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March 30, 2007 Reference No. 047437

Ms. Belinda Campbell
Senior Environmental Specialist
Public Works Government Services Canada
Environmental Services Group
1713 Bedford Row
Halifax, NS B3J 3C9

Re: Assessment of Mine Water Treatment Options
1A Mine Pool, Town of Dominion, Cape Breton County, Nova Scotia

Dear Ms. Campbell:

Please find enclosed a copy of the final report dealing with the above noted project. This report contains the results of the four following project tasks.

1. Initial Options Review - Deals with an assessment of the original nine options proposed to treat mine water in the 1B Mine Pool.
2. Characterization of the 1B Mine Pool. – Summarizes current knowledge of the 1B Mine Pool.
3. Pumping Strategy at the Neville Street Wellfield – Reviews current pumping status at the Wellfield.
4. Development of Mine Water Discharge Criteria – Describes current practice, both international and local, for discharging mine water into marine environments.

In conclusion, we trust that this information is sufficient for your reference at this time. However, if you have any questions or comments, please contact the undersigned at your convenience.

Yours truly,

CONESTOGA-ROVERS & ASSOCIATES

Steve Forgeron, B. Sc., P. Geo.
Senior Project Geologist

SVF/klm/002

Managing Mine Water Quality and Flow in the 1A Mine Pool – Phase 1

TASK 1 – INITIAL OPTIONS REVIEW REPORT

INTRODUCTION

The following report constitutes Task 1 - Phase 1 of investigations into the "Water Treatment Program 1A Mine Pool, Town of Dominion, Cape Breton County, Nova Scotia". Phase 1 of the program involves the preparation of this report on "Initial Options Review", as well as three (3) other tasks including (2) "Mine Pool Characterization", (3) "Mine Water Discharge Criteria Development" and the creation of an external (4) "Advisory Committee". It is noted that Tasks 2 and 3 are to be completed by the end of January 2007, whereas Task 4, the creation of the "Advisory Committee", has already been completed.

Phase 2 of the project will follow the completion of Phase 1 and utilize the information derived to identify "Information Gaps", determine the "Volume of AMD Impacted Water to be Treated", conduct a "Focused Options Review" to arrive at one final option for pilot testing and provide comment on the "Potential Future Liability for CBDC". It is anticipated that Phase 2 will be completed by March 31, 2007

The Project "Terms of Reference" identifies nine (9) options that were previously proposed as possible approaches for developing a "walk away" for the 1B Mine Pool. The purpose of this report is to review these options and identify the advantages and disadvantages associated with each option as well as to develop an evaluation matrix to arrive at three (3) go forward options, using convincing rationale. The three (3) options must vary in approach and not merely be variations of the same option.

All the approaches being considered to develop a walk-away solution will have to deal with the following issues.

1. The Neville Street Wellfield is a crucial component in the water quality improvement process. The Wellfield is required to control mine pool water levels until the walk-away (passive outflow at 1A Outfall) solution can be attained. There may be a requirement for on-site treatment at the Neville Street Wellfield if the current water quality deterioration process persists.

2. Water quality in the 1A Mine Pool must be improved to an acceptable release standard before it can be passively discharged to the sea. An essential element of a walk-away solution will be the ability to maintain that acceptable discharge water quality over time. Once mine water in the upper workings has been initially improved for release, there is a very real concern that AMD in the deeper mine workings will migrate up dip, by diffusion and convection, and negatively impact discharge quality.

   To address this concern the concept of "effective treatment depth" is introduced. Effective treatment depth is that depth (in the mine workings) to which water quality improvement must be affected to insure is can be maintained over time. Its consideration raises the vital question of whether or not a walk-away solution can be attained by only treating mine water in the shallow workings; or must treatment be extended to the far reaches and total depths of all mines making up the mine pool? The effective treatment depth in the 1A Mine Pool is not known at this time. However, one may be able to estimate this depth on the basis of experience in other coalfields, by assessing the connectivity between component mines and by monitoring water quality trends across the mine pool as the water treatment process is implemented.

Work by Younger (2002) suggests that depth may not be an over-riding factor but that an asymptotic water quality may be achieved when approximately four mine volumes have been removed and are replaced by recharge surface water.

The question of how much water must ultimately be treated is an essential one in the selection of the most effective treatment process. It will have a major impact on the total cost of treatment and the timeframe needed to attain a walk-away solution.

3. Once water quality in the 1A Mine Pool has been improved to an established release standard, the water level in the 1A workings must be permitted to rise from elevation -17 to +9 feet. This water level rise is necessary to establish a passive discharge into the Water Level Tunnel and thereafter to the sea via the 1A Outfall. Prior to initiating this water level rise, the following issues will have to be addressed.

    a. As water level rises, acid generating salts in the shallow workings will be dissolved and produce a localized deterioration in water quality within the Water Level Tunnel. A method of treating this water will have to be developed prior to its release.

    b. As water level rises, mine workings under the Town of Dominion will become progressively saturated with water. The potential risk for surface subsidence over these workings will have to be assessed.

4. With the high flow rates expected in the spring and fall (up to 6000 USGPM) the 1A Outfall will be discharging water at rates that surpass those from any other abandoned mine in the Coalfield. Issues involving bank stability at the coastline and water level integrity will have to be considered before the long term walk-away solution can to be implemented.

5. Before mine water can be released, regulators must be convinced that such action will not negatively impact the marine environment. Local residents will also have to be convinced that mine water release will not impact the local fishing and tourist industries. Accordingly, safe mine water release criteria must be developed and approved before passive release can be implemented. The development of release criteria will also be needed to better define the optimum treatment methodology and its cost. I will also define a water quality goal for the treatment process.

OPTION ANALYSES

In the following discussion of water quality improvement options, reference is made to various locations and features associated with the 1A Mine Pool. Please see Figure 1 for orientation.

1. Maintain the Status Quo (Pumping from Neville Street Well field).

Under this option, the current situation would continue without change. This option involves maintaining mine pool water level between elevation –17 to -19 feet by pumping the Neville Street Wellfield to match surface and groundwater infiltration. This is obviously not a walk-away solution because it does not improve water quality, does not provide for a passive discharge and will require pumping in perpetuity. Deterioration of water quality at the Wellfield may also necessitate treatment of the discharge, which would also dictate the inadvisability of maintaining the status quo. The advantages, disadvantages and associated risks of this option are as follows:

Advantages:

- Has so far proven to be an acceptable approach with no direct discharge of AMD to the environment.
- To date, this method has been acceptable to the regulators.
- Method has so far been tolerated by the local community.
- Minimal requirement for new land acquisition.
- The process is straightforward and does not require additional research.

