility. One level, (*e.g.*, moderate) may be defined by more than one combination (*e.g.*, moderate can be defined by four different combinations). The particular combinations of toxicity, spatial extent, duration, and reversibility corresponding to each level of environmental consequence are presented in Table 13.1-1. Although this risk assessment uses the same term (*i.e.*, environmental consequence) as earlier sections of the EA, the environmental consequence is determined differently, as shown in Table 13.1-1.

Table 13.1-1 Definition of Levels of Environmental Consequence

Environmental Consequence Rating (Level)	Magnitude (Based on Toxicity to Aquatic Life)	Spatial Extent	Duration (Duration of Toxic Effects)	Reversibility
A: Negligible	no toxicity	not relevant	not relevant	reversible
	sub-lethal	< 5% of total lake volume	<24 hours	reversible
B: Low	acutely lethal	< 1% of total lake volume	<24 hours	reversible
	sub-lethal	<20% of total lake volume	<24 hours	reversible
	sub-lethal	< 10% of total lake volume	1 year	reversible
C: Moderate	acutely lethal	<10% of total lake volume	<24 hours	reversible
	acutely lethal	<10% of total lake volume	> 24 hours; < 1 year	reversible
	sub-lethal	<20% of total lake volume	1 year	reversible
	sub-lethal	<20% of total lake volume	multi-year	reversible
D: High	acutely lethal	>10% of total lake volume	<24 hours	reversible
	sub-lethal	>20% of total lake volume	multi-year	reversible
	acutely lethal or sub-lethal	not relevant: any irreversible impact rated high regardless of spatial extent	any duration	irreversible

A project risk matrix was developed to estimate environmental risks

The risk is estimated using the project risk matrix presented in Table 13.1-2. A risk matrix is comprised of one index representing the measure of frequency (also called likelihood) and another index representing the measure of environmental consequence. When an accident or malfunction scenario is identified, the associated risk is estimated by locating it within the risk matrix. Indices for this risk matrix were defined previously in Section 13.1.5 and Table 13.1-1.

Risk increases from the bottom left corner of the matrix

The measure of risk increases from the bottom left corner of the risk matrix to the top right as shown by the arrow in Table 13.1-2. If either the frequency or environmental consequence of the risk is less than the range shown in Table 13.1-2, the risk is not determined.

Table 13.1-2 Generic Project Risk Matrix

FREQUENCY INDEX		ENVIRONMENTAL CONSEQUENCE INDEX			
(Events/Year)	(Description)	A Negligible	B Low	C Moderate	D High
1/10	Likely to occur repeatedly*				
1/100	May occur once*				
1/1,000	Unlikely to occur *				
1/10,000	Extremely unlikely to occur*				

Increasing Risk

*During the life of the mine.

13.2 BASELINE

Baseline is the pre-accident condition, not the pre-project condition

The term baseline is defined differently in this section (Section 13) than in the rest of the EA. For the purposes of the accident and malfunction assessment, the baseline was considered to be the pre-accident condition. This could occur during the construction, operation, or closure phases. The baseline before the Snap Lake Diamond Project is developed is addressed in the other components of the EA.

13.3 IMPACT ASSESSMENT

13.3.1 Introduction

Key questions pertain to accidents and malfunctions at the site and on the winter road

The key questions concerning accidents and malfunctions from the Snap Lake Diamond Project are as follows:

Key Question AM-1: What impacts will potential accidents and malfunctions at the Snap Lake Diamond Project site have on the development and the environment?

Key Question AM-2: What impacts will potential accidents and malfunctions on the winter road have on the environment?

The risk assessment used a systems failure modes and effects analysis method

Accidents and malfunctions were considered system failures and associated risks for the mine site were assessed using a standard risk assessment methodology called a systems failure modes and effects analysis. Risks were then estimated for the criteria defined in Table 13.1-1, Section 13.1.5 using a project risk matrix as illustrated in Table 13.1-2. Accident and malfunction risks for the winter access road were assessed using the Tibbitt-Contwoyto winter road accident statistics and project specific hazardous material data. Each of the key questions is addressed separately in the following two subsections.

13.3.2 What Impacts will Potential Accidents and Malfunctions at the Snap Lake Diamond Project Site Have On the Development and the Environment?

The steps of the environmental assessment method have been combined in the risk assessment method

The risk assessment process is designed to identify accidents and malfunctions from all mining facilities and operations. Associated potential consequences for the proposed development or the environment are also determined. The identification of potential systems failures and their associated consequences in this risk assessment achieves the same objective as the linkage and impact analyses carried out for other EA components. Selected safeguards (or mitigation measures) are identified and the residual risk is estimated using a project risk matrix. These steps are combined in the systems failure modes and effects analysis and, therefore, are not presented under separate headings as was done for other EA components.

Since on-site risks will be reduced through implementation of site management systems, this assessment focusses on severe risks

As described in Section 13.1.2, mine site management systems will mitigate most environmental risks. The focus of this assessment is only on those risks with the potential to impact the long-term development viability or the off-site environment. Risks were estimated according to their associated frequencies and environmental consequences. The lowest frequency used to assess risks was one event in 10,000 years which may be considered a boundary for well engineered systems. More rare accidents, such as a meteor strike, may occur but were not included in order to focus on credible scenarios. The environmental consequences were described in terms of magnitude of toxic effect, spatial extent, duration, and reversibility of impacts to off-site aquatic life.

Impacts to terrestrial organisms are likely to be less severe than impacts to aquatic organisms

Terrestrial were not considered the primary receptors because spills in the terrestrial environmental during the winter will be more easily cleaned up. Because mitigation measures are more effective on land than under ice, it is highly unlikely that accidents or malfunctions will cause death or injury to more than a very few terrestrial animals or plants. Onsite environmental impacts will be mitigated through the management systems previously described.

A project team assessed the potential systems failures

Potential systems failure modes were determined to assess the risks from accidents and malfunctions. This approach was based on a team of project personnel lead by a risk facilitator assessing risks for each operating system on the mine site. Potential failure modes were identified along with associated consequences based on the team knowledge and experience. This step also describes how a system may fail and includes all possible causes ranging from natural causes to structural failures, inadequate construction, and improper procedures. The potential failure modes were screened to focus on accident scenarios with off-site consequences.

The risk assessment included all systems and operations on the site

The project team systematically evaluated all operations as shown on the overall site plan and the facilities site plan (Figures 3.1-3 and 3.1-4 in the Project Description). Potential risks were assessed for the following systems or operations on the Snap Lake Diamond Project site:

- airstrip;
- airstrip access road;
- bulk emulsion plant;
- Dams 1 and 2;
- north pile;
- fuel storage and distribution system;

- crushed ore reclaim;
- kimberlite processing and paste backfill plant;
- water treatment system;
- sewage treatment system;
- power and utilities;
- underground mine workings;
- kimberlite ore storage;
- cement storage; and,
- hazardous waste storage.

Scenarios were recorded

The principal accident or malfunction scenarios were recorded in a worksheet presented in Table 13.3-1.

The worksheet includes the principal scenarios, mitigation, consequences, and residual risks

Once the principal failure modes were identified as scenarios, the worksheet was used to determine the next steps in the risk assessment. The following information was recorded in the worksheet (Table 13.3-1):

- accident or malfunction scenarios (numbered one, two, *etc*.);
- selected safeguards (including prevention measures and consequence mitigation measures);
- consequence to the environment and the project after safeguards have been applied (*i.e.* the residual consequence);
- residual risk (with safeguards in place); and,
- notes.

The results of the worksheet are entered on the project risk matrix

Consequences were quantified in terms of residual impacts to the long-term development viability and releases to the off-site environment. Once the frequency and environmental consequence of the residual (*i.e.,* after safeguards were applied) risk was determined in the worksheet, the risk was estimated using the project risk matrix presented in Table 13.1-2. Indices for this risk matrix were defined previously in Section 13.1.5 and Table 13.1-1.

Table 13.3-1 Accident Assessment Worksheet

	Accidents and Malfunctions	Selected Safeguards	Consequences (After Safeguards Applied)	Residual Risk *		Notes
				Freq.	Consq.	
1.	crash of aircraft transporting workers or fuel to site	1. emergency response procedures and preparedness training 2. operational policies and practices 3. use of reputable carrier 4. reclamation contingency - present landfill on-site can be enlarged to store any contaminated soil from fuel spill 5. flight paths do not cross mine site	1. *Environment* offsite and onsite impacts potentially similar, localized fire (loss of vegetation), soil and water contamination depending on location	1/100	A	1. access for onsite incident but potentially limited for offsite incident; no severe secondary environmental consequences from impacts to the proposed development 2. approximately 400 flights/year expected; site landing strip is 2 km from mining facilities
			2. *Proposed Development* emergency response implemented	-	-	
2. Loss of Processed Kimberlite						
2a.	small volume release from breech of Dam 1 (*e.g.*, overtopping during spring freshet, crest settles)	1. robust engineering design of rock filled structure, low crest height and conservative freeboard 2. construction quality assurance 3. operational policies and practices 4. small catchment area (reduces quantity of surface runoff) 5. credible potential only during May (extreme freshet) 6. annual formal inspections, regular monitoring of instrumentation and visual checks 7. pathway to Snap Lake allows time for emergency response to limit amount reaching the lake	1. *Environment* assume 200 cubic metres (m^3) pond water (containing processed kimberlite and chlorides) released in Snap Lake	1/100	A	1. environmental issue would involve total suspended solids (TSS); TSS issue with this volume of release would be short-term; there would be no recovery of processed kimberlite once it was in the lake 2. consequences are less severe than those described in category A; other smaller release scenarios such as from liner failure are associated with less risk 3. traffic accident along airfield access road run-in along crest of Dam 1 may cause liner failure but this would be repaired before causing adverse environmental impacts
			2. *Proposed Development* emergency response implemented; short term impacts on production, water surge capacity unavailable, access road unavailable; repair and rebuild as required	-	-	

Table 13.3-1 Accident Assessment Worksheet (continued)

	Accidents and Malfunctions	Selected Safeguards	Consequences (After Safeguards Applied)	Residual Risk *		Notes
				Freq.	Consq.	
2b.	large volume release from breech of Dam 1(*e.g.*, major failure from substandard construction, improper liner installation, fill failure, foundation failure, overtopping for extended period, improper procedures)	1. robust engineering design of rock filled structure, low crest height and conservative freeboard; designed for rock foundation 2. construction quality assurance 3. operational policies and practices (water management pond will not be kept full since it provides surge capacity) 4. annual formal inspections, regular monitoring of instrumentation and visual checks	1. *Environment* assume 250,000 m^3 pond water (containing processed kimberlite, ammonia, TSS, and chlorides) released in Snap Lake; potential for 1 km dilution zone with acute environmental effects over several days or weeks	1/10,000	C	1. probability estimate for engineered system (including impacts from construction conditions in northern climates)
			2. *Proposed Development* emergency response implemented; impacts production, water surge capacity unavailable, access road unavailable; repair and rebuild as required	-	-	
2c.	any release from breach of Dam 2 (*e.g.*, see failure modes associates with Dam 1)	1. robust engineering design 2. construction quality assurance 3. operational policies and practises 4. annual formal inspections, regular monitoring of instrumentation and visual checks 5. low discharge volume potential	1. *Environment* released pond water contained on-site and remediated through the spill contingency plan	-	-	1. smaller structure compared to Dam 1, holding back less pond volume; consequences from a failure are less than those for Dam 1
			2. *Proposed Development* emergency response implemented; short term impacts on production, water surge capacity unavailable, may impact processed kimberlite pipeline (traverses north of Dam 2); repair and rebuild as required	-	-	

Table 13.3-1 Accident Assessment Worksheet (continued)

	Accidents and Malfunctions	Selected Safeguards	Consequences (After Safeguards Applied)	Residual Risk *		Notes
				Freq.	Consq.	
3. Failure of North Pile						
3a.	small release from shallow slump and erosion	1. pile designed with high density paste and small pond back from face that will mitigate potential failure modes associated with other approaches 2. design allows for flexibility in operation and therefore minimizes potential for creating stability problems 3. designed to expect small slumps on a continuous basis that are contained through a ditch and toe to the north of the face 4. low pile height design (25 m) and resulting 10 degree slope minimizes potential for run-out 5. operational policies and practices 6. annual formal inspections, regular monitoring of instrumentation and visual checks	1. *Environment* greater than design slump flows over toe and runs on surface, erosion and precipitation releases 200 m^3 of processed kimberlite into Snap Lake	1/1000	A	
			2. *Proposed Development* emergency response implemented; revise procedures and/or relocate if appropriate	-	-	
3b.	large release from major slump flowing to Snap Lake (*e.g.*, inadequate compaction, incorrect operating procedures)	1. pile designed with high density paste and small pond back from face that will mitigate potential failure modes associated with other approaches 2. design allows for flexibility in operation and therefore minimizes potential for creating stability problems; construction quality assurance 3. designed to expect small slumps on a continuous basis that are contained through a ditch and toe to the north of the face 4. low pile height design (25 m) and resulting 10 degree slope minimizes potential for run-out 5. operational policies and practices 6. annual formal inspections, regular monitoring of instrumentation and visual checks	1. *Environment* greater than design slump flows over toe and 10,000 m^3 of processed kimberlite runs 50 m into Snap Lake	1/10,000	B	1. potential for deep seated failures is extremely remote given the design foundation conditions 2. only some fines with higher moisture content have the potential to run-out to Snap Lake
			2. *Proposed Development* emergency response implemented; revise procedures and/or relocate if appropriate	-	-	

Table 13.3-1 Accident Assessment Worksheet (continued)

	Accidents and Malfunctions	Selected Safeguards	Consequences (After Safeguards Applied)	Residual Risk *		Notes
				Freq.	Consq.	
4.	catastrophic failure of fuel storage system (*e.g.*, brittle fracture)	1. engineered system with secondary containment for spillage, capacity equal to 110% of largest fuel tank 2. construction quality assurance 3. operational policies and practices	1. *Environment* instantaneous failure mode results in fuel wave over containment wall with 1,000 m^3 reaching Snap Lake	1/10,000	B	
			2. *Proposed Development* emergency response implemented; contaminate potable water intake, shut down until remedied; repair as appropriate	-	-	
5.	failure of fuel distribution system	1. engineered system with secondary containment for spillage, double walled pipe 2. observation wells provide detection capability for leaks 3. operational policies and practices 4. spill contingency plan	1. *Environment* most failure modes result in fuel captured by double walled pipe and leak detected through observation wells; leakage at extremities of system (intake fan) may release 10 m^3 of fuel to Snap Lake	1/1000	A	
			2. *Proposed Development* emergency response implemented with environmental management system; repair as appropriate	-	-	
6.	failure of water treatment system	1. engineered system with excess storage capacity in water management pond for extended downtime periods 2. regular monitoring of discharge water quality 3. treatment incorporates flocculation (a process whereby small particles adhere together with the aid of chemical additions) and filtration, filtration alone may provide required quality, therefore some inherent redundancy 4. operational policies and practises	1. *Environment* blockage failure modes result in diverting mine water to the pond (limited environmental effect); inadequate water quality failure modes result in 1 hour release to Snap Lake (before detection and diversion)	1/100	B	
			2. *Proposed Development* impacts production, underground water must continue being pumped to surface; emergency response implemented; repair as appropriate	-	-	

Table 13.3-1 Accident Assessment Worksheet (continued)

	Accidents and Malfunctions	Selected Safeguards	Consequences (After Safeguards Applied)	Residual Risk *		Notes
				Freq.	Consq.	
7.	power system failure	1. redundant back-up power supply for all essential services including mine water pumping (potential environmental impact); physical separation to minimize common fault failures and fire risk; power plant management system that will automatically shut off low priority loads if only partial power system failure 2. planned outages designed for all critical distribution circuits	1. *Environment* emergency operational mode but no severe environmental impact	-	-	
			2. *Proposed Development* impacts production, underground water must continue being pumped to surface; emergency response implemented; repair as appropriate	-	-	
8.	catastrophic geotechnical failure under Snap Lake impacting underground mine shaft	1. water infiltration handled under standard operating conditions 2. many detailed geotechnical engineering studies carried out 3. operating plan includes drilling test holes ahead of development and grouting where appropriate	1. *Environment* no severe environmental impacts	-	-	1. severe consequences are associated with safety and economic impacts to the proposed development
			2. *Proposed Development* massive water influx impacts safety; potential to shut down production, perhaps permanently	-	-	
9.	failure of kimberlite ore stockpile collection system	1. leaks from this system will flow to the water management pond (remain on-site) 2. operational policies and practices	1. *Environment* no severe environmental impacts	-	-	1. severe consequences are associated with safety and economic impacts to the proposed development
			2. *Proposed Development* emergency response implemented with environmental management system; repair as appropriate	-	-	

* Risk is shown as "-" if either the frequency or consequence of the risk is less than the range shown on the project risk matrix (Table 13.3-2).

Residual risk refers to risk remaining after safeguards have been applied.

Frequency and environmental consequence indices were developed in Section 13.1

The frequency index in the project risk matrix ranges from a low value of 1/10,000 to a high value of 1/10 events per year. The environmental consequence index ranges from a category A (negligible) to a category D (high). These categories were previously described in Section 13.1.5. The measure of risk increases from the bottom left corner of the risk matrix to the top right as shown by the arrow in Table 13.3-2. If either the frequency or environmental consequences of the risk is less than the range shown in Table 13.3-2, the risk is not determined.

Table 13.3-2 Eight Identified Mine Site Risks Located on the Project Risk Matrix

FREQUENCY INDEX		ENVIRONMENTAL CONSEQUENCE INDEX			
(Events/Year)	**(Description)**	**A Negligible**	**B Low**	**C Moderate**	**D High**
1/10	Likely to occur repeatedly*				
1/100	May occur once*	**1, 2a**	**6**		
1/1,000	Unlikely to occur *	**3a, 5**			
1/10,000	Extremely unlikely to occur*		**3b, 4b**	**2b**	

Increasing Risk

*During the life of the mine.

Risk results are shown in the project risk matrix

Results from the risk assessment documented in the Table 13.3-1 worksheet are shown in the project risk matrix presented in Table 13.3-2. The eight risks identified by accident number in the worksheet are located in the lower risk area of the project risk matrix, reflecting their low frequency and/or their negligible or low environmental consequence.

Probability of occurrence is shown as frequency

The probability of occurrence is shown as frequency in Table 13.3-1. The level of confidence is moderate, since the assessment uses a standard method and known project components.

13.3.3 What Impacts Will Potential Accidents and Malfunctions On the Winter Road Have On the Environment?

Winter road transportation requirements were collated

A description of the winter road characteristics and transportation requirements for the Snap Lake Diamond Project is presented in Section 6.6. The winter road location is shown in Figure 13.1-2. Environmental risks from accidents and malfunctions along the Tibbitt-Contwoyto winter road have been successfully managed with negligible environmental impacts for twenty years through construction procedures, traffic management practices, and spill contingency plans. Upgrades to the winter road practices are planned or in progress (see Section 6.6). The 35-km long winter access road connecting the mine to the Tibbitt-Contwoyto winter road will be operated according to the same management standards.

A risk assessment approach involved historical data

Risks associated with the winter road were assessed based on the substantial historical experience from transporting mining commodities. The greatest environmental risk from truck traffic on the winter road is due to potential spills especially those associated with a truck breaking through ice. All truck spills along the Tibbitt-Contwoyto winter road have been documented since 1983 by the Department of Resources, Wildlife and Economic Development (RWED) Environmental Protection Service. Using this record, the probability of spills occurring on the winter road due to transportation activities was assessed.

Historical and estimated future truck traffic data were collated

Truck traffic volumes on the winter road were collated from historical usage since 1995 and predicted usage to the year 2020 as presented in Section 6.6 (Figure 6.6-2). The proportion of the total traffic prediction estimated for the Snap Lake Diamond Project is also shown in Figure 6.6-2.

Distribution of materials is summarized

The estimated average distribution of materials that will be transported in the high volume year 2008 for total truck loads and those associated with the Snap Lake Diamond Project are summarized in Table 13.3-3.

Diesel fuel and cement are the largest volumes transported

Fuel represents a large portion of the total truck transportation volumes as shown in Table 13.3-3. Hazardous material volumes included in the consumables data for the Snap Lake Diamond Project in 2008 are listed according to specified materials in Table 13.3-4. The largest consumable volumes are cement (1,086 loaded trucks/year), lubricants and oils (29 loaded trucks/year), ammonium nitrate (29 loaded trucks/year), and food (29 loaded trucks/year).

Table 13.3-3 Estimated Distribution of Truck Transportation on the Tibbitt-Contwoyto Winter Road, 2008

Material	Total Truck Loads	(%)	Snap Lake Truck Loads	(%)
Fuel	5,276	53%	1,300	46%
Consumables	4,269	42%	1,300	46%
Construction materials	500	5%	200	7%
Total	**10,045**	**100%**	**2,800**	**100%**

Table 13.3-4 Transportation of Hazardous Material Consumables to Snap Lake Diamond Project, 2008

Potentially Hazardous Material	Approx. Annual Quantity	Units	Material Container	Trucks/Year (Years 2005-2009)
Diesel fuel	45,000,000	litres (L)	tanker truck	1,125
Cement	38,000	tonnes (t)	2 t sealed bags	1,086
Ammonium nitrate	1,000	t	1 t sealed bags	29
Sodium nitrate	182	t	25 kg sealed bags	6
Ferrosilicon	350	t	1 or 2 t sealed bags	10
Flocculent	40	t	1 or 2 t sealed bags	2
Lime	450	t	1 or 2 t sealed bags	13
Ferric sulphate	350	t	sealed drums	10
Glycol	10,000	L	205 litre drums	1
Gasoline	9,000	L	205 litre drums	1
Lubes and oils	1,000	t	various drums, pails, cans and tubes	29
Hydrofluoric acid	1,250	L	double-walled drum	1
Nitric acid	1,250	L	double-walled drum	1
Jet B fuel	100,000	L	tanker truck	3
Food	1,000	t	various bags, cans, boxes, crates, *etc*.	29
Miscellaneous[a]			various	454
Total				**2,800**

[a] Miscellaneous includes emulsifiers (N7, N25, and N16), glass beads, dynamite/packaged emulsion, perimeter explosives, and boosters for bulk emulsion.

Historical spill rates were used to estimate future spill probabilities

Historical spill accidents on the winter road since 1983 were assessed in terms of spill rates, causal factors, and amount spilled. This spill rate record was also analyzed to evaluate potential risk mitigation effects due to increased operational experience and increased usage of the winter road. The historical spill rate can be applied to the planned increased traffic associated with the Snap Lake Diamond Project to estimate future spill

incidents if the winter road conditions are not adversely impacted by the increased traffic.

Historical spill incidents were assessed

The RWED Environmental Protection Service maintains a database of truck spill accidents that is summarized in Table 13.3-5. A requirement to report all spills has been strictly enforced by the winter road operator; therefore, the database is comprehensive. Table 13.3-5 shows all recorded spills from 1983 to 2001 according to the spill date, commodity, amount spilled, accident cause, and the identification number. Of all the hazardous materials transported over the winter road, only the following commodities have been spilled:

- diesel;
- gasoline, oil, antifreeze, hydraulic fluid;
- cement;
- kimberlite; and,
- ammonium-nitrate.

Diesel spill volumes impacting exposed aquatic life have been small

Diesel spills account for about 70% of the total; however, diesel also represents the greatest transportation volumes of any commodity. Two types of spill scenarios or failure modes were observed with diesel spills. The first spill scenario includes the more recent larger diesel spills over 1000 litres caused by rollovers occurring on land. These spills were cleaned up and the material properly disposed of with minimal environmental impact, since the trucks did not break through ice and spill diesel into water bodies. The second scenario involves spills less than 200 litres caused by a truck breaking through the winter road when it traverses a lake. These spills result in a direct environmental effect for aquatic life in the lake. Historically, these have occurred with a frequency of one order of magnitude less than the average spill rate described later. The spill volumes have involved less than 200 litres because of check valves that prevent excess flow through pipes damaged from the truck breaking through the ice.

Other materials were recovered

Cement, kimberlite, and ammonium nitrate have also been spilled and these have been recovered with minimal environmental impact.

The average spill rate has not increased since 1994, although traffic volumes have increased some 400% over the past three years

Although the number of spills has increased over the past three years, the truck transportation volume has also increased some 400% as shown in Section 6.6. The spill rate of 10^{-6} per loaded truck km of travel from the last three years is similar to that for the past nine years. Therefore, the spill risk management program has been successful in dealing with major increases in traffic.

Table 13.3-5 Historical Truck Spill Record on the Tibbitt-Contwoyto Winter Road

Year	Day	Commodity	Amount Spilled (litre)	Cause	Spill ID #
1983	5-Mar	Diesel P-40	13,000	vehicle overturned	83016
	13-Mar	Diesel	2,273	vehicle overturned	83019
	20-Mar	Diesel	>5	vehicle overturned	83021
1984	15-Feb	Diesel P-50	16,164	vehicle overturned	84019
	21-Dec	Diesel	>5	other transportation	84126
1985	NONE				
1986	4-Feb	Diesel P-40	180	vehicle overturned	86004
	10-Mar	Diesel P-40	1,800	vehicle overturned	86022
	21-Mar	Diesel	>5	vehicle overturned	86024
1987	17-Jan	Gasoline	>5	collision	87009
1988	21-Mar	Diesel P-40	3,637	other transportation	88027
1989	15-Jan	Diesel	454	pipe leak	89003
	27-Feb	Diesel P-40	682	vehicle overturned	89020
	24-Mar	Diesel	90	other transportation	89031
	31-Mar	Diesel	227	vehicle overturned	89034
1990	25-Jan	Diesel	270	vehicle overturned	90009
1991	05-Feb	Diesel	45	other transportation	91013
1992	22-Feb	Diesel P-50	50	leak	92023
1993	21-Feb	Diesel P-50	454	vehicle overturned	93017
	18-Mar	Diesel P-50	>5	other transportation	93027
	24-Mar	Cement	800	vehicle overturned	93033
1994	5-Feb	Diesel/Cement		other transportation	94025
1995	19-Jan	Diesel	90	tank leak	95005
1996	27-Feb	Cement	80,000	vehicle overturned	96030
	06-Mar	Kimberlite	91	other transportation	96036
	11-Mar	Portland cement	50 kg	other transportation	96037
	10-Mar	Cement	10 kg	vehicle overturned	96040
1997	NONE				
1998	10-Feb	Diesel	5,000	vehicle overturned	98015
	23-Feb	Oil / antifreeze	125 / 23	other transportation	98025
	16-Mar	Diesel	4,000	vehicle overturned	98036
1999	NONE				
2000	17-Feb	Ammonium-nitrate	12,000	leaking container	00033
	03-Mar	Diesel	15,000	vehicle overturned	00048
	30-Mar	Hydraulic fluid	45	blown line	00107
2001	25-Feb	Diesel	300	collision	01051
	28-Feb	Diesel	<300	leaking tank	01059
	28-Feb	Ammonium-nitrate	750 kg	1t bag fell from trailer	01058
	01-Mar	Ammonium-nitrate	100 kg	1t bag fell from trailer	01061
	24-Mar	Diesel	<200	trailer valve leak	01087
	05-Apr	Diesel	50	truck-leaking tank	01103

Planned improvements will manage future increased traffic volumes

A detailed study was undertaken by others on all aspects of the winter road engineering and operation (EBA 2000). Specific improvements were identified in this study to ensure that historical spill rates (and environmental impacts) would not increase due to the predicted increased traffic. Various improvements from this study are summarized in Section 6.6. For the purposes of the present study, the historical experience from operating the winter road was used to assess future risks associated with the Snap Lake Diamond Project.

Spill rates from three to six per year are expected depending on traffic

Results from the risk assessment of transportation activities along the winter road included an estimate of expected spills and residual hazardous material that may impact aquatic life. Spill incident estimates were based on the historical spill rate of 10^{-6} per loaded truck km of travel and the projected traffic volumes presented in Section 6.6. Spills are expected to increase from the recent three per year to six per year over the largest volume years from 2010 to 2015, then return to less than three per year following the predicted decrease in traffic after 2015. The Snap Lake Diamond Project is expected to contribute about 28% of the total based on its proportion of traffic.

Diesel spill volumes were assessed from historical incidents

Diesel is expected to account for 42% of the spills based on predicted traffic for the Snap Lake Diamond Project. Since spills associated with spill scenario #2 (*i.e.*, break through ice) were no greater than 200 litres, the impacts to aquatic life resulting from this scenario were evaluated.

Spills of other hazardous materials were evaluated

Spill frequencies of most other hazardous materials are expected to be less than 1 in 100 years given the comparatively small traffic volumes associated with these materials. Residual spill volumes may remain following the implementation of emergency response measures and these were determined from historical incidents and the trucking containers described in Table 13.3-4. Residual hazardous material spills for 200 litres of liquids and 1 t of solids were assessed to determine potential impacts on aquatic life.

The effect of spills on aquatic life will be addressed

Spills associated with the terrestrial environment under winter conditions are quickly remediated. Because mitigation can usually be more effective in the terrestrial environment, a spill is unlikely to affect habitat suitability and organisms to the same degree as a spill in the aquatic environment. Therefore, this assessment focusses on the effects of spills on aquatic life. Risk of a spill on the winter road affecting aquatic life is defined by the potential for an accident and spill; the type and amount of hazardous material spilled; the effectiveness of spill cleanup; and the environmental effect of the residual material remaining.

Aquatic life toxicity was assessed for hazardous materials

A review of toxicity information was undertaken to define aquatic life toxicity thresholds (lowest level of concentration of a contaminant that shows evidence of a toxic effect) for hazardous materials identified in Table 13.3-4. The resulting toxicity thresholds are provided in Table 13.3-6. Minimum values from the range of toxicity were used as thresholds for this assessment.

Table 13.3-6 Aquatic Life Toxicity Thresholds for Hazardous Materials

Potentially Hazardous Material	Threshold Value (mg/L)	Type of Effect[1]	Source
Diesel	74 - 10299	96 hour (hr) LC_{50} [2]	WHO (1996)
Gasoline	5.4 - 182	48 to 168 hr LC_{50}	CONCAWE (1992)
Lube oils, hydraulic fluids and oils, waste oils, transmission oils, drive oils	1000	LC_{50}	CONCAWE (1997)
Ethylene glycol	100 - 1000	96 hr LC_{50}	Environment Canada (1985)
Ammonium nitrate	9.8	chronic toxicity	Based on chronic toxicity of ammonia (2.2 mg/L) to trout CCME (1999)
Hydrofluoric acid	1.5	affects hatching of fish eggs	Reviewed in Environment Canada (1984a)
Slaked lime	10 - 1000	96 hr LC_{50}	Environment Canada (1984b)
Sodium nitrate [3]	NA [2]	NA	CCME (1999)
Emulsifiers	no information		
Nitric acid	NA [5]	lowering of pH	

1 mg/L = milligram per litre.
2 LC_{50} is the concentration which is lethal to 50% of the test organisms over the duration of the test (*e.g.*, 96 hr).
3 Sodium and nitrate do not have aquatic life thresholds.
4 N/A = not available.
5 Nitric acid could affect aquatic life by lowering the pH of the water.

Magnitudes of effect for spills were described

The environmental consequence of a spill on aquatic life depends on the residual volume of the spill, its toxicity, and the volume of the lake affected by the spill. For the purposes of the risk assessment, the environmental consequence was evaluated for fish-bearing lakes (lakes equal to or greater than 1 hectare (ha) in area). The winter road crosses 20 fish-bearing lakes, ranging in size from 121 to 107,800 ha (Table 13.3-7 and Figure 13.3-1). There is an undetermined number of very small, non fish-bearing water bodies along the winter road route. The environmental consequence rating was determined using the same four levels defined previously in Table 13.1-1 for the mine site risk assessment. These levels are defined according to a combination of magnitude of toxic effect, spatial extent, duration, and reversibility.

Figure 13.3-1 Fish Bearing Lakes Along the Winter Road

Table 13.3-7 Fish-Bearing Lake Sizes Along the Winter Road

Lake Size Affected	Number of Lakes
< 1 ha (=0.01 square kilometres) will not support fish population	undetermined
121-7065 ha	17
7065-18,800 ha	2
18,800-107,800 ha	1

Gasoline, hydrofluoric acid, ammonium nitrate, and lime may affect small non fish-bearing lakes

Materials with the potential to exceed toxicity thresholds if spilled into small, non fish-bearing lakes include gasoline, hydrofluoric acid, ammonium nitrate, and lime. Spills into larger, fish-bearing lakes would be much less likely to cause exceedances of toxicity thresholds, except over very small areas over short periods of time.

A project risk matrix was developed to estimate environmental risks

The risk of an accidental truck spill was estimated using the project risk matrix as was done for the mine site risk assessment. The risk associated with each of the material spill scenarios identified in Table 13.3-8 is estimated by locating it within the risk matrix. Indices for this risk matrix were defined previously in Section 13.1.5 and Table 13.1-1.

Table 13.3-8 Material Spill Scenarios

Material Spill Scenario	Aquatic Life Toxicity Threshold (mg/L)	Spill Volume (m^3)	Maximum Concentration in a Small Lake[a] (mg/L)
1) Diesel	74 (acute)	200	6
2) Gasoline	5.4 (acute)	200	6
3) Lube oils, hydraulic fluids and oils, waste oils, transmission oils, drive oils	1000 (acute)	200	6
4) Ethylene glycol	100 (acute)	200	7
5) Ammonium nitrate	9.8 (chronic, sub-lethal)	1000	58
6) Hydrofluoric acid	1.5 (chronic, sub-lethal)	200	8
7) Slaked lime	10 (acute)	1000	75

[a] Small lake is 1 ha in area and 3 m deep, which is the smallest volume known to support fish.

Risk indices were developed from the residual impact criteria

The frequency index in the project risk matrix ranges from a low value of 1/10,000 to a high value of 1/10 events per year. The environmental consequence index ranges from category A (negligible) to category D (high). These categories were previously described in Section 13.1.5. The measure of risk increases from the bottom left corner of the risk matrix to the top right as shown by the arrow in Table 13.3-9. If either the frequency or environmental consequence of the risk is less than the range shown in Table 13.3-9, the risk is not determined.

Environmental consequences are negligible or low for fish-bearing lakes

Risks to non fish-bearing water bodies fall into the higher-risk categories because of exceedances of toxicity thresholds lake-wide (Table 13.3-9). Risks to the 20 fish-bearing lakes are located in the lower risk area of the matrix because of the combination of low frequency and negligible or low environmental consequences. The environmental consequences are rated negligible or low because concentrations of contaminants are expected to be well below toxicity thresholds for all but a tiny fraction of the lake volume and/or the duration of exposure would be < 24 hours.

Table 13.3-9 Seven Identified Winter Road Risks Located on the Project Risk Matrix

FREQUENCY INDEX		ENVIRONMENTAL CONSEQUENCE INDEX			
(Events/Year)	(Description)	A Negligible	B Low	C Moderate	D High
1/10	Likely to occur repeatedly*				
1/100	May occur once*	1			
1/1,000	Unlikely to occur *	3	5		
1/10,000	Extremely unlikely to occur*	4	2, 6, 7		

Increasing Risk

*During the life of the mine.

Confidence in the assessment is high and the probability of occurrence is 10^{-1} events/year

The level of certainty that effects would not be greater than predicted would be high due to the following assumptions:

- the lowest known toxicity thresholds were used;
- conservative residual spill volumes were used; and,
- conservative fate of materials in lakes was assumed with localized elevations in concentrations persisting for at least 24 hours without rapid mixing and dilution, and with no breakdown or neutralization.

The probability of occurrence is shown as frequency in Table 13.3-9.

13.4 CONCLUSIONS

Each risk scenario was documented on a worksheet

Results from the mine site risk assessment are documented in a worksheet according to the following steps:

- accident or malfunction;
- selected safeguards;
- consequence; and,
- residual risk (with safeguards in place).

Eight risk scenarios were identified

Twelve risk scenarios were assessed and environmental risks were estimated for eight of these scenarios, using a project risk matrix.

All risks were associated with minor environmental consequence except Dam 1 failure which is extremely unlikely

All risks from accidents and malfunctions were associated with the more minor environmental consequence levels A (negligible) and B (low) with the exception of scenario 2b (major failure of Dam 1) which would result in moderate environmental consequences. However, scenario 2b is extremely unlikely, with a frequency of 1/10,000 years.

The probability of spills occurring and their environmental effects were assessed

The risk assessment of accidents on the winter road was based on the spill probability and the potential effects of spills on aquatic life. Risk of a spill on the winter road affecting water bodies was defined by the potential for an accident and spill; the type and amount of hazardous material spilled; the effectiveness of spill cleanup; and the environmental effect of the residual material remaining.

The historical spill rate and historical causes were used to estimate future spills

Historical truck spill accidents on the winter road since 1983 were assessed in terms of spill rates, causal factors, and spill amounts. This spill rate record was also analyzed to evaluate potential risk mitigation effects due to increased operational experience and increased usage of the winter road. Based on this analysis, the historical spill rate was used to estimate future spill incidents.

The magnitude of the spill impact was based on the size of the lake that would be affected

Effects of a spill on aquatic life depend on the residual volume of the spill, its toxicity, and the volume of the lake affected by the spill. For the purposes of the risk assessment, environmental consequences were determined for fish-bearing water bodies (water bodies with an area of 1 ha or greater). A review of toxicity information was undertaken to define aquatic life toxicity thresholds for hazardous materials to be transported to the mine site. Environmental consequences were rated using the same criteria as for mine site accidents and malfunctions.

The environmental consequence of spills from the winter road is predicted to be negligible to low

Risks of spills to aquatic life fell in the low-risk area of the risk matrix because of a combination of low frequency and negligible to low environmental consequences.

13.5 REFERENCES

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13.6 UNITS, ACRONYMS, AND GLOSSARY

UNITS

ha	hectare
km	kilometre
m	metre
m^3	cubic metres
mg/L	milligram per litre
t	tonne

ACRONYMS

CONCAWE	The Oil Companies' European Organization for Environmental and Health Protection (established 1963)
CCME	Canadian Council of Ministers of the Environment
De Beers	De Beers Canada Mining Inc.
EA	environmental assessment
hr	hour
ISO	International Organization for Standardization
LSA	local study area
MVEIRB	Mackenzie Valley Environmental Impact Review Board
LC_{50}	the concentration of a substance which results in a 50% mortality of a test organism over a specified time period
NA	not available
NSMA	North Slave Métis Alliance
RSA	regional study area
RWED	Resources, Wildlife and Economic Development
TSS	total suspended solids
WHO	World Health Organization

GLOSSARY

baseline	describes the environmental setting against which changes in the environment from the accident or malfunction could be assessed; in this section only, baseline is the condition immediately prior to the accident; baseline could occur in any phase of the project
environmental consequence	the overall effect on the environment when the magnitude, spatial extent, duration of toxic effects, and reversibility of the project's impact are considered together; environmental consequence is derived differently in this section (see Table 13.1-1) than in other sections
frequency	an expression of the estimated number of accident or malfunction occurrences per unit time

freshet	a rise or overflowing of a stream caused by heavy rains or melted snow
flocculation	process whereby small particles adhere together with the aid of chemical addition
spatial extent	in this section only, spatial extent is defined as the percentage of the total lake volume that is impacted
level of confidence	the degree of certainly in the impact prediction
magnitude	a measure of the intensity or severity of an impact; it is based on the toxicity (*e.g.*, sub-lethal, acutely lethal) to aquatic life in this section only
paste	tailings material that has been thickened through the removal of entrained water
probability of occurrence	the likelihood that the environmental consequence indicated in the impact prediction will occur if the project goes ahead; it is expressed as the frequency in this section only
residual risk	risk remaining after safeguards are applied
reversibility	refers to changes that occur after the impact ceases allowing the environment to return to a capability or condition equivalent to the baseline
risk	the likelihood or probability that the toxic effects associated with a chemical or physical agent will be produced in populations of individuals under their actual conditions of exposure; risk is usually expressed as the probability of occurrence of an adverse effect
risk assessment	process that evaluates the probability of adverse effects that may occur, or are occurring on target organism(s) as a result of exposure to one or more stressors
risk matrix	a two dimensional table comprised of one index representing the measure of frequency (or likelihood) and another index representing the measure of environmental consequence (or adverse effect)
run-out	the area where tailings may flow if there is a failure in containment
toxicity	the inherent potential or capacity of a material to cause adverse effects in a living organism
toxicity threshold	almost all compounds (except genotoxic carcinogens) become toxic at some level with no evident harm or adverse effect below that level; scientists refer to the level or concentration where they can first see evidence for an adverse effect on an organism as the toxic threshold; genotoxic carcinogens exhibit some toxic potential at any level

DE BEERS
GROUP OF COMPANIES

April 30, 2014

File:L020

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Attention: Mr. Simon Toogood (Review Board) and Ms. Rebecca Chouinard (MVLWB)

Dear Mr. Toogood and Ms. Chouinard,

Re: De Beers Canada Inc.'s Response to Technical Session Information Requests for the Environmental Assessment, Snap Lake Amendment Project ("Project"), (EA1314-02) and the Water License Amendment (MV2011L2-0004)

De Beers Canada Inc. ("De Beers") provides the following responses to Information Requests (IRs) resulting from the April 15/16th Technical Sessions at the Yellowknife Inn, and to IRs provided on April 22nd in Response to the De Beers Supplemental Filing.

Based on the information provided to date by De Beers, the site specific benchmarks developed for TDS and its constituent ions are both appropriate and protective of the aquatic environment. Parameters for which there are benchmarks and other parameters will continue to be monitored through the Aquatic Effects Monitoring Program; the Response Framework would be triggered should a monitored parameter require action.

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De Beers believes that setting effluent quality criteria (EQC) based on site specific testing is appropriate and environmentally protective. De Beers has committed to implementing treatment to protect Snap Lake and downstream water bodies. The treatment options proposed are proven technologies that are currently undergoing feasibility testing to determine the best treatment option applicable to the unique setting of the mine site. Once the optimal system has been approved, a risk assessment will be carried out to assess specific Accident and Malfunction scenarios to this system and its byproducts (i.e., the treatment waste stream). It is expected that discussion regarding the specifics of the risk assessment will be carried out as a component of the permitting and commissioning of the selected treatment system from the MVLWB.

In closing De Beers thanks the Review Board and the MVLWB for this opportunity to respond to the IRs and thus to provide additional supporting evidence to the Boards. We also thank all who attended and participated in the Technical Session for their useful questions and discussion including subsequent IRs.

De Beers appreciates the Review Board's efforts to undertake the review process for this Water Licence Amendment in an efficient and timely manner. Should you have any questions, comments or require further clarification, please do not hesitate to contact the undersigned at (867) 766-7331 or by e-mail at the following address: Erica.Bonhomme@debeersgroup.com.

Sincerely,

DE BEERS CANADA INC.