Disadvantages:

- Not a "walk away" solution.
- Pumping must continue indefinitely since it does not provide for a passive discharge.
- Water quality at the Wellfield has shown progressive deterioration and may require on site treatment.
- If deterioration of water quality continues, this option will not be acceptable to the regulators.
- If deterioration of water quality continues, this option will not be acceptable to the local community.
- Operating costs are high and will increase significantly if on-site treatment is required.

Risks:

Short-term risk is high because on-site water treatment will be required if deteriorating water quality persists at Neville Street Wellfield.

Long-term risk is high because pumping must continue in perpetuity and cost will increase over time due to deteriorating water quality situation.

2. Close 1A Outfall and Thereby Redirect Water Flowing in the 1A Water Level Tunnel Directly to the 1A Mine Pool. (Note that all the methods will eventually have to consider this approach if a "walk-away" status is ever to be realized. This option will be used in conjunction with the other methods).

The underground Water Level Tunnel is currently diverting infiltrating groundwater to the 1A Outfall. Based on one year of monitoring data approximately 35,000,000 gallons of this better quality water could be added to the 1A Mine Pool by closing the Outfall at the coast. This water would contain <2 mg/L iron and a pH of about 6.2 and Alkalinity of 200 mg/L (See Appendix F-1 Water Balance Study). The advantages, disadvantages and risks associated with this option are as follows:

Advantages:

- Help accelerate water quality improvement in the 1A Mine Pool by providing dilution and alkalinity.
- Better quality water will be delivered to where it would be most effective for improving mine pool water quality.
- Cost to close the 1A Outfall would be less than other options.
- Will allow the determination of the mine pool overflow elevation between the main 1A workings and the 1A Water Level Tunnel.
- Will permit an assessment of the integrity and permeability of the ground around the water level tunnel in a non-emergency environment.
- Should be acceptable to the regulators.

Disadvantages:

- Not a "walk-away" solution.
- To make room for added water, good quality water must be removed at Neville Street Wellfield.
- Adding water at 1A Colliery and pumping the Neville Street Wellfield to maintain water level in the mine pool may tend to drive the poorer quality water from the 1A Mine Pool to the Neville Street Wellfield.
- Water quality improvement will be slow because of low inflow rate; it could not be the sole water quality improvement method.
- May not be acceptable to local residents.
- Not a straightforward option; high level of monitoring required to avoid unplanned ground failures.
- Water quality improvement will be localized.

Risks:

Short-term risk is moderate to high because it will take an extraordinarily long time to improve water quality to an acceptable release standard.

Long-term risk is high because it does not constitute a "walk-away" solution.

3. Introduce Sea Water to the 1A Colliery Mine Workings.

This option would involve pumping seawater from the nearby ocean and injecting it into the mine pool at strategic locations using a series of boreholes. A variation would involve the provision of a gravity flow inlet to the mine workings from the seashore. The goal of this option would be to improve mine water quality by diluting it to an established release standard. It is noted that an accurate dilution factor has not been determined. The advantages, disadvantages and risks associated with this option are as follows:

Advantages:

- Will accelerate water quality improvement in the 1A Mine Pool by providing alkalinity and dilution.
- Water can be delivered directly to the area of concentrated AMD in 1A Colliery where it would be most effective.
- Seawater is readily available nearby.
- Water treatment or sludge disposal will not be required.
- Minimal requirement for new land acquisition.

Disadvantages:

- Pumping at Neville Street Wellfield must continue and increased to make room for the added water.
- Requires regulatory approval, and the permitting process may be onerous.
- May require a full Environmental Assessment under CEAA.
- Would probably not be acceptable to local residents.
- Seawater injected by gravity would be expensive to develop.
- Seawater addition by pumping would be costly and its effectiveness difficult to monitor.
- The addition of seawater at 1A Colliery, and pumping from the Neville Street Wellfield to maintain the mine pool water level, may promote the southward movement of AMD and sea water (high chlorides) towards the pumping wells at the Neville Street Wellfield and may necessitate treatment, or cause a regulatory shutdown in the case of chlorides.
- Modeling of hydrology and geochemistry needs to be carried out.
- Wellfield would have to pump at a rate equivalent to both the surface water inflow and seawater addition.
- Could impact third party groundwater users.
- Dilution methods take a long time to be effective.

Risks:

Short-term risk is high. It could negatively impact status quo at the Wellfield and impact third party groundwater users.

Long-term risk is high of many unknowns; effectiveness of method in question due to lack of precedents to serve as guidance.

4. Introduce Groundwater to 1A.

This option is similar to Option 3, however in this case groundwater overlying the mine pool would be introduced into the mine pool at strategic locations. The goal of this option would be to improve water quality by diluting the mine water until it meets an established release standard. It is noted that an accurate dilution factor has not been determined. The advantages, disadvantages and risks associated with this option are as follows:

Advantages:

- Will accelerate rate of water quality improvement in the 1A Mine Pool by providing alkalinity and dilution.
- Water can be delivered directly to the area of concentrated AMD in 1A Colliery where it would be most effective.
- Capital and operating costs would be relatively low when compared to the other options.
- Water treatment or sludge disposal will not be required.
- Minimal requirement for new land acquisition.

Disadvantages:

- Pumping at the Neville Street Wellfield must continue and be increased to make room for added water.
- The addition of groundwater at 1A Colliery and pumping at the Neville Street Wellfield may promote the southward movement of AMD towards the Neville Street Wellfield and necessitate treatment of the discharge.
- Modeling of hydrology and geochemistry needs to be carried out before this option is considered.
- Extent of water-bearing sandstone over mine pool has not been determined. More assessment required.
- Volume of available water for dilution is not accurately known.
- Dilution methods take a long time to be effective.
- Will probably not be acceptable to local residents.
- Will probably meet resistance from regulators
- Dropping the groundwater water table could impact third party water users.

Risks:

Short-term risk is high. Could negatively impact status quo at the Wellfield by causing AMD in the 1A Mine Pool to flow south to pumping wells. Could also impact local well users.

Long term risk is high because effectiveness of method is unknown; lack of precedents to serve as guidance.

5. Pipe Pumped Water from Neville Street Wellfield to 1A Colliery.

This option would involve transporting discharge water from the Neville Street Wellfield using an overland pipeline and injecting the water into the 1A Mine Pool at strategic locations. The goal of this option would be to improve mine water quality by dilution until it meets an established release standard. It is noted that an accurate dilution factor has not been determined. The advantages, disadvantages and risks associated with this option are as follows:

Advantages:

- Water can be delivered directly to the area of concentrated AMD in 1A Colliery where it would be most effective.
- The methodology is relatively straightforward.
- Relatively low operating costs when compared to other options.
- Water treatment or sludge disposal will not be required.
- Minimal requirement for new land acquisition.

Disadvantages:

- Pumping at Neville Street Wellfield must continue and be increased to make room for added water.
- The addition of groundwater at 1A Colliery and pumping at the Neville Street Wellfield to control water level may promote southward movement of AMD towards the Neville Street Wellfield and necessitate treatment of that discharge.
- Modeling of hydrology and geochemistry needs to be carried out.
- Dilution methods take a long time to be effective.
- Will probably not be acceptable to local residents.
- Will probably meet resistance from regulators.

Risks:

Short-term risk is high. Could negatively impact status quo at the Neville Street Wellfield by causing AMD in the 1A Mine Pool to flow south towards the pumping wells. Could also impact third party water users.

Long term risk is high because its effectiveness is unknown; lack of precedents to serve as guidance.

6A. Pump Water from 1A Colliery, Treat On-site and Discharge.

This option would involve the construction of new extraction wells to tap the 1A Mine Pool near the Town of Dominion, and the associated removal and on-site treatment of AMD impacted mine water using a newly constructed treatment plant. The treatment plant effluent would be discharged to the marine environment and sludge would be disposed of off-site. The advantages, disadvantages and risks associated with this option are as follows:
Advantages:

- Proven technology. Method is well understood and tested at many sites including the No. 1B Shaft in Glace Bay.
- Water removal from the 1A Colliery end of mine pool will create differential hydraulic head and tend to drive recharge water north from Neville Street Wellfield towards the 1A Mine Pool.
- Water quality deterioration at the Neville Street Wellfield will be slowed down or halted.
- Pumping effort at Neville Street Wellfield will be reduced in proportion to water treatment rate.
- Will accelerate rate of water quality improvement by removing strongly impacted AMD water and reducing the level of dilution otherwise required.

Disadvantages:

- Expensive to build treatment plant.
- Comparatively high operating costs.
- High sludge disposal costs (might consider on site thickening and disc-filtering).
- May require acquisition of land for new settling pond.
- Will probably generate public resistance.
- Will probably require new regulatory approvals.
- Comparatively long start-up time.

Risks:

Short-term risk is low. Technology is proven.

Long-term risk is low to moderate; low because of high probability of leading to a "walk-away" solution, moderate because of high costs of implementation.

6B. Pump Water from 1A Colliery, Transport to 1B shaft and Treat Using Existing Treatment Plant.

This option is a variation of Option 6A and would involve the construction of a new extraction wells at 1A Colliery and the associated removal, transport using a newly constructed pipeline, and treatment of impacted mine water using the existing treatment plant located near the 1B shaft. The treatment plant effluent would be discharged to the marine environment and sludge would be disposed of off-site. The advantages, disadvantages and risks associated with this option are as follows:

Advantages:

- Proven technology. Method is well understood and tested at many sites including No. 1B in Glace Bay.
- Treatment plant and settling pond already available at the 1B Shaft.
- The 1B site has already received regulatory approval.

- Water removal from the 1A Colliery end of mine pool will create differential hydraulic head and tend to drive recharge water north from Neville Street Wellfield towards the 1A Mine Pool.
- Water quality deterioration at the Neville Street Wellfield be slowed or halted.
- Pumping effort at Neville Street Wellfield will be reduced in proportion to water treatment rate.
- Will accelerate rate of water quality improvement by removing strongly impacted AMD water and reduce the level of dilution otherwise required.
- Precedent has already been set at the 1B treatment plant.
- Land for transporting pipeline is already owned by CBDC.

Disadvantages:

- High capital costs to build pipeline from 1A Colliery to 1B treatment plant.
- High operating costs to treat water.
- High sludge disposal costs.
- Could experience public resistance at the 1B site.

Risks:

Short-term risk is low. Technology is proven.

Long-term risk is low to moderate; low because of high probability of leading to a "walk-away" solution, moderate because of the high costs for implementation.

6C. Remove Poor Quality Water, Mix with Alkaline Chemical, and Return to 1A Workings.

This option is also a variation of Options 6A and 6B. It would involve the construction of new pumping and injection wells at 1A Colliery, the treatment of mine water via the addition of alkaline materials, and the re-injection of the slurry to the mine workings where chemical reaction and settling would take place. The advantages, disadvantages and risks associated with this option are as follows:

Advantages:

- Will accelerate water quality improvement by introducing a strong source of alkalinity directly to the mine pool.
- Chemical end of process should be effective.
- No requirement for costly sludge disposal.
- Permitting expected to be less onerous than for other options.
- Relatively short time period required to implement.
- Relatively low capital cost when compared to other treatment options.

Disadvantages:

- Effectiveness unknown; must be tested by a pilot plant operation in the field.
- May not reduce the deterioration of water quality at Neville Street Wellfield; treatment may be needed at both sites.
- Questions exist regarding extent of mixing within mine pool and ability to monitor reaction effectiveness.
- Will require large number of pumping and injection wells across mine pool.
- Will probably not be well received by local community.
- Could impact third party groundwater users.

Risks:

Short-term risk is moderate. Technology is not proven

Long-term risk is moderate because effectiveness in providing a "walk-away" solution in not known.

7. Pump Water from 1B Shaft, Treat, Settle and Release to Marine Environment.

This option would involve using the 1B Shaft to access and pump the mine pool and use the existing plant to treat the water; effluent would be released to the marine environment. The advantages, disadvantages and risks associated with this option are as follows:

Advantages:

- Proven technology. Method is well understood and tested at many sites including No. 1B in Glace Bay.
- Low initial capital cost because treatment plant infrastructure is already in place.
- Has already received regulatory approval.
- Removal from 1B end of mine pool will create differential hydraulic head and tend to drive recharge water north from Neville Street Wellfield to the 1A Mine Pool.
- Water quality deterioration at the Neville Street Wellfield will be gradually slowed or halted.
- Pumping effort at Neville Street Wellfield will be reduced in proportion to water treatment rate.
- Will accelerate rate of water quality improvement by removing strongly impacted AMD water and reduce the level of dilution otherwise required.
- Can be started up in a relatively short time frame.

Disadvantages:

- High operating costs.
- Upgrading of existing treatment infrastructure will be required.

- High sludge disposal costs; there is some potential to dispose of sludge in workings at site.
- Some public resistance is expected.
- May take some time before mine water quality improves in the shallow mine workings near the 1A Outfall.

Risks:

Short-term risk is low. Technology is proven.

Long-term risk is low to moderate; low because of high probability of leading to a "walk-away" solution, moderate because of high costs of implementation.