Erica Bonhomme
Environment Manager
Snap Lake Mine

Attachments

Information Requests (IR) from April 15, 2014:

MVRB/MVLWB_IR#1: During the presentation entitled "Snap Lake Mine Site Water Balance and Water Quality Model Predictions", the department of Environment and Natural Resources (ENR) enquired about the assumptions used in the model to generate the periodicity shown in the graphs of the model calibration of TDS on page 14 of the presentation. Therefore, DBCI is to provide a description of the assumptions and/or factors used to generate the calibration curves (e.g., ice thickness etc). DBCI also to explain how it carried these assumptions forward in the model. Quantitatively and qualitatively describe level of uncertainty in the model.

Response

The cyclical annual pattern present in the model results is caused by ice formation and ice melting. The magnitude of the cycle varies and depends on ice thickness and the depth of the lake at the monitoring station of interest. For the calibration, ice formation and melting volumes were derived from the annual average of maximum ice thickness measurements between 2004 and 2012 (Table MVRB/MVLWB_IR#1-1), which were calculated by first identifying the maximum ice thickness measurement at each Aquatic Effects Monitoring Program (AEMP) station from each year and then averaging the maximum ice thickness measurements from all AEMP stations in Snap Lake.

Modelling the processes of ice formation and melting involved the following assumptions:

- ice formation occurred over a ninety day period from mid-October to January each year;
- ice melting occurred over a sixty day period from mid-April to mid-June each year;
- for future simulations, an average ice thickness of 1.3 metres (m) was used each year; and,
- as ice forms on the lake, constituents (mass) are rejected from the ice and remain in the lake. As a result, parameter concentrations in the lake increase during the ice-covered season.

Table MVRB/MVLWB_IR#1-1: Snap Lake Ice Thickness Values Used in the Model Calibration

Year	Average of Maximum Measured Ice Thickness (m)
2004	1.3
2005	1.4
2006	1.3
2007	1.4
2008	1.6
2009	1.4
2010	1.3
2011	1.3
2012	1.4

m = metres.

The main model inputs that affect water quality in Snap Lake are effluent discharge and lake water recirculation to the Mine. There is high confidence that the upper and lower bound model scenarios describe the range of variability in effluent discharge and lake water recirculation that will be encountered during future mining. For other calibration inputs and assumptions, refer to Sections 2.2 and 2.3 of the Snap Lake Hydrodynamic and Water Quality Model Report (De Beers 2013). Sections 4 and 5 of the Snap Lake Hydrodynamic and Water Quality Model Report provide further discussion on model uncertainty.

Reference

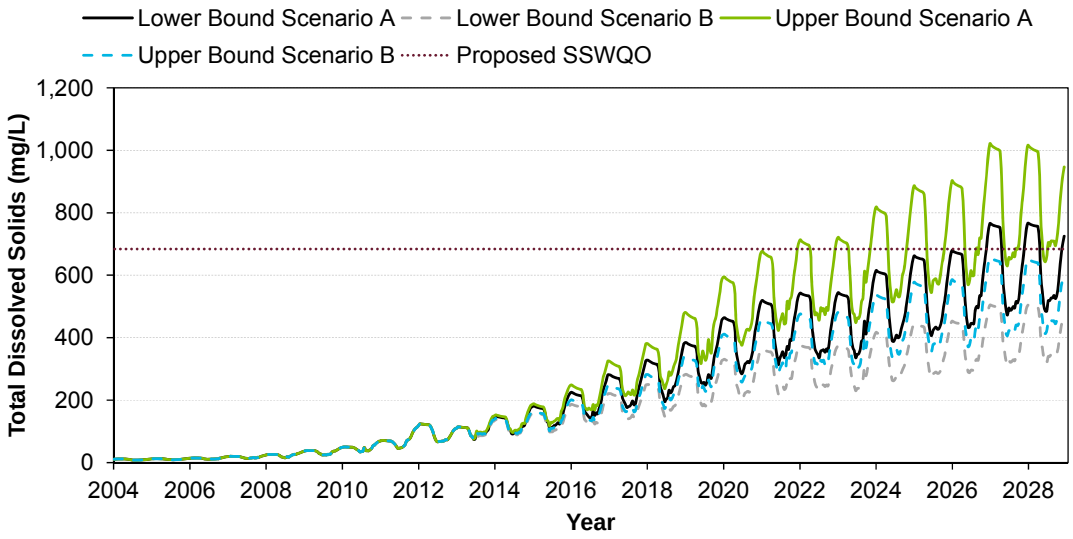
De Beers (De Beers Canada Inc.). 2013. Snap Lake Hydrodynamic and Water Quality Model Report. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

MVRB/MVLWB_IR#2: Based on a request from the Snap Lake Environmental Monitoring Agency, DBCI is to provide information about TDS concentrations in Snap Lake at the water intake location over time.

Response

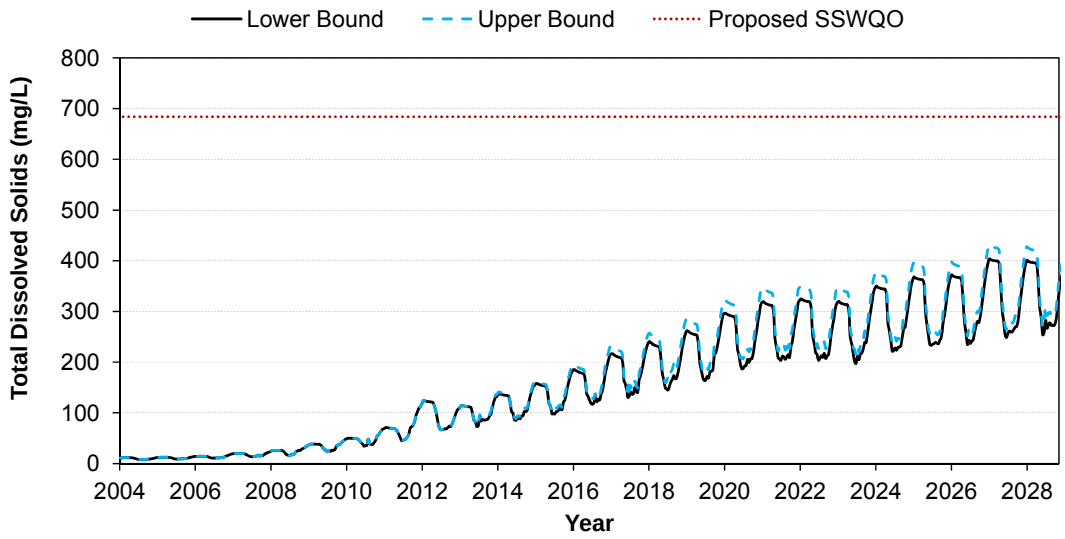
Figures MVRB/MVLWB_IR#2-1 and MVRB/MVLWB_IR#2-2 present predicted depth-averaged TDS concentrations near the water intake location for model scenarios without mitigation and with mitigation, respectively.

Figure MVRB/MVLWB_IR#2-1: Predicted Depth-Averaged Total Dissolved Solids Concentrations in Snap Lake Near the Water Intake (Without Mitigation)



mg/L = milligrams per litre; SSWQO = site-specific water quality objective.

Figure MVRB/MVLWB_IR#2-2: Predicted Depth-Averaged Total Dissolved Solids Concentrations in Snap Lake near the Water Intake (Proposed EQC are Met)



mg/L = milligrams per litre; EQC = effluent quality criteria; SSWQO = site-specific water quality objective.

MVRB/MVLWB_IR#3: DBCI is to provide further information on mitigation options for TDS treatment in the form of historical Best Treatment Available documentation.

Response

The three Best Treatment Available studies that have been completed since 2008 are summarized in the following table together with Interim results from a study completed by Hatch as part of the 10-year review of the Metal Mine Effluent Regulations conducted by Environment Canada. Copies of the reports prepared for De Beers are included in this submission. Please note that a copy of the interim Hatch report is not available for distribution; however, Snap Lake participated in the study and is familiar with the technology assessment results for chloride.

Table MVRB/MVLWB_IR#3-1 Total Dissolved Solids Treatment Study Summary

	2008 SLM Water Management Treatment Alternatives (Golder 2008)	**2012 SLM WTP Alternatives Evaluation (CH2M Hill 2012)**	**2013 Treatment Review Footwall Water TDS Management Plan (Golder 2013)**	**2014 Interim MEND Study BATEA for Mines (Hatch 2014)**
Selected Treatment Systems				
Water to be Treated	Haulage Drifts (Footwall) Water	Mine Water + Water Management Pond (WMP)	Footwall Water	Mine Water, Tailings Seepage
TDS Treatment Processes:				
Forward Flow Treatment Processes (following existing water treatment plant [WTP])	Ultra-filtration (UF), Reverse Osmosis (RO)	Equalization, High-rate Clarification, Micro-filtration (MF)/UF, RO	UF, RO	RO
Brine/Salt Management Processes	1. Evaporator and Crystallizer (isolation cell for salt disposal on-site) 2. Evaporator and Use in Paste Tails 3. Evaporator and Deep Well	Evaporator and Crystallizer (cost analysis by Golder)	Evaporator and Crystallizer	NA
Winter Brine Storage	NA	NA	NA	NA
System Flow Rates (m^3/day)	Initial – 5,000 Future (3 cases) – 1. 10,000 2. 20,000 3. 30,000	Initial – 41,000 Future – 45,000	4,000 to 9,000 5,425 (average for Operational cost estimation)	Average – 48,000 Maximum – 72,000
Treatment Objectives (Water Quality)	TDS-350 mg/L (whole lake limit)	Nitrate-4 mg/L as N Chloride-160 mg/L TDS-NA	TDS-350 mg/L (whole lake limit)	Chloride<13.5 mg/L TDS-NA
Treatment Objectives (Water Management)	Expand treatment as mine development occurs; future footwall flow increases were not understood in 2008	Handle 2015 flow; no phasing; considers split treatment of mine water	Separate footwall water collection and treatment; minimize secondary waste	Meet water quality benchmarks

Table MVRB/MVLWB_IR#3-1: Total Dissolved Solids Treatment Study Summary

	2008 SLM Water Management Treatment Alternatives (Golder 2008)	**2012 SLM WTP Alternatives Evaluation (CH2M Hill 2012)**	**2013 Treatment Review Footwall Water TDS Management Plan (Golder 2013)**	**2014 Interim MEND Study BATEA for Mines (Hatch 2014)**
Notes on Treatment Systems	Technical and regulatory aspects for disposal or reuse of concentrated brine and for disposal of salts were not studied	Brine management/ disposal not studied; although combinations of WMP and partial mine water treatment were discussed, treatment flow was projection of total discharge (mine plus WMP) to Snap Lake	Utilizes ultrafiltration (UF) with flocculant feed for total suspended solids (TSS) removal.	Media filters (best available technology economically achievable [BATEA] and existing treatment) are listed as pretreatment, but it is noted that additional processes could be needed; RO uneconomical so not considered as BATEA for Diamond Sector
Cost Information				
Capital Cost ($Millions-$M)	Initial – $26.2M 1. $56.0M 2. $88.3M 3. $104.6M	$121.5M	$84.0M	$90.3M
Unit Capital Cost ($/m^3/day)	Initial-$5,230/m^3/day 1. $5,600 2. $4,413 3. $3,487	$2,701/m^3/day	$9,333/m^3/day	$1,254/m^3/day
Total Operational Cost ($M/year)	NA	$20.3M/year	$8.1M/year	$7.6M/year
Unit Operational Cost ($/m^3)	NA	$1.24	$4.09	$0.43/m^3
Operational Cost Elements:				
Power Cost ($M/year)	Initial - $5.87M/year 3. $34.7	$13.6M/year	$6.48M/year	NA
Unit Power Rate ($/kw-hr)	$0.264	$0.27	$0.27	NA
Unit Power Cost ($/m^3)	Initial - $3.22 3. $3.17	$0.83	$3.27	NA
Maintenance ($M/year)	NA	$2.03M/year	$1.22M/year	NA
Consumables (chemicals/membranes) ($M/year)	NA	$3.86M/year	$0.16M/year	NA

Table MVRB/MVLWB_IR#3-1: Total Dissolved Solids Treatment Study Summary

	2008 SLM Water Management Treatment Alternatives (Golder 2008)	2012 SLM WTP Alternatives Evaluation (CH2M Hill 2012)	2013 Treatment Review Footwall Water TDS Management Plan (Golder 2013)	2014 Interim MEND Study BATEA for Mines (Hatch 2014)
Labor ($M/year)	NA	$0.81M/year	$0.24/year	NA
Notes on Cost Information	Capital cost includes phased installation of 2,500 m^3/day modules (2 modules initially); only power cost was estimated for annual operations; power cost rate assumes diesel at $1/liter, supplied by De Beers	Costs based on nitrate removal from 45,000 m^3/day; Golder estimated brine management capital and all operational costs; unit power rate supplied by De Beers	Compared to 2008 study, capital cost increase represents 8% inflation; unit power rate supplied by De Beers	Table 10-5 indicates that additional brine management would add significantly to costs
Technical Evaluation				
Water Recovery Rate (% of System Flow Rate)	RO-75% Evaporator-95% Crystallizer-99%	RO – 60–80% RO 2-Stage – 84%	RO-75% Crystallizer-99.5%	NA
System Flexibility	May need equalization to optimize RO	Additional pretreatment steps to handle variations in existing treatment system effluent	Same as 2008	Equalization tank or pond assumed as part of BATEA for TSS to optimize RO
Infrastructure Requirements	Large power demand; makeup water; chemicals	Large power demand; ballast material for some high-rate clarifiers; makeup water; chemicals	Same as 2008	NA
Land Area Requirements	600 m^2; may also need salt/brine disposal cell	260 to 540 m^2 for high-rate clarification (depending on technology selected)	200 m^2; may also need salt/brine disposal cell	NA
Secondary Waste (m^3/year)	18,000 – 110,000 (sludge from UF added to tailings for North Pile disposal)	2,628,000 (large reduction would occur after Evaporator/ Crystallizer; sludge from high-rate clarifier and MF/UF added to tailings for North Pile disposal)	NA	NA; need for brine management/treatment is discussed.

NA = Not analyzed; SLM = Snap Lake Mine; WTP = Water Treatment Plant; WMP = Water Management Pond; RO = Reverse Osmosis; UF = Ultra-filtration; MF = Micro-filtration; TDS = Total Dissolved Solids; TSS = Total Suspended Solids; BATEA = Best Available Technology Economically Achievable.

References

CH2M Hill. 2012. Snap Lake Mine Water Treatment Plant Alternatives Evaluation. Prepared for De Beers Canada Inc. Yellowknife, NWT, Canada.

Golder (Golder Associates Ltd). 2013. Treatment Review for Footwall Water as Part of TDS Management Plan. Technical Memorandum prepared for De Beers Canada, Inc. (Julie L'Heureux and Alexandra Hood), December 12, 2013. Denver, CO, USA.

Golder. 2008. Snap Lake Water Management Treatment Alternatives Report. Technical Memorandum prepared for De Beers Snap Lake Diamond Mine (Josh Harvey and Rob McLean). May 19, 2008. Denver, CO, USA.

Hatch. 2014. MEND Study to Identify BATEA for the Management and Control of Effluent Quality from Mines. Interim Report prepared for the Mine Environment Neutral Drainage Program. February 28, 2014. [Hatch was commissioned by the Mine Environment Neutral Drainage (MEND) Program to complete a study to identify best available technologies economically achievable (BATEA) to manage and control effluent from metal, diamond, and coal mines in Canada].

MVRB/MVLWB_IR#4: During the technical session, Ecometrix pointed out a discrepancy between the selection of TDS concentrations equal to 5728 mg/L and 3,490 mg/L for Scenario A and Scenario B in the water quality predictions models instead of the values of 6,187 mg/L and 3, 170 mg/L TDS, respectively, that were used in August 2013 Itasca model. DBCI provided a clarification for this apparent discrepancy by referencing an additional Itasca model submission dated October 2013. DBCI should now provide this submission for the record (see also IR#6).

Response

The ITASCA October 3, 2013 Memo, "Predicted TDS Concentration in Mine Water Discharge Based on Calculated TDS Values" is attached to this submission.

MVRB/MVLWB_IR#5: In its April 11, 2014 supplemental information submission, DBCI provided predictions of TDS concentrations in lakes downstream of Snap Lake (for 2014 to 2029) under the scenario that no mitigations are applied for TDS and under the scenario that the DBCI's proposed EQC would be met. As initially requested by ENR, DBCI is to provide the same analysis for chloride, as well as the other constituents of TDS that the Review Board scoped in, and hardness downstream of Snap Lake over time.

Response

De Beers acknowledges that the assessment of cumulative effects for this Project is non-traditional given the nature of the development (i.e., a change in a WQ licence limit) and the

nature of the regulatory process. The focus for valued ecosystem components (VECs) was, commensurate with a WQ issue, on the aquatic environment. The AEMP Design Plan (De Beers 2014) details the water quality VECs, which form the basis for the AEMP Response Framework. The AEMP Response Framework was designed to identify the valued components in relation to changes to water quality, 'thresholds' at which change is deemed unacceptable for these components and the level at which action would be taken before any thresholds are exceeded. It was identified that the level of change in Snap Lake that is not acceptable, based on the original EA, would occur when the water might not be safe to drink, and fish might not be plentiful and safe to eat.

Accordingly, De Beers identified the aquatic environment as the overall VEC for assessment of the effects of increased concentrations of total dissolved solids (TDS) on: drinking water, fish; and, food for fish. This approach is consistent with the VECs identified related to TDS in the original EA and in the conceptual design of the recently approved AEMP Design Plan (De Beers 2014). It is also consistent with comments provided on changes to the Snap Lake Water Licence limits since the renewal of the licence in 2011.

The cumulative effects section of the Supplemental Information identified that, while there are developments in the Lockhart River Watershed, there is no overlap between these and the Snap Lake treated effluent discharge; thus, there is no overlap related to possible cumulative effects from TDS. It was acknowledged in the April 14-15, 2014 Technical Session that other developments may potentially occur in the future but that De Beers could not foresee details on TDS concentrations from those developments and as such neither qualitative nor quantitative predictions about either overlap or effects could be made. It was also noted in the Technical Session that concentrations of TDS from Snap Lake will generally remain within the original EA predictions in the downstream environment. Finally, it was noted that the predicted TDS concentrations downstream of Snap Lake are generally low and within regional norms for the watershed; cumulative effects relate to such relatively low concentrations of TDS are not reasonably expected to occur. Thus, further assessment of cumulative effects was not required and was not conducted. De Beers is, however, continuing regional monitoring to document TDS concentrations downstream of the mine to King Lake, near Mackay Lake. The Mine's sampling coupled with the GNWT's as well as Aboriginal Affairs and Northern Development Canada and CIMP data in the Lockhart River will allow continued monitoring of regional water quality.

Reference

De Beers. 2014. 2013 Aquatic Effects Monitoring Program Design Plan. Snap Lake Project. Submitted to the Mackenzie Valley Land and Water Board, Yellowknife, NWT, Canada.

MVRB/MVLWB_IR#6: Ecometrix requested that DBCI submit the Itasca updated model dated October 2013 – see IR#4.

Response

Please see De Beers response to IR#4.

MVRB/MVLWB_IR#7: During the technical session, ENR had several questions related to scientific literature on TDS and chloride water quality objectives and guidelines that, in ENR's opinion, may not be consistent with some of the DBCI's conclusions on the toxicity of those parameters. ENR has committed to providing these references by April 22, 2014. DBCI is to provide clarification and rationale on the exclusion of any relevant studies, including those provided by ENR in response to this IR, and any other comments about the material that the Boards may want to consider.

Response

De Beers provides below, as requested by GNWT (ENR), comments regarding each of the 21 documents provided. There are no inconsistencies with De Beer's conclusions regarding site-specific water quality objectives (SSWQOs). De Beers thanks ENR for providing this documentation, which clarified some of ENR's comments at the Technical Session and supports De Beers position regarding the protective nature of the proposed SSWQOs. For instance, it is now clear that cattails will likely not be affected by TDS in Snap Lake or downstream. This evidence further supports De Beers' position that the proposed TDS SSWQO is reasonable and protective.

De Beers notes that ENR did not include the following document in their submission and provides it for the Board's consideration:

WLWB (Wek'èezhìi Land and Water Board). 2013. Decision from Wek'èezhìi Land and Water Board Issued pursuant to Section 26 of the Northwest Territories Waters Act, R.S.C. 1992, c.39. Yellowknife, NWT, Canada.

On pages 7 and 8 of WLWB (2013) it is stated: "DDMI proposed a new Effects Benchmark for TDS because it triggered Action Level 2 in the proposed Response Framework. A benchmark of 1000 mg/L is proposed, which is adopted from the state of Alaska Department of Environmental Conservation's (DEC) 2012 Water Quality Standards. In their reviews, both EcoMetrix Inc. and Environment Canada noted that the guidelines of 1,000 mg/L TDS stated by the Alaska DEC (2012) is an upper bound and that any proposal to increase TDS to a level between 500 mg/L and 1,000 mg/L requires a special permit where the permit applicant must provide information to the department to show the proposed TDS level will not cause an adverse effect to aquatic life…. the Board concludes that the most appropriate TDS benchmark is 500 mg/L."

Diavik received the default 500 mg/L benchmark because they did not provide scientifically defensible studies justifying a higher benchmark. De Beers has provided such studies in the development of site-specific water quality objectives (SSWQOs) following guidance provided by the Canadian Council of Ministers of the Environment. De Beers has provided evidence that Snap Lake TDS concentrations of 684 mg/L and 1,000 mg/L are not toxic to aquatic life in Snap Lake. Note further that the Alaska Department of Environmental Conservation has issued two permits for TDS concentrations in receiving freshwater bodies of 1,000 mg/L, and one permit for up to 1,500 mg/L, as detailed below.

Examples of Other Relevant Jurisdictions[1] with TDS or Chloride Regulations:

De Beers does not understand this footnote. The Snap Lake Environmental Monitoring Agency (SLEMA) has not to our knowledge, as part of the EA, submitted such a summary. SLEMA has not submitted any IRs related to TDS discharges in the United States. However, on April 17 Zhong Liu, a member of SLEMA, sent an e-mail to Simon Toogood of the MVRB providing a 1988 document entitled "USEPA Water Quality Standards Criteria Summary – A Compilation of State and Federal Criteria". It is not clear how such a 26-year old document is applicable to De Beers' proposed SSWQOs.

1. United States Environmental Protection Agency (US EPA) Aquatic Life Criteria Table for chloride.
   Available online at:
   http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm#altable
   Note: Acute Chloride (Cl) Criteria of 860 mg/L and Chronic Criteria of 230 mg/L. Also in the US EPA Office of Water 1986. Quality Criteria for Water (Gold Book).

The USEPA develops national water quality criteria (WQC) that comprise generic, conservative benchmarks, not site-specific benchmarks. [Note that the Canadian Council of Ministers of the Environment (CCME) develops water quality guidelines (WQGs), not WQC.] USEPA allows states to develop State-specific water quality standards (WQS), although these must be approved by USEPA. For example, Kentucky recently developed selenium WQS that differ from national WQC. Kentucky's state-specific selenium WQS were approved by USEPA. Similarly, within states, site-specific water quality criteria (or standards) can be developed for specific projects or circumstances. See for example items 4 and 5, below (State of Pennsylvania; DoEC 2009). De Beers developed TDS and other SSWQOs specific to Snap Lake.

[1] ENR notes that the Snap Lake Environmental Monitoring Agency has submitted for the Boards consideration a summary of applicable alternate jurisdictions for the regulation of TDS discharges in the United States.

2. British Columbia Ministry of Environment (BC MOE) CAPP Freshwater Salinity Working Group and the Salt Technology Advisory Sub-Committee of the British Columbia Upstream Petroleum Committee. *A Review of the Toxicological Literature for Salt - 2002 to 2007* (attached).
   Note: BC MOE recommends a Cl concentration of 150 mg/L.

This document focuses on NaCl not on TDS in general; it is not relevant to the specific ionic composition of Snap Lake total dissolved solids (TDS). This document predates published research showing the modifying effects of hardness on chloride toxicity; that research is detailed in documentation previously supplied to the Board.

3. BC MOE Ambient water quality guidelines for sulphate- (attached).

The above document was not attached; however, De Beers presumes that ENR is referring to Province of British Columbia, Ministry of Environment, Ambient Water Quality Guidelines for Sulphate (Technical Appendix, Update, April 2013, prepared by Cindy Meays, PhD and Rick Nordin, PhD). This document was used to develop the Snap Lake AEMP benchmark for sulphate as noted in the documentation provided to the Board by De Beers.

4. State of Pennsylvania, Chapter 93. Water Quality Standards. Available online at: http://www.pacode.com/secure/data/025/chapter93/chap93toc.html
   Note: TDS limit of 500 mg/L as a monthly average; maximum grab 750 mg/L.

Section § 93.8d. of the above document is entitled “Development of site-specific water quality criteria.”. This section notes that a request for site-specific criteria will be considered when “There exist site-specific biological or chemical conditions of receiving waters which differ from conditions upon which the water quality criteria were based.” This is in fact the case for Snap Lake where the TDS SSWQO was based on the unique ionic composition of that TDS.

5. Alaska Department of Environmental Conservation (DoEC), Water Quality Standards. 18 ACC 70. 2009 (attached).
   Note: Golder identifies a seasonal limit of 1000mg/L for the Teck Resources Red Dog Mine; however, this is mine is located in close proximity to the ocean (Chukchi Sea) where ecosystems may be more adapted to saline influences and a lower value applies during environmentally sensitive periods. For comparison, at an inland mine (Gold Creek), the Alaska DoEC has set TDS at 300mg/L. In addition the TDS limit is set in Alaska depending on the receiving waterbody. Alaska may limit the concentration of chloride to 200 mg/L as per the US EPA aquatic life criteria.

The above document was not attached. However, De Beers referenced this document in the documentation and presentations provided to the Board both in the 2011 Snap Lake Water

Licence Renewal and in the present process. ENR is correct that "the Alaska DoEC has set TDS at 300 mg/L" for Gold Creek but fails to provide any information on how that limit was set in 2002 in a permit to the City and Borough of Juneau for the inactive (closed in 1944) Alaska-Juneau (A-J) Mine, whose drainage effluent discharges to Gold Creek.

It is noteworthy that Alaska DoEC has also set limits for TDS of 1,000 mg/L for Camp Creek and Sherman Creek TDS, both freshwater bodies. Limits for the Red Dog Main Stem are: "Total dissolved solids (TDS), with calcium greater than 50% by weight of the total cations, may not exceed 1,500 mg/l, and may not exceed 500 mg/l during the spawning period for Arctic grayling". The Red Dog Mine discharges, as documented in the 3rd document of the next sequence provided by ENR (Brix et al. 2009, p109) "to Red Dog Creek, a first order tributary of the Ikalukrok River, which is part of the larger Wulik River drainage". While ENR's conjecture that "[freshwater] ecosystems [near marine systems] may be more adapted to saline influences" may be correct where the Wulik River drains to the Arctic Ocean, it is not correct for upstream freshwater systems such as Red Dog Creek. However, adaptation to saline influences does occur and may occur over time as TDS concentrations increase.

6. Health Canada- Drinking Water Quality Guidelines (attached).
   Note: The Aesthetic Objective is 500 mg/L for TDS.

The above document was cited in the documentation provided to the Board by De Beers including the Supplementary Information, and was discussed at length during the Technical Sessions. As noted in the above document, there are no health issues identified with drinking water containing elevated concentrations of TDS. As stated in the above document, TDS in drinking water has been recorded at concentrations up to 2,510 mg/L in Manitoba, 5,376 mg/L in Saskatchewan, 1,000 mg/L in Alberta, and 4,662 mg/L in British Columbia. The aesthetic objective of 500 mg/L was set based on a panel of tasters who found that waters with TDS concentrations between 300 and 600 mg/L tasted good (but waters with low concentrations of TDS did not ; they had a [p2] "flat, insipid taste"). The 500 mg/L aesthetic objective includes considerations regarding (p2) "excessive scaling in water pipes, water heaters, boilers and household appliances". Note that the panel of tasters only found taste to be unacceptable above 1,200 mg/L; water with 600 to 900 mg/L was rated as "fair".

Note also that mineral water, which many prefer to drink rather than tap water, typically has relatively high TDS concentrations. For example, Vichy water has >3,000 mg/L TDS.

http://www.thenibble.com/reviews/main/beverages/waters/vichy-catalan-mineral-water.asp

Amendment - relevant Scientific Journal Articles (attached within GNWT IR response):

1. Weber-Scannel P.K and Duffy L.K. 2007. Effects of Total Dissolved Solids on Aquatic Organisms: A Review of Literature and Recommendation for Salmonid Species. *American Journal of Environmental Sciences.*

This publication was cited repeatedly in the information provided during the 2011 Water Licence Renewal and in the present Water Licence Amendment process in both written documentation and slide presentations. It was a key document in the development of the Snap Lake TDS SSWQO. Two key points from that publication that form the basis for De Beer's development of a TDS SSWQO are:

- define separate limits for different categories of ions or combinations of ions comprising TDS; and,
- do not set universal TDS limit – all TDS is not the same.

The latter point is important; ENR and others have provided TDS and chloride benchmarks that are not relevant to Snap Lake as they were not developed for the unique TDS composition in Snap Lake.

2. Mount et al. 1997. Statistical Models to Predict the Toxicity of Major Ions to Ceriodaphnia Dubia, Daphnia Magna and Pimephales Promelas (Fathead Minnows). *Environmental Toxicology and Chemistry*.

This publication is concerned with using regression models to screen toxicity of different major ion combinations. Predictions were not perfect and the authors note that over-prediction occurred (e.g., with *Daphnia magna*). As noted by the authors in the first sentence of the Abstract "Toxicity of fresh waters with high total dissolved solids has been shown to be dependent on the specific ionic composition of the water." This is why De Beers developed a SSWQO for the unique TDS in Snap Lake.

3. Brix K.V et al. 2009. The effects of total dissolved solids on egg fertilization and water hardening in two salmonids- Arctic Grayling (*Thymallus arcticus*) and Dolly Varden (*Salvenlinus malma*). *Aquatic Toxicology*.

This publication, which led to the Alaska Department of Environmental Conservation site-specific water quality standard for TDS in Red Dog Creek (see item 5 under Examples of Other Relevant Jurisdictions with TDS or Chloride Regulations, above) was a key consideration in the design of the Snap Lake TDS toxicity tests with Arctic Grayling and Lake Trout, in particular the early life stage testing and the use of both dry and wet fertilization. This publication is cited in the

documentation provided to the Board related to the TDS SSWQO. Note that the authors found that (Abstract and p 114) “Arctic Grayling and Dolly Varden fertilization success is not sensitive to elevated TDS with EC20s (concentration causing 20% effect) of >2782 and >1817 mg/L (the highest concentrations tested), respectively.” Note that this publication also confirms the use of a 20% effect level as having negligible effects.

4. Hallock R.J. and Hallock L.L. 1993. Detailed Study of Irrigation Drainage in and near Wildlife Management Areas, West-central Nevada. United States Geological Survey.

This document is comprised of 5 detailed reports: historical conditions; toxicity of irrigation drainage; movement of selenium and mercury; effects of boron, mercury, and selenium on waterfowl production; and, mercury and selenium in edible tissue of waterfowl. Salinity and contaminant concentrations increased in Carson Lake and Stillwater Marsh after they were hydrologically isolated. In 1863 TDS concentrations in Carson Lake were “about 1,500 mg/L” (p 16); however, in January 1987 they had “reached a dissolved-solids concentration of 20,000 mg/L” (p 17). On page 18 it is noted that cattails are “extremely sensitive to dissolved-solids concentrations” quoting Stewart and Kantrud (1972, Vegetation of prairie potholes, North Dakota, in relation to quality of water and other environmental factors. US Geological Survey Professional Paper 585-D, 36pp), and that cattails “are now found only in scattered patches”.

The Stewart and Kantrud (1972) document was not provided by ENR; however, this document was obtained and reviewed. Figure 20 (Characteristic plant species of deep-marsh emergent vegetation) shows that cattails can be common from fresh to moderately brackish water; two species are not common in fresh water and one of those two species is common even in brackish water. Stewart and Kantrud (1972, p D-5, Table 2) characterize moderately brackish as 1,550 mg/L TDS, brackish water as 5,570 mg/L TDS, and subsaline water as 26,400 mg/L TDS. No cattails are common in subsaline water, which presumably is the salinity of the waters described in Hallock and Hallock (1993) as having cattails “now found only in scattered patches”.

The chapter in Hallock and Hallock (1993) entitled “Toxicity of irrigation drainage and its effect on aquatic organisms” describes toxicity testing conducted in drainwaters from two locations ranging from about 270 to 17,900 mg/L TDS and about 4,000 to 9,700 mg/L TDS. Page 36 states “Although the elevated salinity in tests with drainwater from both locations undoubtedly stressed the organisms, the results suggest that salinity alone does not account for the mortality observed.” Page 37 states “Mortality is attributed primarily to a combination of toxic trace elements regardless of the benefits of increased hardness.” This chapter provides additional evidence that freshwater organisms can survive in elevated TDS concentrations; the above TDS concentrations were up to an order of magnitude higher than worst case predictions for Snap Lake.

5. Bodkin et al. 2007. Limiting Total Dissolved Solids to Protect Aquatic Life. *Journal Of Soil and Water Conservation*.

This 4 page document is focused on TDS concentrations in waters of Virginia, Kentucky, and West Virginia. It notes in the last paragraph "Questions still exist as to the level of TDS that is protective of aquatic communities, and the answer may vary among ecosystems". De Beers derived an SSWQO for Snap Lake TDS because the answer does in fact vary among ecosystems.

6. Carmargo et al. 2005. Nitrate Toxicity to aquatic animals: a review with new data for freshwater invertebrates. *Chemosphere* Volume 58.

This publication had previously been reviewed (pers communication between Peter Chapman, Golder Associates Ltd. and James Elphick, Nautilus Environmental) by the authors of the Dominion Mines Ekati Corporation, Board-approved SSWQO for nitrate (WL W2012L2-0001; Rescan. 2012. EKATI Diamond Mine: Site-Specific Water Quality Objective for Nitrate, 2012. Prepared for BHP Billiton Canada Inc, Yellowknife, NWT, Canada). They did not include it in their SSWQO as Carmargo et al. (2005) conducted acute, not chronic toxicity tests and the SSWQO for nitrate is based on chronic toxicity tests.

De Beers' further review of Carmargo et al. (2005) indicated that nitrate concentrations were not measured and that testing involved 5 day exposures of 5 to 6 nominal nitrate concentrations to 3 invertebrates common in streams in Spain. The toxicity test benchmarks in this publication are thus uncertain and not relevant to the nitrate SSWQO; however, the findings that increasing TDS concentrations reduce nitrate toxicity and that adaptation occurs are relevant. The former finding supports the hardness-based nitrate SSWQO for Snap Lake.

7. Cormier et al. 2013. Assessing causation of the extirpation of stream macroinvertebrates by a mixture of ions. *Environmental Toxicology and Chemistry.*

This publication used a weight of evidence (WOE) approach to implicate specific ion mixtures (different ion mixtures than Snap Lake) in impacts on aquatic invertebrates in Appalachian streams, not a headwater lake. Chloride was not a major component of the specific ion mixtures tested. The WOE approach used was retrospective (i.e., based on events that had already occurred), not prospective (i.e., not based on future possibilities). This publication is not relevant to the development of the Snap Lake TDS SSWQO.

8. Cormier et al. 2013b Relationship of land use and elevated ionic strength in Appalachian watersheds. *Environmental Toxicology and Chemistry.*

This publication focused on exposure to TDS not the effects of TDS. It confirmed that coal mining in Appalachia was the primary source of high conductivity waters in streams. This publication is not applicable to the development of the Snap Lake TDS SSWQO.

9. DeMarch. 1988. Acute Toxicity of Binary Mixtures of Five Cations (Cu2+, Cd2+, Zn2+, Mg2+ and K+) to the freshwater amphipod gammarus lacustris (Sars): Alternative Descriptive Models. *Canadian Journal of Fisheries Aquatic Science.*

This publication, as the title indicates, was focused on acute not chronic toxicity. The TDS SSWQO developed for Snap Lake is based on chronic toxicity. Metals are not a factor in Snap Lake TDS and none of the major ions comprising Snap Lake TDS were tested in this publication (magnesium only comprises 3% of Snap Lake TDS, while potassium comprises less than 1%); thus, the mixtures tested are not relevant to the development of the Snap Lake TDS SSWQO.

10. Kunz et al. 2013. Use of reconstituted waters to evaluate effects of elevated major ions associated with mountaintop coal mining on freshwater invertebrates. *Environmental Toxicology and Chemistry.*

This publication conducted toxicity tests with *Ceriodaphnia dubia*, an amphipod, and a mayfly. None of the species tested are found in Snap Lake. Chloride was not a major constituent of the major ions tested; thus, the toxicity tests are not directly applicable to the development of the Snap Lake TDS SSWQO. However, the publication did note (Abstract) “waters with similar conductivities but, with different ionic compositions had different effects on the test organisms…although elevated TDS can be correlated with toxicity, the specific major ion composition of the water is important”. The publication (p 2834) recommends “conducting toxicity tests with environmentally relevant and sensitive species”. These statements support the approach taken by De Beers in developing a SSWQO for Snap Lake TDS.

11. Pond and North. 2013. Application of a benthic observed/expected-type model for assessing Central Appalachian streams influenced by regional stressors in West Virginia and Kentucky. *Environmental Monitoring and Assessment*.

This publication is concerned with the development of indices for retrospective evaluation of TDS impacts and is specific to Central Appalachian waters. As stated at the end of the Abstract “These indices can be used to supplement existing bioassessment tools crucial to detecting and diagnosing stream impacts in the Central Appalachian region of WV and KY.” This publication is not relevant to the prospective approach of developing a SSWQO for Snap Lake TDS or to freshwater lakes in the NWT.

12. Sorenson et al. 1977. Suspended and dissolved solids effects on freshwater biota: A review. US EPA document number EPA-600/3-77-042.

This 1977 report focuses on literature prior to 1971 and thus does not include scientific studies conducted between 1971 and the present. However, relevant information was used in the literature review of TDS toxicity conducted as part of the Snap Lake TDS SSWQO development.

13. Suter and Cormier. 2013. A Method for assessing the potential for confounding applied to ionic strength in central Appalachian streams. *Environmental Toxicology and Chemistry*, Vol 32.

This publication is not concerned with toxicity testing; it comprises a weight of evidence (WOE) assessment of 12 potential confounders of the relationship between ionic strength and impaired benthos in Central Appalachian streams, not a headwater lake. This publication is relevant to the WOE approach used in the AEMP (the authors of the Snap Lake AEMP benthos and WOE components are aware of this publication), but not to the prospective approach of developing a SSWQO for Snap Lake TDS.

Other Amendment-relevant Articles for the Proponents Response to IR#7 (not attached):

14. Banack et al. 2012. Toxicity of fluoride to a variety of aquatic species and evaluation of toxicity modifying factors. In Harkness J, van Aggelen G, Kennedy CJ, Jarvis RA, Burridge LE (eds), Proceedings of the 39th Annual Aquatic Toxicity Workshop: September 30 to October 3, 2012, Sun Peaks, BC, Canada. Fisheries and Oceans Canada, St. Andrews Biological Station, St. Andrews, NB, Canada, p. 54.

This publication was extensively cited and used in the development of the fluoride SSWQO; documentation to this effect was provided to the Board.

15. Borgmann. 1996. Systematic analysis of aqueous ion requirement of *Hyallea Azteca*- A standard artificial medium including the essential bromide ion. *Environmental Contaminants Toxicology*, 30:356-363.

This publication concerns an artificial medium for culturing the amphipod, *Hyalella azteca*; it has no relevance to the development of a SSWQO for TDs for Snap Lake.

16. Brannock et al. 2002 Salt and Salmon: The effects of hard water ions on fertilization. Aquatic Science Meeting. *American Society of Limnology and Oceanography* Feb 11-15

This reference is a non-peer reviewed presentation at a scientific meeting. The document was not provided but was one of the references relied upon in Weber-Scannel and Duffy (2007; item 1 above under Amendment - relevant Scientific Journal Articles). As previously noted, the Weber-Scannel and Duffy publication was a key document used in the development of the Snap Lake TDS SSWQO.

17. Cowgill and Milazzo. 1991 The sensitivity of Two Cladocerans to Water Quality Variables: Salinity <467 mg NaCl/L and Hardness <200 mg $CaCO_3$/L. *Environmental Contaminants and Toxicology.*

This peer reviewed publication documents no effects to either *Ceriodaphnia dubia* or *Daphnia magna* from <467 mg NaCl/L or > 200 mg $CaCO_3$/L, but does document effects at low hardness. It is not relevant to the development of a SSWQO for TDs for Snap Lake.

18. Evans and Prepas. 1996. Potential effects of climate change on ion chemistry and phytoplankton communities in prairie saline lakes. *Limnology Oceanography.*

This peer reviewed publication documents changes in phytoplankton biomass in P-sufficient lakes; Snap Lake is not a P-sufficient lake. The authors also noted (p 1075) that such changes are “not observed in all saline ecosystems”. This publication has no relevance to the development of a SSWQO for TDs for Snap Lake.

19. Zalizniak et al. 2006. Is all salinity the same? The effect of ionic compositions on the salinity tolerance of five species of freshwater invertebrates. *Marine and Feshwate*r Research 57:75-82.

The conclusions of this peer-reviewed publication support the development of a SSWQO for Snap Lake TDS. As noted in the Abstract, “Variation in ionic proportions should be taken into account when considering sub-lethal effects of salinity on freshwater invertebrates”. In other words, the specific ionic composition of TDS is critically important.

20. EVS Environment Consultants. 1998. Effects of TDS on fertilization and viability of rainbow trout and chum salmon embryos. Revised Final Draft EVS Project No. 9/302-28. Prepared for Cominco Alaska.

This report was prepared by Peter Chapman, presently with Golder Associates Ltd. Dr. Chapman directed development of the Snap Lake TDS SSWQO. The information in the report was used in the development of the Snap Lake TDS SSWQO.

21. Ivey et al. 2013. Sensitivity of freshwater mussels at two life stages to acute or chronic effects of NaCl and KCl. SETAC poster. Society of Environmental Toxicology and Chemistry.

This non-peer reviewed poster presentation at a scientific meeting was not provided but the Abstract was obtained and reviewed. The research outlined indicates that freshwater mussels are sensitive to NaCl and KCl and that toxicity decreases as hardness increases. The latter finding supports the hardness-based chloride SSWQO. The former finding was based on two-ion mixtures not on the TDS-specific ion mixture in Snap Lake, which includes chloride.

MVRB/MVLWB_IR#8: DBCI to provide revised version of CH2MHill Assessment Report.

Response

Please refer to IR#3.

MVRB/MVLWB_IR#9: DBCI to provide the Golder 2008 Snap Lake Water Management Treatment Alternatives Report.

Response

Please refer to IR#3.