8. Controlled Release of Mine Water at the 1A Outfall (Note that all the methods will eventually have to consider some aspects of this approach if a walk-away status is to be realized).

This option involves closing the 1A outfall at the coastline, turning off pumps at Neville Street Wellfield and allowing mine water to fill 1A water level. The well field would then be used to control the water level and keep a minimum pressure on the dam. The mine water would be released in a controlled manner using valve-controlled pipes in the dam. Prior to allowing the water level to flood, alkaline materials would be placed in workings along the level, and the integrity of the dam and ground would be checked by allowing the water to back up into the level. The advantages, disadvantages and risks associated with this option are as follows:

Advantages:

- Low technology approach.
- Removal from 1A end of mine pool will create differential hydraulic head and tend to drive recharge water north from Neville Street Wellfield to the 1A Mine Pool.
- Water quality deterioration at the Neville Street Wellfield will eventually be slowed or halted.
- Pumping effort at Neville Street Wellfield will be reduced in proportion to water release rate.
- Will accelerate rate of water quality improvement by removing strongly impacted AMD water and reduce the level of dilution otherwise required.
- Can be implemented in short period of time.

Disadvantages:

- Not a "walk-away" solution.
- Will probably generate public resistance.
- Contains many unknowns, which are difficult to assess with certainty; for example, the integrity of Water Level Tunnel and potential risk for surface subsidence.

- Mine water discharge criteria must be developed and receive regulatory approval.
- Will probably require an ecological risk assessment.
- Must release mine water at a rate that will not cause iron plume; loading criteria to accomplish this is currently not available.
- Requires a high level of monitoring and control.

Risks:

Short-term risk is high. Will have to overcome public resistance and rise of water may induce surface subsidence.

Long-term risk is moderate to high because it is not a "walk-away" solution.

9. Use Option 6A or 6C in Conjunction with Option 7.

This option would involve the use of Option 6A (new extraction wells and treatment plant at 1A) **or** Option 6C (new extraction wells, on-site alkaline treatment and injection), in conjunction with Option 7 (pumping using the 1B shaft and treatment using the existing treatment plant). The partnership of Option 6A and 7 is favored because there is less uncertainty regarding its technical viability. The advantages, disadvantages and risks associated with this option are as follows:

Advantages:

- Because of the higher water treatment rate, time required for establishing a walk-away status will be greatly reduced. This is the primary advantage of this option.
- Employs mostly proven technology. Water treatment side is well understood.
- Treatment plant is available at 1B Shaft.
- Removal of mine water from 1A and 1B Collieries will create differential hydraulic head and tend to pull recharge northwards from Neville Street Wellfield to the 1A Mine Pool.
- Water quality deterioration at the Neville Street Wellfield will be gradually slowed or halted.
- Pumping effort at Neville Street Wellfield will be reduced in proportion to water treatment rate.
- Will accelerate rate of water quality improvement by removing strongly impacted AMD water and reduce the level of dilution otherwise required.
- Will probably be viewed favorably by the regulators.
- Provides the best opportunity to assess the effective treatment depth for the mine pool.

Disadvantages:

- Highest capital costs of all options considered.
- Highest operating costs of all options considered.
- Highest sludge disposal costs.

- Could experience public resistance at both sites.
- Will require new regulatory approval at the No. 1A Colliery site and may require an ecological risk assessment.

Risks:

Short-term risk is low. Technology is generally proven.

Long-term risk is low to moderate; low because of high probability of leading to a "walk-away" solution, moderate because of high costs of implementation.

EVALUATION MATRIX

In order to assess, in relative terms, the acceptability and effectiveness of the nine (9) options put forward, an evaluation matrix has been developed. This matrix, which is attached as Figure 1, has been adapted from the document "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, EPA/540/G-89/004 - 1988" and is used herein, to reduce the number of options from the current nine (9) to three (3). The matrix includes considerations such as Implementability (8 items), Environmental Impacts (7 items), Community Impacts (7 items) and Costs (3 items) in concert with a Weighting Factor for each item. It is noted that the matrix will be further refined and utilized during Phase 2 (see Introduction) of this investigation in order to arrive at the final most acceptable option for a "walk away" solution for the treatment and safe discharge of water from the 1A mine pool.

CONCLUSIONS

Initially, a review of the advantages, disadvantages and risks associated with each option, indicates that Option 1 (Status Quo), Option 2 (Close 1A Outfall) and Option 8 (Controlled Release at 1A Outfall) are not stand alone "walk away" solutions and are therefore not considered further as independent solutions to the mine pool treatment/discharge issue.

However, it is noted that Option 1 – Status Quo, which involves the continuation of mine water removal at the Neville Street Wellfield must continue as a water level control mechanism, in conjunction with the final chosen option, until final discharge criteria have been met and free discharge is permitted through the 1A Outfall.

It is also noted that, Option 2 – Close the 1A Outfall, although not considered a "walk away" solution should be strongly considered as an add-on or supplemental process, to the final option. The implementation of this add-on will not only add good quality water to the 1A mine pool in a heavily impacted area, but more importantly enable an evaluation of the integrity of the 1A Outfall Water Level Tunnel as well as the determining the overflow elevation between the deeper 1A workings and the 1A Water Level Tunnel.

Furthermore, Option 8 – Controlled Release at the 1A Outfall, although not considered further as a "walk away" option, is considered as the final mechanism by which uncontrolled treated mine water discharge will occur, once the final discharge criteria have been met.

This process of elimination leaves six (6) remaining options, of which three (3) involve dilution of the mine pool and three (3) involve removal and treatment of the affected mine pool. The three (3) dilution options score the lowest of the six (6) remaining options, due to difficulties in implementation, regulatory approval, potential lack of public acceptance, long duration time frames and associated cost implications. This is mainly related to the supposition that it will require a significant factor of dilution to render the mine water acceptable for direct discharge and the inherent difficulties and costs related to controlling the overall increase in water volume requiring pumping from the Neville Street Wellfield during the course of any dilution exercise.

Therefore, as the Evaluation Matrix scoring indicates, the recommended final three (3) options which should be considered for further evaluation include Option 6 – Pumping from the 1A Mine Pool, Treating and Discharging using variations 6A, 6B, or 6C; Option 7 – Pumping from 1B Shaft, Treating and Discharging, and Option 9 – A Combination of 6A or C and Option 7. It is noted that the preferred integration for Option 9 is a combination of Option 6A and Option 7.

Evaluation Matrix

1B Hydraulic System Preliminary Conceptual Evaluation

Assessment Criteria based on document "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" EPA/540/G-89/004, 1988

Assessment Criteria	Weighting Factor	#1 Maintain Status Quo	#2 Close 1A Water Outfall	#3 Introduce Sea Water	#4 Introduce Ground Water	#5 Pipe Water From Neville Street	#6(A,B,C) Pump from 1A, treat and discharge	#7 Pump from the 1B Shaft, treat and discharge	#8 Controlled Release of Water At 1 A Outfall	#9 Combination of Options 6 and 7.
General										
		Not a Walk Away Option	Not a Walk Away Option						Not a Walk Away Option	
Implementability										
Reliability of Technology	**10**	0	0	1	2	3	5	5	0	5
Amenability to Site Characteristics	**7**	0	0	2	3	4	5	5	0	5
Ability to monitor effectiveness	**7**	0	0	3	4	4	5	5	0	5
Availability of Equipment & Operators	**8**	0	0	4	5	5	5	5	0	5
No Need for Additional Investigation	**10**	0	0	1	1	1	4	4	0	3
Short Timeframe to Implement	**7**	0	0	2	2	2	4	5	0	5
Time to Effect desired outcome	**10**	0	0	1	1	1	3	5	0	5
Potential to Negatively Impact Wellfield	**10**	0	0	1	3	3	5	5	0	5
Environmental Impacts										
Acceptable to Regulators	**8**	0	0	1	2	2	4	5	0	5
Ability to Obtain approvals	**8**	0	0	1	2	2	4	5	0	5
Will Not Generate Waste Material	**7**	0	0	5	5	5	2	2	0	2
Material disposal requirements	**7**	0	0	5	5	5	1	1	0	1
Will not Impact Groundwater	**10**	0	0	1	3	3	5	5	0	5
Will not Cause Subsidence Impacts	**10**	0	0	5	5	5	5	5	0	5
Will not Cause Marine Impacts	**10**	0	0	5	5	5	5	5	0	5
Community Impacts										
Will be Acceptable to community	**10**	0	0	1	3	3	4	5	0	5
Can protect community	**10**	0	0	2	3	3	5	5	0	5
Will not Reduce Property Value	**10**	0	0	2	3	3	5	5	0	5
Will not generate Noise	**7**	0	0	3	3	3	3	4	0	3
Will not pose Health Hazards	**10**	0	0	2	3	3	5	5	0	5
Will not Generate Dust	**7**	0	0	5	5	5	4	5	0	5
Will not Generate Odor	**7**	0	0	5	5	5	4	4	0	4
Costs										
Low Capital Cost	**8**	0	0	1	2	3	2	5	0	2
Low Operating and Maintenance	**8**	0	0	2	3	4	1	2	0	1
High Residual Value	**3**	0	0	1	1	1	1	1	0	1
Total Score (with weighting factors considered)		**0**	**0**	**505**	**659**	**692**	**837**	**936**	**0**	**887**
Total Score (without considering weighting factors)		**0**	**0**	**62**	**79**	**83**	**96**	**108**	**0**	**102**