MVRB/MVLWB_IR#10: On slide 14 of DBCI's presentation on the TDS Response Plan, DBCI outlined a timeline of the planning, testing and implementation of mitigations to reduce TDS levels in the effluent. At the technical session, MVLWB staff expressed a concern about how to best align the water licensing process to amend the TDS EQC with DBCI's constraints around making final decisions on TDS mitigations and then implementing those mitigations before the current TDS EQC is exceeded. Therefore, the MVLWB staff requests that DBCI provide a graphic or table that aligns their timeline for the TDS mitigations with the predictions of end-of-pipe TDS concentrations. It would be helpful if DBCI could discuss its vision of how best to ensure that the water licensing process can be carried out to ensure that EQC for TDS are in place that are both protective and achievable.

Response

Predictions of TDS concentrations at end-of-pipe (i.e., surveillance network program [SNP] 02-17B) without mitigation and the anticipated timeline for implementation of mitigation are presented in Figure MVRB/MVLWB_IR#10-1. Pilot-scale testing and design are planned for the remainder of 2014, followed by approvals, construction, and implementation in 2015. De Beers anticipates that mitigation will be operational by January 2016 (Figure MVRB/MVLWB_IR#10-1).

However, by January 2015, end-of-pipe TDS concentrations are predicted to be higher than the proposed average monthly limit (AML) of 684 milligrams per litre (mg/L) for all four modelled scenarios; De Beers would, therefore, be out of compliance with the Water Licence, should an AML of 684 mg/L be adopted as early as January 2015.

Predictions of TDS concentrations at the diffuser stations (i.e., SNP 02-20) and in the whole-lake without mitigation are presented in Figures MVRB/MVLWB_IR#10-2 and MVRB/MVLWB_IR#10-3, respectively, including the anticipated timeline for implementation of mitigation. TDS concentrations at the diffuser stations are predicted to slightly exceed the proposed site-specific water quality objective (SSWQO) of 684 mg/L by April 2015 under Upper Bound Scenario A, without mitigation (Figure MVRB/MVLWB_IR#10-2 and Table MVRB/MVLWB_IR#10-1). Concentrations of TDS are expected to remain below the SSWQO in all other scenarios until February 2016. Concentrations of TDS and major ions in Snap Lake during operations are anticipated to fall within the range of concentrations predicted by the Upper and Lower Bound model scenarios. As a result, predicted TDS concentrations in Snap Lake are expected to remain below the proposed SSWQO of 684 mg/L in 2015.

The proposed AML of 684 mg/L was calculated based on conditions in Snap Lake at the end of Mine life when concentrations in Snap Lake are predicted to be at steady-state. The factor or condition that has the largest effect on the AML is the proportion of effluent in Snap Lake. The proportion of effluent in Snap Lake is expected to be approximately 90 percent (%) during ice-covered conditions at the end of Mine life (i.e., 2028). As a result, the ability of Snap Lake to dilute TDS concentrations at end-of-pipe would be at a minimum in late operations. In 2015, the proportion of effluent in Snap Lake would be approximately 64%. Therefore, Snap Lake has a greater assimilative capacity and a greater ability to dilute TDS concentrations at end-of-pipe in 2015 than in later years.

To allow for implementation of mitigation, De Beers proposes an interim protective TDS AML of 850 mg/L, which would apply between January 2015 and January 2016 and be inclusive of TDS, chloride, fluoride, and sulphate. The Snap Lake model was used to test whether an end-of-pipe TDS concentration of 850 mg/L would maintain TDS concentrations in Snap Lake below the proposed SSWQO of 684 mg/L. End-of-pipe TDS concentrations were set to a constant value of 850 mg/L from June 2014 to January 2016. The model predicted that an interim TDS AML of 850 mg/L would maintain TDS concentrations in Snap Lake below the proposed SSWQO of 684 mg/L (Figure MVRB/MVLWB_IR#10-4).

An interim TDS AML of 850 mg/L is achievable without mitigation if TDS concentrations at end-of-pipe to January 2016 match predicted TDS concentrations from Upper Bound Scenario B or Lower Bound Scenario B (Figure MVRB/MVLWB_IR#10-5). Monitoring in 2013 and 2014 showed that TDS concentrations at end-of-pipe matched predicted TDS concentrations from Upper Bound Scenario B and Lower Bound Scenario B (Figure MVRB/MVLWB_IR#10-6).

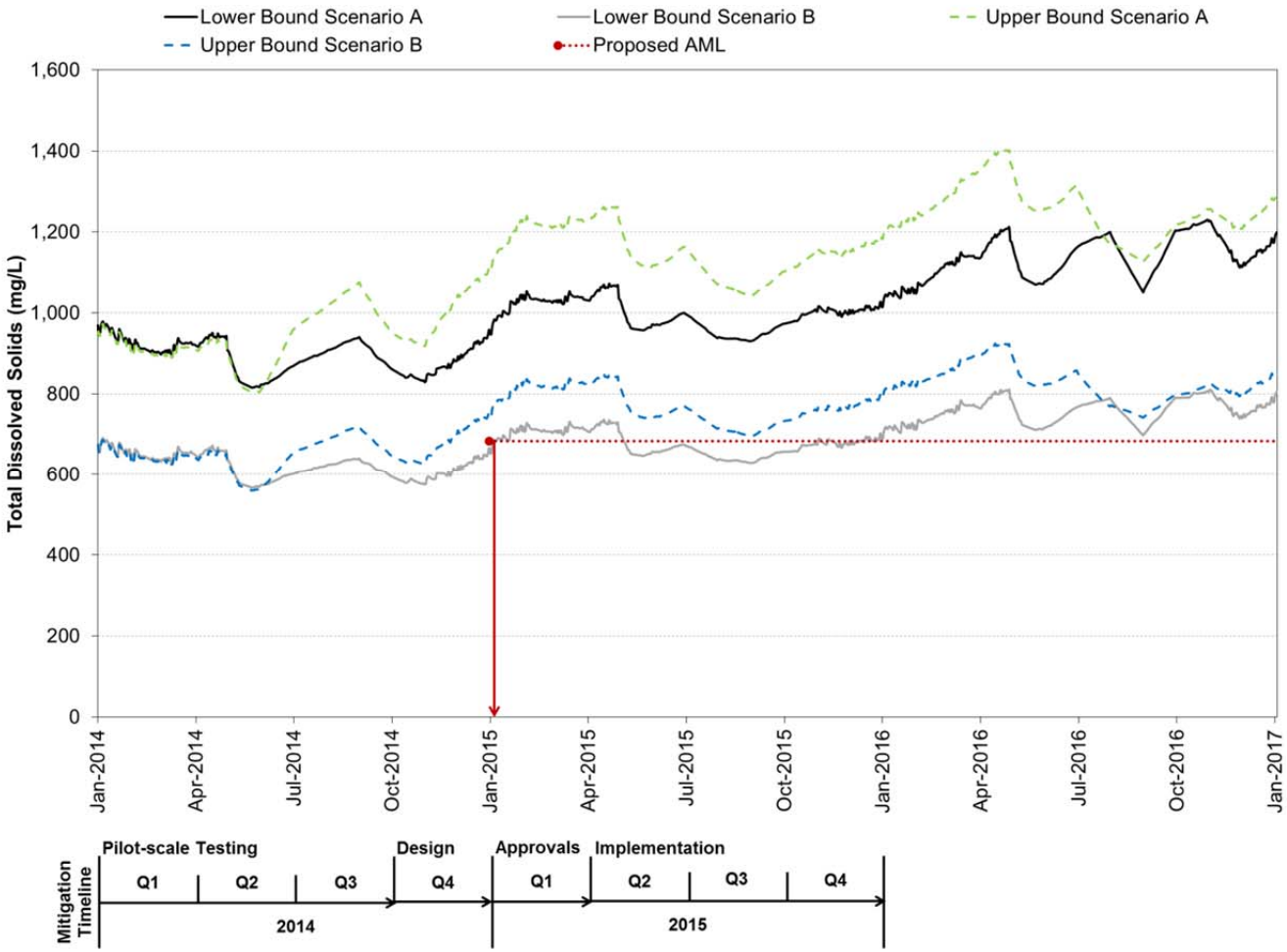
Table MVRB/MVLWB_IR#10-1: Predicted Dates of Exceedance of the Proposed Site-specific Water Quality Objective of 684 mg/L in Snap Lake Without Mitigation

Scenario[(a)]	Predicted Dates of Exceedance of the Proposed SSWQO (684 mg/L)	
	Based on Predicted Maximum TDS Concentration near the Diffuser Stations	Based on Predicted Whole-lake Average TDS Concentration in Snap Lake
Upper Bound Scenario A	Apr-2015	Jan-2016
Upper Bound Scenario B	Mar-2017	Jan-2018
Lower Bound Scenario A	Feb-2016	Jan-2017
Lower Bound Scenario B	Jan-2019	Feb-2021

(a) De Beers (2013b)

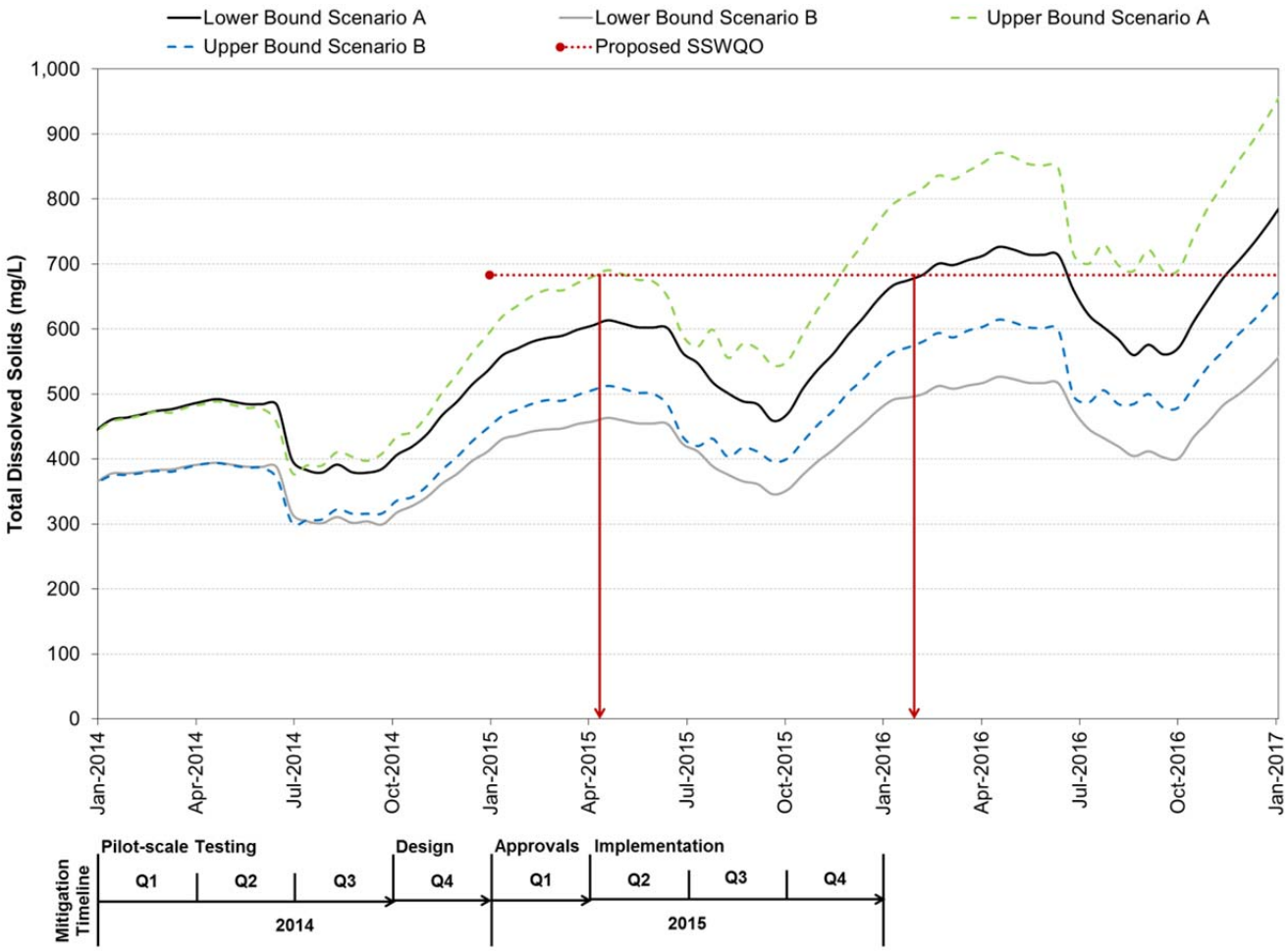
mg/L = milligrams per litre; TDS = total dissolved solids; SSWQO = site-specific water quality objective.

Figure MVRB/MVLWB_IR#10-1: Predicted Total Dissolved Solids Concentrations at End-Of-Pipe Without Mitigation and Anticipated Timeline for Implementation of Mitigation



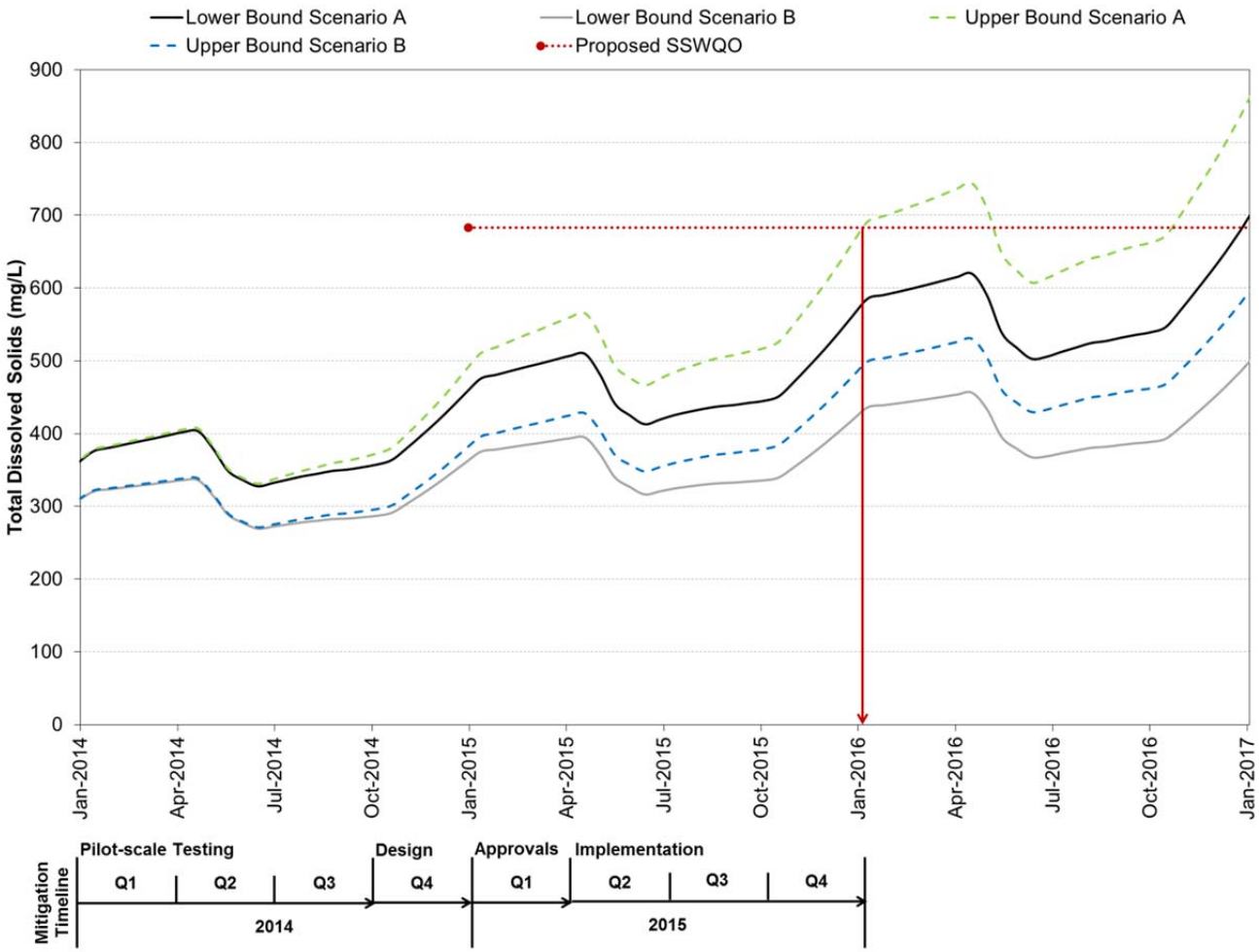
mg/L = milligrams per litre; AML = average monthly limit; Q = quarter.

Figure MVRB/MVLWB_IR#10-2: Predicted Maximum Total Dissolved Solids Concentrations at Diffuser Stations Without Mitigation and Anticipated Timeline for Implementation of Mitigation



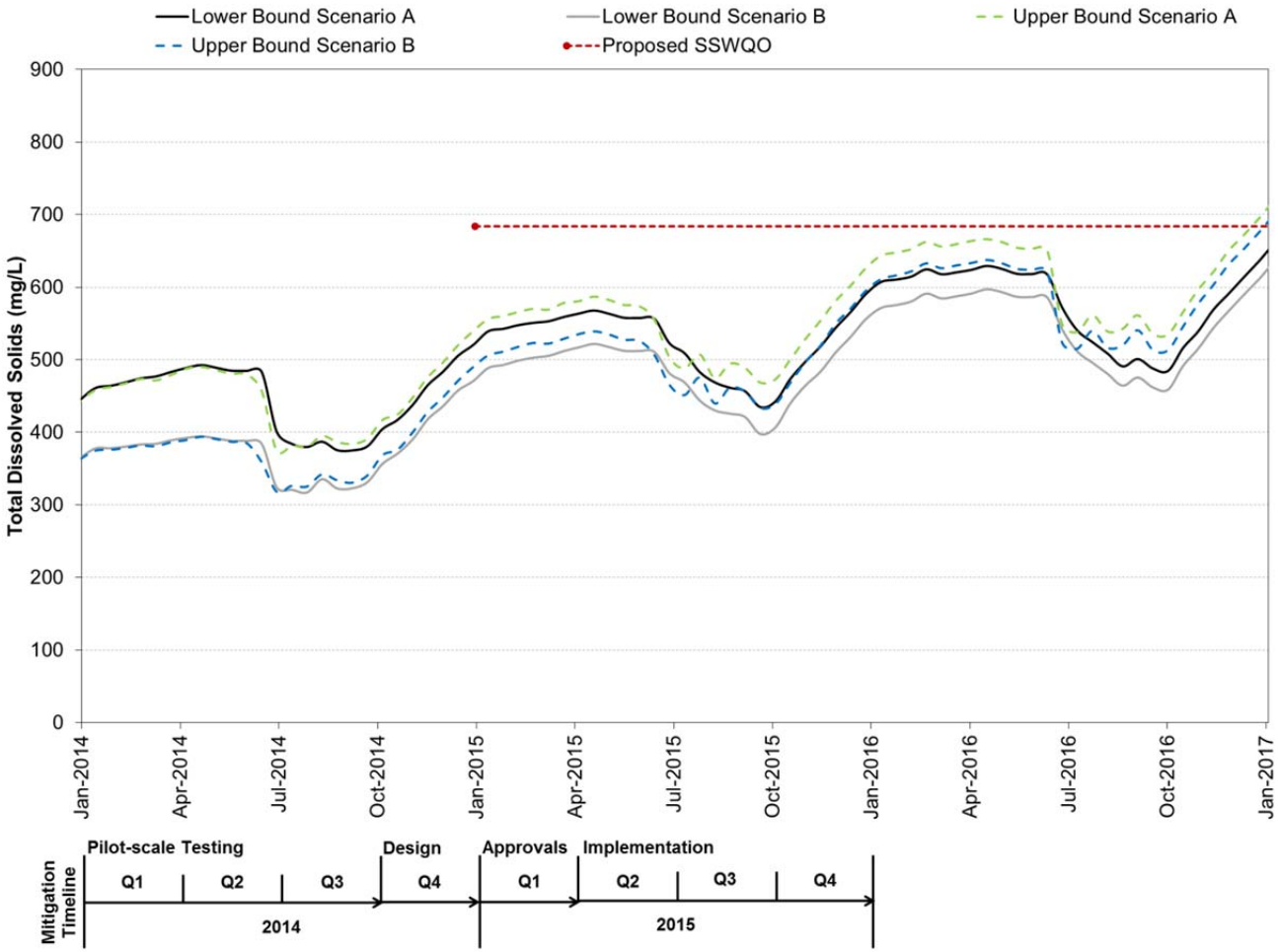
mg/L = milligrams per litre; SSWQO = site-specific water quality objective; Q = quarter.

Figure MVRB/MVLWB_IR#10-3: Predicted Whole-lake Average Total Dissolved Solids Concentrations in Snap Lake Without Mitigation and Anticipated Timeline for Implementation of Mitigation



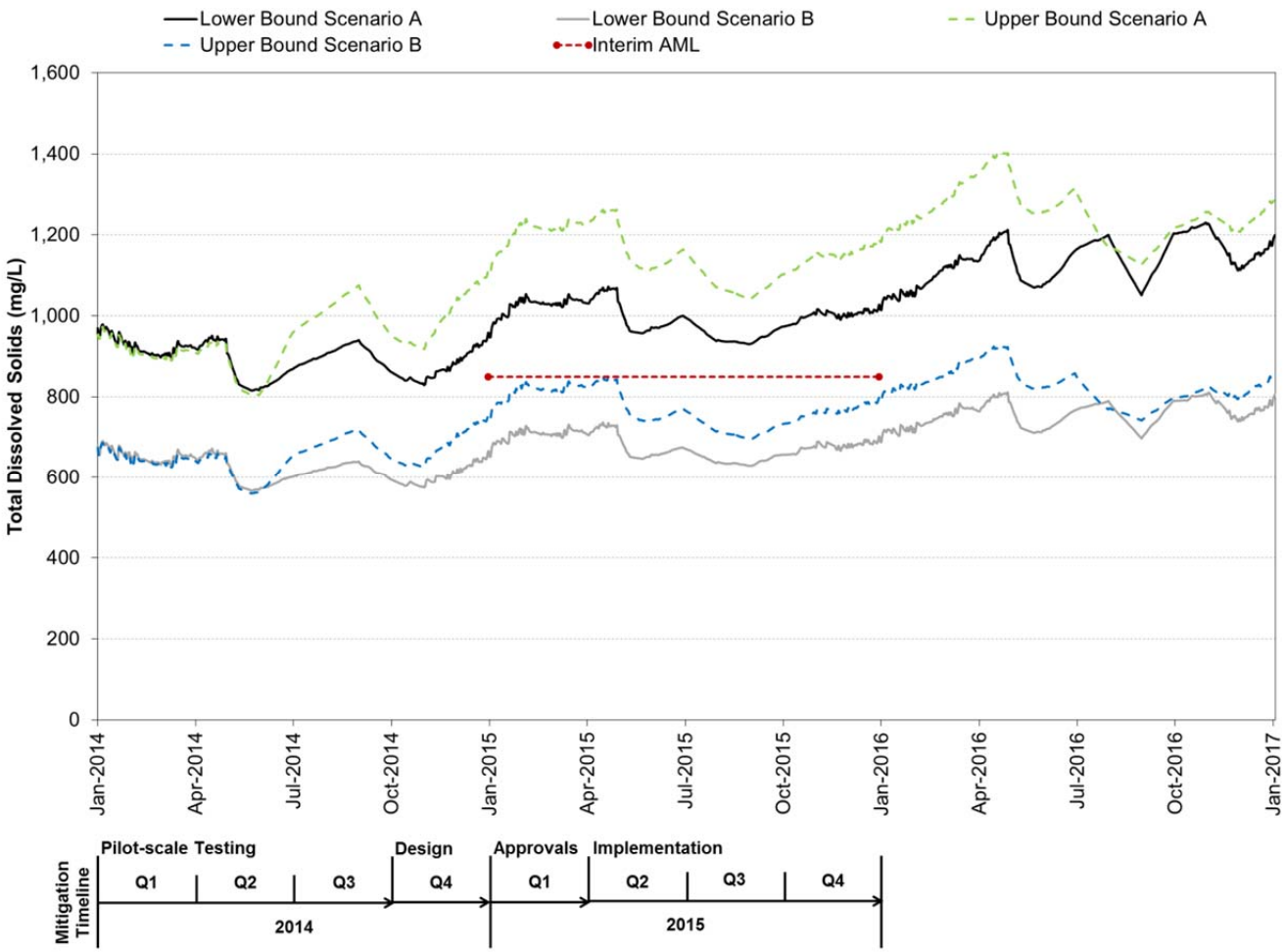
mg/L = milligrams per litre; SSWQO = site-specific water quality objective; Q = quarter.

Figure MVRB/MVLWB_IR#10-4: Predicted Maximum Total Dissolved Solids Concentrations at Diffuser Stations with an Interim Average Monthly Limit of 850 mg/L and Anticipated Timeline for Implementation of Mitigation



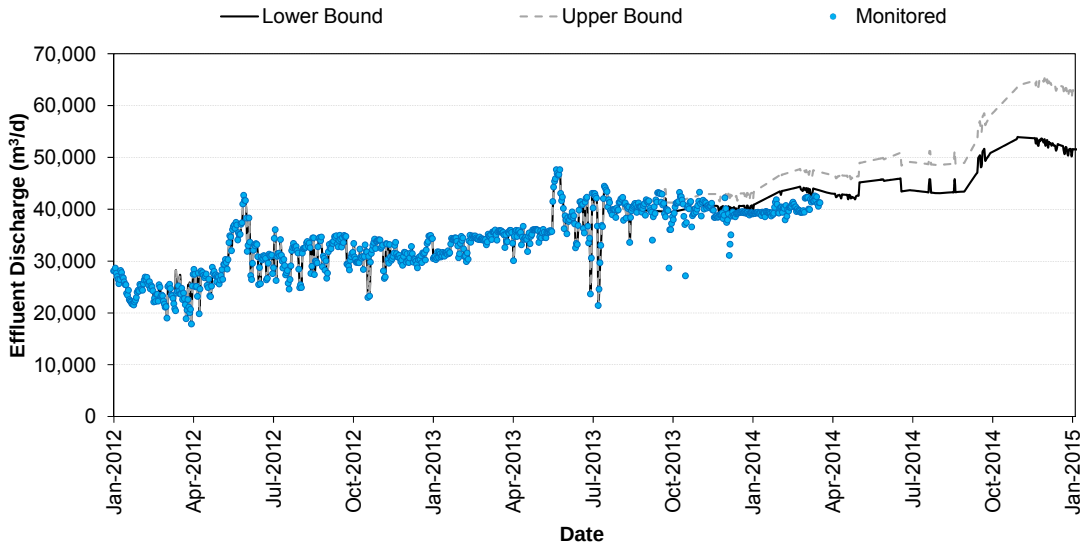
mg/L = milligrams per litre; SSWQO = site-specific water quality objective; Q = quarter.

Figure MVRB/MVLWB_IR#10-5: Predicted Total Dissolved Solids Concentrations at End-Of-Pipe Without Mitigation and Anticipated Timeline for Implementation of Mitigation

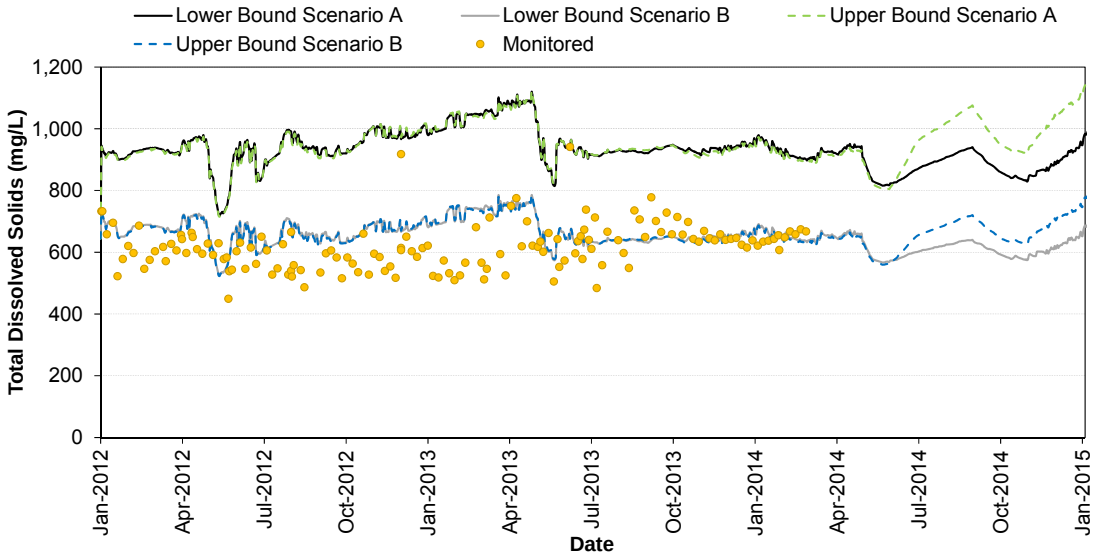


mg/L = milligrams per litre; SSWQO = site-specific water quality objective; Q = quarter.

Figure MVRB/MVLWB_IR#10-6: Predicted and Monitored Effluent Discharge Rates and Total Dissolved Solids Concentrations at End-Of-Pipe



(a) Predicted and Monitored Effluent Discharge



(b) Predicted and Monitored Total Dissolved Solids Concentrations at End-of-Pipe

m^3/d = cubic metres per day; mg/L = milligrams per litre.

References

De Beers (De Beers Canada Inc). 2013a. Evaluation of Effluent Quality Criteria. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

De Beers (De Beers Canada Inc). 2013b. Snap Lake Hydrodynamic and Water Quality Model. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

Health Canada. 2012. Guidelines for Canadian Drinking Water. Prepared by the Federal-Provincial-Territorial Committee on Drinking Water. Ottawa, ON, Canada.

MVRB/MVLWB_IR#11: In the absence of firm details about the mitigations to be put in place to reduce TDS, Board staff request that DBCI provide an assessment of what the environmental effects on Snap Lake would be if no additional mitigation was put in place for TDS at the Snap Lake Mine. The assessment should be similar what was provided by DBCI in the "Accidents and Malfunctions" section of the supplemental material submitted on April 11, 2014. This assessment should be done with respect to any parameter that is predicted to exceed its respective SSWQO in the receiving environment if no additional mitigation is put in place (i.e., TDS, chloride). The purpose of this assessment is to ensure that the Boards have all the information they need to assess this project.

Response

Summary:

Without mitigation, maximum TDS concentrations during operations are predicted to range from: 827 to 1,735 mg/L at the outlet of Snap Lake; from 640 to 1,552 mg/L in Downstream Lakes 1 and 2; from 94 to 562 mg/L in Lac Cabot Blanc; from 89 to 176 mg/L upstream of King Lake, which is approximately 25 kilometres (km) from the Mine; and, lower downstream (Tables 1 to 4). TDS concentrations will decrease following the cessation of mining in 2029 (Figure MVRB/MVLWB_IR#11-1). On the basis of the TDS Benchmark Study (De Beers 2013a), toxicity testing of the effluent at the mine from 2005 to 2013 (Table 5), and the rationale below, there would be:

- minor environmental effects (on daphnid reproduction, a small percentage of the zooplankton community) on Snap Lake up to approximately 1,000 mg/L TDS comprising 46% chloride;
- potentially slightly mineral-tasting drinking water in Snap Lake and the immediate downstream area (areas exceeding 1,200 mg/L TDS [WHO 1996; Health Canada 2012]); and,

- an uncertain level of environmental effects on Snap Lake above approximately 1,400 to 1,500 mg/L TDS comprising 46% chloride (predictions are not possible above tested concentrations).

Note: the assessment conducted for Accidents and Malfunctions was developed for short-term exposures to elevated TDS concentrations. The duration of the exposure in the unmitigated scenario is longer (see Figure 3-1 in De Beers 2013b and Figure MVRB/MVLWB_IR#11-1 below); a qualitative assessment is provided (details below) based on knowledge to date from site-specific testing and the Mine's Surveillance Network Program (SNP) data.

Rationale

The toxicity of TDS is dependent on the ratio of its ionic composition; interaction between ions modifies overall TDS toxicity (Weber-Scannell and Jacobs 2007; McPherson and Dwyer 2011; Soucek et al. 2011). For example, chloride (Cl^-) can modify the toxicity of some substances: Alonso and Camargo (2008) found that chloride ameliorated nitrite toxicity to freshwater invertebrates; Wuertz et al. (2013) recommended a chloride concentration of 240 mg/L as a preventive measure against nitrite toxicity to Pike Perch; Galvez and Wood (1997) found that chloride modified the aquatic toxicity of silver. Other ions including nitrate can also modify toxicity. For instance, Iglesias et al. (2004) found that nitrate modified chloride uptake by salt-stressed plants.

Laboratory toxicity tests that typically provide "worst case" information compared to field conditions (Chapman 2000) were conducted with TDS at an ionic composition specific to Snap Lake (De Beers 2013a; De Beers 2014). Laboratory toxicity tests of TDS concentrations that resulted in negligible effects (i.e., 10 or 20% effect concentrations; Suter et al. 1995) ranged, including the results of the second *Daphnia* test, from 1,005 to >1,490 mg/L (De Beers 2014). Testing of TDS concentrations above 1,500 mg/L was not performed because at the time that concentration was well above the maximum predicted TDS concentration for Snap Lake. Chloride comprises 46% of the TDS in Snap Lake; thus, these toxicity tests involved chloride concentrations of between 462 and >685 mg/L, substantially higher than the chloride SSWQO of 388 mg/L developed based on the Ekati SSWQO at a maximum hardness of 160 mg/L (Rescan 2012). Further, acute toxicity testing has been completed quarterly on Mine effluent since 2005 as part of the SNP under the Water Licence; results indicate that at historical chloride and TDS concentrations, no acute toxicity was detected (Table MVRB/MVLWB_IR#11-5).

Because Snap Lake TDS ionic composition has remained constant for more than seven years and no changes in ionic composition are expected, the Response to this IR is provided based on TDS as a whole; this Response considers the overall toxicity of Snap Lake TDS including chloride rather than considering chloride separately from TDS. As a conservative, worst-case scenario, Snap Lake is considered to be completely mixed such that TDS concentrations are the same throughout the lake. Such complete mixing of Snap Lake waters is not predicted to occur until 2020 as explained in the Technical Session on April 15-16, 2014 (Figure MVRB/MVLWB_IR#11-2).

Based on laboratory toxicity testing conducted to date (De Beers 2013, 201; Table 5), minor environmental effects in Snap Lake are expected up to 1,005 mg/L TDS; toxicity lower than a 20% effect level is not considered environmentally relevant (Suter et al. 1995). At higher TDS concentrations, reproduction of daphnids (i.e., cladocerans) will be reduced. The IC50 (50% effects concentration) for the two *Daphnia* toxicity tests was >1,470 mg/L, which means that reproduction was not reduced by half at the highest tested TDS concentration. TDS concentrations between 1,005 mg/L and 1,470 mg/L would likely result in effects to daphnids in the form of reduced reproduction (greater than 20% reduction but less than 50% reduction), and a corresponding minor environmental effect to Snap Lake as explained below. Note that the daphnid, *Ceriodaphnia dubia*, which does not occur in Snap Lake, also had unbounded IC50 values (i.e., less than 50% inhibition of reproduction occurred at the highest tested TDS concentrations, close to 1,500 mg/L). Daphnid lethality would occur at some presently undetermined TDS concentration greater than 1,470 mg/L, likely above 2,660 mg/L (Table MVRB/MVLWB_IR#11-5).

As discussed at the Technical Session in April 2014 and in the 2011 Water Licence Amendment Application, prior to mining in 2004 daphnids made up 3% of the zooplankton (the small animals living in the water that provide food for fish); between 2005 and 2012 this proportion ranged from <1 to 7% (De Beers 2013b). As TDS concentrations increase above 1,000 mg/L this component of food for fish may be reduced. However, other plankton components (including both phytoplankton [small plants] and zooplankton) will not be affected until TDS concentrations are greater than approximately 1,500 mg/L. Exactly what concentration of TDS above 1,500 mg/L will result in adverse effects to the other plankton has not been established; higher concentrations were not tested. Beneficial effects of the TDS are also not considered at this time, for instance the availability of increased calcium to create shells for those plankton and benthos with shells.

A reduction in daphnids in the zooplankton is not likely to have a significant adverse effect on fish because daphnids comprise a relatively small proportion of the zooplankton, as noted above. The more abundant copepods and rotifers (together 93 to 97% of the zooplankton between 2004 and 2013) would still be available as fish prey up to at least approximately 1,500 mg/L TDS (rotifers showed negligible toxicity to 1,474 mg/L TDS [the maximum tested concentration]; copepods are expected to be similarly tolerant, laboratory toxicity testing is underway). It is presently uncertain at what point above 1,500 mg/L rotifers would be adversely affected by TDS in Snap Lake as higher concentrations were not tested. Sublethal effects (e.g., growth reduction, reduced reproduction) would occur before lethality.

The other components of food for fish are the benthic (bottom-dwelling) invertebrates (animals without backbones). Laboratory toxicity testing with chironomids (insect larvae), which dominate the benthic invertebrate community in Snap Lake, indicated that negligible adverse effects occur up to 1,379 mg/L TDS (the highest tested concentration). Thus, up to this TDS concentration there would be no change to the availability of chironomids as prey for fish; it is presently uncertain at what point above this concentration they would be adversely affected by TDS in

Snap Lake as higher concentrations were not tested for reasons outlined above. Sublethal effects (e.g., growth reduction) would occur before lethality.

Reduced food for fish at elevated TDS concentrations (i.e., at some point above approximately 1,400 or 1,500 mg/L) could result in an energetic bottleneck where fish have less energy available for growth and reproduction. If an energetic bottleneck were to occur, it would likely result in reduced growth and size of fish as energy was shifted from growth to fecundity to maintain reproductive, sustainable fish populations (Sherwood et al. 2002; Campbell et al. 2003). An energetic bottleneck would occur before lethality.

Laboratory toxicity testing with the sensitive early life stages of both Lake Trout and Arctic Grayling indicated negligible adverse effects above approximately 1,400 mg/L for all tests and endpoints except dry fertilization with Lake Trout and only for fry survival, not fry growth. Dry fertilization involved fertilizing the eggs before exposing them to elevated TDS concentrations; wet fertilization, which involved fertilizing the eggs during the exposure to elevated TDS concentrations, is more reflective of actual exposures and showed no such effects. Again, it is presently uncertain at what point above approximately 1,400 mg/L fish in Snap Lake would be adversely affected by TDS as higher concentrations were not tested. Effects on reproduction would occur before lethality.

Effects of longer-term exposure to elevated TDS concentrations were not tested. The resiliency of freshwater aquatic systems to salinity is variable and not well studied (James et al. 2003), although most studies are focused on concentrations of TDS orders of magnitude higher than at Snap Lake. Recently, both Lake Trout and Arctic Grayling have been documented at multiple life stages in northern waters, both in Alaska and in the Northwest Territories, at TDS concentrations of 1,000 to 1,500 mg/L and even higher (Harwood and Sparling 2008; Ott and Morris 2011; Gantner and Gareis 2012; Kissinger et al. 2013). Species such as Slimy Sculpin, Burbot, and Round Whitefish, which are found in Snap Lake, have also been found in these higher TDS waters. Although the TDS composition is not the same as Snap Lake, this suggests that the fish and other organisms in Snap Lake may be adaptable in the long-term (operations through closure) to the concentrations of TDS proposed by De Beers. However, as previously noted, at concentrations above 1,400 to 1,500 mg/L, there is additional uncertainty.

In the unmitigated scenario, the TDS concentrations in the downstream lakes area beyond Lac Capot Blanc are within EAR predictions (Table MVRB/MVLWB_IR#11-4). This is likely due to the assimilative capacity of Lac Capot Blanc. Thus, TDS concentrations in the larger Lockhart River watershed are expected to remain within the original EAR predictions (De Beers 2002). De Beers will continue to monitor the areas downstream of the project and report annually in the AEMP and Environmental Agreement reports on the water quality results. See Response to YKDFN IR#1 for a review of potential effects to land users under the mitigated scenario.

Without mitigation, waters in Snap Lake and into Lac Capot Blanc would be above the aesthetic drinking water guidelines for TDS and chloride (500 mg/L and 250 mg/L, respectively; Health

Canada 2012). Aesthetic effects to water quality could persist from 2018 to approximately 2035 without mitigation, although water quality is predicted to improve quickly in Snap Lake once the mine stops discharging in 2029 (Figure MVRB/MVLWB_IR#11-1).

At the TDS concentrations in the upper-bound scenarios, the predicted maximum chloride concentration of approximately 806 mg/L exceeds the CCME (2011) short-term guideline of 640 mg/L and approaches the USEPA (1988) acute criterion of 860 mg/L for protection of freshwater aquatic life. As noted above, site-specific testing indicated that with the current TDS composition at Snap Lake, chloride concentrations at approximately 600 mg/L did not results in sublethal (chronic) effects to aquatic life other than daphnid reproduction. The SNP acute testing also shows this (Table MVRB/MVLWB_IR#11-5) and that TDS concentrations as high as 2,660 mg/L did not kill young rainbow trout or daphnids. However, as noted above, it is presently uncertain at what point above approximately 1,400 mg/L TDS invertebrates and fish in Snap Lake would be adversely affected by TDS or by chloride as higher concentrations were not tested for reasons previously outlined.

Given the uncertainty of effects to aquatic life beyond 1,400 mg/L TDS, De Beers has proposed mitigation that would result in TDS concentrations below the proposed SSWQO of 684 mg/L in the lake.