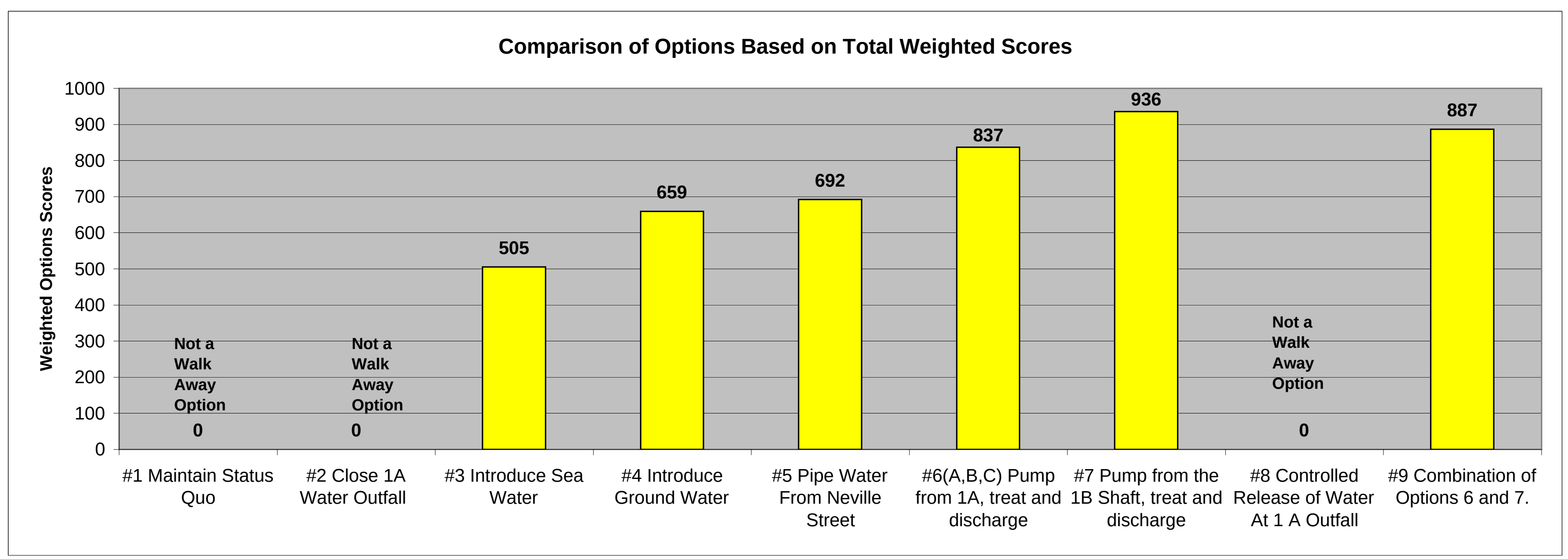
LEGEND

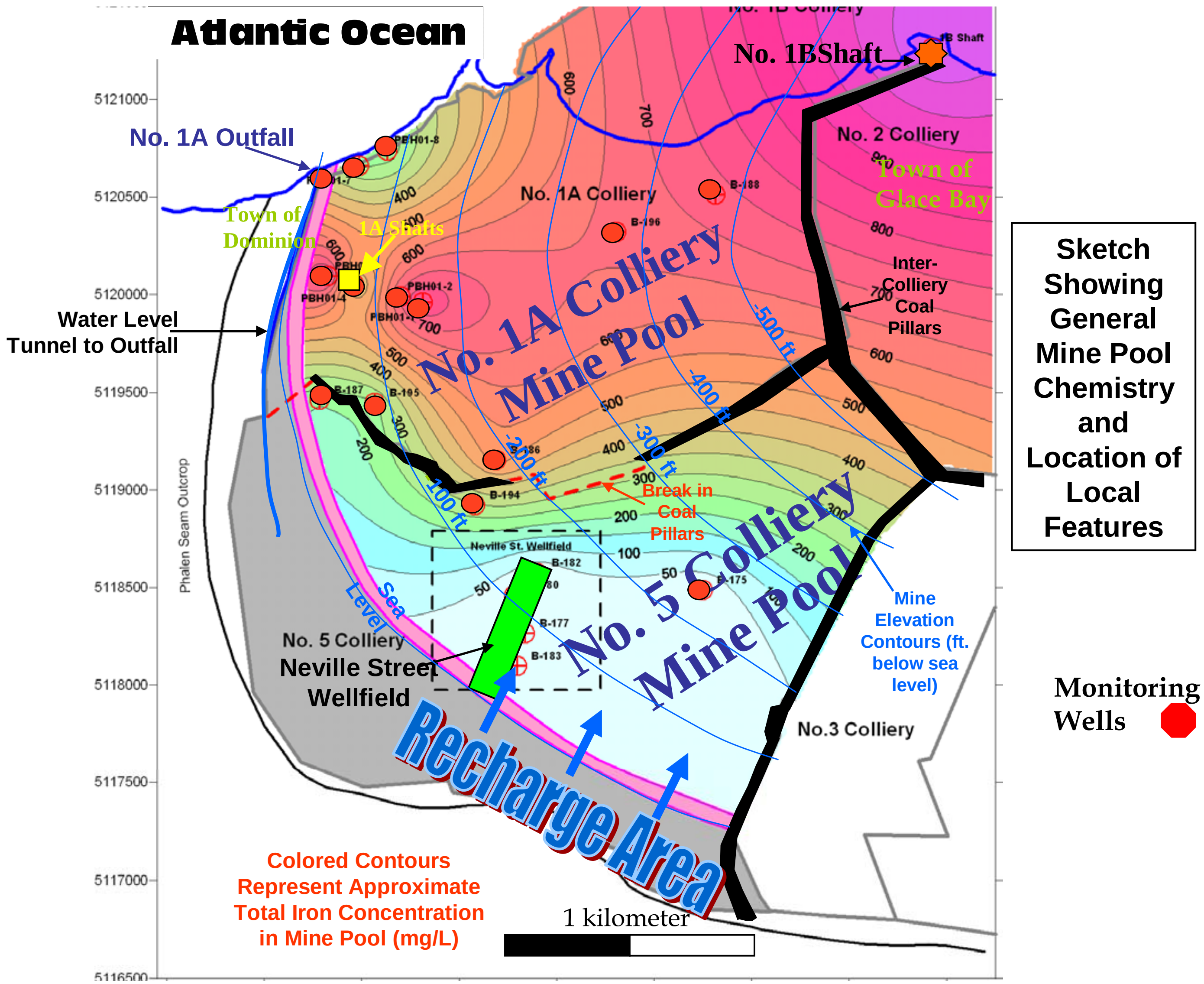
Weighting Factor Values (0 to 10)

- 0 - 3 Poor
- 3 - 5 Fair
- 5 - 7 Good
- 7 - 10 Very Good

Criteria Assessment Values (0 to 5)

- 0 - 1 Poor
- 1 - 2 Fair
- 2 - 3 Good
- 3 - 4 Very Good
- 4 - 5 Best





Atlantic Ocean
No. 1BShaft
No. 1A Outfall
No. 2 Colliery
Town of Glace Bay
No. 1A Colliery
Town of Dominion
1A Shafts
Water Level Tunnel to Outfall
No. 1A Colliery Mine Pool
Inter-Colliery Coal Pillars
Break in Coal Pillars
Neville St. Wellfield
No. 5 Colliery Mine Pool
Mine Elevation Contours (ft. below sea level)
No. 5 Colliery Neville Street Wellfield
Sea Level
Recharge Area
No.3 Colliery
Phalen Seam Outcrop
Colored Contours Represent Approximate Total Iron Concentration in Mine Pool (mg/L)
1 kilometer
Sketch Showing General Mine Pool Chemistry and Location of Local Features
Monitoring Wells

Review comments on report 'Task 1 – Initial Options Review Report'

Paul L Younger

11-2-2007

1. General

The report is clearly written and well-argued. I have only one really substantive comment (see point 3.6 below), and a number of lesser comments.

2. Minor typos

The word 'it' failed to make it to the page at the top and tail of page 2:
 first line – should replace 'is'
 final line – should replace 'I'

3. Technical comments

3.1. "Walk-away" is used throughout the report without elaboration, and (if the text is to be accepted as it stands) with implicit, subtle changes in meaning from one option to the other. I'm not sure the use of 'walk-away' is really advisable in any case. The term has largely been dropped by the mining industry globally, in recognition that even a minor residual inspection schedule (which any engineered structure will always need) means that some residual activity will need to be retained in the long-term. In the case of mining legacies, the experience in the UK is that the number of problems with unanticipated subsidence, localised water breakouts etc from the abandoned coalfields is now steady at around 450 events per year. Scaling this to Cape Breton would suggest maybe 10% of this number. Most of these would not require much action, some require considerable engineering works. Walking away is one option we don't have. I realise that this report is only responding to the prior use of this term in the specification given by CBDC, but I think it's an important issue, not least in terms of handling public expectations. Rather than 'walk away' we should be talking of 'minimal maintenance'.

3.2. 'Effective treatment depth' is essentially the idea behind 'Partial First Flush', as I described in my presentation to the BC ML-ARD meeting a couple of years back. (Copy attached). The work on this was done by Agnès Blachere and colleagues in the consultancy CESAME, in France. Most of the detail is in reports to Charbonnages de France, naturally written in French (fortuitously handy for Canada!). It might be worth seeking some input from Agnès if this concept is to be taken further.

3.3. Page 2 point 3a - the *desire* to assess surface subsidence risk in the event of further rebound is laudable, but *how* will this be done? I'm not aware of any reliable methodologies. Same comment applies to the curiously termed 'unplanned ground failures' in the second-last bullet point under 'disadvantages' on p. 4. (I didn't think we ever 'planned' these sorts of failures!).

3.4. Page 5 (fourth bullet-point under 'Advantages'): To say that this option will not require water treatment or sludge disposal is rather misleading, given that it may well require more treatment at Neville Street (seventh bullet under 'disadvantages'). Much the same comment also applies to Option 4 (page 6).

3.5. Page 7 (second bullet under 'disadvantages'): Presumably the goal for water quality improvement will be less in this case, if the treated water is to be reinjected, than it might be for surface disposal in the other options that involve treatment at Neville Street?