Table MVRB/MVLWB_IR#11-1: Maximum Predicted TDS Concentrations in Snap Lake During Operations, Unmitigated Case

SSWQO	Units	Maximum Concentrations at Diffuser Stations				Maximum Concentrations at Lake Outlet			
		Lower Bound Scenario A	Lower Bound Scenario B	Upper Bound Scenario A	Upper Bound Scenario B	Lower Bound Scenario A	Lower Bound Scenario B	Upper Bound Scenario A	Upper Bound Scenario B
684	mg/L	1,311	845	1,753	1,117	1,280	827	1,735	1,101

Table MVRB/MVLWB_IR#11-2: Maximum Predicted Whole-lake Average TDS Concentrations in Downstream Lakes 1 and 2 During Operations, Unmitigated Case

SSWQO	Units	Downstream Lake 1				Downstream Lake 2			
		Lower Bound Scenario A	Lower Bound Scenario B	Upper Bound Scenario A	Upper Bound Scenario B	Lower Bound Scenario A	Lower Bound Scenario B	Upper Bound Scenario A	Upper Bound Scenario B
684	mg/L	989	640	1,381	879	1,114	722	1552	989

Table MVRB/MVLWB_IR#11-3: Maximum Predicted TDS Concentrations in Lac Capot Blanc During Operations, Unmitigated Case

SSWQO	Units	Maximum Concentrations at Inlet				Maximum Concentrations at Lake Outlet			
		Lower Bound Scenario A	Lower Bound Scenario B	Upper Bound Scenario A	Upper Bound Scenario B	Lower Bound Scenario A	Lower Bound Scenario B	Upper Bound Scenario A	Upper Bound Scenario B
684	mg/L	507	388	562	478	136	94	192	127

Table MVRB/MVLWB_IR#11-4: Maximum Predicted Concentrations in Lakes Downstream of Lac Capot Blanc During Operations, Unmitigated Case

Downstream Site	Distance Downstream from Snap Lake (km)	Baseline TDS (mg/L) (range = 10 to 53)	Maximum TDS Concentrations (mg/L)				
			EAR Predictions	2013 Model Predictions			
				Lower Bound Scenario A	Lower Bound Scenario B	Upper Bound Scenario A	Upper Bound Scenario B
37 (upstream of King Lake)	24	17	119	126	89	176	119
22 (Mackay Lake)	44	20	41	57	45	74	55
11 (Mackay Lake)	54	12	16	21	18	24	20
23 (Mackay Lake)	65	10	13	17	14	20	16
24 (Mackay Lake)	81	14	16	19	18	22	19
26 (Mackay Lake)	109	17	19	22	20	24	22
3 (Inlet of Aylmer Lake)	155	20	22	24	22	25	23
4 (Aylmer Lake)	172	24	22	27	26	28	27
53 (Clinton Colden Lake)	227	35	36	37	36	38	37
52 (Ptarmigan Lake)	310	24	25	26	26	27	26
43 (Lockhart River)	419	53	54	55	54	55	55
19 (Lockhart River outlet)	434	14	14	15	15	16	15

Table MVRB/MVLWB_IR#11-5: Acute Toxicity Test Results for Effluent Samples Collected From the Water Treatment Plants at Snap Lake Mine, 2005 to 2013

Sampling Location	Date	Acute Toxicity Testing Results[a]						Water Quality	
		Trout LC50[b] (%)	Trout LC25[c] (%)	Daphnia LC50[b] (%)	Daphnia LC25[c] (%)	Daphnia EC50[d] (%)	Daphnia EC25[e] (%)	Total Dissolved Solids, calculated (mg/L)	Chloride (mg/L)
SNP 02-17	2005-Nov-28	>100	>100	>100	>100	>100	>100	-	357
SNP 02-17	2006-Feb-06	>100	>100	>100	>100	>100	>100	666	340
SNP 02-17	2006-Apr-02	>100	>100	>100	>100	>100	>100	719	384
SNP 02-17	2006-Jul-04	>100	>100	>100	>100	>100	>100	1,060	546
SNP 02-17	2006-Dec-04	>100	>100	>100	>100	>100	>100	1,080	605
SNP 02-17	2006-Dec-20	>100	>100	-	-	-	-	941	523
SNP 02-17	2007-Jan-09	>100	>100	>100	>100	>100	>100	984	527
SNP 02-17	2007-Apr-03	>100	>100	>100	>100	>100	>100	922	524
SNP 02-17B	2007-Apr-23	>100	>100	>100	>100	>100	>100	821	436
SNP 02-17B	2007-Jul-09	>100	>100	>100	>100	>100	>100	783	418
SNP 02-17B	2007-Nov-14	>100	>100	>100	>100	>100	>100	821	430
SNP 02-17B	2008-Mar-16	>100	>100	>100	>100	>100	>100	789	399
SNP 02-17B	2008-Apr-02	>100	>100	>100	>100	>100	>100	782	385
SNP 02-17	2008-Apr-13	>100	>100	>100	>100	>100	>100	2,660	1,200
SNP 02-17B	2008-Jul-09	>100	>100	>100	>100	>100	>100	845	359
SNP 02-17B	2008-Oct-22	>100	>100	>100	>100	>100	>100	625	293
SNP 02-17B	2009-Jan-14	>100	>100	>100	>100	>100	>100	650	297
SNP 02-17B	2009-Apr-08	>100	>100	>100	>100	>100	>100	589	278
SNP 02-17B	2009-Jul-13	>100	>100	>100	>100	>100	>100	657	259
SNP 02-17B	2009-Oct-12	>100	>100	>100	>100	>100	>100	674	271
SNP 02-17B	2010-Jan-03	>100	>100	>100	>100	>100	>100	497	242
SNP 02-17B	2010-Apr-06	>100	>100	>100	>100	>100	>100	512	244
SNP 02-17B	2010-Jul-14	>100	>100	>100	>100	>100	>100	716	240
SNP 02-17B	2010-Oct-12	>100	>100	>100	>100	>100	>100	518	216
SNP 02-17B	2011-Jan-17	>100	>100	>100	>100	>100	>100	567	272
SNP 02-17B	2011-Apr-10	>100	>100	>100	>100	>100	>100	529	249

Table MVRB/MVLWB_IR#11-5: Acute Toxicity Test Results for Effluent Samples Collected From the Water Treatment Plants at Snap Lake Mine, 2005 to 2013

Sampling Location	Date	Acute Toxicity Testing Results[a]						Water Quality	
		Trout LC50[b] (%)	Trout LC25[c] (%)	Daphnia LC50[b] (%)	Daphnia LC25[c] (%)	Daphnia EC50[d] (%)	Daphnia EC25[e] (%)	Total Dissolved Solids, calculated (mg/L)	Chloride (mg/L)
SNP 02-17B	2011-Jul-12	>100	>100	>100	>100	>100	>100	454	198
SNP 02-17	2011-Jul-31	>100	>100	>100	>100	>100	>100	509	165
SNP 02-17B	2011-Oct-24	>100	>100	>100	>100	>100	>100	570	232
SNP 02-17B	2012-Jan-22	>100	>100	>100	>100	>100	>100	534	243
SNP 02-17	2012-Mar-11	>100	>100	>100	>100	>100	>100	627	295
SNP 02-17B	2012-Apr-17	>100	>100	>100	>100	>100	>100	606	272
SNP 02-17B	2012-Sep-09	>100	>100	>100	>100	>100	>100	593	288
SNP 02-17B	2012-Oct-15	>100	>100	>100	>100	>100	>100	653	249
SNP 02-17B	2013-Jan-07	>100	>100	>100	>100	>100	>100	523	234
SNP 02-17B	2013-May-07	>100	>100	>100	>100	>100	>100	634	284
SNP 02-17B	2013-Sep-08	>100	>100	>100	>100	>100	>100	778	354
SNP 02-17B	2013-Oct-07	>100	>100	>100	>100	>100	>100	714	307

(a) Acute toxicity testing was conducted with Rainbow Trout, *Oncorhynchus mykiss*, following method EPS 1/RM/13 (Environment Canada 2000a), and a water flea, *Daphnia magna*, following method EPS 1/RM/14 (Environment Canada 2000b)

(b) LC50, or median lethal concentration, is the concentration of sample estimated to be lethal to 50% of the test organisms.

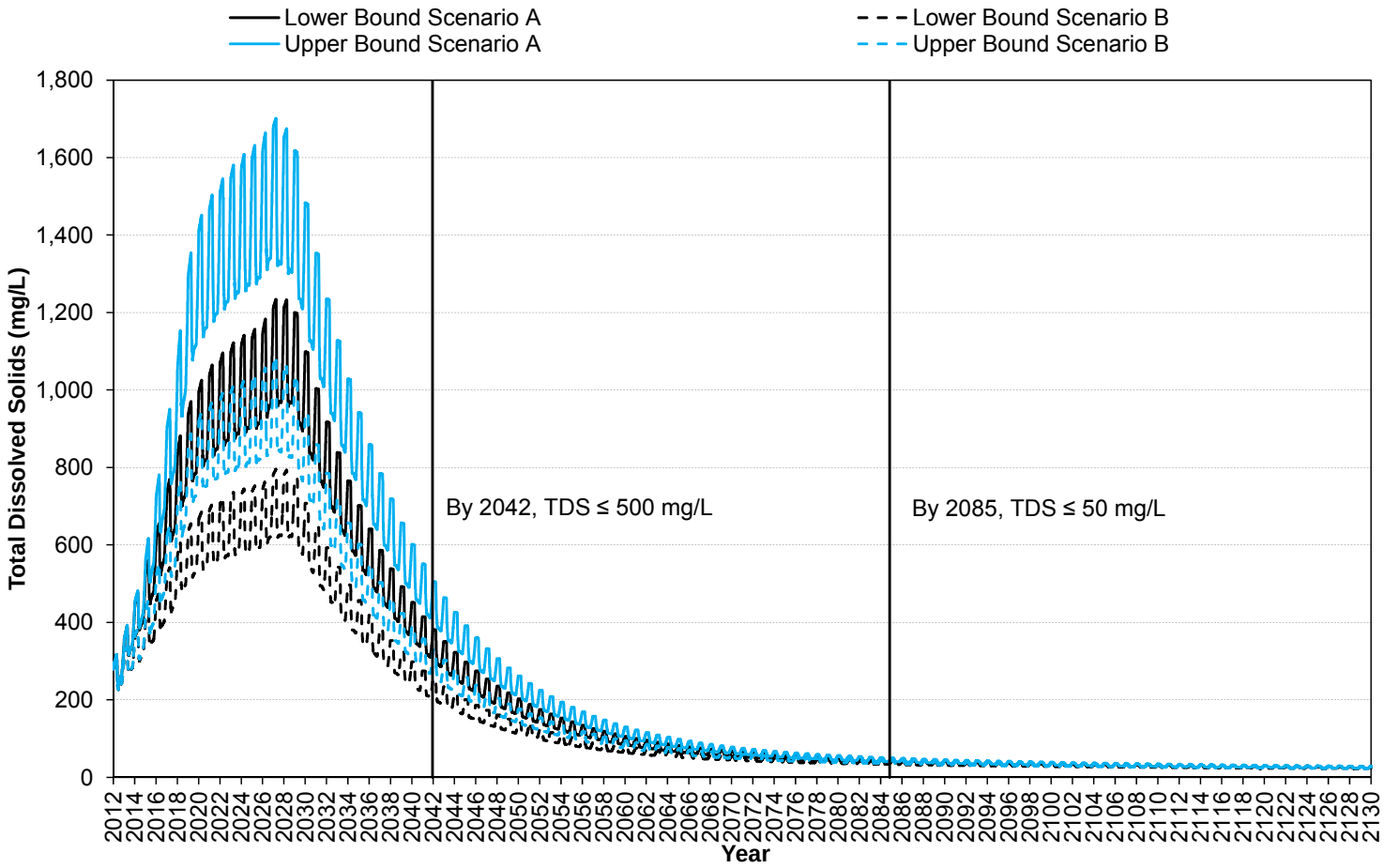
(c) LC25 is the concentration of sample estimated to be lethal to 25% of the test organisms.

(d) EC50, or median effective concentration, is the concentration of sample estimated to cause a specified effect to 50% of the test organisms.

(e) EC25 is the concentration of sample estimated to cause a specified effect to 25% of the test organisms.

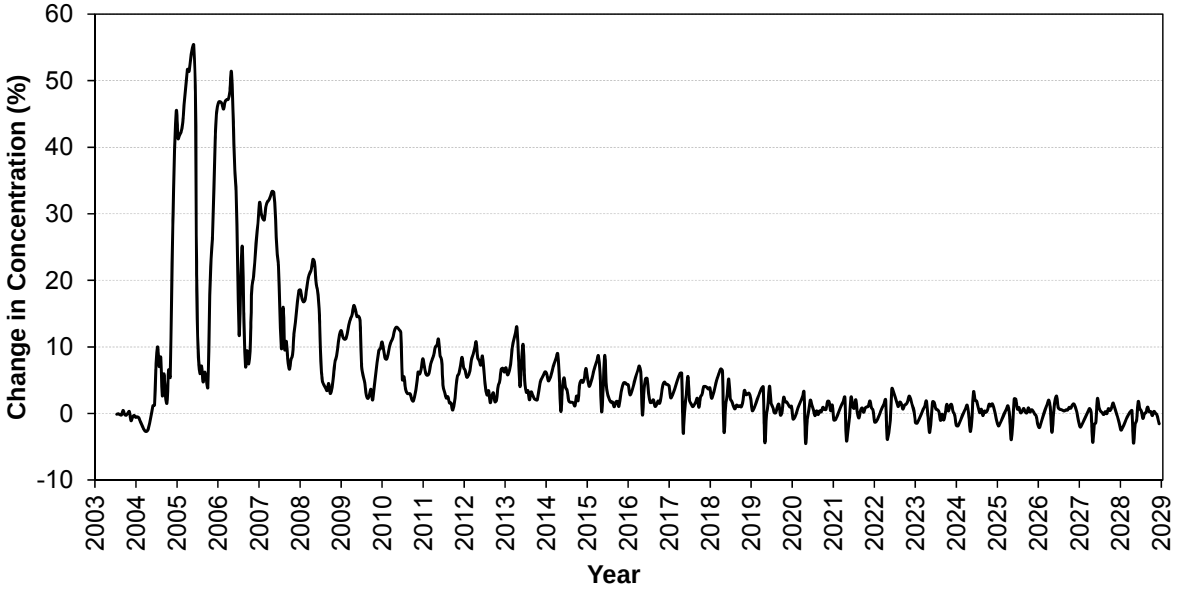
LCx = concentrations of sample estimated to be lethal to x% of the test organisms; ECx = concentrations of sample estimated to cause a specified effect to x% of the test organisms; % = percent; mg/L = milligrams per litre; SNP = Surveillance Network Program; SNP 02-17 = temporary water treatment plant; SNP 02-17B = permanent water treatment plant.

Figure MVRB/MVLWB_IR#11-1: Predicted Whole-lake Average Total Dissolved Solids Concentrations in Snap Lake, 2012 to 2130, Unmitigated Scenario



mg/L = milligrams per litre; TDS = total dissolved solids; ≤ = less than or equal to.

Figure MVRB/MVLWB_IR#11-2: Change in Total Dissolved Solids Concentrations between the Diffuser Stations and the Outlet of Snap Lake, Unmitigated Scenario



% = percent.

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MVRB/MVLWB_IR#12: As requested by EcoMetrix, DBCI is to provide information in regards to nitrate toxicity to Rotifers and Copepods as dominant taxa in Snap Lake.

Response

An extensive review of the available literature has been conducted. The following databases, search engines, and compendia were accessed to search for information regarding the toxicity of nitrate to freshwater copepods and rotifers:

- Google;
- Google Scholar ;
- CCME (2012);
- Rescan (2012);
- Web of Science™ Core Collection (1900-present);
- BIOSIS Previews® (1969-present);
- Proquest (43 databases; 1817-present);
- US EPA ECOTOX Database; and,
- Wiley Online Library.

The databases were searched using combinations of the following keywords: toxic; copepod or rotifer; and, nitrate. At least the first 50 hits from a return were screened manually to check their relevance. Searching the USEPA ECOTOX database involved performing queries for aquatic data with keywords “rotifer” and “copepod”; all results were screened manually. Data on the toxicity of nitrate to aquatic life have also been previously reviewed and compiled by CCME (2012) and Rescan (2012) for use in deriving generic water quality guidelines (WQGs) or site-specific water quality objectives (SSWQOs). Those documents were reviewed to determine whether they contained any nitrate toxicity data from studies using copepods or rotifers.

Hickey et al. (2009) listed three freshwater copepods as being included in a nitrate toxicity database that was compiled to support development of a nitrate WQG for the Canterbury region of New Zealand, but no data for those taxa were presented or used in the New Zealand WQG derivation. Barium nitrate and mercuric nitrate were tested using rotifer (*Brachionus calyciflorus*) and copepod (Cyclopoida, *Acartia tonsa*, *Mesocyclops edax*) taxa (Calleja et al. 1994; Menasria and Pavillon 1994); however, nitrate was the anionic counterpart to the elements that the authors were investigating. Di Lorenzo et al. (2014) conducted acute toxicity tests with two copepod species (*Eucyclops serrulatus* and *Diacyclops belgicus*) using ammonium nitrate, but the test results were reported in terms of ammonia concentrations.

No acute or chronic studies on the toxicity of nitrate to rotifers or copepods were found during our review, although these taxa have been used for toxicity testing of other substances such as: silver (Pedroso et al. 2007; Buikema et al. 1974); lead (Sharma and Selvaraj 1994; Arshaduddin et al. 1989); cadmium (Ghosal and Kaviraj 1996; Radix et al. 1999); nitrogen-based fertilizers and pesticides (Di Lorenzo et al. 2014); and, 50 inorganic and organic substances listed in the Multicentre Evaluation of In Vitro Cytotoxicity (MEIC) program (Calleja et al. 1994). Of 11 Canadian Council of Ministers of the Environment (CCME) WQGs published since 2007, copepod toxicity data were not used to derive any of those WQGs and rotifer toxicity data were only used in 4 of them (chloride, endosulfan, permethrin, and trichlorfon).

Neither rotifers nor copepods are as well established as standard laboratory test species as other freshwater invertebrates such as cladocerans. Cladocerans are generally more sensitive than copepods to trace metals (Baudouin and Scoppa 1974; Brown 2001). Cairns et al. (1977) reported that the rotifer *Philodina acuticornis* was more sensitive to chlorine and zinc, but less sensitive to chromium, copper, and phenol, than two Daphnia species (*Daphnia pulex* and *D. magna*) in acute tests. Of the 50 chemicals tested by Calleja et al. (1994), the rotifer *B. calyciflorus* showed either similar or less sensitivity to the majority of chemicals as compared to acute tests with *D. magna*.

Note that the Dominion Mines Ekati Corporation, Board-approved SSWQO for nitrate (WL W2012L2-0001) was derived by Rescan (2012) using CCME-approved procedures which do not require testing of all possible organisms or groups of organisms present in a water body, but rather representative organisms. As noted by Rescan (2012) “CCME (2007b) data requirements regarding types and number of biological groups were met.”

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MVRB/MVLWB_IR#13: During the technical session, there were several questions by the Yellowknives Dene (YKDFN) and Board staff with respect to DBCI's efforts to reduce the amount of nitrate through improvements to blasting practices underground. In Section 2.3 of the Nitrogen Response Plan, DBCI lists a recommendation to "continue to monitor trends in the amount of explosives used per tonne of ore mined (kg/tonne) as a means of monitoring the effectiveness of explosives management measures". The YKDFN has requested whatever monitoring data has been collected in this regard.

Response

The amount of explosive energy imparted to a rock mass per unit weight blasted is referred to as the "powder factor". It is important to keep in mind when using powder factors that blasting is a dynamic event and each rock mass is unique. Aspects affecting the powder factor are complex and include: rock character (e.g., density, strength, structure), blasthole diameter and spacing, type of explosive, method of loading the holes, number of meters drilled, etc. It is generally recognized that for the similar types of rock underground mines have higher powder factors than open-pit mines, and powder factors are higher in wet versus dry conditions. As requested, the following table, Table MVRB/MVLWB_IR#13-1, provides the annual powder factors for rock blasted underground at Snap Lake.

Table MVRB/MVLWB_IR#13-1: Explosive Use per Tonne Rock Blasted

Year	2012	2013	2014 (to Apr 27, 2014)
Tonnes Blasted	1,079,616	1,332,175	426,844
Explosives Used (kg)	1,436,885	1,747,368	513,853
Explosive Useage (kg) per tonne mined	1.33	1.31	1.20

MVRB/MVLWB_IR#14: In the same line of questioning as IR#13, DBCI said that the rate of mining is driving the increase in Nitrogen loading making it hard to see increased efficiencies of blasting techniques. DBCI to provide supporting rationale for this statement and/or a clarification of how improvements in blasting techniques may be evaluated in future.

Response

Improving blasting efficiency is a continuous process. Improvements made over the last 16 months have focused on:

1. A re-design of the blasting round that results in the drill holes being reduced from 50 holes per round to 43 holes per round;

2. An increase in the collar length from one foot to three feet, which minimizes spillage and over-loading of blast holes by the loading crews; and,

3. Educating miners on proper loading and blasting techniques.

The mine plans to undertake reviews by independent experts of its blasting design, and practices for storage, handling and loading of explosives to ensure the most effective use of explosives in maintained.

The mine will continue to monitor the powder factor as a broad indicator of the effectiveness of explosives management.

Information Requests from April 16, 2014

MVRB/MVLWB_IR#15: In response to questions from EcoMetrix on the EQC Report, DBCI is to provide an Excel spreadsheet containing the calculations that were used to develop the results in Tables I-1 to I-6 of Appendix 1 of the EQC report.

Response

De Beers referenced the Day 2 Transcript from the April 14-15 Technical Session to identify the supporting dialogue for this request. Mr. Ian Collins specifically asked what parameter, other than the Aquatic Effects Monitoring Program (AEMP) benchmark, was varied to calculate the different AML and MDL values in the Appendix tables. The “other parameter” was the proportion of treated effluent in Snap Lake, as shown in the second column of Appendix Tables I-1 to I-6 of De Beers (2013). The appended spreadsheet provides the relationship between proportion of treated effluent, hardness and AEMP benchmarks as well as calculations for deriving the proposed effluent quality criteria. Because Mr. Collins referred to sulphate, an example worksheet for sulphate is provided. Calculations for other parameters were completed in a similar manner. Please refer to Appendix I of the Effluent Quality Criteria report for further information.

Reference

De Beers. 2013. Evaluation of Effluent Quality Criteria. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada

MVRB/MVLWB_IR#16: MVEIRB staff requests that DBCI submit, for placement on the MVEIRB registry, all pertinent information regarding accidents and malfunctions related to the project. This should include the draft Water Management Plan (which in turn contains a risk assessment matrix) and the risk assessment submitted to the MVLWB for the North Pile.

Response

As per the attached North Pile Risk Assessment (De Beers 2012), potential risks that could result in the incident as described in the Supplemental filing are:

Risk 4 Water Treatment (Major WTP Breakdown or Significant Reduction in Treatment Capacity) Residual Risk: 17

Risk 6 Sampling and Analytical Errors / Missed Samples
Residual Risk 16

A table of the Risk Name and the inherent and residual risk are listed in Section 4 of this document.

In *Risk 4*, the malfunction/accident from a WTP breakdown could result in two incidents:

1) Noncompliant water being released to the environment undiluted when the plant malfunctioned, or;

2) Water stored in the underground and on surface due to a system failure overextends the system holding capacity and water is released undiluted to the receiving environment upon commissioning to prevent flooding and/or spills.

In *Risk 6*, the malfunction/Accident would occur if the inline analytical monitoring devices for chloride and nitrate malfunction allowing elevated levels of TDS to enter the receiving environment unchecked. In a typical scenario these inline meters would trigger a response in the WTP operator's room which would lock out the system and pump water to the WMP.

After the TDS Treatment system is installed in 2015/2016, errors could occur if the TDS treatment system malfunctions, preventing treatment of a portion of the managed water from underground. This would allow for higher than expected TDS water to enter Snap Lake. At this time De Beers is unable to comment on the likelihood of this event, however it would form a component of the design analysis and installation. The resulting risk assessment would align with eth Anglo American Integrated Risk Management Matrix.

The initial Accidents and Malfunction Section of the original EA (February 2002) was resubmitted to the MVEIRB on April 16, 2014.

Please refer to GNWT_IR#3 for additional information.

Reference

2012. Snap Lake Mine – North Pile Risk Assessment. De Beers Canada Inc. Submitted to the MVLWB September 15, 2012.

MVRB/MVLWB_IR#17: DBCI to provide its most recent AEMP Annual Report for the MVEIRB record.

Response

The 2012 Aquatic Effects Monitoring Program Annual Report (AEMP) will be provided on CD to the MVRB on May 1, 2014; it is also available on-line at the MVLWB public registry at: http://www.mvlwb.ca/Boards/MV/SitePages/search.aspx?app=MV2011L2-0004. The 2013 AEMP will be provided May 1, 2014 and will be submitted to both the MVLWB and MVEIRB.

MVRB/MVLWB_IR#18: DBCI to provide the grouting study recently completed by DBCI's grouting expert.

Response

The April 24, 2014 Grouting Letter from MSE Drilling and Grouting is attached to this submission.

MVRB/MVLWB_IR#19: DBCI to provide a PDF version of the Poster titled Effect of total dissolved solids on fertilization and development of two salmonids. Alternatively, DBCI may submit the meeting notes from its information session in January (which contains this poster) to MVEIRB for its registry.

Response

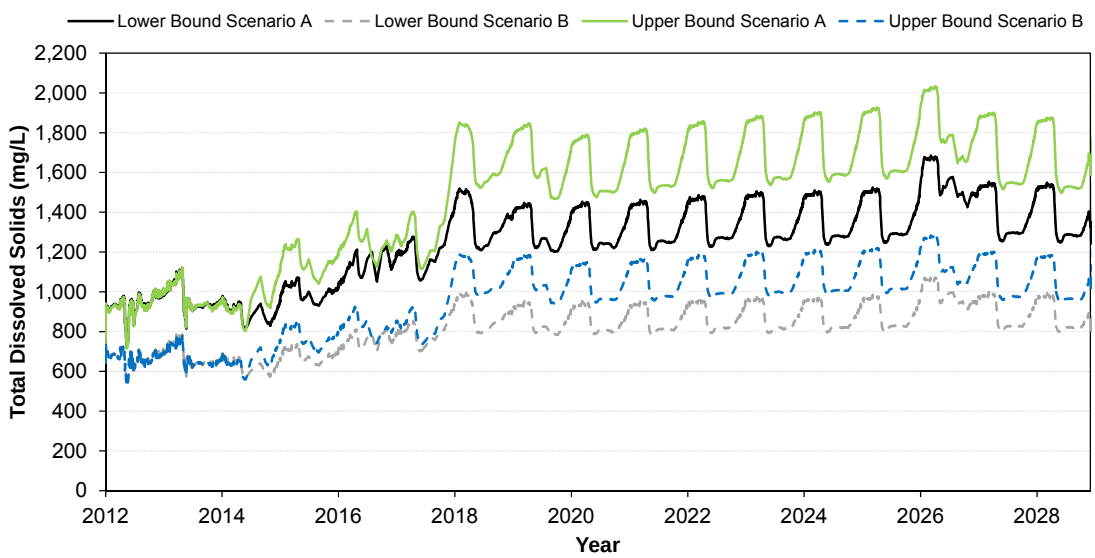
Electronic copies of both the Poster and the meeting notes were provided to Simon Toogood of the MVRB by email the afternoon of April 16, 2014. A hard copy of the Poster was provided to Simon Toogood later that same afternoon.

Attachment 2-EC_IR#1: In IR MVLWB 2, the proponent indicated that " ... effluent discharged to Snap Lake from the Snap Lake Mine will be treated such that TDS concentrations in the effluent will not exceed the proposed average monthly limit (AML) of 684 mg/L from January 1, 2015 to January 1, 2029. For the simulation, if the concentration of TDS in the effluent was predicted to be greater than 684 mg/L in De Beers (2013a), the concentration of TDS was reduced to 684 mg/L." Could the proponent explain what parameter(s) was changed in the simulation to ensure that the concentration of TDS stayed below 684 mg/L?

Response

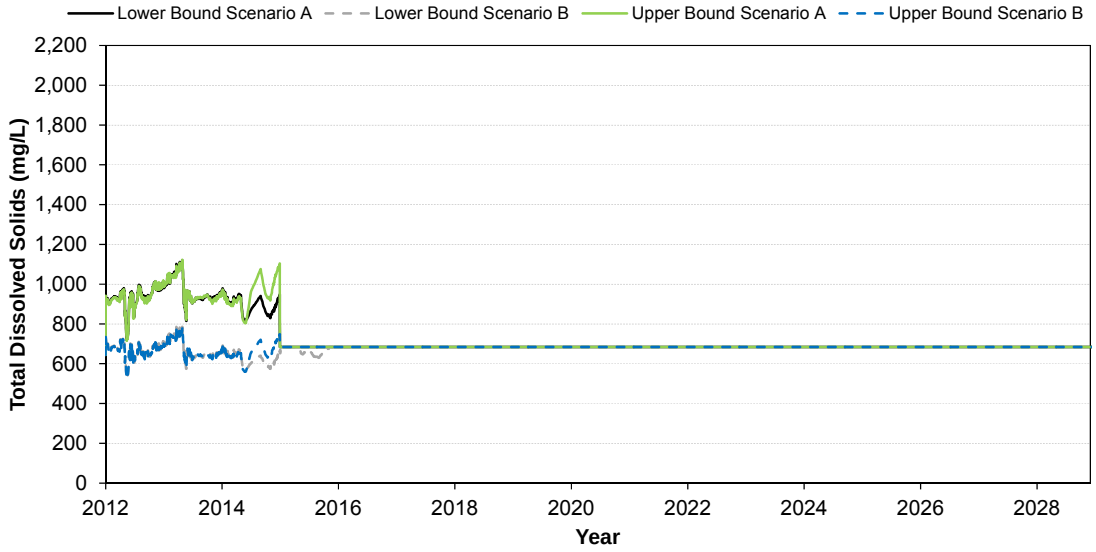
In the scenarios without mitigation the concentrations of TDS in the effluent were predicted to be greater than 800 milligrams per litre (mg/L) (Figure Attachment 2-EC_IR#1-1). Predictions of parameter concentrations in the effluent were generated using the site model (De Beers 2013) and subsequently used as input in the Snap Lake model. In the scenarios with mitigation the predicted concentrations of TDS in the effluent from the scenarios without mitigation (Figure Attachment 2-EC_IR#1-1; De Beers 2013) were directly adjusted such that they did not exceed the average monthly limit (AML) of 684 mg/L from January 1, 2015 to January 1, 2029 (Figure Attachment 2-EC_IR#1-2). For the mitigation scenarios, TDS predictions from Lower Bound Scenario B (i.e., Lower Bound) and Upper Bound Scenario B (i.e., Upper Bound) were input in the Snap Lake model.

Figure Attachment 2-EC_IR#1-1 Predicted Total Dissolved Solids Concentrations in Effluent Discharge to Snap Lake Without Mitigation



mg/L = milligrams per litre.

Figure Attachment 2-EC_IR#1-2 Total Dissolved Solids Concentrations in Effluent Discharge to Snap Lake With Mitigation



mg/L = milligrams per litre.

Reference

De Beers (De Beers Canada Inc.). 2013. Snap Lake Site Model Water Quality Report. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

Attachment 2-EC_IR#2: In the response to IR MVLWB 2, Figure MVLRB 2-1 showed predicted depth averaged total dissolved solids concentrations in Snap Lake "with mitigation". In the response to IR MVLWB 8, Figure MVLWB 8-1 showed predicted depth averaged chloride concentrations in Snap Lake "with treatment". Could the proponent explain the difference between "with mitigation" and "with treatment"? If they mean the same thing, could the proponent explain what percentage of effluent was treated to develop these two figures.

Response

“With mitigation” and “with treatment” mean the same thing.

To develop Figure MVLWB 2-1, the predicted concentrations of TDS in the effluent from the scenarios without mitigation (De Beers 2013) were changed such that they did not exceed the average monthly limit (AML) of 684 mg/L from January 1, 2015 to January 1, 2029. To develop Figure MVLWB 8-1, predicted chloride concentrations in Snap Lake with mitigation were generated by taking 46 percent (%) of the predicted TDS concentrations in Snap Lake with

mitigation. Calculations were thus not based on the percent volume of effluent that would require treatment.

Reference

De Beers (De Beers Canada Inc.). 2013. Snap Lake Site Model Water Quality Report. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

Attachment 3-EC_IR#1: In Figure 2-4, the three graphs show that the depth-averaged fluoride concentrations in Snap Lake are well below the proposed SSWQO of 2.463 mg/L from 2014 to 2028. Could the proponent explain why such a high SSWQO is needed for fluoride?

Response

The proposed fluoride SSWQO (2.46 mg/L F-) was not derived relative to fluoride concentrations in Snap Lake. It was derived based on available, applicable toxicity data using the Canadian Council of Ministers of the Environment protocol (CCME 2007. A protocol for the derivation of water quality guidelines for the protection of aquatic life 2007. In Canadian Environmental Quality Guidelines, Winnipeg, MB, Canada). Available data on the chronic toxicity of fluoride to freshwater aquatic life were compiled and reviewed. A total of 11 chronic studies representing 15 species (three fish, eight invertebrates, and four algae/aquatic plants) were used to derive a chronic effects benchmark, applying the species sensitivity distribution approach. A manuscript is currently being prepared for peer-reviewed publication proposing this chronic effects benchmark as generally applicable to freshwaters. The working title of this manuscript is “Development of a fluoride chronic effects benchmark for aquatic life in freshwater”.

Attachment 3-EC_IR#2: In Figure 2-5, the three graphs show that the depth-averaged sulphate concentrations in Snap Lake are well below the proposed SSWQO of 429 mg/L from 2014 to 2028. Could the proponent explain why such a high SSWQO is needed for sulphate?

Response

The proposed sulphate AEMP benchmark (not a proposed SSWQO) was not derived relative to sulphate concentrations in Snap Lake. It was derived based on the Province of British Columbia, Ministry of Environment, Ambient Water Quality Guidelines for Sulphate (Technical Appendix, Update, April 2013, prepared by Cindy Meays, PhD and Rick Nordin, PhD), adjusted for the hardness of Snap Lake water.

Attachment 3-EC_IR#3: In Figure 2-6, the three graphs show that the depth-averaged nitrate concentrations in Snap Lake are well below the proposed SSWQO of 16.4 mg/L from 2014 to 2028. Could the proponent explain why such a high SSWQO is needed for nitrate?

Response

The proposed nitrate SSWQO was not derived relative to nitrate concentrations in Snap Lake. It was derived based on the Dominion Mines Ekati Corporation, Board-approved SSWQO for nitrate (WL W2012L2-0001), following additional toxicity testing with Snap Lake water, and adjustment for the hardness of Snap Lake water.

YKDFN_IR#1: Socio-Economic and Cultural Impacts

Preamble

The developer's submission to the Review Board is not in conformity with the direction it has been provided. Particularly, it fails to meet the requirements set forth by the Review Board in their Reasons for Decision, as found on p.ll within that decision- under "Next Steps":

> *'The Review Board wiJJ require the developer to file information to satisfy ss. 114, 115, and 117 of the MVRMA. These sections require that the developer describe the biophysical, socioeconomic and cultural impacts that result from activities associated with the amendments that are within the scope of this assessment. Further, the developer must describe the cumulative impacts; accidents and malfunctions; and alternate means of carrying out these activities".*

YKDFN accept that sufficient information has been placed on the record to illustrate *the company's perspective* regarding the bio-physical impacts, but there are no submissions to address the socioeconomic or [particularly] cultural impacts. Furthermore, the transcript clearly shows that this was not accomplished through the 'engagement sessions' nor is it elsewhere on the registry as evidence.

This Environmental Assessment is not simply about the cheapest way to achieve 684 mg/L of TDS. It is about the consequences of that decision and the methods employed to get there- matters which we have very little about. It is the Yellowknives who will live with the result- and the long view must be that land and water must be clean enough to be accepted as a functional and productive part of the land base again. As Dave Putnam stated during lead up of the last licensing phase- De Beers is only "borrowing" the land- it must be returned in a manner that fits the intended use by those who depend on it.

Request

1) For the 'active mining' period, describe the socio-economic and cultural impacts that will result from the proposed activities and submit evidence to support their position, including community perception of Snap Lake, the adjacent area and the water quality.

2) Following active mining, describe the socio-economic and cultural impacts that will be a consequence of the proposed activities and submit evidence to support their position, with a focus on the perception of Snap Lake, the surrounding area, and the downstream environment

3) The alternatives provided are not 'true' alternatives, as they are non-viable. If something is unacceptable, then it is a false choice- parties cannot see the projects trade-offs and the consequential impacts.

Response

QUESTIONS 1) and 2)

As per the MVEIRB EA guidelines screening forms (MVEIRB 2004), the types of socio-economic effects considered are typically defined as planning / zoning changes or conflicts, increase in facility use or services in a community, airport operation, capacity changes, human health hazards, impairment to recreational use or aesthetic quality of water, effects to water use for other purposes, effects to other land use operations, and quality of life changes. Cultural effects generally include effects to traditional land use and resources, historic property, increased economic pressure on historic properties, change to or loss of historic resources, change to or loss of archaeological resources or change to or loss of aesthetically important site(s), effects to aboriginal lifestyle, and increased pressure on archaeological sites. The effects of the Snap Lake Mine on socio-economic and cultural and aesthetic aspects were assessed in the original environmental assessment for the Mine (De Beers 2002; MVEIRB 2003). For the purposes of addressing this IR, the potential socio-economic or cultural effects are considered to be through traditional land use or changes to water quality.

Water Quality and Traditional Land Use

For this ‘development’ (TDS at SSWQO of 684 mg/L), the area where TDS would exceed the original EA predictions is limited to the main basin of Snap Lake and into the inlet into Lac Capot Blanc, after which concentrations return to near regional background (<50 mg/L; see MVRB/MVLWB_IR#11, Table MVRB/MVLWB_IR#11-3). As such, the focus of the assessment was on the immediate area and not further downstream into the receiving environment.

As noted above, changes to the quality of drinking water, including aesthetic quality, may be considered a socio-economic effect. The SSWQO of 684 mg/L is above an aesthetic drinking water quality guideline of 500 mg/L for TDS in the main basin of Snap Lake downstream into Lac Capot Blanc. This was noted in the Supplemental Information filed in April 2014 (Section 2; De Beers 2014a). The increased TDS is not expected to change the appearance of the water, but may result in a slight saline taste. Most of the northwest arm of Snap Lake, where the camp drinking water is obtained, will remain below the aesthetic drinking water guideline for TDS (see

MVRB/MVLWB_IR#2, Figure MVRB/MVLWB_IR#2-2) and, if necessary, can be treated separately.

The TDS drinking water guideline was obtained by having the palatability of drinking water rated by a panel of tasters (Health Canada 2012). Table YKDFN_IR#1-1 summarizes the ranges of TDS concentrations and the corresponding palatability ratings. Water with extremely low TDS concentrations may also be unacceptable because of its flat, insipid taste (Health Canada 2012).

Table YKDFN_IR#1-1: Total Dissolved Solids Concentration and Corresponding Palatability Ratings

TDS Concentration (mg/L)	Palatability Rating
<300	Excellent
Between 300 and 600	Good
600 and 900	Fair
900 and 1,200	Poor
>1,200	Unacceptable

mg/L = milligrams per litre.

On this basis, lakes receiving the treated mine effluent at TDS 684 mg/L would be rated as ‘good’ to ‘fair’ for drinking water taste in the area of the main body of Snap Lake to the inlet of Lac Capot Blanc, and would still be of ‘excellent’ quality in the main body of Lac Capot Blanc and downstream to Mackay Lake. In a worst case scenario with upper bound flows and no mitigation, the TDS concentrations in the immediate project area would remain above 500 mg/L during the closure and post-closure of the mine until approximately 2040 (see MVRB/MVLWB_IR#11, Figure MVRB/MVLWB_IR#11-1). With mitigation, the TDS in the immediate project area is predicted to drop below the drinking water aesthetic guideline before 2040. There are communities in the Northwest Territories that have TDS concentrations in their drinking water with concentrations similar to the SSWQO (GNWT 2011) and communities elsewhere in Canada with drinking water concentrations well above the SSWQO (Health Canada 2012).

There are few land users in the area immediately surrounding Snap Lake, largely due to the rocky habitat (De Beers 2002). A traditional knowledge study also outlined that the area immediately around Snap Lake was not likely an area of substantial historical use (De Beers 2002). There are other land users (including non-traditional users) further away from Snap Lake (De Beers 2002, 2010) including tourist lodges, hunting camps, trap lines, and other land leases for exploration activities (map to be provided as soon as is available from the GNWT). Due to the distance from the Snap Lake Mine, these other users are not expected to be affected by the increase in TDS in the immediate mine area.

Therefore, while the development will result in a change in aesthetic drinking water quality in the immediate area of the Mine during operations and closure (2040), the water is safe to drink, there are few users in the immediate Snap Lake area who would be affected, the area will return to a TDS level below the drinking water guideline within 10 years of operations, and the area with elevated TDS concentrations would be localized.

On the basis of site specific toxicity studies, effects to fish are not expected. Further, in higher TDS areas in the Husky Lakes areas in Northwest Territories, fish size and fishing catch improved in areas of higher salinity (Harwood and Sparling 2008). Given this, changes to fishing opportunities for traditional land users are not expected. Fish abundance, health, tissue concentrations and taste in the Snap Lake area are monitored by De Beers (De Beers 2014b). Communities have gathered annually at Snap Lake for fish-tasting since 2004, fish were generally thought to taste good and sometimes rated as excellent (De Beers 2012, 2014b). Monitoring will continue such that the taste of fish can be evaluated annually by Elders.

Monitoring and Mitigation

This analysis recognizes that, notwithstanding the above anticipated changes, traditional land users may avoid using Snap Lake (including water, fish, or wildlife consumption) due to perception of contamination. De Beers acknowledges the importance of the regional area, the Lockhart River watershed. The watershed is of cultural and socio-economic value to the Northwest Territories and to local Aboriginal people. It is also acknowledged that land use in the immediate Snap Lake area may have changed since the Snap Lake EA or since community interviews on land use for the Gahcho Kué Project EA in 2009 and 2010 (De Beers 2010). De Beers is working with the Government of Northwest Territories Lands Department to determine whether land use has altered since 2009. This information will be provided as soon as it becomes available. Further, De Beers will be hosting YKDFN Chiefs Sangris and Sangris at Snap Lake Mine on May 14, 2014 and plans to meet with community members at the end of May. De Beers will document these meetings, particularly information on the perception of Snap Lake and water quality, to the Boards.

De Beers will continue to conduct regional water quality monitoring as it has since 1999, and to report on the regional water quality three times a year reports to the MVLWB, a summary annual water license report to the MVLWB, and the annual AEMP report, as well as reporting to Aboriginal groups in the annual Environmental Agreement report. De Beers will also share data with the GNWT and Aboriginal Affairs and Northern Development Canada and communities as part of regional cumulative effects monitoring.

QUESTION 3

3) De Beers notes this is not a question, but provides a statement of clarification.

In the Supplemental Information filed April 2014, De Beers outlined alternatives to the development (SSWQO of 684 mg/L TDS). De Beers has suggested alternatives dating back to the original EA and has worked to test many of them. De Beers has provided evidence that the alternatives are ineffective on their own at managing TDS. De Beers tried the alternative of grouting to control the water inflows and areas of high TDS inflows for numerous years. It is now clear that this is not a practical method for controlling TDS (see Response to MVRB/MVLWB_IR#18). De Beers did not consider leaving TDS unmitigated. De Beers has accordingly proposed an option that balances mining method, economics, feasibility, and environmental protection: a SSWQO of 684 mg/L TDS.

References

De Beers (De Beers Canada Inc.). 2002. The Snap Lake Diamond Mine Environmental Assessment Report. Submitted to the Mackenzie Valley Environmental Impact Review Board. Yellowknife, NWT, Canada.

De Beers. 2010. Environmental Impact Statement for the Gahcho Kué Project. Volumes 1, 2, 3a, 3b, 4, 5, 6a, 6b, 7 and Annexes A through N. Submitted to Mackenzie Valley Environmental Impact Review Board. Yellowknife, NWT, Canada.

De Beers. 2012. Aquatic Effects Monitoring Program Re-evaluation Report: Snap Lake AEMP. Submitted to the Mackenzie Valley Land and Water Board, Yellowknife, NWT, Canada.

De Beers. 2014a. Supplemental Information to the EA#201314-002. Submitted to Mackenzie Valley Environmental Impact Review Board and the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada. April 2014.

De Beers. 2014b. 2013 Aquatics Effects Monitoring Program Design Plan in Support of Water Licence (MV2011L2-0004). Snap Lake Project. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

GNWT (Government of the Northwest Territories). 2011. 2010 GNWT Report on Drinking Water. Yellowknife, NWT.

Harwood LA, Sparling P. 2008. Lake trout distribution and salinity: an assessment of the relative abundance and distribution of lake trout throughout Husky Lakes, 2001-2004. In Mills KH, Dyck M, Harwood AL (eds), Proceedings of the Second North American Lake Trout

Symposium 2005, Yellowknife, Northwest Territories. Canadian Technical Report of Fisheries and Aquatic Sciences 2778, 247 pp.

Health Canada. 2012. Drinking water guidelines: total dissolved solids. Ottawa, ON, Canada.

MVEIRB (Mackenzie Valley Environmental Impact Review Board). 2003. Report of Environmental Assessment and Reasons for Decision on the De Beers Canada Mining Inc. Snap Lake Diamond Project. Yellowknife, NWT, Canada

MVEIRB. 2004. Environmental Impact Assessment Guidelines March 2004. Yellowknife, NWT, Canada.

GNWT_IR1: GNWT requests that the proponent provide projected TDS concentrations (both mitigated and unmitigated) spatially in Snap Lake over time to assess cumulative effects, as per the supplemental information.

Response

Please refer to Figure 3-4 of the Total Dissolved Solids Response Plan (De Beers 2013), which presents predicted TDS concentrations at the diffuser area, main basin, and outlet of Snap Lake from 2004 to 2028 for model scenarios without mitigation.

Please refer to Figure 2-2 of the Snap Lake Water Licence Amendment Supplemental Information (De Beers 2014), which presents predicted TDS concentrations at the diffuser area, main basin, and outlet of Snap Lake from 2004 to 2028 for model scenarios with mitigation.

Reference

De Beers. (De Beers Canada Inc.). 2013. Total Dissolved Solids (TDS) Response Plan. Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

De Beers. 2014. Snap Lake Water Licence Amendment Environmental Assessment EA201314-002 Supplemental Information. Submitted to the Mackenzie Valley Environmental Impact Review Board and the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

GNWT_IR2: In the supplemental information the proponent indicated that they require mitigation. GNWT requests that the proponent provide all mitigation options for TDS treatment, including all full reports.

Response

Please see De Beers response to MVRB/MVLWB_IR#3.

GNWT_IR3: The proponent has stated during the presentation of supplemental information (accidents and malfunctions), that the required mitigation for the treatment of water will likely generate a waste product. The proponent has not provided an impact assessment for these waste streams. The proponent must describe all potential waste streams generated from all proposed mitigation options and the potential for accidents and malfunctions.

Response

De Beers has identified high-efficiency Reverse Osmosis (RO) technology as the preferred mitigation alternative and is presently conducting to determine the design parameters and system configuration. Please note that the following information is representative of the type of system being considered and will need to be confirmed during the detailed engineering phase of implementation.

RO generates a continuous liquid reject stream containing 90-95% of the TDS in the original mine water influent. This brine stream would be expected to be approximately 25% of the mine water flow or less. RO brine would receive additional management/treatment (e.g. through evaporation and crystallization) to recover additional treated water and reduce the final volume that would require storage and disposal. A concentrated brine would be high in solids slurry from concentration of the ions that makeup TDS; its volume is expected to be less than 5% of the original mine water flow. If a crystallizer is used, the low moisture salt solids volume is expected to be less than 1% of the mine water flow.

Potential accidents and malfunctions that may occur with these types of system are:

1. A malfunction in one of several modules of the RO treatment system could allow RO brine to enter the permeate system. This would potentially occur due to a breach in the RO membrane, allowing leakage into the effluent discharge to Snap Lake. The consequence in this type of malfunction would likely be an incremental increase in the TDS of the lake discharge.

2. An accidental release of high solids slurry could occur from a pipeline conveyance between treatment and storage or a crystallizer. Consequences would depend on the rate of release, the location of the leak or failure, secondary containment features built

into the design, and the response actions taken to contain and remove the released material.

3. Transport of crystallizer salts in a truck could result in an accident with spillage of salt onto the ground. Such an accident would have a minor consequence in that the release of dry material would be known quickly and the lack of a liquid stream would allow for relatively easy containment and cleanup.

As noted in the response to MVRB/MVLWB_IR#16 it is not possible to assess the likelihood of the above unwanted events until the pilot testing and engineering is complete at which time a detailed risk assessment will be completed and reviewed as part of the regulatory approval process.

GNWT_IR4: The proponent stated during the Technical Session that baseline data will be collected for the downstream environment. GNWT requests a timeline for the submission of this baseline data.

Response

The downstream lakes assessment of the EAR includes baseline data collected in 1993/94 and 1999 from the Lockhart River Watershed (i.e., pre-development). The same dataset was used in the Snap Lake Water Licence Amendment Supplemental Information (De Beers 2014).

Additional data has been collected in the Lockhart River Watershed since the original EAR was prepared, including sampling conducted by De Beers as part of the Aquatic Effects Monitoring Program (AEMP). During the Technical Session, De Beers indicated that it would request recent water quality data from Environment and Natural Resources (ENR), collected as part of the Government of Northwest Territories (GNWT) Water Stewardship program. That request was submitted on April 25, 2014 by Golder Associates Ltd. on behalf of De Beers (Staples 2014, personal communication; Gue 2014, personal communication). Once that information is obtained (projected to be the week of April 28, 2014), it will be reviewed, and a determination will be made as to whether the information can be incorporated into the downstream lakes modelling assessment.

Reference

De Beers. 2014. Snap Lake Water Licence Amendment Environmental Assessment EA201314-002 Supplemental Information. Submitted to the Mackenzie Valley Environmental Impact Review Board and the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

Staples R. 2014. Aquatic Specialist. Environment and Natural Resources. Yellowknife, NWT, Canada. Telephone conversation with Tasha Hall (Golder Associates Ltd). April 25 2014.

Gue A. 2014. Aquatic Scientist. Water Quality Monitoring and Surveillance, Science and Technology Branch. Environment Canada. Yellowknife, NWT, Canada. Email to Tasha Hall (Golder Associates Ltd). April 25 2014.

GNWT_IR5: In the supplemental information the proponent was required by the Mackenzie Valley Review Board to provide a cumulative effects assessment. The information provided in the supplemental information did not identify valued ecosystem components (VECs), nor did it identify potential effects from the project or other stressors to the valued components. GNWT request that the proponent provide a cumulative effects assessments as per the direction provided in the Mackenzie Valley Environmental Impact Review Board's *Environmental Impact Assessment Guidelines, Appendix H, 2004.*

Response

De Beers acknowledges that the assessment of cumulative effects for this Project is non-traditional given the nature of the development (i.e., a change in a WQ licence limit) and the nature of the regulatory process. The focus for valued ecosystem components (VECs) was, commensurate with a WQ issue, on the aquatic environment. The AEMP Design Plan (De Beers 2014) details the water quality VECs, which form the basis for the AEMP Response Framework. The AEMP Response Framework was designed to identify the valued components in relation to changes to water quality, 'thresholds' at which change is deemed unacceptable for these components and the level at which action would be taken before any thresholds are exceeded. It was identified that the level of change in Snap Lake that is not acceptable, based on the original EA, would occur when the water might not be safe to drink, and fish might not be plentiful and safe to eat.

Accordingly, De Beers identified the aquatic environment as the overall VEC for assessment of the effects of increased concentrations of total dissolved solids (TDS) on: drinking water, fish; and, food for fish. This approach is consistent with the VECs identified related to TDS in the original EA and in the conceptual design of the recently approved AEMP Design Plan (De Beers 2014). It is also consistent with comments provided on changes to the Snap Lake Water Licence limits since the renewal of the licence in 2011.

The cumulative effects section of the Supplemental Information identified that, while there are developments in the Lockhart River Watershed, there is no overlap between these and the Snap Lake treated effluent discharge; thus, there is no overlap related to possible cumulative effects from TDS. It was acknowledged in the April 14 to 15, 2014 Technical Session that other developments may potentially occur in the future but that De Beers could not foresee details on TDS concentrations from those developments and as such neither qualitative nor quantitative

predictions about either overlap or effects could be made. It was also noted in the Technical Session that concentrations of TDS from Snap Lake will generally remain within the original EA predictions in the downstream environment. Finally, it was noted that the predicted TDS concentrations downstream of Snap Lake are generally low and within regional norms for the watershed; cumulative effects relate to such relatively low concentrations of TDS are not reasonably expected to occur. Thus, further assessment of cumulative effects was not required and was not conducted. De Beers is, however, continuing regional monitoring to document TDS concentrations downstream of the mine to King Lake, near Mackay Lake. The Mine's sampling coupled with the GNWT's as well as Aboriginal Affairs and Northern Development Canada and CIMP data in the Lockhart River will allow continued monitoring of regional water quality.

Reference

De Beers. 2014. 2013 Aquatic Effects Monitoring Program Design Plan. Snap Lake Project. Submitted to the Mackenzie Valley Land and Water Board, Yellowknife, NWT, Canada.

SLEMA_April 22/14_IR#1: During the Technical Sessions from April 15 to 16, 2014, De Beers presented options to reducing Total Dissolved Solids (TDS) in effluent, and stated that treatment of full mine effluent was not cost-effective.

Snap Lake Environmental Monitoring Agency (SLEMA) investigated the impacts of TDS level in mine water and TDS removal efficiency of mitigations such as reverse osmosis on the ratio of mine water which must be treated to meet the proposed Effluent Quality Criterion (EQC) for TDS. SLEMA would like to request De Beers review the equation and results provided below and confirm whether they are justifiable.

$$R>100(C-EQC/(\eta C)$$

Where, R – Ratio of mine water to be treated, %

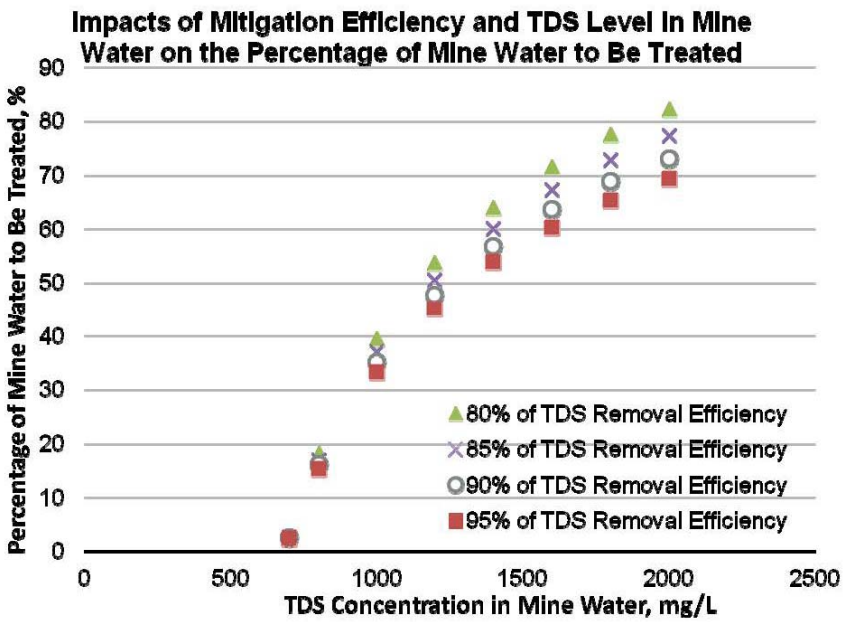
C – TDS concentration in mine water, mg/L

EQC - Effluent Quality Criterion for TDS, mg/L

η – TDS removal efficiency, %

If EQC for TDS is 684 mg/L, the percentage of mine water to be treated is calculated and illustrated as below.

TDS Removal Efficiency, %	TDS Concentration in Mine Water, mg/L							
	700	800	1000	1200	1400	1600	1800	2000
80	2.9	18.1	39.5	53.8	63.9	71.6	77.5	82.3
85	2.7	17.1	37.2	50.6	60.2	67.4	72.9	77.4
90	2.5	16.1	35.1	47.8	56.8	63.6	68.9	73.1
95	2.4	15.3	33.3	45.3	53.8	60.3	65.3	69.3



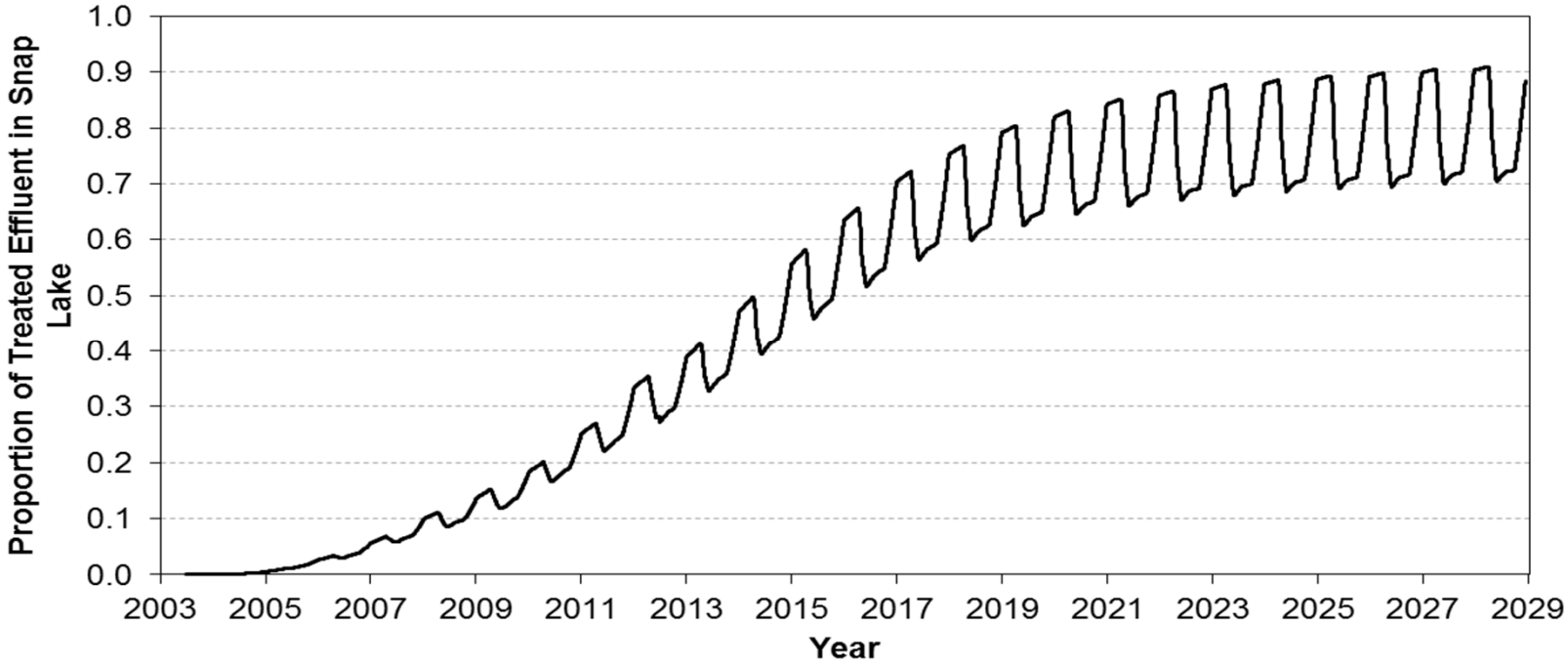
It is clear that the more TDS removal efficiency could be achieved, the less mine water has to be treated; the more TDS is in mine water, the more mine water has to be treated.

Response

The equation provided by SLEMA is a valid approximation of the volume of water that will require treatment. It is important to keep in mind that the type of technologies under consideration and being pilot tested are well understood and are capable of TDS removal efficiencies greater than 90%.

This worksheet contains a timeseries plot of model results for the proportion of effluent in Snap Lake, based on the Lower Bound minewater discharg

Figure 2-2 Proportion of Treated Effluent in Snap Lake Based on Predicted Treated Effluent Discharge Rates from the Lower Bound Scenar



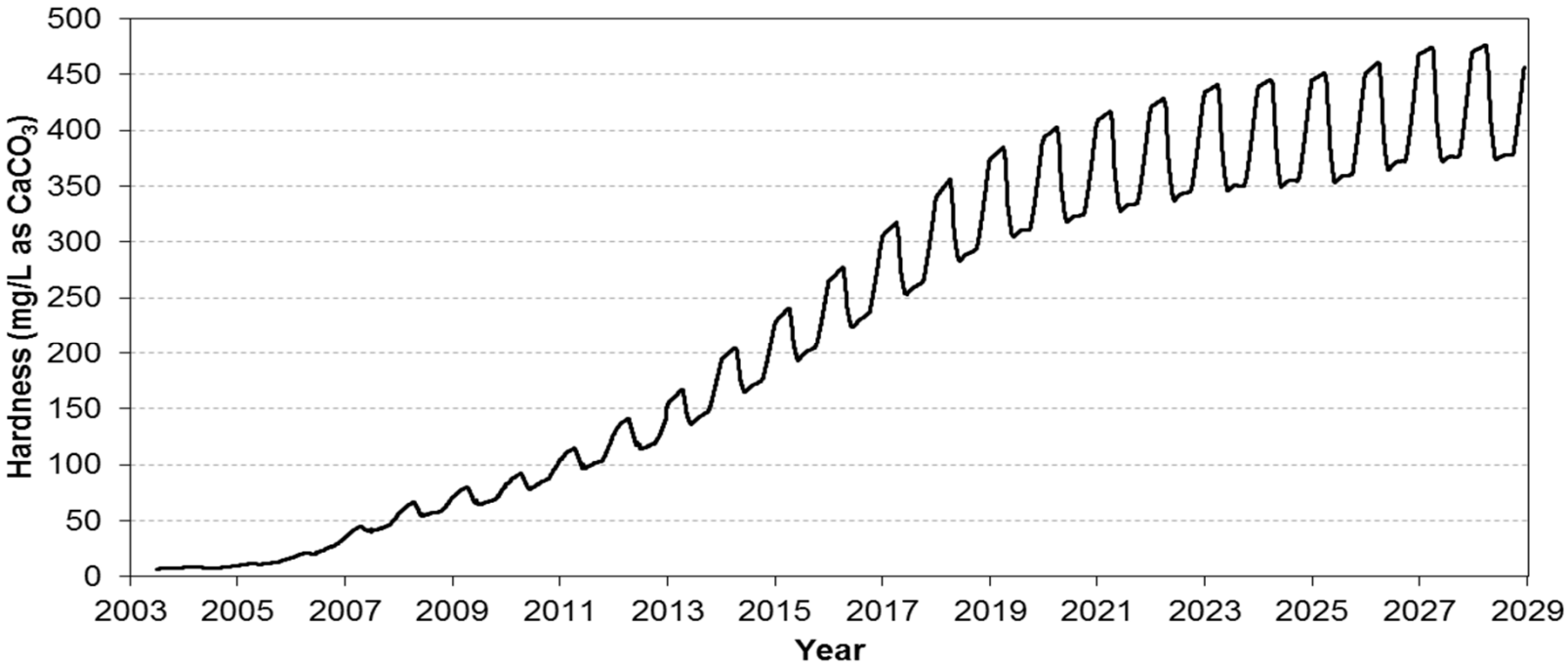
Note: Based on whole-lake average concentrations in Snap Lake.

ge scenario.

io

This worksheet contains a timeseries plot of model predictions for hardness (derived from predicted calcium and magnesium in Snap Lake). The model predictions are for Lower Bound Scenario B.

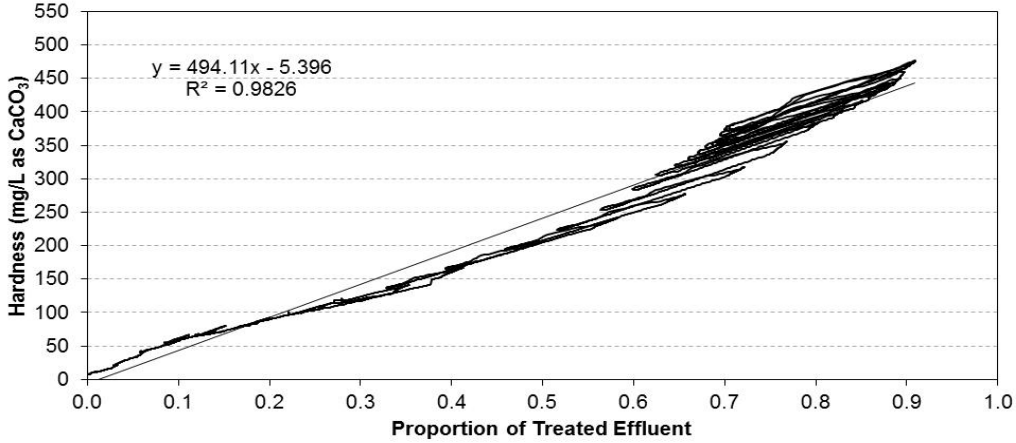
Figure I-1 Predicted Hardness Concentration in Snap Lake



Note: Based on whole-lake average concentrations in Snap Lake.
mg/L = milligrams per litre; $CaCO_3$ = calcium carbonate.

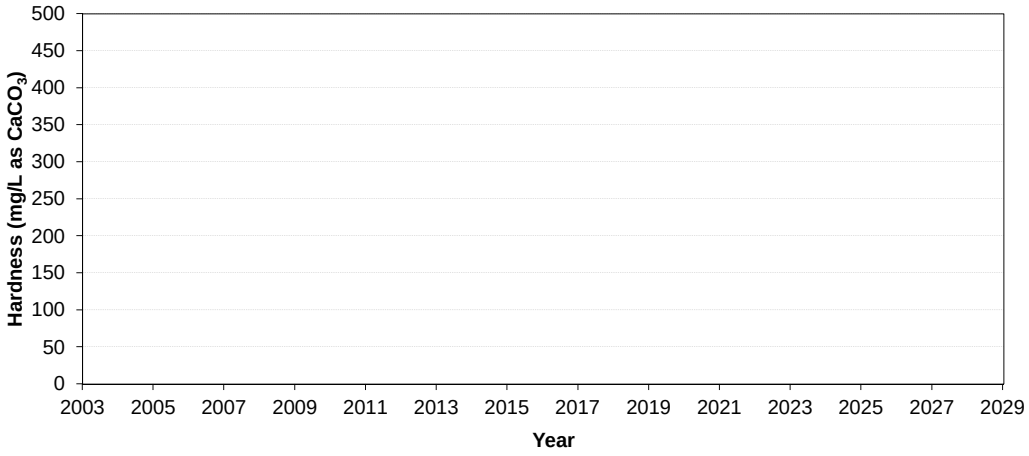
This worksheet contains the relationship between hardness and the proportion of effluent in Snap Lak
As the proportion of treated effluent in Snap Lake increases, the hardness of Snap Lake water increases

Figure I-2 Correlation between Hardness Concentrations and the Proportion of Treated Effluent in Snap Lake



Hardness (mg/L as $CaCO_3$)	Proportion of Treated Effluent in Snap Lake
10	0.01
20	0.03
30	0.05
40	0.07
50	0.09
60	0.11
70	0.13
80	0.15
90	0.17
100	0.19
110	0.21
120	0.23
130	0.25
140	0.27
150	0.29
160	0.31
170	0.33
180	0.35
190	0.37
200	0.39
210	0.41
220	0.43
230	0.45
240	0.47
250	0.50
300	0.60
350	0.70
400	0.80
450	0.90
500	1.00

Note: Based on whole-lake average concentrations in Snap Lake
mg/L = milligrams per litre; $CaCO_3$ = calcium carbonate


500
450
400
350
300
250
200
150
100
50
0
Hardness (mg/L as CaCO3)
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
2023
2025
2027
2029
Year

Calculation of Water Quality Based Effluent Quality Criteria for De Beers Snap Lake Mine

Treated effluent discharge:	57,013	m^3/day	*based on average predicted treated effluent discharge duri*
Dilution provided by diffuser:	12		*volumes of lake water that mix with 1 volume of effluent*
Samples taken per month:	4		*equivalent to sampling frequency in DBCI water licence (or*

Parameter	Concentrations in Natural Inflows To Snap Lake (mg/L)	Effluent Variability (Coefficient of Variation) Observed	Proportion of Treated Effluent in Snap Lake	Equivalent Natural Inflow Rate (m^3/day)	Snap Lake Hardness (mg/L as $CaCO_3$)	AEMP Benchmark (mg/L)
Sulphate	2.12	0.30	0.27	152,273	140	309
	2.12	0.30	0.29	137,800	150	309
	2.12	0.30	0.31	125,199	160	309
	2.12	0.30	0.33	114,129	170	309
	2.12	0.30	0.35	104,327	180	309
	2.12	0.30	0.37	95,588	190	429
	2.12	0.30	0.39	87,746	200	429
	2.12	0.30	0.41	80,671	210	429
	2.12	0.30	0.43	74,255	220	429
	2.12	0.30	0.45	68,411	230	429
	2.12	0.30	0.47	63,065	240	429
	2.12	0.30	0.50	58,156	250	429
	2.12	0.30	0.60	38,609	300	429
	2.12	0.30	0.70	24,735	350	429
	2.12	0.30	0.80	14,377	400	429
	2.12	0.30	0.90	6,348	450	429

ng the year of maximum discharge (2026).

ıce every 6 days)

Waste Load Allocation		Long Term Average		Maximum Daily Limit		Average Monthly Limit	
(mg/L)	Averaging Period	Multiplier	Concentration (mg/L)	Multiplier	Concentration (mg/L)	Multiplier	Concentration (mg/L)
937	4	0.715	669	1.90	1269	1.26	846
886	4	0.715	633	1.90	1201	1.26	801
841	4	0.715	601	1.90	1140	1.26	760
800	4	0.715	572	1.90	1085	1.26	723
763	4	0.715	546	1.90	1035	1.26	690
1014	4	0.715	725	1.90	1374	1.26	916
971	4	0.715	694	1.90	1316	1.26	877
932	4	0.715	666	1.90	1263	1.26	842
895	4	0.715	640	1.90	1213	1.26	809
862	4	0.715	616	1.90	1168	1.26	779
831	4	0.715	594	1.90	1126	1.26	750
802	4	0.715	573	1.90	1086	1.26	724
683	4	0.715	488	1.90	925	1.26	617
594	4	0.715	425	1.90	806	1.26	537
526	4	0.715	376	1.90	713	1.26	476
473	4	0.715	338	1.90	640	1.26	427

Table 1-3 Effluent Quality Criteria for Sulphate based on Increasing Snap Lake Hardness Concentrations

Parameter	Proportion of Treated Effluent in Snap Lake	Snap Lake Hardness	AEMP Benchmark	Waste Load Allocation Concentration	Long Term Average Concentration	Maximum Daily Limit Concentration	Average Monthly Limit Concentration	Annual Loading Limit
		(mg/L as CaCO3)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(kg/day)
Sulphate	0.27	140	309	937	669	1,269	846	38,112
	0.29	150	309	886	633	1,201	801	36,065
	0.31	160	309	841	601	1,140	760	34,227
	0.33	170	309	800	572	1,085	723	32,568
	0.35	180	309	763	546	1,035	690	31,063
	0.37	190	429	1,014	725	1,374	916	41,267
	0.39	200	429	971	694	1,316	877	39,521
	0.41	210	429	932	666	1,263	842	37,916
	0.43	220	429	895	640	1,213	809	36,437
	0.45	230	429	862	616	1,168	779	35,069
	0.47	240	429	831	594	1,126	750	33,801
	0.50	250	429	802	573	1,086	724	32,621
	0.60	300	429	683	488	925	617	27,776
	0.70	350	429	594	425	806	537	24,188
	0.80	400	429	526	376	713	476	21,422
	0.90	450	429	473	338	640	427	19,226

Note: The effluent quality criteria in the highlighted row were recommended for the Mine

a) Calculations were based on an average predicted treated effluent discharge of 57,013 cubic metres per day (m^3/d) (average predicted treated effluent discharge during the year of maximum discharge [2026]), a dilution factor of 12 (volumes of lake water that mix with one volume of treated effluent), and on the assumption that four samples were collected per month (equivalent to sampling frequency in De Beers Water Licence of once every six days

b) Long term average concentrations were calculated assuming an averaging period of four days

AEMP = Aquatic Effects Monitoring Program; mg/L = milligrams per litre; $CaCO_3$ = calcium carbonate.

TECHNICAL MEMORANDUM

Golder Associates Ltd.
1000, 940 - 6 Avenue SW
Calgary, Alberta, Canada
T2P 3T1

Telephone No.: 403-299-5600
Fax No.: 403-299-5606

DATE: May 19, 2008 Proj. No. 071-3340052

TO: Rob McLean, Josh Harvey

CC: K. Conroy, K. DeVos, M. Digel, L. Young, S. House

FROM: Paul Pigeon, Peter Lemke

RE: Snap Lake Water Management Treatment Alternatives Report

This Technical Memorandum presents the results of the De Beers Snap Lake Diamond Mine Water Management Alternatives Study. The work plan dated November 2, 2007 included the following:

1. Identifying what treatment systems for removal of total dissolved solids (TDS) appear to be the most economically feasible for treatment of the water originating from the waste rock mine workings (haulage drifts).

2. Developing order-of-magnitude costs to design, construct, install, operate and maintain a TDS removal treatment system at flow rates of:

   - An initial capacity of 3,000 cubic meters (m^3) per day that can be expanded to 10,000 m^3/day;

   - An initial capacity of 3,000 m^3/day that can be expanded to 20,000 m^3/day; and

   - An initial capacity of 3,000 m^3/day that can be expanded to 30,000 m^3/day.

   - (After the site visit for project kickoff, on November 27, 2007, it was noted that the haulage drift water flow rate had already at times exceeded 3,000 m^3/day. For purposes of this study, the initial flow rate was changed from 3,000 m^3/day to 5,000 m^3/day).

50 BEST EMPLOYERS IN CANADA 2007

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

To complete these objectives, the project work was divided into four tasks including the Kick-off and Site Visit, Characterization and Design Basis, Alternatives Development, and Evaluation and Recommendations. The Work Plan and the Site Visit and Project Kickoff Report are provided as attachments to this report. The balance of this report addresses the influent water quality characterization (or design basis influent), treatment alternatives and evaluation, and a recommended treatment system

WATER QUALITY CHARACTERIZATION

Key to the development of viable treatment alternatives is the understanding of the influent water quality characterization. De Beers provided fifteen data sets from routine sampling and analysis events covering the time period from March through October 2007, for several monitoring points. The monitoring points that are most representative of the water to be treated were drift water sampling points 10 and 11 (DW10 and DW11). These two sampling points were later combined into a single sample for analysis and the location was designated as DW1011. These data are summarized in Table 1.

Based upon review of the available data, Golder requested performance of additional sampling and analyses to generate an adequate design basis influent data set for development of treatment alternatives. The list of additional analyses requested is provided as an attachment to this report. This list also provides justification and comments on the utility of the data. Of primary importance to the identification and screening of potential treatment technologies for TDS removal were the concentrations of trace metals in dissolved form, as opposed to “total” (dissolved and particulate) form as previously reported.

Sampling to obtain the additional data was conducted on February 25, 2008, and samples were submitted to ALS with a request for expedited analysis. Results were provided on March 4, and a revised design basis influent water quality characterization was developed. This design basis influent is presented in Table 2.

Table 1. Water Quality Characterization (2007 data available at project kickoff)

	Avg	Min	Max
Alkalinity	49	11	93
Bicarbonate	59	ND	114
Carbonate	16	ND	20
Hardness (mg/l as CaCO3)	2,124	214	3,070
Hydroxide	10	ND	17
Acidity	<5	ND	ND

	Avg	Min	Max
Ammonia	3.22	0.36	8.71
Total Kjeldahl Nitrogen	3.44	0.35	8.71
Nitrate	9.05	ND	30.1
Nitrite	0.34	ND	0.97
Nitrate + Nitrite	6.26	ND	31.8

	Avg	Min	Max
pH	8.1	6.9	10.8
Conductivity (uS/cm)	4,800	901	8,380
Turbidity (NTU)	1,491	4	5,700

	Avg	Min	Max
Total Dissolved Solids	3,178	596	5,090
TDS (calculated)	2,748	418	4,890
Total Suspended Solids	1,967	ND	6,250
Total Organic Carbon	6	ND	12

	Avg	Min	Max
Fluoride	0.94	0.66	1.09
Chloride	1,561	191	2,820
Sulphate	154	32	252
Orthophosphate	<0.001	ND	ND
Phosphorus Total	0.48	0.008	1.63
Phosphorus, Total Diss.	0.03	ND	0.04
Calcium	631	85	1,210
Magnesium	33	0.7	46.7
Potassium	23	ND	436
Sodium	306	69	543
Silica, Reactive Soluble	13.13	9.6	15.4

TOTAL METALS	Avg	Min	Max
Aluminum (ug/l)	21,300	11,200	31,400
Antimony (ug/l)	6	ND	6
Arsenic (ug/l)	24	5	42
Barium (ug/l)	365	60.7	669
Beryllium (ug/l)	0.50	1	-
Bismuth (ug/l)	0.60	0.2	1
Boron (ug/l)	370	190	550
Cadmium (ug/l)	1.2	ND	1.2
Cesium Total	<50	ND	ND
Chromium (ug/l)	97	24.8	169
Cobalt (ug/l)	7	5.2	9.6
Copper (ug/l)	17	6	27
Iron (ug/l)	23,150	13,000	33,300
Lead (ug/l)	124	15.4	233
Lithium (ug/l)	84	47	121
Manganese (ug/l)	208	97	318
Mercury (ug/l)	2	0.5	4
Molybdenum (ug/l)	10	9.2	11.2
Nickel (ug/l)	54	19.2	89
Rubidium (ug/l)	80	ND	80
Selenium (ug/l)	<0.4	ND	ND
Silver (ug/l)	<0.4	ND	ND
Strontium (ug/l)	5,365	1,420	9,310
Thallium (ug/l)	2	1.3	1.80
Tin (ug/l)	9	2.9	15.80
Titanium (ug/l)	929	507	1,350
Uranium (ug/l)	4	3.4	4.5
Vanadium (ug/l)	50	31.2	68.1
Zinc (ug/l)	197	54	340

Ion Balance	97.96%

Table 1 Note. All values are milligrams per litre (mg/l) except as noted. ND = non-detect. Avg = average of all reported values for DW-10 and DW11. Min and Max are minimum and maximum reported values.

Table 2. Water Quality Characterization (Supplemental sampling and analysis, February 2008)

	Avg	Max	Min
Alkalinity	32	49	14
Bicarbonate	35	58	11
Carbonate	<5	<5	<5
Hardness (mg/l as CaCO3)	2,124	3,070	214
Hydroxide	<5	<5	<5
Acidity	<5	<5	<5

	Avg	Max	Min
Ammonia	3.22	8.71	0.36
Total Kjeldahl Nitrogen	3.44	8.71	0.35
Nitrate	8.5	8.5	8.5
Nitrite	0.394	0.394	0.394
Nitrate + Nitrite	8.8	8.8	8.8

	Avg	Max	Min
pH	8	8.5	8.4
Conductivity (uS/cm)	3191	6090	292
Turbidity (NTU)	340	340	340
Total Dissolved Solids	3,178	5,090	596
TDS (calculated)	2,748	4,890	418
Total Suspended Solids	795	795	795
Total Organic Carbon	6	12	ND
Fluoride	0.94	1.09	0.66
Chloride	1016	1980	52
Sulphate	154	252	32
Orthophosphate	<0.001	<0.001	<0.001
Phosphorus Total	0.48	1.63	0.008
Phosphorus, Total Diss.	0.03	0.04	ND
Calcium	631	1,210	85
Magnesium	33	46.7	0.7
Potassium	23	436	ND
Sodium	306	543	69
Silica Reactive Soluble	13.13	15.4	9.6

	Dissolved metals - 5 samples			Total metals
TRACE METALS	Avg	Max	Min	L609513-5
Aluminum (ug/l)	<10	<10	<10	7180
Antimony (ug/l)	<0.8	<0.8	<0.8	<5
Arsenic (ug/l)	2.7	5.7	<0.4	<1
Barium (ug/l)	57	61.6	54	132
Beryllium (ug/l)	<0.5	<0.5	<0.5	<1
Bismuth (ug/l)	0.09	0.1	0.06	0.3
Boron (ug/l)	405	556	341	450
Cadmium (ug/l)	0.1	0.1	<0.1	<0.2
Cesium (ug/L)	0.2	0.2	0.2	<50
Chromium (ug/l)	<5	<5	<5	41
Cobalt (ug/l)	0.8	0.9	0.7	8.6
Copper (ug/l)	2.2	2.8	1.7	17
Iron (ug/l)	12	30	<5	11100
Lead (ug/l)	0.2	0.3	0.1	17
Lithium (ug/l)	113	115	109	156
Manganese (ug/l)	21	27	14	132
Mercury (ug/l)	<0.1	<0.1	<0.1	<0.2
Molybdenum (ug/l)	6.4	7.8	5.7	7.2
Nickel (ug/l)	35.1	107	16	69.4
Rubidium (ug/l)	<50	<50	<50	<50
Selenium (ug/l)	0.6	0.7	0.4	0.5
Silver (ug/l)	<0.2	<0.2	<0.2	<0.4
Strontium (ug/l)	10492	11200	9860	12200
Thallium (ug/l)	0.09	0.1	0.08	0.2
Tin (ug/l)	<0.2	<0.2	<0.2	0.6
Titanium (ug/l)	1.2	1.5	1	399
Uranium (ug/l)	2	2.8	1.6	3.4
Vanadium (ug/l)	1.4	2	<1	24.1
Zinc (ug/l)	21.4	83	<2	60

Table 2 Notes. All values are milligrams per litre (mg/l) except as noted. ND = non-detect. Avg = average of all reported values for DW-10 and DW11. Min and Max are minimum and maximum reported values. The following analyses were not performed for the Feb 25 sampling event, and values for these parameters are copied from the 2007 historical data: hardness, ammonia, total kjeldahl nitrogen, TDS, TDS (calculated), total organic carbon, fluoride, phosphorus total, phosphorus dissolved, calcium, magnesium, potassium, sodium and silica.

The water quality characterization as presented in Table 2 along with the flow rate requirements over the project life, the treated effluent requirements, and general guidance as to acceptable forms and quantities of secondary waste were used to identify and pre-screen the field of potentially applicable treatment technologies. Technology pre-screening is described below.

POTENTIALLY APPLICABLE TREATMENT TECHNOLOGIES

Typical TDS removal technologies

Potentially applicable treatment technologies for removal of TDS include evaporation, reverse osmosis, ion exchange, electrodialysis reversal, and chemical precipitation. Development of treatment alternatives may require implementation of a single primary technology from the candidate list (with minimal pre- or post-treatment steps) or may involve a combination of technologies (e.g., reverse osmosis and chemical precipitation). Minimization of secondary waste is an important aspect of the Snap Lake Water Management project. While any of the above technologies can produce an effluent of acceptable quality, additional processing steps may be necessary to produce a secondary waste stream of manageable quality and volume.

Each of the candidate technologies is briefly described. Table 3 presents a summary and comparative screening evaluation for the treatment of De Beers Snap Lake drift water.

Evaporation – Mechanical Process Equipment

Evaporative techniques produce a treated effluent by vaporizing and then condensing pure water. In cases where "zero liquid discharge" is preferred or required, the vaporized water is released to atmosphere rather than condensed. The evaporation waste byproduct (or "bottoms") is a concentrated brine stream, which may in turn be processed to a dry residue.

Mechanical methods

Mechanical evaporation involves boiling off the water phase of the waste stream leaving a concentrated brine stream. The vapor can either be discharged to atmosphere as a steam plume or condensed to produce an essentially distilled water effluent stream. Evaporation is broadly applicable to removal of non-volatile contaminants in wastewater including TDS. A mechanical vapor recompression (MVR) brine concentrator is a commonly used process for this type of application. The brine concentrator typically evaporates approximately 95 to 98 percent of water and produces a small volume slurry stream that must be disposed of or managed. Typical management methods for evaporative slurry include crystallization to near dryness, deep well disposal, and off-site disposal. On-site disposal with waste rock is also a possibility for the Snap Lake site. The total volume of crystallized waste and potential for reintroduction of TDS to ground water or surface water (if leached from waste rock storage) would have to be evaluated to assess the viability of on-site disposal.

Reverse Osmosis

Reverse osmosis (RO) treatment is essentially an extremely fine filtration technique that utilizes a series of fine pore membranes. Water and extremely low levels of some contaminants pass through the membranes while the majority of the contaminants are retained on the brine side of the membrane. The system is relatively simple, consisting primarily of membranes in a series flow configuration and a high pressure pump. Some pretreatment to protect the membranes is typically required, and may include filtration for suspended solids removal, antiscalent addition, and preheating of the waste stream. The osmotic pressure required for RO treatment is inversely related to the temperature of influent water. Thus

preheating can increase treatment efficiency while reducing the pumping power requirement. The RO-treated effluent is termed the "permeate". The RO waste stream is referred to as brine or reject. Based on experience with similar water sources the TDS of the permeate produced at Snap Lake could be in the 50 to 100 mg/l range. TDS in the RO brine stream could be in the range of 10,000 and 15,000 mg/l. The brine stream volume is typically in the range of 20 to 50 percent of the influent stream. Like the evaporation process an RO is broadly applicable to TDS contaminants and can provide a 95 to 99 percent reduction in the contaminant concentrations.

Ancillary equipment requirements for a fully functional RO treatment system may include prefiltration, antiscalent addition, preheating, and a membrane cleaning system.

Electrodialysis Reversal

Electrodialysis reversal (EDR) is an electrochemical separation process that removes ions and other charged species from water and other fluids. EDR uses small quantities of electricity to transport these species through membranes composed of ion exchange material to create separate purified and concentrated streams. The ion exchange membranes are configured in an alternating series of anionic and cationic membranes. Ions are transferred through the membranes by means of direct current (DC) voltage and are removed from the feed water as the current drives the ions through the membranes to desalinate the process stream. When membranes become saturated, the DC current is reversed, effectively cleaning the membranes for continued use.

EDR presents an advantage over RO in that it typically requires less pretreatment. Control of influent pH and addition of antiscalent are usually not necessary with EDR. EDR has been demonstrated effective on groundwaters containing up to 5,000 mg/l TDS, recovering clean water at a 94% rate. Polarity reversal allows for concentrating brine beyond saturation. Through this electrically driven process the product water quality can essentially be "turned up" or "turned down" by adjusting the DC current flow.