3.6. Options 6A through 6C: I can think of two further 'Option 6' types of operation, and I would say they would merit careful consideration from the point of view of engineering robustness. Both would involve switching off Neville Street and allowing rebound to proceed to completion. Then two options arise (they'd have to be built before you switched off Neville Street, of course!):
(i) Implement engineering works to direct all present and future outflows from the 1A Outfall into a long sea outfall, as they are doing at Gardanne (Marseille), and as is also being considered for the Durham Coalfield.
(ii) If (i) above is not acceptable to the regulators, then instead of drilling boreholes into the 1A Colliery workings, excavate a catch-pit through the tail-end of the 1A Outfall water level, right near where it reaches the beach, and pump from this, either then sending the water to the 1B Shaft site (so like Option 6B, but with a catch-pit instead of boreholes) or treating it on site for disposal to the sea (like Option 6A). Incidentally, treatment on-site does not need a lagoon – I would advocate a set-up like we have on the Durham Coast with lamellar plate thickeners and a centrifuge, all of which will fit in a basic 'hangar' type building. The further benefits of this option over 6A or 6B are:

- when water quality has finally settled down, you can just stop pumping from the catch-pit and let all future flows go to the sea without treatment, without ever having to worry about that last wee bit of rebound causing a further deterioration of water quality, and
- as long as you have to pump-and-treat, all pumping can be on a single site (you could decommission Neville Street) and,
- it would be very low-lift pumping with simple centrifugal (suction) pump rather than submersible pumps – a far more robust option than dangling expensive submersible pumps in acidic water (as we know from bitter experience …).

From what I saw at the 1A Outfall, neither of these two options would be out of the question on engineering grounds, and I see great advantages to them both in terms of moving to a 'minimal maintenance' future.

3.7. Page 9 (first bullet under 'Advantages'): The high capital cost of a pipeline to 1B ought to be accompanied by a high operating costs, as scaling of the pipe with ochre will be a constant issue, and a high level of inspection and maintenance will be needed to avoid any highly-embarrassing leaks of (very conspicuous) untreated water from the pipeline. (Same would apply to treating my option (ii) above anywhere other than near the 1A Outfall).

3.8. Page 11 (first para under option 8): What ‘alkaline materials’ do you have in mind, and how would these be placed in workings along the level? A dam is always going to be a long-term liability in maintenance terms. They tend to get forgotten about, the valve scales with ochre, and every now and then you get an outrush of built-up water causing a plume. I’d not be too happy with this approach personally, given experiences in the UK.

3.9. Page 12 (final line under Option 8, ‘Risks’): If it worked as planned, and I’m wrong about the hassle of dams, why wouldn’t this become ‘walk away’ (= minimal maintenance)? You’d have completed rebound and a gravity outflow – what more can you ask? Put simply, if Option 8 cannot be ‘walk away’, then certainly none of the others can! (This comment applies also to the first para. of the Conclusions on p. 13).

Comments on
Managing Mine Water Quality and Flow in the 1A Mine Pool –Phase 1

Jeff Skousen
West Virginia University

A large underground mine pool is being pumped in order to maintain a water level in the mine which will not allow spillage into the sea. At the location of pumping (Neville Street Wellfield), water quality has been good during the past 3 years since the pumping station was built and the water has been discharged into the sea without harming the marine ecosystem. However, the pumped water appears to be gradually deteriorating. At some point in the future, it is anticipated that the pumped water may not be suitable for discharge. As a result, a walk-away strategy is being sought where pumping can cease and the water will naturally flow out of the mine pool without treatment and cause no damage to the environment. Therefore, options for control and treatment of the water are being considered in this Phase 1 report.

1. **Status Quo** – continue perpetual pumping at the Wellfield where the water is currently suitable for discharge.

Comment: The Neville Street Wellfield area (the pumping station) is located in the No. 5 Colliery mine pool, where the water quality is quite good and suitable for discharge without treatment. This option would maintain the desired water level in the mine. However, the water quality appears to be deteriorating. This does not appear to be viable option and would not allow a walk-away solution to the mine pool.

2. **Close 1A outfall and allow water being directed to the sea by the 1A Water Level Tunnel to flow into the 1A mine pool.**

Comment: Recharge to the 1A and No. 5 Colliery mine pools appears to be about 1900 gpm. Allowing more water into the mine pool would require greater pumping in order to maintain the mine pool level. Eventually, however, the Water Level Tunnel will be removed and the recharge water will flow into the mine.

3. **Introduce Sea Water**.

Comment: Pumping rates would have to be increased in order to allow for sea water to be introduced since the water level in the mine pool must be maintained. This is a viable idea and the extra alkalinity from the sea water could treat the acidity in the mine pool and cause metal precipitation. Possible problems could result from high concentrations of chloride being introduced to the mine pool from sea water.

4. **Introduce Groundwater**.

Comment: Pumping rates must be increased to allow room for groundwater inflow. Groundwater is probably already moving in that direction (although SS-bearing rock units lie above the mine, which may not be conveying much water) and increasing groundwater inflow rate would probably result in other problems relating to domestic use of this resource. In general, this is not a very good idea.

5. **Pump water from No. 5 Colliery (Wellfield) back into 1A mine pool**.

Comment: The pumping rates must be increased to keep the water level constant, and the water inflow must be balanced with the water that is being pumped. Since an average of about 1900 gpm are recharging the mine pool and the pumped water is being re-introduced to the mine pool, the amount of recharge (varying from not much during summer months to 6,000 gpm during spring thaw) must be released somewhere if the mine pool water level is to be kept constant. The delivery of water to the 1A mine pool and the pumping of water at the Wellfield pump location would probably drive poorer quality water from 1A mine pool to the No. 5 Colliery mine pool, where the Wellfield pump station is located, accelerating the deterioration of water quality there. Mixing good water with bad water almost always results in more bad water. Dilution takes a long time to work.

6A. **Pump 1A mine pool water and treat in newly built treatment plant, then discharge at new discharge point.**

Comment: A tried and true option, but expensive and long-term. New extraction shafts and a treatment plant must be constructed, as well as permitting a new discharge point. If acid generation has ceased, pumping the 1A mine pool at the recharge rate, treating it and discharging it into the sea allows for a quicker turnover period for water circulation in the mine, and hence after some time should cause the water in the mine pool to improve in quality.

6B. **Pump 1A mine pool water to existing treatment plant at 1B shaft through overland pipeline and discharge at permitted discharge point.**

Comment: Another tried and true option, but less expensive than Option 6A since a treatment plant is already operational with an approved discharge point, but still a long process to turnover the water in the mine pool from recharge and pumping.