Ion Exchange

Ion exchange is the reversible exchange of ions between the stream to be treated and an insoluble solid ion exchange resin. It is a well-developed process for extraction of cations (such as calcium or magnesium) or anions (such as sulphate or nitrate) from contaminated wastewater. Ions present in the wastewater are exchanged with ions on the resin, without producing any permanent change to the resin structure. The most commonly used exchange ions (present on fresh resin) are sodium for cation exchange and chloride for anion exchange. Thus, the treated water stream will contain elevated levels of sodium and chloride. When the active sites on the resin are exhausted, the resin is regenerated by contacting it with a concentrated solution of the exchange ions originally associated with the resin. The contaminant ions are carried off the resin with the regeneration liquor. The regeneration liquor is the secondary waste stream resulting from primary treatment by ion exchange.

Ion exchange treatment efficiency can be in the range of 90 to 99 percent for common anions and metals. Suspended solids and organics must be removed from the wastewater prior to treatment by ion exchange to prevent fouling of the resin.

The ion exchange media is contained in a column or series of two to three columns and the water flows by gravity or is pumped through the system. Support systems include tanks for the regeneration fresh and used regeneration chemicals.

Chemical Precipitation

Chemical precipitation is a pH adjustment process that involves the addition of a chemical to adjust the pH to the point of minimum solubility for target compounds. For the primary constituents of the TDS in the leachate, addition of lime to pH values in the 10 to 11 range could reduce the sulphate, alkalinity, and metals levels and provide an overall TDS reduction in the 40 to 60 percent range on the raw leachate. Sodium will not be affected by lime treatment and it is unlikely that nitrate or selenium will be removed. The solid precipitate must be removed by filtration or settling and then managed and disposed. Typically the sludge volume is reduced by a sludge dewatering step such as a filter press. Since the sludge is expected to be primarily gypsum (calcium sulphate) and calcite (calcium carbonate) it is likely that the sludge can be disposed in a municipal-type landfill. Disposal with mine tailings could be a satisfactory repository.

Support systems include the chemical storage and feed system, and solids separation which is typically accomplished by a clarifier and polishing filter. Final pH adjustment to reduce the pH from the elevated treatment pH to a more neutral pH is typically required. The sludge can be further treated by dewatering in a filter press or other mechanical dewatering device. Some mines utilize pond systems for treatment and solids separation.

TECHNOLOGY SCREENING

In most water management alternatives studies, there are two or three viable process trains that can be developed with equivalent capabilities to meet the treatment goals, which can then be evaluated against criteria such as capital and operating costs, labour requirements, ancillary equipment, utilities consumption, etc. However, the Snap Lake Diamond Mine site presents unique conditions which severely restrict the range of viable treatment technologies. These conditions include the influent water quality characterization and treatment goals, site location, and limited secondary waste storage/disposal options. These conditions and their bearing on the technology identification and screening process are described below.

Influent Water Quality Characterization and Treatment Goals

Water chemistry. The influent water quality characterization includes the chemistry summarized in tables 1 and 2 above, and other parameters affecting treatment technology identification. The design basis influent water chemistry is not well-suited to treatment by EDR, ion exchange or chemical precipitation. EDR is best-suited to a relatively “clean” influent of about 500 mg/l TDS concentration which is lower than the minimum reported TDS value for 2007. Ion exchange is not viable for TDS reduction due to its contaminant removal mechanism of replacing the resin-absorbed contaminant ions from the treated flow with ions released from the resin which are considered to be innocuous. In the case of Snap Lake’s discharge requirement to remove TDS, ion exchange is not viable. Chemical precipitation for metals and sulphate removal is generally performed by addition of hydrated lime (calcium hydroxide). The hydroxide ions bond with dissolved metals and form insoluble metal-hydroxides. Calcium ions bond primarily with the sulphate in the influent stream, forming an insoluble solid. The metal-hydroxides and calcium sulphate are removed from the influent stream as a sludge. As noted above, the TDS removal efficiency for chemical precipitation is limited to approximately 40 to 60%, which is inadequate for the worst case design basis influent. The sludge would also require additional handling to minimize volume.

The water quality characterization has process impacts on an RO- or evaporation-based treatment system but can be handled with pretreatment steps, primarily filtration to remove suspended solids.

Temperature. Influent water temperature is another prime consideration for viability of treatment technologies. The operational efficiency of an evaporation system is relatively unaffected by influent temperature, although additional energy consumption is required for lower temperature influents. RO operates more efficiently on an influent stream with a moderate temperature of approximately 20°C to 30°C.

Flow rates. The initial flow rate of 5,000 m^3/day, and future expansions to 10,000, 20,000 and 30,000 m^3/day can also be handled by either evaporation or RO as the main treatment operation. These technologies are constructed in modules which will facilitate capacity expansion as mine dewatering flows increase.

Site Location

The primary issue with location is the inaccessibility of the site by surface transportation except during the limited time period of winter road operation. This presents problems for treatment processes that are dependent on routine use and replacement of chemical reagents or resins in bulk quantities. Requirements for chemical or resin storage or shipment are prohibitive for ion exchange and for chemical precipitation treatment systems.

Again, RO and evaporation will require some pretreatment steps but are more viable than ion exchange or chemical precipitation treatment systems with regard to storage or delivery of bulk materials required for continuous operation.

Secondary Waste

Similar to the constraints of bulk deliveries to the site for process operations, location is also a constraint relative to storage or disposal of secondary wastes generated by treatment processes. The options for final disposition of secondary waste are limited to storage in the North Pile or use in paste backfill returned to the mine workings.

The waste stream generated by a chemical precipitation system would be a sludge, consisting of calcium sulphate and metal hydroxides. By adding a dewatering step, the volume could be somewhat reduced but is still anticipated to be prohibitively large, especially at the increased treatment flow rates in the out-years of production. The characteristics of the sludge may or may not be suitable for use in paste backfill. The planned volume and rate of paste backfill in relation to mine development may also be a limiting factor in disposal of chemical precipitation sludge.

Ion exchange will produce a concentrated waste stream when the resins are regenerated. The regenerant stream will require additional treatment for volume reduction and stabilization. Untreated ion exchange regenerant will not be suitable for use as a paste backfill additive, nor can it be disposed in an uncontained waste pile. Disposal would require an isolation cell, and the volume of untreated backwash over the life of the project would make isolation infeasible.

Similar to ion exchange regenerant, EDR and RO will both produce a concentrated liquid waste stream. This reject (or brine) stream will also require additional treatment for volume reduction and stabilization.

Brine is not suitable for addition to paste backfill, and cannot be disposed in an uncontained waste pile. Disposal of RO or EDR waste without additional treatment is infeasible.

Evaporation will produce the lowest volume of secondary waste. If a crystallizer is utilized, evaporation will produce only dry solids as a waste stream. This dry solid waste is unlikely to be useful as a paste backfill additive, but will require the smallest volume of isolated disposal of any of the technology options. As such, evaporation is a viable option as the main treatment process and is also viable as an additional treatment step, for volume reduction of the secondary waste streams from other processes.

The advantages and disadvantages of each technology are summarized in Table 3. As noted in the comments column, EDR, ion exchange, and chemical precipitation have been deemed infeasible due to failing the screening criteria described above. The development of viable treatment processes will consider evaporation and RO with a supplemental evaporation process.

Table 3. Comparative Evaluation of Treatment Technologies for De Beers Snap Lake Drift Haulage Water

Technology	Advantages	Disadvantages	Comments
Evaporation	Zero liquid discharge treatment is an option, or a condenser can be utilized to recover a treated effluent in liquid form. Treated water quality with condenser is essentially contaminant free. Residual stream requiring management or disposal is extremely low volume. Can be operated continuously or batch-wise.	Distilled water can be corrosive and aggressive. Reuse and/or discharge may require post-treatment. Most costly capital and operating costs of all technologies screened. Lead time on equipment may be up to one year. Requires significant energy input.	Probably not cost effective as the primary treatment unit for the full stream. Treating a split stream and blending back with untreated water to maintain TDS effluent goal may be viable. May also be appropriate as a secondary treatment unit, to manage a smaller volume brine or concentrate stream.
Reverse Osmosis (RO)	Produces an extremely low TDS, high quality treated water stream. Proven technology for TDS treatment. Can be operated continuously or batch-wise, but best operated in continuous mode.	Brine stream flow rate may be as high as 25-50% of the influent flow, and would likely require further treatment. Higher capital and operating costs than other technologies with the exception of mechanical evaporation. May require several months of equipment order lead time. Operations become problematic if system is shut down. Membranes must be properly cleaned and stored when not used for more than 1-2 days. Requires relatively skilled operations personnel.	Treatment of RO brine for volume reduction could be accomplished by series RO treatment or by mechanical evaporation. Similar to evaporation a split stream could be treated and recombined with untreated flow while maintaining effluent quality at the required TDS effluent discharge limit.
Electrodialysis Reversal (EDR)	Produces an extremely low TDS, high quality treated water stream. Proven technology for TDS treatment. Can be operated continuously or batch-wise.	Brine stream flow rate may be as high as 25-50% of the influent flow, and would likely require further treatment. Generally used on TDS influent of 500 mg/l or less. Same pretreatment requirements as RO. Requires more power than RO and is more sensitive to influent temperature.	Technically infeasible for this site.

Technology	Advantages	Disadvantages	Comments
Ion Exchange	Simple "flow-through" technology. Could be implemented extremely quickly. Can be operated continuously or batch-wise.	Ineffective for TDS reduction at levels projected for Snap Lake's design basis influent. Typically used to remove specific contaminant ions when replacement of the removed contaminant with an innocuous ion is acceptable. Produces a concentrated waste stream when resin is regenerated that would have to be treated or disposed.	Technically infeasible for this site.
Chemical Precipitation	Simple technology can be implemented relatively quickly. Equipment is relatively inexpensive. Provides gross TDS reduction when primary constituents are sulphate and metals.	Produces sludge stream that must be managed. May not provide enough TDS reduction for discharge or reuse, given the relatively low sulphate and metals concentrations in the design basis influent. Calcium is a significant contributor to the TDS load, and will not be removed by this process. Onsite lime storage is needed, and storage capacity could be prohibitive.	Technically infeasible for this site.

TREATMENT ALTERNATIVES

Based on the technology screening, the viable treatment technologies for the Snap Lake Diamond Mine are RO and evaporation. In the development of treatment alternatives, these technologies are used as the main treatment step, along with the likely pre-treatment and post-treatment steps that will be required. Influent water quality characterization, effluent treatment requirements and flow rates were provided to commercial providers of RO and evaporation equipment. These vendors included GE Infrastructure Water & Process Technologies, Siemens Water Technologies Corporation, and Aquatech International Corporation. GE and Siemens provided equipment descriptions and budgetary cost estimates for RO-based treatment systems, while Aquatech provided estimates for an evaporator-based system as well as an RO-based system. GE and Siemens provided considerably different pre-treatment equipment, which is discussed in the later sections of this report. The RO treatment alternative described below is based on GE's estimate. The evaporative treatment alternative is based on Aquatech's estimate.

ALTERNATIVE 1 – REVERSE OSMOSIS BASED TREATMENT

Pretreatment

The efficiency of RO operation is dependent on several factors in the influent stream. These factors include temperature, presence of suspended solids, and presence of dissolved species which are considered to be membrane "foulants". Based on review of available water quality characterization data, pretreatment will be required for RO.

In some cases foulant species must be removed from the RO influent stream, while others can be controlled by addition of antiscalant. GE modeling based on the maximum constituent concentrations (Table 2) indicated that scaling of RO membranes will not be a problem in treatment of the Snap Lake drift water. Species which tend to scale in RO include calcium carbonate, calcium sulphate, barium sulphate, strontium sulphate calcium fluoride, iron, manganese, aluminum, silica dioxide and calcium phosphate. None of these species, even in the "worst case" are present in concentrations which would require removal prior to RO treatment and can be controlled by addition of antiscalant.

The presence of total suspended solids (TSS) in the influent at concentrations as high as 6,250 mg/l, will require a pretreatment step. TSS removal could be accomplished with treatment equipment similar to the existing multi-media pressure filters. Alternatively, ultrafiltration units could be utilized. Vendor information on ultrafiltration is provided as an attachment. It is also important to note that the method of pumping water from the drift haulage tunnel has significantly reduced the TSS load observed at the existing treatment plant. However, due to the uncertainties of increased flows and quality, it is prudent in the pre-feasibility phase of study to carry forward with a "worst case" approach. GE's ultrafiltration recommendation is carried forward as the preferred pretreatment step for RO.

As noted above, the efficiency of RO treatment will be optimal if the influent water temperature can be raised to 20° to 30°C. Preheating, either by a dedicated heat exchanger or through re-use of waste heat should also be considered for RO pretreatment steps.

Reverse Osmosis Treatment

The RO unit is capable of producing treated water at an efficiency of 75 percent. That is, 75 percent of the influent flow becomes RO permeate, while 25 percent becomes RO brine. Total dissolved solids (TDS) in the RO permeate is projected at approximately 20 mg/l based on an RO membrane efficiency of 99.6 percent. High quality permeate production will allow for some bypass and blending of untreated water with treated RO permeate while maintaining the effluent discharge limit for TDS of 350 mg/L. Assuming an initial influent flow rate of 5,000 m^3/day, RO treatment would produce a treated effluent flow of 3,750 m^3/day. A bypass flow of 250 m^3/day could be blended in to the RO permeate without reaching the TDS limit, effectively increasing the influent flow to 5,250 m^3/day. RO reject flow, requiring further treatment for volume reduction, would be 1,250 m^3/day.

GE's ultrafiltration/RO systems are available in a range of throughput capacities from 50 to 450 gallons per minute (190 l/min to 1,700 l/min). Two of the largest units would very nearly provide the initial treatment requirement (5,000 m^3/day), if installed in parallel. A break tank and transfer pump would also be required to receive ultrafiltration outflow and provide equalization for RO inflow. The floorspace requirement would be approximately 3,200 square feet (300 m^2) in a 40-ft by 80-ft (12.2-m by 24.4-m) arrangement. The system capacity could be expanded in any flow increment with skid-mounted "stock" units. Capacity expansion increments of 1,700 l/min would require additional floorspace of 150 m^2. Additional specifications and drawings for this equipment are provided as an attachment.

Post-treatment of Secondary Waste

Two secondary waste streams will result from ultrafiltration and RO unit processes. Ultrafiltration will produce a solids-laden filter backwash and RO will produce a contaminant-concentrated brine stream. Both of these streams can be treated for volume reduction by evaporation. The RO brine stream will contribute the majority of flow to the evaporation process.

An evaporative process, capable of initially treating approximately 900 l/min of RO brine will be required to minimize the volume of secondary waste.

Evaporation of RO brine should achieve a volume reduction of approximately 95 percent, resulting in a secondary waste slurry volume of 62.5 m^3/day. Additional volume reduction could be achieved with a crystallizer, if isolation cell volume is inadequate for this volume of waste generation.

ALTERNATIVE TWO – EVAPORATION-BASED TREATMENT

Pretreatment

Bicarbonate must be removed to prevent scale accumulation in the brine concentrator tubes in the form of calcium carbonate. Aquatech's pretreatment stage will include feed water acidification to pH 5.5 with sulphuric acid to convert bicarbonate to dissolved carbon dioxide. Dissolved carbon dioxide will then be removed in the de-aerator. A small amount of anti-scalant will also be added to avoid scaling in the feed/distillate plate heat exchanger.

The feed will be preheated through a plate-and-frame type heat exchanger with feed running counter-current to the evaporator distillate stream. The feed stream then flows to the deaerator for removal of

oxygen and dissolved carbon dioxide. A flashing deaerator is utilized with spray feed into a pressurized chamber, heated with evaporator vent vapour followed by a low pressure chamber in which the carbon dioxide and oxygen flash out of solution.

Evaporative Treatment

The pretreated feed flows to a brine concentrator vessel. The brine concentrator is a seeded slurry vessel, with calcium sulphate solids homogenously dispersed in the slurry. The solids in suspension provide surface area for additional crystal growth while ensuring that the calcium sulphate does not form a hard scale on the heat transfer surface. Seed crystals are added as gypsum to the seed makeup tank at startup to establish the circulating slurry. As the brine is concentrated and transferred to the crystallizer, seed crystals are replenished by generation from calcium and sulphate ions in the feed water. Calcium chloride can be added if the feed concentration of calcium is too low to maintain the seeded slurry.

The overhead product from the brine concentrator next contacts a vapour separator with mist eliminators to remove entrained droplets of brine from the pure vapour stream before it flows to the compressor. Mist eliminators are periodically sprayed with hot distillate to dissolve any accumulated solids.

Vapour generated in the brine concentrator flows to a mechanical compressor which increases its saturation temperature and pressure. From the compressor the vapour flows to the feed pre-heat heat exchanger as described above. The pressurized vapour condenses in the heat exchanger, giving up its heat to the feed stream and condensate is pumped out of the system. The condensate is the “treated effluent”, ready for blending and discharge. (Similar to the discussion of RO bypass and blending above, the highly purified condensate stream may be blended with untreated water and still meet the effluent target for TDS concentration of 350 mg/l).

The evaporator brine is concentrated to approximately 25 percent solids. Brine is continuously removed as feed water enters to maintain the brine in the concentrator. Removed brine flows to the forced circulation crystallizer.

Post-treatment

Brine is pumped to a forced circulation heat exchanger where it is heated with steam from the brine concentrator to a temperature higher than its normal boiling point. Boiling is suppressed by the static head pressure in the unit. The superheated brine then passes to a flash tank operating at a slightly lower pressure resulting in flash evaporation of water and formation of salt crystals in the brine. High recirculation rates are used to minimize the contact time on the heat transfer surface, again to avoid scale formation.

Slurry is discharged from the crystallizer batchwise to a filter press feed tank. The slurry is fed to the belt filter press which removes salt-saturated liquid, and produces a “cake” of salt crystals. The salt-saturated liquid is returned to the forced circulation crystallizer.

Vendor flow sheets depicting the two treatment alternatives are provided in Attachment 3.

ALTERNATIVES TECHNICAL EVALUATION

Technical factors for evaluation of the two treatment alternatives include the following:

- Capacity expansion – the initial treatment system for evaluation must be capable of treating 5,000 m3/day, with increasing capacity to 10,000 m3/day, 20,000 m3/day, or 30,000 m3/day over the 20-year life of the mine. Technical issues associated with adding treatment capacity are evaluated.

- Flexibility – the treatment system must have flexibility to treat a range of flow rates that will vary with mining and grouting activities. The known water quality also shows a range of concentrations of individual constituents as well as TDS. Current data shows a minimum TDS value of about 600 mg/l and a maximum of about 5,000 mg/l. The treatment system must produce a license-compliant treated effluent regardless of changes in the influent water quality.

- Secondary waste generation – both the quantity and the physical form are evaluated. Brine slurry wastes will be much more costly to dispose due primarily to volume when compared with wastes in solid form. Removing secondary wastes from the site for disposal can only be accomplished during winter road operations. Both liquid and solid form wastes could require development of waste isolation cells to prevent mobilization and migration of contaminants into either ground water or surface water. The viability of incorporating secondary waste into paste backfill for placement in the mine is unknown at this time.

Technical evaluation of Alternative 1 – RO based treatment.

Capacity expansion. The RO treatment process can be expanded for increased treatment capacity by adding new banks of RO units in parallel to the base treatment system. RO units can be stacked and would not necessarily require continuous expansion of the treatment facility footprint through the life of the project. An initially oversized building could be provided as a long-term cost benefit. GE's maximum sized RO unit is 450 gallons per minute (approximately 2,450 m^3/day). The initial requirement to treat 5,000 m^3/day could be met through installation of two units, followed by addition of two units to reach a capacity of 10,000 m^3/day. The 20,000 m^3/day capacity would require addition of four units, and finally reaching 30,000 m^3/day would require addition of four units for a total of twelve to reach the full capacity. The initial footprint of a three-unit system including feed tanks, pumps, and cleaning skid would be approximately 140 square meters. Assuming no economy of floor space design during expansion, the final treatment system would have a footprint of approximately 600 square meters.

RO units can be added to a treatment system with a relatively short lead time of approximately 3 to 4 months. RO units of "standard design" can be relatively quickly fabricated upon order. Use of a vendor's standard unit presents some capacity expansion advantage to RO. In fact, assuming that long-term storage space is available, the units required for capacity expansion could be ordered and delivered to storage as early as economically advantageous in the life of the mine. Units could be brought out of storage and installed into the treatment system as needed. Advanced procurement for future expansion could also be unnecessarily costly if mine dewatering flow rates over time do not require increased treatment capacity.

As noted in the process alternative description, the secondary waste treatment step (evaporation) would initially be sized for an RO reject stream of 900 liters per minute. Expansions over the life of the mine would likely require the evaporator capacity to increase to 1,800 liters per minute, 3,600 liters per minute and finally 5,400 liters per minute if the system must be expanded to treat 20,000 m^3/day or 30,000 m^3/day.

Flexibility. RO operates optimally when there is little change in influent flow rate and water quality characterization. An RO-based treatment system could require a relatively large equalization basin to ensure that influent flow and quality are consistent and the treated effluent can continually meet the discharge requirements. RO treatment efficiency can also vary based on influent quality with permeate recovery varying from 50 to 80 percent. While the permeate would still be of "high quality" the reject stream volume could increase by a factor of 2.5, which would carry through the secondary waste treatment process. Flow equalization or oversizing the secondary treatment unit could be required.

Secondary waste. RO will produce a brine stream that is assumed to be 20 percent of the influent flow, and at worst 50 percent of the influent flow. RO brine must be further volume-reduced for process viability. The RO brine evaporator should provide an additional volume reduction on the RO brine stream of 95 to 99 percent. A final product of brine slurry or crystallized waste in a solid form will require isolated disposal if kept on site. At an RO efficiency of 80 percent and a secondary evaporator efficiency of 95 percent, the initial 5,000 m3/day treatment system will produce 50 m^3/day or approximately 18,250 m^3/year. Evaporator bottoms produced over the 20-year life of the mine could reach a total volume of almost 1.6-million cubic meters if mine dewatering flows increase to 30,000 m3/day. Annual production of RO brine and evaporator concentrate are shown in Table 3. Onsite disposal is assumed, if adequate volume of isolated storage can be developed.

Table 3. Projection of Alternative 1 RO-based treatment system treated effluent and waste generation over the life of the mine, assuming maximum capacity expansion to 30,000 $m^{3/}$day.

Year	Daily flow	Annual flow	Treated effluent discharged	Secondary waste (RO reject)	Final waste (evaporator bottoms)
1	5,000	1,825,000	1,460,000	365,000	18,250
2	7,083	2,585,417	2,068,333	517,083	25,854
3	9,167	3,345,833	2,676,667	669,167	33,458
4	11,250	4,106,250	3,285,000	821,250	41,063
5	13,333	4,866,667	3,893,333	973,333	48,667
6	15,417	5,627,083	4,501,667	1,125,417	56,271
7	17,500	6,387,500	5,110,000	1,277,500	63,875
8	19,583	7,147,917	5,718,333	1,429,583	71,479
9	21,667	7,908,333	6,326,667	1,581,667	79,083
10	23,750	8,668,750	6,935,000	1,733,750	86,688
11	25,833	9,429,167	7,543,333	1,885,833	94,292
12	27,917	10,189,583	8,151,667	2,037,917	101,896
13	30,000	10,950,000	8,760,000	2,190,000	109,500
14	30,000	10,950,000	8,760,000	2,190,000	109,500
15	30,000	10,950,000	8,760,000	2,190,000	109,500
16	30,000	10,950,000	8,760,000	2,190,000	109,500
17	30,000	10,950,000	8,760,000	2,190,000	109,500
18	30,000	10,950,000	8,760,000	2,190,000	109,500
19	30,000	10,950,000	8,760,000	2,190,000	109,500
20	30,000	10,950,000	8,760,000	2,190,000	109,500
Total		159,687,500	127,750,000	31,937,500	1,596,875

All values in Table 3 are reported as cubic meters. An 80% RO efficiency is assumed. The secondary waste is treated by evaporation and assumes a 95% volume reduction from the RO brine secondary waste stream to the evaporator bottoms as the final waste product. RO and evaporator efficiencies are based on vendor data provided by Aquatech.

Note that the waste volume estimates as presented in Table 3 is a "worst case" projection based on the maximum capacity expansion case. In the smaller expansion scenarios, the 20-yr totals are presented in Table 4.

Table 4. 20-year projected total flows and wastes for 10,000 m^3/day and 20,000 m^3/day expansions of RO-based treatment alternative.

Expansion flow rate	20-year flow	Treated effluent discharged	Secondary waste (RO reject)	Final waste (evaporator bottoms)
5,000 to 10,000 m^3/day	61,137,500 m^3	48,910,000 m^3	12,227,500 m^3	611,375 m^3
5,000 to 20,000 m^3/day	110,412,500 m^3	88,330,000 m^3	22,082,500 m^3	1,104,125 m^3

Secondary waste may also be used in paste backfill production. The characteristics of the secondary waste cannot be predicted at this time and their suitability for incorporation into paste is unknown. If later work is performed to demonstrate the compatibility of the secondary waste with paste, this would be the preferred method for final disposition.

The potential for development of a deep disposal well is also a possibility. A high capacity deep well could reduce the need for secondary treatment of RO brine. Under the scope of this study, deep well disposal is not evaluated, but would also likely be a preferred option over development of isolation cells for surface disposal over the 20-year life of the mine.

Technical evaluation of Alternative 2 – Evaporator based treatment.

Capacity expansion. The evaporation based system can be expanded by adding parallel units when needed. Evaporation equipment must be run at or close to its design capacity. It has little tolerance for "turn down". The footprint of the initial system will be approximately _____ square meters (10k, 20k, 30k), with footprint expanding in proportion to each throughput step increase (i.e., doubling the footprint to double the flow rate). Some ancillary tankage and equipment could initially be provided as "oversized" but the main processing units of the evaporative system would have to be added in parallel, and almost immediately put into full-flow service.

Evaporation equipment generally has a much longer delivery lead time than RO units. Evaporators may take up to a year to fabricate and deliver, with additional onsite installation time before becoming operational. Capacity expansion will be at least logistically more difficult with evaporators than RO units. With the extreme remoteness of the site, a relatively short schedule slip in evaporator fabrication could result in delivery being delayed by a full year if winter road shipment is required.

Flexibility. Evaporation provides more flexibility in operation that RO for influent water quality characteristics. The influent water quality characteristics do not need to be consistent for efficient operation of an evaporator. Variations in TDS concentrations or the concentrations of individual dissolved species have little effect on the efficiency of evaporator operations.

The influent flow rate must be kept at or close to the full capacity of the evaporator. The evaporator cannot be effectively operated at a "turned down" rate. Given sufficient equalization storage an evaporator based system could be operated semi-continuously to effectively control the throughput rate.

Secondary waste. The secondary waste issues for an evaporator based treatment system are the same as discussed above for the RO based system. An evaporator system may be able to achieve a volume reduction in excess of 99 percent, creating a small waste stream of highly concentrated slurry or crystalline waste. Aquatech's equipment description estimates a 99.8% volume reduction in the evaporator-based treatment system including a brine concentrator followed by a forced circulation concentrator. At this rate the initial 5,000 m^3/day system would produce a secondary waste stream of less than 10 m^3/day. Table 5 shows the accumulation rate for evaporator waste over the 20-year life of the project.

Table 5. Projection of Alternative 2 Evaporation-based treatment system treated effluent and waste generation over the life of the mine, assuming maximum capacity expansion to 30,000 $m^{3/}$day.

Year	Daily flow	Annual flow	Treated effluent discharged	Final waste (Evaporator bottoms)
1	5,000	1,825,000	1,821,350	3,650
2	7,083	2,585,417	2,580,246	5,171
3	9,167	3,345,833	3,339,142	6,692
4	11,250	4,106,250	4,098,038	8,213
5	13,333	4,866,667	4,856,933	9,733
6	15,417	5,627,083	5,615,829	11,254
7	17,500	6,387,500	6,374,725	12,775
8	19,583	7,147,917	7,133,621	14,296
9	21,667	7,908,333	7,892,517	15,817
10	23,750	8,668,750	8,651,413	17,338
11	25,833	9,429,167	9,410,308	18,858
12	27,917	10,189,583	10,169,204	20,379
13	30,000	10,950,000	10,928,100	21,900
14	30,000	10,950,000	10,928,100	21,900
15	30,000	10,950,000	10,928,100	21,900
16	30,000	10,950,000	10,928,100	21,900
17	30,000	10,950,000	10,928,100	21,900
18	30,000	10,950,000	10,928,100	21,900
19	30,000	10,950,000	10,928,100	21,900
20	30,000	10,950,000	10,928,100	21,900
Total		159,687,500	159,368,125	319,375

All values in Table 5 are reported as cubic meters. A 99.8 percent evaporation efficiency is assumed, based on vendor data provided by Aquatech.

Note that the waste volume estimates as presented in Table 5 is a "worst case" projection based on the maximum capacity expansion case. In the smaller expansion scenarios, the 20-yr totals are presented in Table 6.

Table 6. 20-year projected total flows and wastes for 10,000 m^3/day and 20,000 m^3/day expansions of evaporator-based treatment alternative.

Expansion flow rate	20-year flow	Treated effluent discharged	Final waste (evaporator bottoms)
5,000 to 10,000 m^3/day	61,137,500 m^3	61,015,225 m^3	122,275 m^3
5,000 to 20,000 m^3/day	110,412,500 m^3	110,191,675 m^3	220,825 m^3

Similar to the onsite disposal options for the RO-based system, the evaporator waste product will require isolated storage, or could potentially be incorporated into paste backfill, or disposed by deep well injection. Based on the vendor's estimated efficiency of volume reduction for evaporation, the injection capacity of a deep well for evaporation waste disposal could be considerably less than for the RO-based system. It is important to note that over the life of the mine, the flow rate and secondary waste generation rate could increase by a factor of six. The initial feasibility of deep well disposal also needs to take into account the future waste flows.

Technical Evaluation Summary

Capacity Expansion. The RO-based system presents advantages over the Evaporation-based system for the factors of capacity expansion as it can be increased in a wide range of incremental modules. Assuming that adequate pretreatment and post treat capacity is initially installed, relatively small annual increases in capacity are possible with the RO system that are not possible with the evaporation system. RO units also present advantage in ordering/delivery lead times and installation time on site prior to being put into operation.

Flexibility. The Evaporation-based system presents an advantage over RO in flexibility of operation, with regard to influent water quality characterization. The evaporator will run equally as effectively over a broad range of influent characterizations, while the RO unit is considerably less tolerant of changing influent quality. RO efficiency could drop considerably, or operational problems (membrane fouling) could develop due to changes in influent quality. Assuming that the influent equalization basin is of sufficient size to equalize fluctuations in both flow and contaminant concentrations, the potential for changes in water quality are minor and do not present a significant disadvantage for RO operation.

RO provides some level of flexibility in changes to flow rate, in that the RO system would utilize a number of units in parallel operation which could be used in any combination to match incoming flow. The evaporator must be operated at its rated capacity. While storing influent for evaporator campaigns could be done, the evaporator operation will be more efficient if continuous rather than batchwise (with start-ups and shutdowns).

Secondary Waste. The Evaporation-based system presents a significant advantage in consideration of generation of secondary waste. The achievable volume reduction through evaporation as estimated by Aquatech is 99.8 percent. RO efficiency is estimated at 80 percent, with an additional volume reduction of 95 percent when RO brine is evaporated. The overall volume reduction of the RO-Evaporation system is 99 percent. Over the life of the project the five-fold difference in waste generation amounts to the need for disposal of an additional 1,277,500 cubic meters of waste. While the wastes ultimately have similar disposal options and requirements (isolated waste cells, deep well disposal, or incorporation into paste backfill) the considerable difference in volume presents a significant advantage for evaporation operation.

Technical Recommendation

Based on the technical evaluation factors, the Alternative 1, RO-based system is recommended. While producing a much larger volume of waste for disposal, all other factors favour the RO-based system. And if the efficiency of the RO-based system's secondary waste evaporator could be increased from 95 percent to 99 percent, the final waste volume would be equal for both alternatives. The smaller secondary waste evaporator system would also be easier to expand throughout the life of the mine, when compare to the full-scale evaporative system to treat the entire flow.

EVALUATION OF ORDER-OF-MAGNITUDE CAPITAL AND OPERATING ESTIMATES

Capital cost estimates were obtained for the RO-based treatment system and the Evaporation based treatment systems at their initial operating capacity. Estimates were obtained as follows:

- GE Infrastructure Water & Process Technologies (GE), for an ultrafiltration pretreatment, RO treatment system at 5,000 m^3/day. Note that this system did not include equipment for secondary waste volume reduction,

- Aquatech International Corporation (Aquatech), for brine concentrator/forced circulation crystallizer system at 3,000 m^3/day;

- Aquatech for an RO/brine concentrator system at 3,000 m^3/day.

The Aquatech and GE estimates are not directly comparable due to the difference in quoted flow rates and the "completeness" of the estimates. GE did not directly estimate the secondary waste components, but only their main process units (ultrafiltration for pretreatment followed by RO units). Aquatech estimated complete treatment systems but at a lower flow rate than requested. The Aquatech estimates can be scaled in proportion to the necessary increase in flow for comparison purposes.

Another estimate was obtained from Siemens for the fully expanded system capacity of 30,000 m^3/day. Siemens proposal provided for chemical precipitation which is a chemical reagent- and equipment-intensive process. Included in Siemens estimate were clarifiers, filters, RO units, and sludge management equipment including storage tanks and belt filter presses. Chemical reagents required included sodium hypochlorite, coagulant and polymer as flocculation aids, lime and soda ash, and hydrochloric acid for pH adjustment. While the chemical precipitation process was deemed infeasible in the technology screening phase, Siemens estimate is provided as an order-of-magnitude for the fully expanded operational capacity. The budgetary proposal for the Siemens system is USD $28,500,000. This budgetary estimate is inclusive of all required equipment but does not include construction and installation costs. The Siemens proposal, although not used in the cost evaluation, is provided with the other estimates in the attachments.

The primary source of cost data are the Aquatech estimates for both the RO-based and Evaporator-based alternatives. Use of the GE or Siemens estimates would require additional assumptions to be made, while the two estimates from Aquatech are directly comparable as received.

CAPITAL COST COMPARISON

The best direct comparison of capital cost estimates is the two estimates provided by Aquatech, as the basis and equipment supply scope is exactly the same for both. Again as noted above these estimates were for a system capacity of 3,000 m^3/day. In order to scale to the initial baseline capacity of 5,000 m^3/day the "six-tenths rule" (ref. *Chemical Engineers' Handbook, Perry and Chilton, 5th ed., McGraw-Hill*.) is used. The six-tenths rule is expressed as follows:

$$C_n = r^{0.6}C$$

Where C_n is the new plant cost, C is the previous plant cost and r is the ratio of new to previous capacity. Aquatech's estimate for Alternative 1 RO-based treatment for a 3,000 m^3/day system is USD $7,700,000. Scaling to 5,000 m^3/day gives a resulting estimate of $10,460,000.

Aquatech's estimate for Alternative 2 Evaporator-based treatment for a 3,000 m^3/day system is USD $9,500,000. Scaling to 5,000 m^3/day gives a resulting estimate of $12,907,000.

These estimates are for process equipment capital cost only. Associated site work is not included. Additional work is estimated as percentages of total installed cost by the following guidelines:

Table 7. Constructed cost estimation guidelines.

Item	% of Total Constructed Cost
Process equipment	40%
Concrete substructures	4%
Electrical	3%
Insulation	3%
Process structural	7%
Process material labor	10%
Home office engineering	8%
Field expenses	25%
Total	100%

Reference: *Chemical Engineers' Handbook, Perry & Chilton, Fifth Edition, McGraw-Hill.*

Utilizing the scaled estimates for process equipment and the factors for estimation of other associated costs, the capital cost estimates for Alternatives 1 and 2 are as follows:

Table 8. Initial Capital Cost Estimates for RO-based and Evaporator-based Treatment.

Item	Alternative 1 RO-based	Alternative 2 Evaporation-based
Process equipment	$10,460,000	$12,907,000
Concrete substructures	1,046,000	1,290,700
Electrical	784,500	968,000
Insulation	784.500	968,000
Process structural	1,830,500	2,258,700
Process material labor	2,615,000	3,226,700
Home office engineering	2,092,000	2,581,400
Field expenses	6,537,500	8,067,000
Total installed capital estimate	**$26,150,000**	**$32,267,500**

While site-specific item estimates could vary from the comparison provided above, it is assumed that any changes would equally affect both alternatives, and would not change the "ranking" of capital cost estimates. Alternative 1 presents a 20 percent advantage in initial capital cost estimate.

OPERATIONS COSTS

Operations costs include operations labor, supervision, maintenance support, chemical reagents, utilities and waste disposal. The two alternatives will have similar labor, supervision and maintenance requirements. Significant differences in operations cost estimates will arise in utilities (electrical power) and waste disposal.

UTILITIES COST ESTIMATION

Initial utilities cost estimate for the RO-based system. Aquatech's estimates for the two systems includes estimates of total power consumption. The RO-based system power consumption is estimated at 2,500 kilowatts (kW). Assuming continuous operations this treatment alternative will consume 21,900,000 kW-hours over the course of a year. Based on information provided by De Beers, the cost of electricity at the mine is $0.264 per kW-hr. The annual cost estimate for power to supply the RO-based treatment system is $5,782,000. Note that when the power cost estimate was obtained, a diesel fuel cost was also provided. Diesel fuel at the time (December, 2007) was quoted at "$1.00 per liter with a $0.85 per liter off the rack fee and $0.15 freight and surtax". All electrical power at the mine is provided by diesel-fueled generators. If the diesel fuel price has increased since the previous estimate, then the estimated cost of an "onsite kW-hr" should also be increased.

Diesel fuel storage for annual operation of the RO-based treatment system is estimated at 1,932,000 liters. If excess storage capacity is not available on site, new storage capacity will have to be installed to support operation of the proposed wastewater treatment plant.

Initial utilities cost estimate for the Evaporator-based system. Aquatech estimates total power consumption for the brine concentrator / forced circulation crystallizer treatment system at 5,800 kW. Again, under continuous operation this treatment system will consume 51,100,000 kW-hrs per year. The annual cost estimate for power to the supply the evaporator-based treatment system is $13,491,000. Diesel fuel storage required (available or new) is estimated at 4,507,000 liters.

Projected Utilities Cost Estimates. Utilities costs will increase in proportion to water treatment capacity expansion. For the purpose of waste volume estimation, a "straight-line" increase in water treatment capacity was assumed through the first thirteen years of mine operation, from initial capacity at 5,000 m^3/day to a maximum capacity of 30,000 m^3/day. Capacity for years 13 through 20 remain at the maximum value. A similar approach to power cost estimation over the life of the mine yields the following:

Table 9. Projected 20-year Utilities Annual and Total Cost Estimates for RO-based and Evaporator-based Treatment at 30,000 m3/day

			Alternative 1 RO-based Treatment		Alternative 2 Evaporator-based Treatment	
Year	**Daily flow (m^3)**	**Annual flow (m^3)**	**Annual power (kw-hr)**	**Power cost ($)**	**Annual power (kw-hr)**	**Power cost ($)**
1	5,000	1,825,000	21,900,000	5,781,600	50,808,000	13,413,000
2	7,083	2,585,417	31,025,000	8,190,600	71,978,000	19,002,000
3	9,167	3,345,833	40,150,000	10,599,600	93,148,000	24,591,000
4	11,250	4,106,250	49,275,000	13,008,600	114,318,000	30,180,000
5	13,333	4,866,667	58,400,000	15,417,600	135,488,000	35,769,000
6	15,417	5,627,083	67,525,000	17,826,600	156,658,000	41,358,000
7	17,500	6,387,500	76,650,000	20,235,600	177,828,000	46,947,000
8	19,583	7,147,917	85,775,000	22,644,600	198,998,000	52,535,000
9	21,667	7,908,333	94,900,000	25,053,600	220,168,000	58,124,000
10	23,750	8,668,750	104,025,000	27,462,600	241,338,000	63,713,000
11	25,833	9,429,167	113,150,000	29,871,600	262,508,000	69,302,000
12	27,917	10,189,583	122,275,000	32,280,600	283,678,000	74,891,000
13	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
14	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
15	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
16	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
17	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
18	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
19	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
20	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
Total		**159,687,500**	**1,916,250,000**	**$ 505,890,000**	**4,445,700,000**	**$1,173,665,000**

As shown in the table above, over the 20-year life of the mine, the power cost estimated for operating an RO-based system is less than half the power cost estimated for the evaporator-based system and amounts to an estimated difference of $667,775,000.

The 20-year total comparison of power consumption and cost for the capacity expansions to 10,000 m^3/day and 20,000 m^3/day are shown below.

Table 10. 20-year projected total power consumption and cost for 10,000 m^3/day and 20,000 m^3/day expansions of RO-based and Evaporator-based treatment alternatives.

		Alternative 1 RO-based Treatment		Alternative 2 Evaporator-based Treatment	
Capacity expansion	**Total flow (m^3)**	**Annual power (kw-hr)**	**Power cost ($)**	**Annual power (kw-hr)**	**Power cost ($)**
5,000 to 10,000 m^3/day	159,687,500	733,650,000	$ 193,683,600	1,702,068,000	$ 449,349,000
5,000 to 20,000 m^3/day	159,687,500	1,324,950,000	$ 349,786,800	3,073,884,000	$ 811,504,000

WASTE DISPOSAL COST ESTIMATION

As described above in the alternatives evaluation of technical factors, there are a variety of waste disposal options including isolation cells, incorporation of waste into paste backfill, or deep well injection. Both alternative waste forms (RO brine, or evaporator bottoms) would require isolation if disposed in the North Pile. Both wastes forms are expected to have similar compatibility if incorporated into paste backfill. And both waste forms could be deep well injected if the site geology and hydrogeology allows for this alternative. The primary difference in waste that will affect the operations cost estimate for disposal is the volume of waste produced. As noted in Tables 3 and 4 above, the RO-based treatment system is estimated to produce a volume of 1,596,875 cubic meters over the 20-year life of the mine. The evaporator-based treatment alternative is estimated to produce 319,375 cubic meters over the 20-year life of the mine.

Since all three disposal options are possible for the two waste forms, the cost differential that can be estimated is based on waste volume only. The evaporator-based system is estimated to produce only 20 percent of the waste volume when compared with the RO-based system. Without an estimated unit cost for disposal, the cost estimation comparison is limited to the relative volumes of waste produced, with the clear advantage to the Evaporator-based system.

The waste disposal savings realized by the evaporator-based system would have to be greater than the power consumption cost difference described above, in order for the evaporator-based system to show an estimated operations cost advantage over the RO-based system. The power cost disparity is estimated at $667,775,000 over the 20-year life of the mine. The evaporator waste volume is estimated at 1,277,500 cubic meters less than the RO waste. Dividing the power cost differential by the waste volume differential results in the cost per cubic meter of waste disposed to reach a “break even” point between the operating cost estimates for the two alternatives. The “break even” unit cost for waste disposal is

approximately $520 per cubic meter. This unit cost estimate is approximately double the unit cost for disposal of "hazardous waste" in a specialized landfill.

Onsite disposal, as an internal cost should be less than the threshold value of $520 per cubic meter. Without additional data, it is assumed that the RO-based system is preferred over the Evaporator-based system based on evaluation of utilities and waste disposal costs. Key to this evaluation is the assumption that adequate disposal space is available onsite for the wastes generated by either treatment alternative.

20-YEAR CAPITAL AND OPERATING COST ESTIMATES

Cost analysis for operations and capital improvements (capacity expansions) have also been performed as described below.

Capacity expansion under three scenarios has been considered:

- Increasing capacity from 5,000 to 10,000 m^3/day;
- From 5,000 to 20,000 m^3/day; and
- From 5,000 to 30,000 m^3/day.

"Straight-line" increases to the maximum values are assumed through year 13, then continuing operation at the maximum value is assumed through year 20. As discussed in the evaluation of technical factors, RO units can be added incrementally year-by-year, while evaporation capacity is somewhat more difficult to increase. Excess evaporation capacity will have to be provided by installation of parallel units, with one unit running continuously at full capacity, with the second unit run in campaign fashion until the influent flow requires both units in full operation.

ALTERNATIVE 1 - RO-BASED TREATMENT SYSTEM 20-YEAR COST ESTIMATE

Capital equipment purchases for the RO-based system, combined with operating costs (utilities only) are estimated in constant dollars as follows:

Table 11. Estimated capital and operating costs (constant dollars) for RO-based plant capacity expansions to maximum flow of 10,000 m^3/day.

Year	Daily flow (m^3)	Estimated Capital Cost for Expansion	Operations Cost Estimate (Utilities)	Total Annual Estimated Cost
1	5,000	26,150,000	5,781,600	31,931,600
2	5,417		6,263,400	6,263,400
3	5,833	5,970,000	6,745,200	12,715,200
4	6,250		7,227,000	7,227,000
5	6,667	5,970,000	7,708,800	13,678,800
6	7,083		8,190,600	8,190,600
7	7,500		8,672,400	8,672,400
8	7,917	5,970,000	9,154,200	15,124,200
9	8,333		9,636,000	9,636,000
10	8,750	5,970,000	10,117,800	16,087,800
11	9,167		10,599,600	10,599,600
12	9,583	5,970,000	11,081,400	17,051,400
13	10,000		11,563,200	11,563,200
14	10,000		11,563,200	11,563,200
15	10,000		11,563,200	11,563,200
16	10,000		11,563,200	11,563,200
17	10,000		11,563,200	11,563,200
18	10,000		11,563,200	11,563,200
19	10,000		11,563,200	11,563,200
20	10,000		11,563,200	11,563,200
Total		**$ 56,000,000**	**$ 193,683,600**	**$ 249,683,600**

For the capacity expansion from 5,000 to 10,000 m^3/day as shown in Table 11, expansions in 1,000 m3/day increments are assumed, and scaled from the equipment cost for the initial 5,000 m3/day facility. It is also assumed that out-year infrastructure improvements can be made at a cost of 1.5 times the equipment cost. Expansions are made in out-years to ensure that the facility is always slightly larger than the daily required flow.

Table 12. Estimated capital and operating costs (constant dollars) for RO-based plant capacity expansions to maximum flow of 20,000 m^3/day.

Year	Daily flow (m^3)	Estimated Capital Cost for Expansion	Operations Cost Estimate (Utilities)	Total Annual Estimated Cost
1	5,000	26,150,000	5,781,600	31,931,600
2	6,250		7,227,000	7,227,000
3	7,500	10,350,000	8,672,400	19,022,400
4	8,750		10,117,800	10,117,800
5	10,000	10,350,000	11,563,200	21,913,200
6	11,250		13,008,600	13,008,600
7	12,500	10,350,000	14,454,000	24,804,000
8	13,750		15,899,400	15,899,400
9	15,000	10,350,000	17,344,800	27,694,800
10	16,250		18,790,200	18,790,200
11	17,500	10,350,000	20,235,600	30,585,600
12	18,750		21,681,000	21,681,000
13	20,000	10,350,000	23,126,400	33,476,400
14	20,000		23,126,400	23,126,400
15	20,000		23,126,400	23,126,400
16	20,000		23,126,400	23,126,400
17	20,000		23,126,400	23,126,400
18	20,000		23,126,400	23,126,400
19	20,000		23,126,400	23,126,400
20	20,000		23,126,400	23,126,400
Total		**$ 88,250,000**	**$ 349,786,800**	**$ 438,036,800**

For the capacity expansion from 5,000 to 20,000 m^3/day as shown in Table 12, expansions in 2,500 m^3/day increments are assumed, and scaled from the equipment cost for the initial 5,000 m^3/day facility. It is also assumed that out-year infrastructure improvements can be made at a cost of 1.5 times the equipment cost. Expansions are made in out-years to ensure that the facility is always equal to or slightly larger than the daily required flow.

Table 13. Estimated capital and operating costs (constant dollars) for RO-based plant capacity expansions to maximum flow of 30,000 m^3/day.

Year	Daily flow (m^3)	Estimated Capital Cost for Expansion	Operations Cost Estimate (Utilities)	Total Annual Estimated Cost
1	5,000	26,150,000	5,781,600	31,931,600
2	7,083	15,690,000	8,190,600	23,880,600
3	9,167	15,690,000	10,599,600	26,289,600
4	11,250		13,008,600	13,008,600
5	13,333	15,690,000	15,417,600	31,107,600
6	15,417		17,826,600	17,826,600
7	17,500		20,235,600	20,235,600
8	19,583	15,690,000	22,644,600	38,334,600
9	21,667		25,053,600	25,053,600
10	23,750	15,690,000	27,462,600	43,152,600
11	25,833		29,871,600	29,871,600
12	27,917		32,280,600	32,280,600
13	30,000		34,689,600	34,689,600
14	30,000		34,689,600	34,689,600
15	30,000		34,689,600	34,689,600
16	30,000		34,689,600	34,689,600
17	30,000		34,689,600	34,689,600
18	30,000		34,689,600	34,689,600
19	30,000		34,689,600	34,689,600
20	30,000		34,689,600	34,689,600
Total		**$ 104,600,000**	**$ 505,890,000**	**$ 610,490,000**

For the capacity expansion from 5,000 to 30,000 m^3/day as shown in Table 13, expansions in 5,000 m^3/day increments are assumed, and scaled from the equipment cost for the initial 5,000 m^3/day facility. It is also assumed that out-year infrastructure improvements can be made at a cost of 1.5 times the equipment cost. Expansions are made in out-years to ensure that the facility is always equal to or slightly larger than the daily required flow.

ALTERNATIVE 2 - Evaporator-Based Treatment System 20-Year Cost Estimate

Capital equipment purchases for the Evaporator-based system, combined with operating costs (utilities only) are estimated in constant dollars as follows:

Table 14. Estimated capital and operating costs (constant dollars) for Evaporator-based plant capacity expansions to maximum flow of 10,000 m^3/day.

Year	Daily flow (m^3)	Estimated Capital Cost for Expansion	Operations Cost Estimate (Utilities)	Total Annual Estimated Cost
1	5,000	48,910,000	13,413,000	62,323,000
2	5,417		14,531,000	14,531,000
3	5,833		15,649,000	15,649,000
4	6,250		16,767,000	16,767,000
5	6,667		17,884,000	17,884,000
6	7,083		19,002,000	19,002,000
7	7,500		20,120,000	20,120,000
8	7,917		21,238,000	21,238,000
9	8,333		22,356,000	22,356,000
10	8,750		23,473,000	23,473,000
11	9,167		24,591,000	24,591,000
12	9,583		25,709,000	25,709,000
13	10,000		26,827,000	26,827,000
14	10,000		26,827,000	26,827,000
15	10,000		26,827,000	26,827,000
16	10,000		26,827,000	26,827,000
17	10,000		26,827,000	26,827,000
18	10,000		26,827,000	26,827,000
19	10,000		26,827,000	26,827,000
20	10,000		26,827,000	26,827,000
Total		**$ 48,910,000**	**$ 449,349,000**	**$ 498,259,000**

For the capacity expansion from 5,000 to 10,000 m^3/day as shown in Table 14, an initial installation of 10,000 m3/day capacity is assumed. Excess treatment capacity would be utilized batchwise campaigns to meet the annual flow requirements. No out-year expansions would be necessary.

Table 15. Estimated capital and operating costs (constant dollars) for Evaporator-based plant capacity expansions to maximum flow of 20,000 m^3/day.

Year	Daily flow (m^3)	Estimated Capital Cost for Expansion	Operations Cost Estimate (Utilities)	Total Annual Estimated Cost
1	5,000	48,910,000	13,413,000	62,323,000
2	6,250		16,767,000	16,767,000
3	7,500		20,120,000	20,120,000
4	8,750		23,473,000	23,473,000
5	10,000	19,360,000	26,827,000	46,187,000
6	11,250		30,180,000	30,180,000
7	12,500		33,533,000	33,533,000
8	13,750		36,887,000	36,887,000
9	15,000	19,360,000	40,240,000	59,600,000
10	16,250		43,593,000	43,593,000
11	17,500		46,947,000	46,947,000
12	18,750		50,300,000	50,300,000
13	20,000		53,653,000	53,653,000
14	20,000		53,653,000	53,653,000
15	20,000		53,653,000	53,653,000
16	20,000		53,653,000	53,653,000
17	20,000		53,653,000	53,653,000
18	20,000		53,653,000	53,653,000
19	20,000		53,653,000	53,653,000
20	20,000		53,653,000	53,653,000
Total		**$ 87,630,000**	**$ 811,504,000**	**$ 899,134,000**

For the capacity expansion from 5,000 to 20,000 m^3/day as shown in Table 15, an initial installation of 10,000 m^3/day capacity is assumed followed by expansions in 5,000 m^3/day increments. Excess treatment capacity would be utilized batchwise campaigns to meet the annual flow requirements. It is also assumed that out-year infrastructure improvements can be made at a cost of 1.5 times the equipment cost. Expansions are made in out-years to ensure that the facility is always equal to or greater than the daily required flow.

Table 16. Estimated capital and operating costs (constant dollars) for Evaporator-based plant capacity expansions to maximum flow of 30,000 m^3/day.

Year	Daily flow (m^3)	Estimated Capital Cost for Expansion	Operations Cost Estimate (Utilities)	Total Annual Estimated Cost
1	5,000	48,910,000	13,413,000	62,323,000
2	7,083		19,002,000	19,002,000
3	9,167		24,591,000	24,591,000
4	11,250	29,350,000	30,180,000	59,530,000
5	13,333		35,769,000	35,769,000
6	15,417		41,358,000	41,358,000
7	17,500		46,947,000	46,947,000
8	19,583	29,350,000	52,535,000	81,885,000
9	21,667		58,124,000	58,124,000
10	23,750		63,713,000	63,713,000
11	25,833		69,302,000	69,302,000
12	27,917		74,891,000	74,891,000
13	30,000		80,480,000	80,480,000
14	30,000		80,480,000	80,480,000
15	30,000		80,480,000	80,480,000
16	30,000		80,480,000	80,480,000
17	30,000		80,480,000	80,480,000
18	30,000		80,480,000	80,480,000
19	30,000		80,480,000	80,480,000
20	30,000		80,480,000	80,480,000
TOTAL		**$ 107,610,000**	**$ 1,173,665,000**	**$ 1,281,275,000**

For the capacity expansion from 5,000 to 30,000 m^3/day as shown in Table 16, an initial installation of 10,000 m3/day capacity is assumed followed by expansions in 10,000 m^3/day increments. Excess treatment capacity would be utilized on a daily, intermittent basis to meet the annual flow requirements. It is also assumed that out-year infrastructure improvements can be made at a cost of 1.5 times the equipment cost. Expansions are made in out-years to ensure that the facility is always equal to or greater than the daily required flow.

CONCLUSIONS AND RECOMMENDATIONS

The technical factors evaluated favor the RO-based system, as do the cost-based evaluation factors. The recommended treatment alternative on the basis of pre-feasibility evaluation factors is the RO-based system with a brine concentrating evaporator for volume reduction of RO reject.

Based on vendor review of design basis influent data, pretreatment for both alternatives may be limited to a relatively simple injection of antiscalant. Pretreatment equipment and costs have not been extensively researched, as they would be insignificant by comparison to the main treatment units.

The primary operating cost factor is power consumption. All other operating costs (labor, supervision, maintenance, and chemical reagents) are considered to be approximately equal for the two alternatives. Since they would weigh in equally on both alternatives, these costs have not been extensively researched.

Waste disposal is considered to be of critical importance due to the extremely remote location of the mine. The evaporation-based treatment alternative is preferred for generation of the smallest possible volume of secondary waste. The final disposition options for both waste streams include isolation cell storage in the North Pile, incorporation into paste backfill, or deep well injection. In the event that a deep well of adequate capacity can be developed, the cost advantage of the RO-based system will be enhanced. If waste must be stored in isolation cells, a "trade-off" analysis between power consumption costs for the smallest possible waste stream versus isolation cell construction and installation costs for a larger waste stream should be performed.

Further evaluation of the suitability of the waste as a paste backfill additive would also play into the cost evaluation for waste disposal.

The RO alternative was developed assuming a permeate generation rate (throughput rate) of 75%. The RO treatment efficiency can be increased to 90% using secondary, higher pressure RO modules for reduction of the reject stream flow rate. Since power requirements are a predominant O&M cost, a trade-off analysis should be conducted comparing the increased capital cost associated with achieving up to a 60% reduction in reject (from 25% down to 10% of the influent flow rate) with the reduced O&M cost associated with the concomitant reduction in power requirement for evaporation of the smaller reject stream.

A "hybrid" of the two alternatives could also be developed, utilizing RO for the primary treatment unit, and a smaller (compared to the full-scale) brine concentrator/crystallizer as a secondary waste treatment unit. While power costs would increase due to the increased level of evaporation intensity, the majority of waste volume reduction would still be achieved by the more economical RO treatment process.

The future quantity of haulage drift water generated by mine dewatering operations is a driving force in the cost and scale of the water treatment facility. The cost of minimizing or controlling the total flow of dewatering flow should be evaluated as a cost/benefit against the cost of increasing treatment capacity.

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ATTACHMENT 1

KICKOFF – SITE VISIT REPORT

ATTACHMENT 1 Kickoff - Site Visit Report

MEMORANDUM

Golder Associates Ltd.
1000, 940 - 6 Avenue SW
Calgary, Alberta, Canada
T2P 3T1

Telephone No.: 403-299-5600
Fax No.: 403-299-5606

DATE: December 7, 2007 Proj No. 07-1334-0052

TO: Rob McLean

FROM: Paul Pigeon

RE: Snap Lake Water Management Project, Site Visit Follow-up and Project Schedule

CC: Pete Lemke, Lasha Young, Ken DeVos, Mark Digel, Dawn Kelly

This memorandum confirms key points of the site visit by Paul Pigeon and Pete Lemke on November 27, 2007, and the project kick-off meeting. Specifically, agreements on project approach and assumptions for the Phase 1 evaluation are listed, and commitments by De Beers and Golder to supply information or results are also identified here. A deliverable-based schedule is provided.

Water Quality & Quantity Characterization

In response to Golder's request for expanded water quality data sets on the haulage drift ground water, De Beers provided scanned copies of laboratory reports from samples collected during 2007, with a sample number key to identify those samples representing the haulage drift water quality. Those samples included only a few with data for parameters other than the major cations and anions that comprise total dissolved solids (TDS). Some more recent analyses are going to be provided by De Beers. Also, Golder has agreed to supply a list of analytes that are significant in the evaluation of water treatment technologies, with additions such as total organic carbon (TOC) and certain metals (iron, aluminum, etc.). That list is attached.

The change in haulage drift water quality that may occur with depth of the workings is not well understood at this point. Golder will initially rely upon its own geochemical knowledge of the Snap Lake water chemistry. We also understand that a 65o boring is being drilled to 300 meters and packed and instrumented to allow water quality sampling from discrete depths, which will contribute to the knowledge base about ground water quality and variations of water quality with depth of the mine workings: Data sets from that effort may be available before Phase 1 work is scheduled to be concluded in January (see below). Golder understands that the completion schedule of Phase 1 might be altered to allow assessment of information from this and other emergent investigations, if it appears that the conclusions and recommendations of Phase 1 would be too tentative without such data.

De Beers has asked Golder to incorporate the effects of grouting on haulage drift water quality and dewatering flow rates. For the monitoring period prior to July 21, 2007, De Beers has identified samples collected during or immediately following grouting of water-bearing fractures in the haulage drift. Golder will extrapolate the limited data set to establish maximum pH, TDS and ionic strength values in the water quality design basis for haulage drift water treatment. We understand that grouting activities also can increase haulage drift flow by about 200 m3/day, with a possible maximum increase of 1000 m3/day if a really large area of fracturing is encountered.

Since the site visit, Golder has identified additional water quality data that are needed for Phase 1. The water quality of the effluent from the existing water treatment plant is of interest, because it will help in gauging the effectiveness of chemical conditioning and media filtration as a pre-treatment process train for haulage drift ground water. Also, Golder would like to see field (instantaneous) temperature readings for the haulage drift sump water and for water influent to the existing water treatment plant. These data should include ore zone temperature as well, since the ore and haulage drift waters are commingled at the WTP. Temperature data will help Golder in estimating resistance to chemical conditioning and potential permeation rates of candidate membrane treatment technologies.

Phase 1 Technical Scope

We had an excellent discussion of a number of items that define the scope of Phase 1.

Alternatives for treatment of haulage drift water will have an effluent target of 350 mg/l TDS, even though higher TDS effluents might be sufficient to control whole lake average TDS levels and avoid exceeding the permit limit by effective water management. This conservative approach will account for higher than expected flows, increases in TDS in the ore zone water and reduced natural inflows to Snap Lake.

The existing surge pond will be evaluated for influent and reject water storage for a haulage drift water management system. Golder needs design drawings for the surge pond in addition to drawings of the industrial area.

Management options for treatment residuals will include incorporation of sludges into tailings. When paste backfilling begins in two years, the sludge could be partially dewatered and incorporated as a flowable material. For reject flows (brines), liquid disposal will not be assumed available. Brine dewatering and crystallization will be needed; disposal in a specially contained section of a tailings disposal area.

Since haulage drift flows have already exceeded 3,000 m3/day on occasion, the initial plant size considered for all three of the requested flow rate scenarios will be 5,000 m3/day.

For estimating when treatment plant additions are needed and for calculation of net present value (NPV) of the alternatives, a project life of 20 years will be assumed. De Beers will provide escalation and discount percentage rates.

Although separate pre-treatment facilities will be provided for the haulage drift water, the existing treatment plant tour was very helpful in identifying facilities that may be compatible for use on the haulage drift water. De Beers will provide additional drawings of the existing plant. As discussed above, Golder would also like to review effluent quality data for the plant. We note that a second phase expansion of the existing plant, which on first review appears to double plant capacity, might be used as a separate pre-treatment facility for the haulage drift water.

Phase 1 Schedule

Golder plans to complete a draft report for Phase 1 by January 18, 2008. To do this, we will have to complete our technology analysis and put out requests for vendor cost quotations on major equipment by December 21, 2008. December 21 is also a good target date for receipt of all the items we are requesting from De Beers.

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ATTACHMENT 2

GOLDER REQUEST FOR ADDITIONAL SAMPLING AND ANALYSES

ATTACHMENT 2 – Golder Request for Additional Sampling and Analyses

Analyte/Analyte Group	Justification for analysis	Comments
Volatile organic compounds (VOCs) and chlorine	Will degrade membranes in a filter application and would be untreated by evaporation (carried over with water vapour).	If presence of VOCs and/or chlorine can be ruled out by "process knowledge" then sampling and analysis will not be necessary. Golder can identify method(s) of analysis if required.
Oil and grease (O&G), hydrogen sulphide (H_2S), surfactants	Will degrade membranes in a filter application.	If presence of O&G, H_2S and/or surfactants can be ruled out by "process knowledge" then sampling and analysis will not be necessary.
Total organic carbon (TOC)	Maximum acceptable concentration for membrane filtration influent is 2 mg/L. Some of the existing data shows TOC at or above this limit.	If higher values for TOC in the existing data are representative of short-term spikes, then no additional sampling and analysis is needed. If TOC levels remain elevated for days or weeks, treatment by membrane filtration will fail. Time-weighted composite samples for future analysis would be preferred.
Barium, Strontium	Barium and strontium salts are of very low solubility and form as a fine powdery solid – fouling filtration membranes, even at low concentrations.	Limited data in historical sampling and analysis records.
Aluminum, Iron, Manganese	Manganese can foul filtration membranes at an influent concentration of 0.5 mg/L by oxidation and precipitation at membrane surfaces. Aluminum can precipitate with pH changes at permeation membrane surfaces, while Iron can foul filtration membranes at influent concentrations of 0.1 to 0.2 mg/l by oxidation and precipitation at membrane surfaces over a wide range of pH.	Limited data in historical sampling and analysis records.
Silica, reactive soluble and colloidal	Limited data in historical sampling and analysis records. Silica will scale membranes. Colloidal fraction determined by laboratory filtration; filter pore size per procedure.	Influent concentration of <10 mg/L is preferred for membrane filtration. Higher concentrations can be handled with addition of anti-scalant. Additional data will allow for determination of whether anti-scalant equipment will be needed.

NOTE: The above list assumes that water treatment will be targeted solely on reduction of TDS; therefore, the need to monitor constituents that may have human health or aquatic toxicity effects is omitted from the determination of analytes.

Sampling Regime

In all cases, it would be preferable to collect volume/flow-weighted or time paced, 24-hour composite samples. The existing data, even for the common ions which have been analyzed frequently, shows a wide range between minimum and maximum observed values. If a very short-term spike in contaminant concentration has been caught by a grab sample, the treatment process may be "over-designed" due to anomalous data. Development of the design basis influent on a nominal (average) basis and design for maximum anticipated spike concentrations will benefit from collection of time-weighted composites, if possible.

As a fallback approach, assuming that De Beers will institute collection of samples at DW 1011 on a twice monthly frequency, grab sampling could be used. In this monitoring approach, the minimum water treatment influent database for establishing a detailed design/equipment procurement basis would be 40 to 50 samples for major constituents and a minimum of 20 samples for the above additional analytes, allowing for use of a statistically-based determination of the maximum influent quality design basis. In so doing, the effect of a single anomalous spike in water quality data (a spike not attributable to a known condition that is expected to repeat itself periodically) can be smoothed out of the data set.

Assumed Existing Routine Analyte List

The above additions are assumed to add to the analyte list Golder sees in a large number of the DW10 and DW11 analytical reports provided by De Beers. That list is as follows:

Routine Water Analysis–Low Level	**Other Analytes**
ICP metals	Acidity
Calcium	Ammonia-as N
Magnesium	Fluoride
Potassium	Nitrate-as N
Sodium	Orthophosphate
Ion Balance	Phosphorus-Total & Total Dissolved
Hardness	Silica-Reactive Soluble
Ion Balance (%)	Selenium

- TDS (calc)

pH, Conductivity, Alkalinity

- Alkalinity (total)
- Bicarbonate
- Carbonate
- Conductivity (EC)
- Hydroxide
- pH

Other Anions

- Chloride
- Nitrite
- Sulphate

TDS

Total Kjeldahl Nitrogen

Total Suspended Solids

Turbidity

ATTACHMENT 3

VENDOR DATA

Aquatech International Corporation
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f) 724 746 5359
www.aquatech.com

April 16, 2008

Peter Lemke
Golder Associates Inc.
44 Union Blvd. Suite 300
Lakewood, CO 80228

Ref.: DeBeers Mine WWT AIC #08-5035

Peter,

Thank you for contacting me in regards to this project. The following is Aquatech's budgetary proposal for the waste water treatment system for the DeBeers Canadian Diamond mine.

This system would be designed to treat a waste stream of 550GPM as described in supplied water analysis. We are offering two options for your review, a membrane system for initial concentration and a thermal based system.
I have considered the existing pretreatment clarifier and multimedia filter will remain in service in conjunction with the proposal systems.

Scope of Supply for 550 gpm Brine Concentrator/Forced Circulation Crystallizer:

Brine Concentrator

1.	One (1) Wastewater Storage Tank with agitation
2.	Two (2)Wastewater Transfer Pump with Feed Strainer
3.	One (1) Feed Tank and Pump Skid
4.	Three (3) Chemical Dosing Skids
5.	One (1) Pre-heater and Deaerator
6.	One (1) Brine Concentrator Vessel
7.	One (1) Vapor Compressor Skid
8.	One (1) Recirculation Pump Skid
9.	One (1) Distillate Tank and Pump Skid

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10.	One (1) Lot of Prefabricated Recirculation Piping and Vapor Ducting
11.	One (1) Lot of On-skid Piping
12.	One (1) Lot of Instrumentation and PLC Based Controls within Battery Limits
13.	One (1) Lot of Structural Steel platforms, access ladders for BC Vessel
14.	One (1) Interconnecting Piping between Skids
15.	One (1) Lot of Electrical Conditioning and MCC by others
16.	One (1) Lot of Power and Instrument Wiring to Skid Junction Boxes by Others

FCC and Filter Press

1.	One (1) Concentrate Tank
2.	Two (2) Concentrate Pumps
3.	One (1) MVC forced circulation evaporation unit
4.	One (1) Heat exchanger
5.	One (1) Flash tank
6.	One (1) Mist eliminator
7.	One (1) Vapour compressor with motor and auxiliaries
8.	One (1) Distillate receiver
9.	One (1) Lot of pumps and motors for liquid flows within the Crystallizer unit
10.	One (1) Lot of chemical dosing systems for crystallizer
11.	One (1) Lot of process piping and ducting
12.	One (1) Lot of Instrumentation
13.	One (1) Slurry Pump
14.	One (1) Belt Filter Press
14.	One (1) PLC Based Control Panel with HMI

Base budget Price for BC/FCC/Filter Press, Ex-works ***$ 9,500,000***

Approximate Distillate from System; 549 GPM
Total Power Consumption; 3500 kW
Solid waste at 10% solids content; 1100 #/hour

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Typical expected delivery of this equipment would be 55-60 weeks.

The equipment described is constructed of high end alloys which are subject to material cost escalations due to volatility in availability and pricing.

Scope of Supply 550 GPM UF/RO - 220 GPM Brine Concentrator/Forced Circulation Crystallizer

RO System

1.	One (1) Sodium Hypochlorite Dosing Skid
2.	One (1) 3000 gallon Sodium Hypochlorite Storage Tank
3.	One (1) Ultrafiltration system
4.	Two (2) UF Backwash pump
5.	One (1) Filtrate Storage Tank 10,000 gallons
6.	Two (2) Filtrate Forwarding Pumps
7.	One (1) Sodium Bisulfite Dosing Skid
8.	One (1) 5000 gallon Sodium Bisulfite storage Tank
9.	One (1) Acid Dosing system
10.	One (1) 5000 gallon Acid Storage Tank
11.	Two (2) RO Cartridge Prefilter
12.	Two (2) RO Booster Pumps
13.	One (1) RO Membrane System
14.	One(1) Membrane CIP Skid

Brine Concentrator

1.	One (1) Wastewater Storage Tank with agitation
2.	Two (2)Wastewater Transfer Pump with Feed Strainer
3.	One (1) Feed Tank and Pump Skid

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4.	Three (3) Chemical Dosing Skids
5.	One (1) Pre-heater and Deaerator
6.	One (1) Brine Concentrator Vessel
7.	One (1) Vapor Compressor Skid
8.	One (1) Recirculation Pump Skid
9.	One (1) Distillate Tank and Pump Skid
10.	One (1) Lot of Prefabricated Recirculation Piping and Vapor Ducting
11.	One (1) Lot of On-skid Piping
12.	One (1) Lot of Instrumentation and PLC Based Controls within Battery Limits
13.	One (1) Lot of Structural Steel platforms, access ladders for BC Vessel
14.	One (1) Interconnecting Piping between Skids
15.	One (1) Lot of Electrical Conditioning and MCC by others
16.	One (1) Lot of Power and Instrument Wiring to Skid Junction Boxes by Others

FCC and Filter Press

1.	One (1) Concentrate Tank
2.	Two (2) Concentrate Pumps
3.	One (1) MVC forced circulation evaporation unit
4.	One (1) Heat exchanger
5.	One (1) Flash tank
6.	One (1) Mist eliminator
7.	One (1) Vapour compressor with motor and auxiliaries
8.	One (1) Distillate receiver
9.	One (1) Lot of pumps and motors for liquid flows within the Crystallizer unit
10.	One (1) Lot of chemical dosing systems for crystallizer
11.	One (1) Lot of process piping and ducting
12.	One (1) Lot of Instrumentation
13.	One (1) Slurry Pump
14.	One (1) Belt Filter Press

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14.	One (1) PLC Based Control Panel with HMI

Base budget Price for UF/RO/FCC/Filter Press, Ex-works ***$ 7,700,000***

Approximate RO Permeate & Distillate from System; 530 GPM
Total Power Consumption; 1500 kW
Solid waste at 10% solids content; 1500 #/hour
Typical expected delivery of this equipment would be 55-60 weeks.

The equipment described is constructed of high end alloys which are subject to material cost escalations due to volatility in availability and pricing.

If I can be of further assistance please feel free to contact me at your convince.

Regards,

Terry LaPrise
Regional Sales Manager

Zero Liquid Discharge System

Overview

The Aqua-Chem ICD Zero Liquid Discharge System is a fully integrated automated system incorporating a mechanical vapor compression brine concentrator, a forced circulation crystallizer, and solids dewatering. High purity distillate produced in this system can be used for cooling tower or boiler makeup water.

The Aqua-Chem ICD Zero Liquid Discharge System typically follows a reverse osmosis (RO) preconcentrator. High TDS and saturation in low solubility scaling salts such as calcium sulfate ($CaSO_4$) and silica (SiO_2) limit the percentage of water which can be recovered by an RO system. Feedwater saturated in $CaSO_4$ and/or SiO_2 is also very difficult to concentrate in a normal evaporator but can be handled in the Aqua-Chem ICD brine concentrator. The process, also called seeded slurry evaporation, involves establishing and maintaining a slurry of calcium sulfate seed crystals in the circulating brine in the evaporator. With careful thermal and mechanical design, the SiO_2 and $CaSO_4$ will precipitate preferentially on the recirculating crystals instead of on the tubes. The brine concentrator is capable of concentrating the wastewater to near saturation in the sodium salts without scaling the heat transfer tubes.

The remaining water is evaporated in the forced circulation crystallizer. This evaporator easily handles the crystallization of the remaining salts regardless of the exact chemical analysis. The salts are removed as a cake by a (filter press, centrifuge).

The Aqua-Chem ICD Zero Liquid Discharge System is designed for automatic steady state operation and will require little operator attention. The materials of construction have been selected to resist corrosion and ensure a long plant life. The system is very reliable. The pumps and compressor typically operate years without significant problems, given periodic maintenance typical for rotating equipment. Almost any problem can be fixed in a day. The system is designed to minimize scaling of the heat transfer surfaces; however, it is also designed to operate in a slightly fouled condition, so normal fouling or scaling will not affect the design capacity of the unit. Chemical cleaning of the system is typically required once or twice per year.

Process Description

The feed is acidified with H_2SO_4 to a pH of 5.5 which converts bicarbonate to dissolved CO_2 for removal in the deaerator. The bicarbonate is removed to prevent scaling of the brine concentrator tubes with calcium carbonate ($CaCO_3$). A small amount of scale inhibitor is metered into the feed to avoid scaling in the feed/distillate plate heat exchanger. Depending on the amount of calcium in the feed, the anti-scale may be reduced or eliminated.

The feed/distillate heat exchanger, a plate and frame type with titanium plates, preheats the feed with outgoing hot distillate. The heated feed flows to the deaerator to remove dissolved carbon dioxide and oxygen, to minimize corrosion in the system. Aqua-Chem ICD uses a flashing deaerator which does not utilize packing, thereby avoiding plugging problems. The feed is sprayed into the pressurized, barometric half of the deaerator which further heats the feed with low pressure evaporator vent vapors. The feed then flashes into the low pressure portion of the deaerator. A small fraction of water from the feed is vaporized, along with the dissolved carbon dioxide and oxygen, which are virtually eliminated by this step. Typical dissolved oxygen content in the deaerated feed is 10 ppb.

The feed then flows to the brine concentrator vessel. Calcium sulfate scale is managed in this vessel by proper feed pretreatment and by providing adequate seed crystal surface area dispersed homogeneously in the brine slurry. The seed crystals prevent supersaturation extremes and promote crystal growth rather than scaling on the heat transfer surface.

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The seed crystals are added as gypsum to the seed makeup tank at startup to establish the circulating slurry. As the brine is concentrated and some is pumped to the crystallizer, seed crystals are replenished by natural generation from calcium and sulfate ions in the incoming feed water. A seed thickening tank is provided to recycle seed crystals back into the brine concentrator if the natural seeding level is too low. A $CaCl_2$ injection system is provided to add Ca+2 directly into the feed line if the incoming Ca+2 concentration is too low. Both of these systems are used to maintain adequate seed crystal concentration in the brine concentrator.

The brine concentrator vessel is designed with a long bottom channel to provide sufficient residence time for crystal growth. A vapor separator with mist eliminators is used to remove entrained droplets of brine from the vapor before it flows to the compressor. The mist eliminators are periodically sprayed with hot distillate to dissolve any accumulated solids.

Vapor generated in the brine concentrator flows to a mechanical compressor, which increases its saturation pressure and temperature. Then the compressed vapor flows to the shell side of the brine concentrator in lieu of external heating steam. The vapor is condensed on the outside of the tubes, transferring heat to the circulating brine on the tubeside. Condensed vapor (distillate) is pumped out of the system. Some of the distillate is sprayed into the compressor discharge duct to desuperheat the compressed vapor.

The brine concentrator is designed with a very low delta-T (temperature difference between the heating medium and the boiling brine) and a high recirculation rate. The two main benefits are reduced scaling rate and a lower compressor power requirement. Energy economy is maximized by utilizing distillate and vent stream heat. The system is designed for low make-up steam at steady state operation.

The brine is concentrated to approximately 25% total solids in the brine concentrator. To maintain a solids balance in the system, part of the concentrated brine is continuously pumped from the brine concentrator to the forced circulation crystallizer.

Recirculated brine is pumped through the forced circulation heat exchanger where it is heated with steam from the brine concentrator to above its normal boiling temperature. Boiling of the brine in the heat exchanger is suppressed due to sufficient static head. Boiling in the heat exchanger would cause scale formation on the heat transfer surface. The heated brine then enters a flash tank operating at a slightly lower pressure, causing flash evaporation of water and formation of salt crystals in the brine. High recirculation rates are used to keep the contact time on the heated surface low, reducing the scaling rate of the heat transfer surface.

Once every eight hours the a batch of slurry is discharged from the crystallizer to the filter press feed tank. This slurry is fed to the filter press, which separates out the salt crystals as a cake. The liquid portion, saturated in dissolved salts, is returned to the forced circulation crystallizer. The salt cake is dumped at 8 hour intervals into a hopper for disposal. This sequence is manually initiated, and requires an operator to be present to assure that the plates have properly released the salt cake.

Vertical Tube Falling Film Evaporator (Brine Concentrator)

Falling film vertical tube evaporators use vertical tube bundles with brine evaporating from a thin film on the inside of the tubes. Brine is distributed in a thin film down the inside of the tubes. The brine absorbs heat from condensing water vapor on the outside of the tubes. The latent heat of vaporization transfers from the water vapor through the tube wall to the thin brine film on the inside of the tube. For every kilogram of water vapor that condenses, approximately one kilogram of water is evaporated from the brine film.

The vapor condensing on the tube bundle is primarily water vapor but can also contain air and other non-condensables. These non-condensables will stay in the vicinity of the tube walls and impede heat transfer unless swept away by sufficiently high vapor velocities. A vent on the evaporator body continuously removes the non-condensables to maintain high heat transfer coefficients and to prevent loss of driving force (differential temperature) through excess subcooling of the heating vapor.

The brine is introduced at the top of the vessel and flows in a downward direction as a falling film. The brine is uniformly and generously directed to the full circumference of each tube as a thin film. Because the recirculation rate is many times greater than the evaporation rate, only a small change in concentration occurs down the tube length as evaporation takes place. The recirculation rate is chosen conservatively to ensure that the heat transfer surface is well wetted and localized drying is not encountered.

A proprietary dual perforated plate distributor ensures that the liquid is evenly distributed to the tubes. The plates have holes larger than 13 mm and have been proven to be much less susceptible to plugging than other designs including individual weir inserts or swirler inserts.

Careful design eliminates areas where the solids and impurities may collect and impede liquid flow and heat transfer. Design features include large holes in the distribution system, sloped bottoms, and smooth entrance to pump suctions.

Mechanical Vapor Compression (VC)

Vapor compression is a highly efficient process using mechanical energy input to achieve evaporation and condensation. The fundamental difference between the vapor compression unit and the conventional evaporator is that the latent heat of vaporization is fully utilized in the VC evaporator. Since the evaporator also serves as the condenser, essentially all of the latent heat is recycled, with no rejection of heat to cooling water.

The evaporated vapor flows through the mist eliminator to the suction of the compressor. The compressor does work on the water vapor increasing the saturation pressure of the water vapor so that when it condenses, it does so at a higher temperature. The compressed vapor flows to the heating side of the evaporator. As it condenses, it transfers the latent heat of vaporization back to the liquid film on the tubeside.

The compression process produces discharge vapors that are superheated (i.e. hotter than the corresponding saturation temperature). Scaling, excessive fouling, and stress corrosion can occur if the superheated vapor is allowed to condense on the evaporator tube bundle. This scaling would occur as the sensible heat is transferred through the tube. To remove the superheat in the compressed vapor discharge, desuperheating water (in the form of distillate) is sprayed into the vapor stream. This distillate is very near the saturation temperature so latent heat is not removed from the vapor stream and can be used for the evaporation process.

A multi-stage centrifugal blower is used for the brine concentrator. It is coupled to a motor-driven gearbox. This type of compressor is very simple and easy to maintain. System turndown is achieved by the adjustment of the blower discharge damper valve. Turndown to 65% of rated capacity can be attained in this manner.

Control

The system is designed for automatic cascade control. Evaporation rate in the brine concentrator is based on an operator setpoint. The damper valve at the compressor discharge controls vapor flow to the brine concentrator based on the distillate flow rate out of the system. All other flow rates automatically adjust based on this setpoint. The feed rate is based on distillate outflow and brine level in the brine concentrator. Pressure (and indirectly temperature) in the brine concentrator is controlled by venting excess steam to the atmosphere or by allowing external steam into the system. The

concentrated brine flow rate is remotely set based on feed and distillate flows. Operational parameters of system pressure, sump level, distillate level, and concentrate flow will be automatically controlled based on changes to the desired evaporation rate.

Operation

The system is designed for manual start-up and automatic operation. The feed chemistry should be monitored periodically. Sufficient safeguards and interlocks to prevent unsafe conditions or equipment damage are included in this design. When the system is shut down it is important to either keep the system pressurized with steam to keep oxygen out or drain and flush the system to remove the chlorides. Chlorides in the presence of oxygen will accelerate corrosion and reduce equipment life.

Maintenance

The required maintenance for this Aqua-Chem ICD Zero Liquid Discharge System is typical for commercial process equipment containing high quality industrial duty components. The unit's rotating equipment, such as pumps and compressors, require periodic adjustment, lubrication, and servicing of components such as seals. Instrumentation was specifically chosen to be durable and trouble free, but will require periodic adjustment and recalibration. If recommended spare parts are kept on hand and a preventative maintenance program is implemented, then the net availability (operating factor) can be expected to exceed 95%. The required maintenance procedures, recommended spare parts, and recommended preventative maintenance program will be provided by Aqua-Chem ICD.

Washing

The heat transfer surface has been designed to operate at capacity with lightly scaled heat transfer surfaces. An occasional manual adjustment of the compressor valve will maintain the system capacity as the evaporators slowly scales and loses performance. When this valve has been fully opened and the necessary capacity can no longer be maintained, a chemical wash will be required to restore performance. A complete chemical cleaning procedure will normally take between 12 and 24 hours. The evaporators are normally cleaned by recirculating a hot 10% EDTA solution (diluted Nalco 760 for example) with the recirculation pumps. The cleaning solution is injected into the recirculation line. The solution is maintained hot (70 °C) by using a small amount of steam flow through existing controls. Cleaning frequency for an evaporator of this type is typically once or twice per year.

It may be economical to hydroblast prior to cleaning with EDTA. This reduces the amount of EDTA required. We recommend a professional hydroblast crew do this work. Two 600 mm manholes on the top channel facilitate easier distribution plate removal and tube blasting.

Materials of Construction

Due to the relatively high chloride content the major vessels wetted materials are 6% molybdenum stainless steel such as 254 SMO or AL6XN. Tubes are titanium grade 2. Other materials used for brine service include fiberglass, CD4MCu, Hastelloy C, and 316L Stainless Steel as applicable. Use of these materials will assure equipment life beyond 20 operating years.

Spare Parts

Installing spare pumps in brine service would lead to stagnant areas and potential corrosion. Considering the high reliability of these pumps, it is better not to install spares but keep shelf spares. In the event a pump replacement is necessary, the feed storage tank would be used to collect the feed flow as it would be when the unit was shut down for cleaning. Upon startup the excess capacity designed into the unit will process the stored feed.

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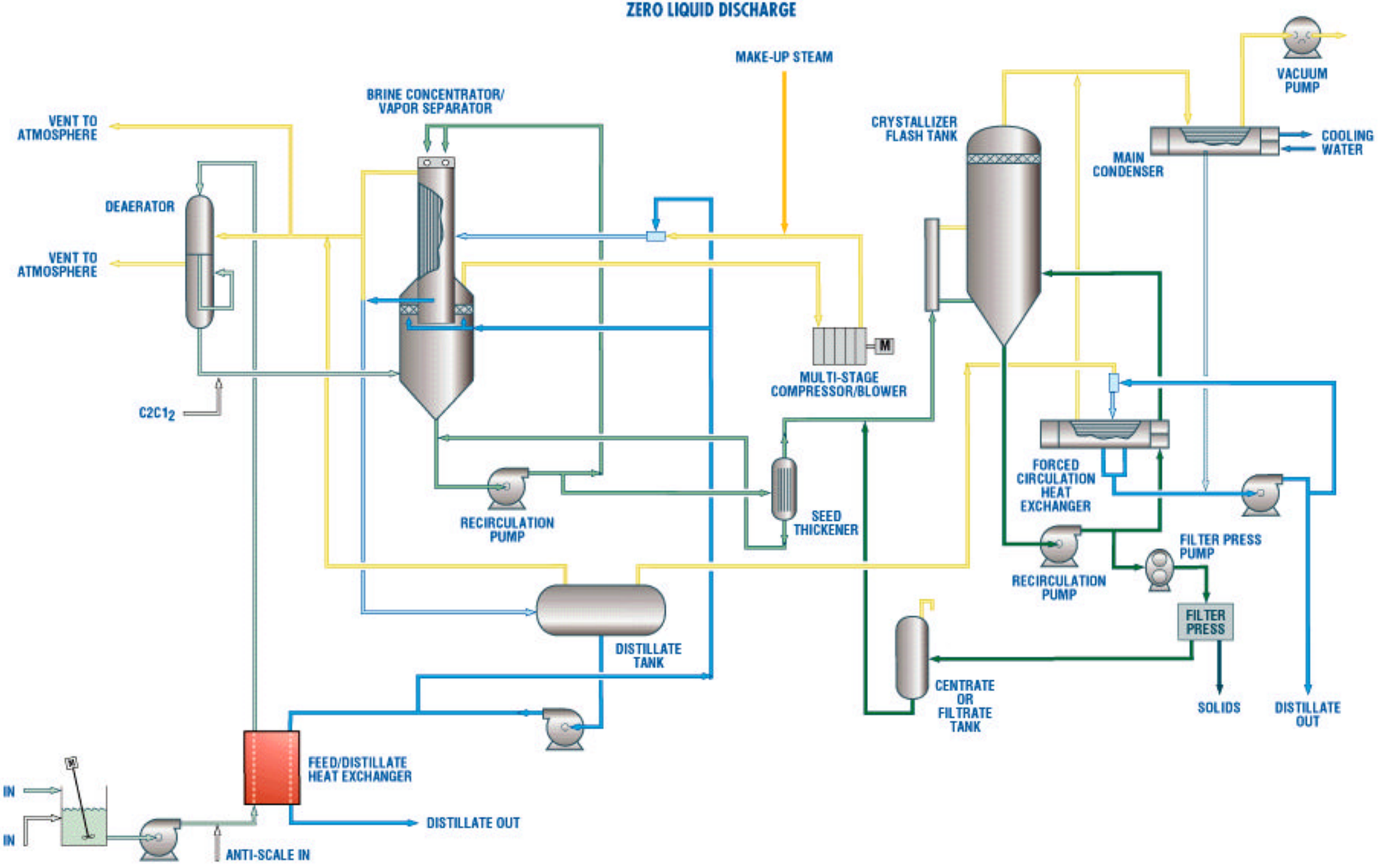
www.aquatech.com

Aquatech

aqua-chem ICD
Industrial Concentration & Desalination

ZERO LIQUID DISCHARGE



GE Infrastructure
Water & Process Technologies

Jonathon Dueck BSc PChem
Equipment Solutions Specialist

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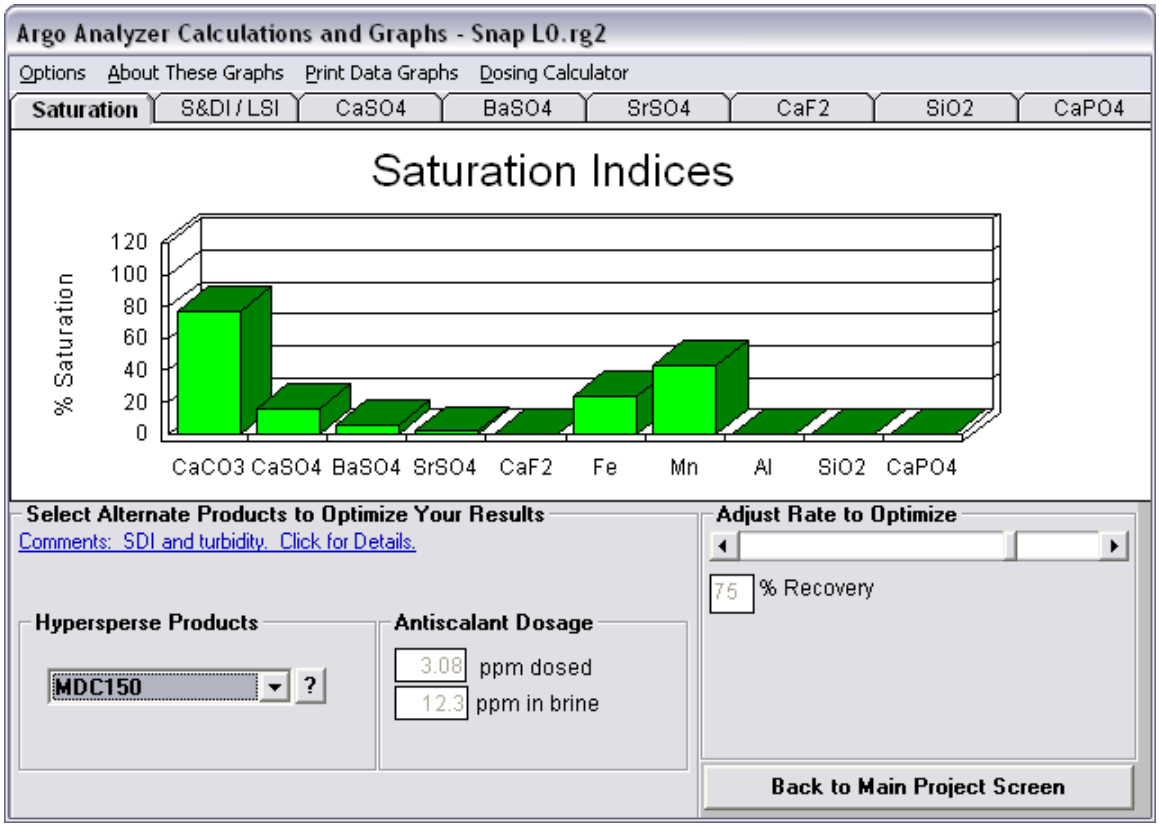
April 10, 2008

Peter Lemke
Golder Associates
Denver, CO

Dear Pete;

RE: DeBeer's Snap Lake Drift Water Treatment

From an initial modeling of the data provided, this water looks to be very treatable with a combination of UF to remove suspended solids and RO to reduce the TDS. Below you will see a graphical output from our modeling tool showing the scaling tendency of the water. None of the mineral scales are even within 80% of saturation, indicating that scaling issues should not be of concern for this application. This graph was generated using the maximum concentration values from the analyses provided to give an indication of worst-case scenario. The entire report from this modeling is included with this email as a separate file.



To treat this water with standard equipment at the flow rates you require, we would suggest using two Z+PRO450, Zeeweed (UF) and RO trains fitted with high recovery, low energy, cold water membranes. Each of these trains would produce 450 gpm of permeate and would come with a VFD to reduce the total flow through the RO by up to 25%. Dual train operation would allow you to continue to process water from the mine at a rate of 450 gpm while one of the trains is in cleaning, while also permitting higher water production rates than the 550 gpm requirement without having to expand the system.

A spec sheet and general dimensional drawing of these units is attached. These trains will remove the suspended solids via the UF component and remove >95% of the dissolved solids via the RO component. The ZeeWeed UF membrane is ideal for this type of application due to the high solids loading, which would plug spiral wound membranes and cause excessive backwashing of conventional multimedia filters (MMF). The overall water recovery of the system would be around 75%. It can be estimated that the RO permeate (good) water quality will contain approximately 3% of the inlet TDS, with slightly higher passage of the monovalent cations and anions and lower passage of the divalent ions. Virtually all the trivalent and higher ions would be removed from the permeate stream.

Budgetary pricing on 2 Z+PRO450 trains would be $1,900,000 plus freight, installation, interconnecting piping and any PLC changes to make the machines communicate with each other. Engineering specifications would be reviewed and changed to meet customer requirements, and pricing would be adjusted accordingly.

I will give you a call in a week or so, once you have had a chance to review this, and we can discuss what other information you need for a path forward.

Best regards,

Jonathon Dueck BSc PChem
Equipment Solutions Specialist

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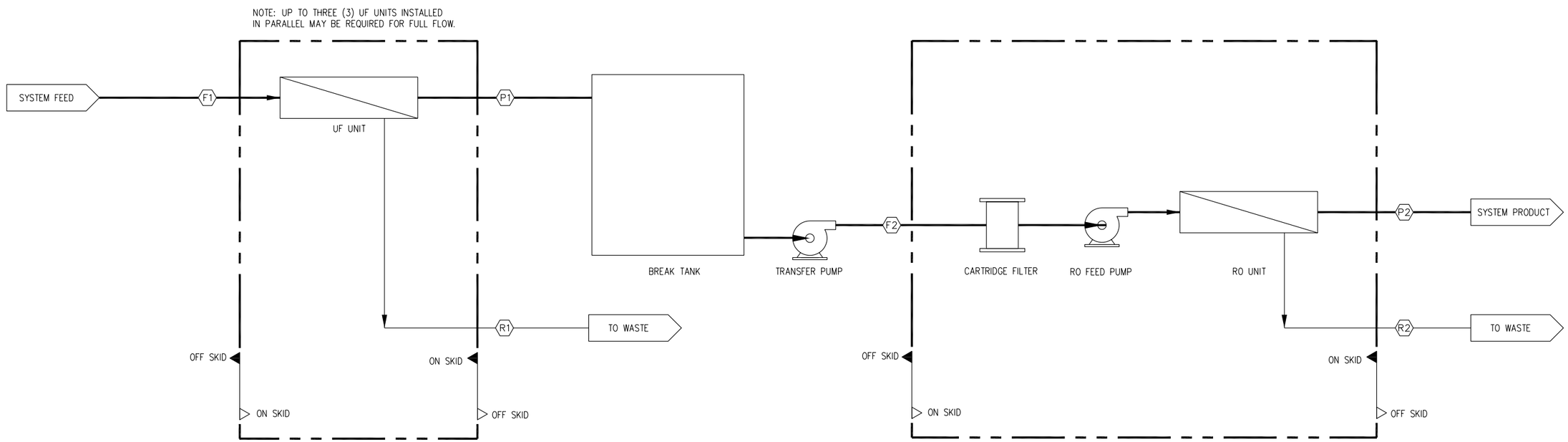
Jonathon.Dueck@ge.com



*NOTE: ACTUAL FEEDWATER SPECIFICATIONS NEED TO BE REVIEWED PRIOR TO FINAL DESIGN.

FEED WATER	LIMIT
AVERAGE TURBIDITY	<100 NTU
SILICA	SEE SCALING LIMITS
CONCENTRATION NaCl TDS (MG/L)	1500–2500
pH	5.0–8.5
MINIMUM INLET PRESSURE	4 PSI
F+Mn	<15Mg/L
TSS (SECONDARY EFFLUENT)	<30Mg/L

MODEL	UF MODEL AND QUANTITY	RO MODEL AND QUANTITY	F1 SYSTEM FEED FLOW (GPD)	P1 INSTANTANEOUS UF PERMEATE (GPD)	R1 INSTANTANEOUS UF REJECT (GPD)	F2 RO FEED (GPD)	P2 RO PERMEATE (GPD)	R2 RO CONCENTRATE (GPD)	TANK CAPASITY (GALLONS)	TANK DIMENSIONS (INCHES) (DxH)
Z+PRO–50	S12 QTY 1	PRO–50–PRE FRP QTY 1	107,200	96,480	10,720	96,480	72,000	24,480	360	48"x42"
Z+PRO–100	S18 QTY 1	PRO–100–PRE FRP QTY 1	212,500	191,520	21,250	191,520	144,000	47,520	540	48"x75"
Z+PRO–150	S24 QTY 1	PRO–150–PRE FRP QTY 1	320,000	288,000	32,000	288,000	216,000	72,000	840	48"x109"
Z+PRO–200	S18 QTY 2	PRO–200–PRE FRP QTY 1	427,200	384,480	42,720	384,480	288,000	96,480	540	48"x75"
Z+PRO–300	S24 QTY 2	PRO–300–PRE FRP QTY 1	640,000	576,000	64,000	576,000	432,000	144,000	840	48"x109"
Z+PRO–450	S24 QTY 3	PRO–450–PRE FRP QTY 1	960,000	864,000	96,000	864,000	648,000	216,000	840	48"x109"

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	–	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS .X ± .XX ± .XXX ± ANGLES ± FRAC ±

DRAWN BY B.N. DATE 20Sep06
CHECKED BY DATE
APPROVED BY DATE
APPROVED BY DATE

GE Infrastructure
Water & Process Technologies
4101 E. WOOD STREET, PHOENIX, AZ 85040 USA (602) 437-1355 WWW.GEWATER.COM

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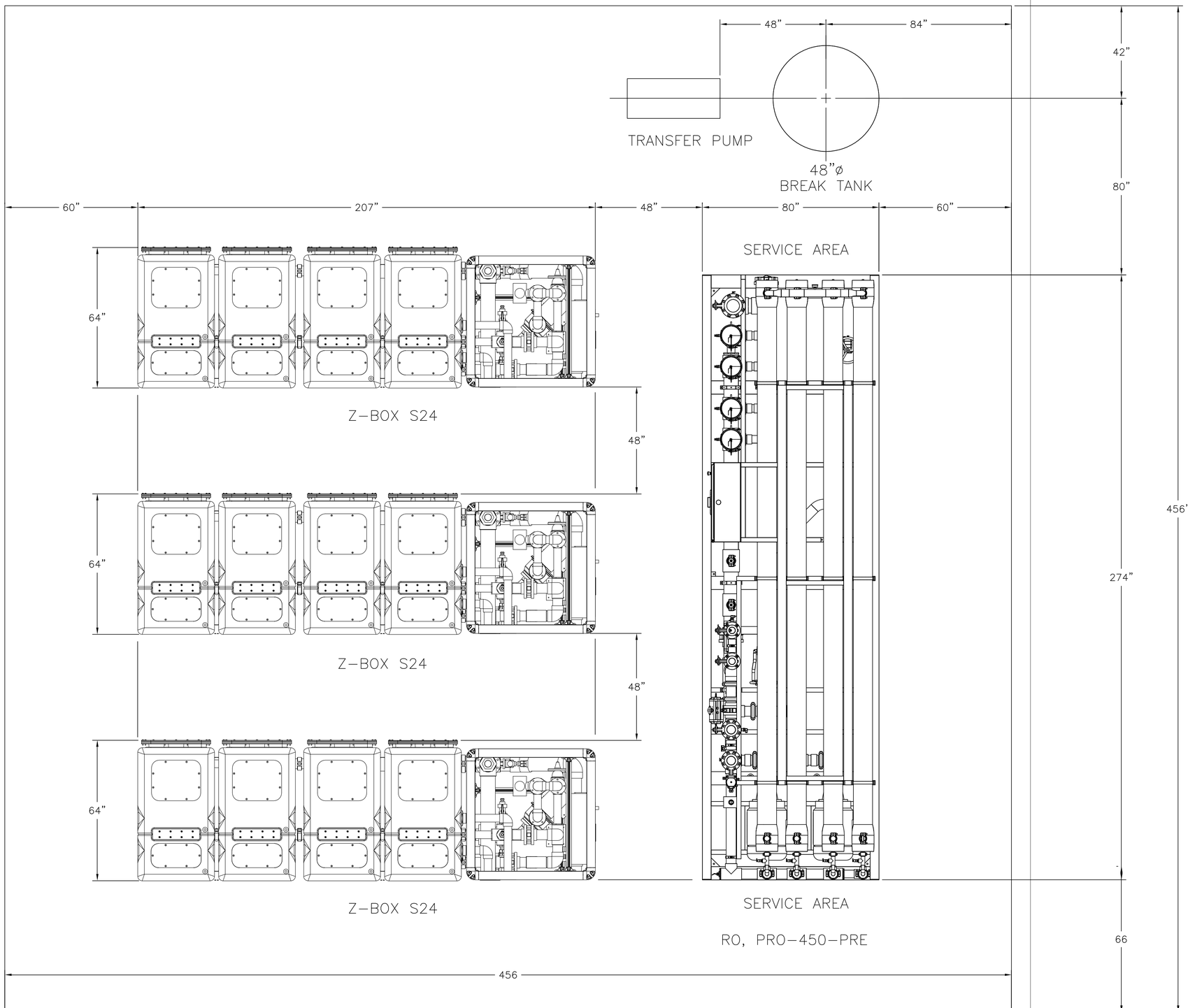
CLIENT/JOB
FILE ACR2004

DWG DESCRIPTION: Z+PRO SERIES PDF
MATERIAL/BOM NO.

SIZE D | DRAWING NO. | REV A
PROJECT
SCALE | SHEET 1 OF 1

P/N 1300486–RAP01



REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	12313	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS .X ± .XX ± .XXX ± ANGLES ±
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DRAWN BY	DATE 20Sep06	
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APPROVED BY	DATE	

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CLIENT/JOB

FILE ACR2004

DWG DESCRIPTION: FLOOR LAYOUT SKETCH,Z+PRO-450

MATERIAL/BOM NO.

SIZE	DRAWING NO.	REV
D	1302182	A

PROJECT

SCALE

SHEET 1 OF 1

P/N 1300486-RAP01

Argo Analyzer

Report for
550 USGPM
Membrane Separation Plant
at
Snap Lake

Prepared by : Jonathon Dueck
Thursday, April 10, 2008

If you have questions or concerns about the use or distribution of Argo Analyzer please contact your regional GE representative.

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Belgium
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Argo Analyzer

Report for 550 USGPM Membrane Separation plant at Snap Lake

INTRODUCTION.

The following report is prepared from the details completed for the Raw Water prepared to be supplied to a Membrane Separation Plant operating as specified. The information is given for guidance only.

RAW WATER.

The Raw Water details show :
Well Water has been selected as the source of the raw water.
The date of analysis is not known. It is advisable to have the results confirmed with an up to date analysis

FEEDWATER.

The following is reported for the Feedwater using the Raw Water as basis :

Total Hardness is derived from Calcium ion and Magnesium ion values
Calcium Hardness is derived from the Calcium ion Value
Magnesium Hardness is derived from the Magnesium ion Value
Alkalinity value is derived from the Bicarbonate ion Value
CO_2 value is calculated from the raw water pH and Bicarbonate/Alkalinity value
The raw water TDS value has been calculated by summing the individual ions
The Sodium Absorption Ratio (SAR) indicates that this water is suitable for irrigation

PRETREATED WATER.

The Pretreated Water is as follows :
The feedwater has been prepared for introduction into a membrane separation plant operating at 75.0% recovery.
The pH does not need adjustment. Scale control will be by the addition of Chemical Inhibitor only.
In order to control the precipitation of limited solubility salts it will be necessary to dose 3.08 ppm of Hypersperse MDC150
An arrangement to flush out pretreated water from the membranes at each plant shutdown is highly recommended.
The following ions are presented at the maximum permitted concentration (mg/l) as the presence was not indicated in the Raw Water:
Fluoride - 34.12mg/l Aluminium - 0.25mg/l Silica - 31.25mg/l
The maximum values are given for guidance only and are not considered in the program calculations.It may be necessary to increase the dose of antiscalant to control the above salts at these levels.

BRINE.

The following is reported for the Brine :
The Brine projection is from the pretreated feedwater passing over polyamide spiral wound membranes when operating at a recovery of 75.0%
The S&DI of the brine is 2.31
The saturation indicies of the limited solubility salts being controlled by inhibition are :
$BaSO_4$:0.1,
The above are based on the maximum inhibition possible for the selected product
The maximum possible recovery using this pretreated water, with the selected antiscalant, based on the scale potential, is 98.0%
The limiting salt is Barium Sulphate

CHEMICAL DOSING.

Feed water chemical consumption :
The plant output is 550 USGPM operating at 75% recovery
The raw water requirement will be 733 USGPM
Based on the plant operating 24 hours per day, 7 days per week, 52 weeks per year, this plant will produce 288,300,000 US Gallons per year from a feed flow of 384,400,000 US Gallons per year . The plant will consume a total of 9,890 pounds per year of Hypersperse MDC150

Argo Analyzer

	Raw Water	Feed Water	Pretreated Water	Brine	units
Calcium Hardness	1210.00	1210.00	1210.00	4840.00	as CaCO3
Magnesium Hardness	46.70	46.70	46.70	186.80	as CaCO3
Total Hardness	1256.70	1256.70	1256.70	5026.80	as CaCO3
Alkalinity		47.53	47.54	190.10	as CaCO3
pH	8.50	8.50	8.49	9.10	
Temperature	15.00	15.00	15.00	15.00	as °Cent
Conductivity	6090.00	6090.00	6090.00	24452.37	µS / cm
TDS	3178.00	3729.73		14918.92	mg/l
Chlorine	0.00	0.00	0.00	0.00	mg/l
Calcium	484.97	484.97	484.97	1939.87	mg/l
Magnesium	11.36	11.36	11.36	45.43	mg/l
Sodium	543.00	557.08	557.08	2228.34	mg/l
Potassium	436.00	436.00	436.00	1744.00	mg/l
Iron	0.03	0.03	0.03	0.12	mg/l
Manganese	0.03	0.03	0.03	0.11	mg/l
Barium	0.06	0.06	0.06	0.25	mg/l
Strontium	11.20	11.20	11.20	44.80	mg/l
Aluminium	0.00	0.00	0.00	0.00	mg/l
Copper	0.00	0.00	0.00	0.00	mg/l
Lead	0.00	0.00	0.00	0.00	mg/l
Zinc	0.00	0.00	0.00	0.00	mg/l
Chloride	1980.00	1980.00	1980.00	7920.00	mg/l
Sulphate	191.00	191.00	191.00	764.00	mg/l
Bicarbonate	58.00	58.00	58.00	232.00	mg/l
Nitrate	0.00	0.00	0.00	0.00	mg/l
Fluoride	0.00	0.00	0.00	0.00	mg/l
Silica	0.00	0.00	0.00	0.00	mg/l
Phosphate	0.00	0.00	0.00	0.00	mg/l
Bromide	0.00	0.00	0.00	0.00	mg/l
TOC	0.00	0.00	0.00	0.00	mg/l
BOD	0.00	0.00	0.00	0.00	mg/l
COD	0.00	0.00	0.00	0.00	mg/l
Phenols	0.00	0.00	0.00	0.00	mg/l
Hydrocarbons	0.00	0.00	0.00	0.00	mg/l
Bacteria	0.00	0.00	0.00	0.00	mg/l
CO2		0.30	0.30	0.30	mg/l
H2S	0.00	0.00	0.00	0.00	mg/l
RSI				9.10	
LSI					
S&DI				2.31	
Ionic Strength	0.08		0.08	0.30	
SAR	4.75	4.87	4.87	9.74	
Total cations	3008.12	3038.75	3038.75	12155.00	as CaCO3
Total anions	3038.22	3038.22	3038.22	12152.87	as CaCO3

Argo Analyzer

This projection has been prepared for the 550 USGPM membrane plant at Snap Lake

Dose Projection and Product Selection Summary

Selected Product : Hypersperse MDC150
Required Dosage : 3.08 mg/l
Usage Rate : 27.16 lb/day

Degrees of Saturation in Concentrate as %

Saturation	CaSO4	BaSO4	SrSO4	CaF2	SiO2	CaPO4
No Inhibitor	55.6	576.3	57.3	0.0	0.0	0.0
Inhibitor	15.9	5.5	1.6	0.0	0.0	0.0

The projected calcium carbonate saturation level is 2.31 expressed as S&DI
The limit for S&DI is 3 with inhibitor and 0.0 without.

The projection is for a 550 USGPM membrane separation plant, operating at 75% recovery.

The foregoing recommendations are given in good faith and are based on the analytical and operation data you have entered, and on application data which we believe to be correct. No warranty as to specific application is expressed or implied since conditions of use and other contributory factors are beyond our control Please seek advice from your GE membrane specialist with regard to any particular query.

Argo Analyzer

This projection has been prepared for the 550USGPM membrane plant at Snap Lake

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Without Inhibitor	55.6	576.3	57.3	0.0	0.0	0.0
With Inhibitor	15.9	5.5	1.6	0.0	0.0	0.0

The projected calcium carbonate saturation level is 2.31 expressed as S&DI
The limit for S&DI is 3 with inhibitor and 0.0 without

The projection is for a 550 USGPM membrane separation plant, operating at 75% recovery.

Water Analysis

The above recommendations have been made based on the following feed water analysis :

Ion	Raw Water	Feed Water	Brine	
Calcium	484.97	484.97	1939.87	
Magnesium	11.36	11.36	45.43	
Sodium	543.00	557.08	2228.34	
Potassium	436.00	436.00	1744.00	
Iron	0.03	0.03	0.12	
Manganese	0.03	0.03	0.11	
Barium	0.06	0.06	0.25	
Strontium	11.20	11.20	44.80	
Aluminium	0.00	0.00	0.00	
Chloride	1980.00	1980.00	7920.00	
Sulphate	191.00	191.00	764.00	
Bicarbonat	58.00	58.00	232.00	
Nitrate	0.00	0.00	0.00	
Fluoride	0.00	0.00	0.00	
Silica	0.00	0.00	0.00	
Phosphate	0.00	0.00	0.00	
pH	8.50	8.49	9.10	
Temperatur	15.00	15.00	15.00	°Cent

The foregoing recommendations are given in good faith and are based on the analytical and operation data you have entered, and on application data which we believe to be correct. No warranty as to

specific application is expressed or implied since conditions of use and other contributory factors are beyond our control Please seek advice from your GE membrane specialist with regard to any particular query.

GE
Water & Process Technologies

Fact Sheet

Z+PRO 60 Hz

UF+RO Packaged Plants
50-450 gpm (11.4-102.2 m^3/hr)

Key Benefits:

- Compact treatment system for variable water quality
- Fully skid-mounted; reduces onsite installation time and costs
- Easy to install
- Simple to operate
- Easily integrated into an existing facility
- UF side-loading tank provides easy access to membrane modules

Standard Features:

- GE Fanuc control package mounted on frame
  Text and pictorial operating screens
  Keypad and touchscreen controls
- 4-20 mA instruments on QuickPanel
- Permeate/backpulse pump and associated valving mounted on equipment frame
- Extruded aluminum equipment frame for UF unit; painted carbon steel on RO
- Polyethylene membrane and backwash tanks mounted on equipment frame
- 0.5 mm self cleaning screen
- RO permeate flush on shutdown
- Voltage 480 or 575 V, 3 phase, 60 Hz (other voltages available)

Documentation Included

- Operation and maintenance manuals included
- Drawings: piping and instrumentation, electrical general dimensional, and process flow diagram

Operating Parameters

Recovery	65-85%
Design temp.	60°F (15.6°C)
Operating range	35 to 85°F (1.6 to 29.4°C)
Minimal inlet pressure	4 psi

Materials of Construction

High-pressure piping	Stainless Steel, Sch. 10
Low-pressure piping	Sch. 80, PVC
Enclosure	NEMA 12 (painted blue)
Clamps/fittings	Zinc-plated[jh1]

Membrane Elements

UF membrane model	ZeeWeed® 1000
RO membrane model	OSMO PRO RO 365
RO membrane rejection	99.6%
Manufacturer	GE

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*Trademark of General Electric Company; may be registered in one or more countries.

Table 1: Standard Instrumentation

Flow	RO permeate, concentrate, UF permeate
Turbidity meter	UF permeate
Conductivity	RO feed, permeate
PH	RO feed
ORP	RO feed
Pressure	Pre-filter, post-filter, primary, final, pump discharge, interstage, UF permeate suction/backpulse
Pressure Switch	RO feed, permeate, concentrate
Level Transmitter	Membrane tank, UF/RO break tank

Table 2: Major Component Manufacturers

Equipment	Manufacturer
UF permeate pump	G&L
RO high pressure pump	GE Tonkaflo
Air compressor	Quincy
Cartridge filter housing	GE
RO membrane housing	Wave Cyber
Flow & level measure-ment	E&H, GF Signet
Conductivity, pH, ORP	Thornton
Turbidity meter	Hach
PLC Components	GE Fanuc
Chemical Pumps	Prominent
Valves	Keystone, Bray, Chemline

Table 3: Application Dependent Options

Option	Description
Feed water turbidimeter	Feed water turbidity monitoring
Enhanced coagulation (E.C.) system	Coagulant dosing pump, flocculation tank, and mixers for TOC removal
Oxidation system	Oxidation dosing pump, oxidation tank, and mixers for iron and manganese removal
+/- pH adjustment	Automatic feed pH adjustment and monitoring system for E.C. and Oxidation.

Table 4: Optional Features

Option	Description
Allen Bradley Control Package	Replaces GE Fanuc components with equivalent AB
PRO Clean-in-Place	Cone-bottom HDPE tank with painted carbon steel stand for chemical recirculation
PRO Chemical Feed Systems	Electronic metering pump for antiscalant or sodium bisfulfite injection
RO Motor Starters	Motor starters for high pressure and CIP pumps, shipped loose for field installation
NaOCl cleaning system	Cleans organics from UF membranes
Citric cleaning system	Cleans inorganics from UF membranes
Chemical neutralization pumps	Neutralize cleaning solution after membrane cleaning
Air compressor	Valve operation, membrane aeration and MIT
Online spare air compressor	Redundant air compressor[jh2]

GE Water & Process Technologies Z+PRO Models

	Z+PRO-50	Z+PRO-100	Z+PRO-150	Z+PRO-200	Z+PRO-300	Z+PRO-450
Product rate:	72,000 gpd	144,000 gpd	216,000 gpd	288,000 gpd	432,000 gpd	648,000 gpd
Concentrate Rate:	35,200 gpd	68,500 gpd	104,000 gpd	139,200 gpd	208,000 gpd	312,000 gpd
Feed Rate:	107,200 gpd	212,500 gpd	320,000 gpd	427,200 gpd	640,000 gpd	960,000 gpd
Models						
Z-BOX-S Model:	S12	S18	S24	S18	S24	S24
Z-BOX-S Quantity:	1	1	1	2	2	3
PRO Model:	PRO-50-PRE, FRP	PRO-100-PRE, FRP	PRO-150-PRE, FRP	PRO-200-PRE, FRP	PRO-300-PRE, FRP	PRO-450-PRE, FRP
PRO Quantity:	1	1	1	1	1	1
Break Tank & RO Feed Pump						
Tank Volume:	360 gallon	540 gallon	840 gallon	540 gallon	840 gallon	840 gallon
Tank Dimensions (DxH):	48"x 42" (122cm x 107cm)	48"x 75" (122cm x 191cm)	48"x 109" (122cm x 277cm)	48"x 75" (122cm x 191cm)	48"x 109" (122cm x 277cm)	48"x 109" (122cm x 277cm)
Pump Flow:	70 gpm	135 gpm	200 gpm	270 gpm	400 gpm	600 gpm
Pump Pressure:	60 psig (4.1 bar)	50 psig (3.4 bar)	40 psig (2.8 bar)	55 psig (3.8 bar)	40 psig (2.8 bar)	45 psig (3.1 bar)
Pump Power:	5 HP (3.7 KW)	7.5 HP (5.6 KW)	10 HP (7.5 KW)	15 HP (11 KW)	15 HP (11 KW)	20 HP (14.9 KW)
Installation and Utility Requirements						
UF Inlet:	4.0" flange	6.0" flange	6.0" flange	6.0" flange	6.0" flange	6.0" flange
UF Permeate:	3.0" flange	4.0" flange	4.0" flange	4.0" flange	4.0" flange	4.0" flange
UF Drain:	4.0" flange	6.0" flange	6.0" flange	6.0" flange	6.0" flange	6.0" flange
RO Inlet:	2.0" flange	3.0" flange	3.0" flange	4.0" flange	4.0" flange	6.0" flange
RO Permeate:	1.5" flange	3.0" flange	3.0" flange	3.0" flange	4.0" flange	4.0" flange
RO Concentrate:	1.0" flange	1.5" flange	1.5" flange	2.0" flange	2.0" flange	3.0" flange
Inlet Water Pressure:	5 psig, minimum	5 psig, minimum	5 psig, minimum	5 psig, minimum	5 psig, minimum	5 psig, minimum
Air Pressure:	100 psig	100 psig	100 psig	100 psig	100 psig,	100 psig
Drain to be Sized for:	67 gpm (15.2 m^3/hr)	133 gpm (30.2 m^3/hr)	200 gpm (45.4 m^3/hr)	267 gpm (60.6 m^3/hr)	400 gpm (90.9 m^3/hr)	600 gpm (136.3 m^3/hr)
Power:	460 VAC, 3-phase, 60Hz	460 VAC, 3-phase, 60Hz	460 VAC, 3-phase, 60Hz	460 VAC, 3-phase, 60Hz	460 VAC, 3-phase, 60Hz	460 VAC, 3-phase, 60Hz
Control Circuit:	120 VAC, 1-phase, 60Hz	120 VAC, 1-phase, 60Hz	120 VAC, 1-phase, 60Hz	120 VAC, 1-phase, 60Hz	120 VAC, 1-phase, 60Hz	120 VAC, 1-phase, 60Hz
UF Skid (per train)						
Height:	71" (180 cm)	71" (180 cm)	71" (180 cm)	71" (180 cm)	71" (180 cm)	71" (180 cm)
Width:	59" (150 cm)	59" (150 cm)	59" (150 cm)	59" (150 cm)	59" (150 cm)	59" (150 cm)
Depth:	121" (307 cm)	155" (394 cm)	190" (483 cm)	155" (394 cm)	190" (483 cm)	190" (483 cm)
Operating Weight Estimate:	9,000 lb (4082 kg)	13,000 lb (5897 kg)	16,500 lb (7484 kg)	13,000 lb (5895 kg)	16,500 lb (7484 kg)	16,500 lb (7484 kg)
RO Skid						
Height:	76" (193 cm)	76" (193 cm)	76" (193 cm)	76" (193 cm)	76" (193 cm)	99" (251 cm)
Width:	46" (117 cm)	46" (117 cm)	46" (117 cm)	80" (203 cm)	80" (203 cm)	80" (203 cm)
Depth:	194" (493 cm)	194" (493 cm)	274" (696 cm)	194" (493 cm)	274" (696 cm)	274" (696 cm)
Operating Weight Estimate:	4400 lb (1996 kg)	5850 lb (kg)	7800 lb (3538 kg)	9200 lb (4173 kg)	12500 lb (5670 kg)	18,000 lb (8165 kg)

ISO 9001 registered

SIEMENS

February 4, 2008

Mr. Chris Beck
Golder Associates Inc. - Denver Office
Phone No. 303-980-0540
e-mail: chris_beck@golder.com

Reference: Diamond Mine Project

Subject: Budgetary Proposal to Supply a Wastewater Treatment System

Siemens Water Technologies Proposal No. PK-0802-01-SYS-1

Dear Mr. Beck:

In response to your request, Siemens Water Technologies Corp. (Siemens) is pleased to provide the following preliminary information and budget pricing for the wastewater treatment system for the above-referenced project.

PROCESS OVERVIEW

- **Basis of Design**
  - Influent analyses are as listed in your document "Design Basis Influent."
  - All ions are assumed to be reported as the substance, except for total hardness and alkalinity.
  - To balance the analysis provided, either the sodium or chloride values have been increased from the reported values.
  - Objective of the treatment system is to achieve treated water quality TDS of ≤ 375 ppm.
- **Treatment Scheme Proposed**
  - **Primary Treatment - For Feed Water Treatment**
    - The feed water is treated in the primary solids contact clarifier (SCC) for the purpose of reducing TSS and precipitating hardness and other heavy metals, to make it suitable as feed to the reverse osmosis (RO) units. Chemicals used are:
      - Sodium Hypochlorite - For disinfection
      - Coagulant - To coagulate the larger floc particles
      - Lime and Soda Ash - To precipitate hardness and other heavy metals
      - Polymer - To agglomerate the finer floc particles and enhance the coagulation process
      - Acid - To pH adjust after lime and soda ash softening to avoid post precipitation

- The SCC effluent goes through a filtration step for reduction and removal of any iron, manganese and suspended solids.

  The filter effluent is treated with sodium bisulfite, antiscalent and acid for destroying residual chlorine, prevent scaling in the reverse osmosis membranes and pH adjustment, respectively.

- The filter effluent is treated in primary RO units using brackish water membranes for reduction of TDS. RO permeate is discharged back to the lake and the primary RO reject undergoes further treatment, as described below under "Secondary Treatment."

- The primary SCC blowdown undergoes further treatment, as described below under "Waste Treatment."

- **Secondary Treatment - For Treatment of Primary Reject**

  - The scheme employed is similar to that employed for the primary treatment, except for the following:

    - The filters employ multimedia in lieu of iron and manganese media.
    - The RO units use sea water membranes in lieu of brackish water membranes.

  - The RO permeate is discharged back into the lake and the RO reject and secondary SCC blowdown is sent to the evaporation pond.

- **Waste Treatment - For Treatment of the Primary SCC Blowdown**

  - The primary SCC blowdown is concentrated by gravity separation and stored. When a sufficient volume has accumulated, the solids are pumped to the filter press. Filter cake from the press is discharged while the press filtrate is returned to the secondary SCC for reprocessing.

PRIMARY TREATMENT - EQUIPMENT LIST

Note: Equipment quantities listed are for the maximum flow rate of 5,500 gpm.

- Three (3) Clarifiers - Solids contact type, 50% capacity each, 40 ft diameter, coated concrete construction. Concrete tank by Purchaser.
- Clarified Water Storage Tank - By Purchaser
- Four (4) Filter Feed/Filter Backwash Pumps - CD4MCu construction
- Five (5) Horizontal Filters - 10 ft diameter x 42 ft long
- Seven (7) High Pressure Reverse Osmosis Pumps - Shipped loose
- Seven (7) Reverse Osmosis Units - 24 x 12 array, shop fabricated
- Treated Wastewater Effluent Tank - By Purchaser, if required
- Treated Waste Forwarding Pumps - By Purchaser, if required
- One (1) Lime Silo - 8,000 cu ft capacity. Requires field erection.
- One (1) Lime Slurry Feed System - Including slurry tank and 2 x 100% slurry feed pumps. Shop fabricated.
- One (1) Soda Ash Silo - 8,000 cu ft capacity. Requires field erection.
- One (1) Soda Ash Feed System - Including solution tank and 2 x 100% solution feed pumps. Shop fabricated.
- One (1) Sodium Hypochlorite Storage Tank - FRP construction. Shop fabricated.
- One (1) Sodium Hypochlorite Feed System - Including 2 x 100% metering pumps. Shop fabricated.
- One (1) Ferric Chloride Storage Tank - FRP construction. Shop fabricated.
- One (1) Ferric Chloride Feed System - Including 2 x 100% metering pumps. Shop fabricated.
- One (1) Polymer Feed System - Including 3 x 100% Polyblends. Shop fabricated. Chemical is supplied in totes by others.
- One (1) Hydrochloric Acid Feed Tank - FRP construction, with fume scrubber. Shop fabricated.
- One (1) Hydrochloric Acid Feed System - Including 3 x 100% metering pumps, shop fabricated.

SECONDARY TREATMENT - EQUIPMENT LIST

Note: Equipment quantities listed are for the maximum flow rate of 5,500 gpm.

- Three (3) Clarifiers - Solids contact type, 50% capacity each, 18 ft diameter, coated carbon steel construction. Requires field erection and coating.
- Clarified Water Storage Tank - By Purchaser
- Three (3) Filter Feed/Filter Backwash Pumps - CD4MCu construction
- Four (4) Vertical Filters - 12 ft diameter x 5 ft SSH
- Three (3) High Pressure Reverse Osmosis Pumps - Shipped loose
- Three (3) Reverse Osmosis Units - Single array with 20 housings each, shop fabricated.
- One (1) Sodium Hypochlorite Feed System - Including 2 x 100% metering pumps. Shop fabricated.
- One (1) Ferric Chloride Feed System - Including 2 x 100% metering pumps. Shop fabricated.
- One (1) Polymer Feed System - Including 3 x 100% Polyblends. Shop fabricated. Chemical is supplied in totes by others.
- One (1) Hydrochloric Acid Feed System - Including 3 x 100% metering pumps, shop fabricated.

WASTE TREATMENT - EQUIPMENT LIST

Note: Equipment quantities listed are for the maximum flow rate of 5,500 gpm.

- Two (2) Sludge Storage Tanks - 35 ft diameter x 32 ft high, coated carbon steel construction. Requires field erection and coating. Agitator included.
- Five (5) Belt Filter Press Feed Pumps - Centrifugal type, rubber-lined, ductile iron construction. Skid-mounted. Shop fabricated.
- Five (5) Belt Filter Presses - 2 m each, semi-automatic. Shop fabricated.
- One (1) Filtrate Sump - By Purchaser
- Two (2) Filtrate Sump Pumps - Vertical sump pumps, high chrome construction. Field installation.
- One (1) Polymer Feed System - Including 5 x 100% Polyblends. Shop fabricated. Chemical is supplied in totes by others.

COMMON EQUIPMENT

- One (1) set of interconnecting piping
- One (1) PLC-based control system

PROJECT SCHEDULE

Delivery of equipment is typically 11 to 12 months from date of order. Installation and start-up will require an additional 8 to 10 months.

BUDGETARY PRICE

Siemens would supply the wastewater treatment system as described herein for approximately TWENTY-EIGHT MILLION FIVE HUNDRED THOUSAND DOLLARS . . . . . $28,500,000.

Any applicable taxes or duties are not included.
Freight to the jobsite is included.

We trust this information meets your requirements. Please contact us if you have any questions.

Sincerely,

Jeffrey L. Gutierrez
Capital Sales Engineer
480-706-1022

cc:

Siemens Water Technologies
Chris Edmonds
Prakash Khanolkar

c.

April 24, 2014

Julie L'Heureux
Water Manager
Snap Lake Mine
De Beers Canada Inc.
c/o Det'on Cho Logistics Ltd.
101 McMillan Street, PO Box 2608
Yellowknife, Northwest Territories X1A2P9

Dear Ms. L'Heureux;
Further to our discussion and our visit to Snap Lake in early March, we were asked to comment on the ability to provide a grout curtain as an impermeable barrier between the lake and the developed mine.

To accomplish this objective all known and unknown pathways that hydraulically connect the developed mine and the lake need to be grouted.

Upon review and analysis of the available data provided, we have determined that while this option is technically possible it is far from practical due to the following:

a) There are 6 known families of faults hydraulically connecting the lake and the mine. Some faults are more than 2km long and approximately 30m wide. The time required to drill and grout even one of these faults would be extremely lengthy with a probable duration of 1 to 4 years per fault. The operation itself would be extremely costly (with estimates ranging from $200 million upwards) and would have other cost implications through the impact of the mining production rates.

b) It is our understanding that while there are some detailed reports on the hydraulic pathways, the information is still insufficient for a detailed grout program. This severely minimizes the possibility for precision grouting of the main feeder conduits and therefor limits the probability of success.

c) There is limited information on the infill of the faults (such as percentages of fines, clays, etc.) which is important for a grouting program. Based on the provided information and what was actually observed, the infill of the faults may vary drastically therefore meaning that the permeability of these faults may also vary and may result in some formations that are not injectable through conventional permeation grouting techniques. Collection and analysis of the data needed would take a dedicated engineering team two or more years.

d) The developed mine is a very large area. A complete grout curtain would have to cover the entire area taking several years of grouting operations (unless the inflow can be attributed to a relatively small and clearly defined point of entry – which, from our understanding it is not).

e) A grout curtain located above the mining horizon may not provide a solution to the high TDS inflows as these inflows may have different driving forces therefore additional grouting may be required to seal these inflows.

In conclusion – while it is technically possible to grout the faults or other hydraulic paths (as if water can travel through a media, a type of grout can also travel through the same media); However, the geological mapping of the pathways may not be complete and the cost and time associated with such an investigation and grouting program would be enormous and therefore impractical.

We hope this answers your inquiry. Please contact me directly for further information or details.

Sincerely,

General Manager