6C. **Pump 1A mine pool water, treat with alkaline chemical, and return treated water into 1A mine pool.**

Comment: This approach is being done at the Mettiki Mine in Maryland and has slightly raised the pH of the mine pool and increased the alkalinity, but has also increased chloride concentrations. The Mettiki mine pool size is not given, so a comparison of the 1A and No. 5 Colliery mine pools to the Mettiki mine pool cannot be made. See websites for Mettiki Mine results.

http://www.mcrcc.osmre.gov/PDF/Forums/CCB5/2.1.pdf
http://www.wvu.edu/~agexten/landrec/coalcomb.htm

7. **Pump water at the 1B shaft where an existing treatment plant has operated, treat the water and discharge into the sea.**

Comment: This is certainly an option because it gradually removes the poor-quality water by pumping and hopefully slowly replaces the 1A and No. 5 Colliery mine pool waters with recharge (good quality) water. Careful monitoring of pumping rates would be required to maintain the water level in the mine. During some seasons, very low recharge occurs and the pumping could be reduced or shut off, while at spring thaw periods, the pump may not be able to keep up with the recharge water. If water is being pumped from 1B shaft, the Wellfield pumps could be largely shut off except during high recharge periods, when the pumps may have to be turned on to maintain water levels. The water in the No. 5 Colliery should improve in quality as the poor quality water is drawn toward the 1B shaft. It appears that the 1B shaft also would draw water from other mine pools not shown on the map, which could greatly decrease the desired turnover rate of the 1A and No. 5 Colliery pools.

It is also possible that the treated water and solids at the 1B shaft could be re-introduced into the mine. This re-introduction of water to the 1A mine pool would eliminate the 1B discharge point for a time while the water is being recirculated, but other pumping at the Wellfield may be necessary to maintain water levels.

8. **Allow the mine working to completely flood and the water to be released through control valves to the Water Level Tunnel and out through the 1A discharge.**

Comment: Another viable option, especially if treated water is being re-introduced to the mine after treatment at the 1B shaft. Allowing alkaline recharge water and 1B shaft treated water to the 1A mine pool may accelerate the process of mine pool exchange and turnover. Alkaline materials, such as steel slag or other limestone based material, could be placed in the Tunnel to treat the water.

9. **Combination of pump and treat (6A or 6C) of 1A water by new treatment plant, injection of treated water back into the 1A mine pool, and also pumping and treating at 1B shaft and discharging into sea.**

Comment: I believe this is also a good idea, but requires the construction of a new treatment plant over the 1A mine pool.

General Comment:

I think all the potential options have been outlined in this document. The constraints of maintaining the water level to very specific limits is an important consideration to control water inflow and outflow. The fact that two pumping locations exist (1B shaft and Neville Street Wellfield) gives some control in relieving the water fluctuations.

Comments on Managing Mine Water Quality and Flow in the 1A Mine Pool – Phase 1

by

Syd S. Peng

1. General

In order to develop an effective treatment method or methods, the source, quantity and rate of generation of AMD must be known as much as possible. In addition, the flow pattern of the water should also be known. If this information is not available, how does one know the selected treatment method will maintain the standard in perpetuity after it has reached the established standard. In this respect, all the 9 methods proposed are conceptual and qualitative and can not be assessed quantitatively. Consequently, it can not be assured that they are "walk-away" solutions.

If the water is allowed to overflow to the water level tunnel, the subsidence potential for the town of Dominion where the abandoned underground workings is flooded is high. Because those workings are 90-100 ft deep and experience has shown that water saturation on such shallow workings under suitable geological conditions will induce surface subsidence. In addition, fluctuation of water level in such shallow workings could accelerate roof strata deterioration leading to surface subsidence. But in order to accurately assess the subsidence potential, the following information must be available for analysis: mine map, stratigraphic sequence of the overburden and their rock mechanic properties.

2. Specific

A.Regarding Figure 1 evaluation matrix:

1. The weighting factors of several items, in my opinion are too low. For instance, *ability to monitor effectiveness* and *will not generate waste materials*.
2. The following pairs are related and therefore, over-emphasized the items:
   (1) *Acceptable to regulators* vs *ability to obtain approval*
   (2) ***Under Community Impacts***, the first item "*will be acceptable to community"* covers all the other items except "*can protect community,"* isn't it?
   (3) Under ***Cost***, what is *residual value*? Since they are all so low and the same, why listed it?

B. Figure 2, sketch – In legend, the monitoring wells use a hexagon, but inside the sketch, they are circles.

Managing Mine Water Quality and Flow in the 1A Mine Pool – Phase 1

TASK 2 PART 1 – CHARACTERIZATION OF THE 1B MINE POOL

INTRODUCTION

The following report constitutes Phase 1 – Task 2 of investigations into the "Water Treatment Program 1A Mine Pool, Town of Dominion, Cape Breton County, Nova Scotia". Phase 1 of the program involves the preparation of reports on "Initial Options Review", as well as three other tasks including (2) "Mine Pool Characterization", (3) "Mine Water Discharge Criteria Development" and the creation of an external (4) "Advisory Committee". Tasks 2 and 3 were to have been completed by the end of January 2007, but have been slightly delayed due to the timing of responses from the Advisory Committee. Tasks 1 and 4 have already been completed.

Phase 2 of the project will follow the completion of Phase 1 and utilize the information derived to identify "Information Gaps", determine the "Volume of AMD Impacted Water to be Treated", conduct a "Focused Options Review" to arrive at one final option for pilot testing and provide comment on the "Potential Future Liability for CBDC". It is anticipated that Phase 2 will be completed by March 31, 2007.

Task 2 of the Phase 1 investigations, (described below) is made up of two parts.

Part 1 involves the characterization of the 1B Mine Pool by conducting a review and updating of all available information (reports, chemical data, maps, cross sections) on the water body. This review is to provide the basis for identifying gaps in information and the potential requirement for additional sampling and analyses. The need for additional information is to support feasibility analysis of the water treatment options.

Part 2 involves a review of the pumping strategy currently being used at the Neville Street Wellfield. CRA has also been asked to provide an opinion on this strategy.

TASK 2, PART 1 - CHARACTERIZATION OF THE 1B MINE POOL

THE 1B HYDRAULIC SYSTEM:

The 1B Hydraulic System is a complex of ten abandoned underground coal mines in the Sydney Coalfield beneath the towns of Reserve Mines, Dominion and Glace Bay. The body of water that now fills these mines is known as the 1B Mine Pool (See Figure 1). The mining history of the constituent mines spans a period of 127 years, which began with the opening of No. 5 Colliery in 1872 and ended with the closure of Phalen

Colliery in 1999. The older mines were operated by the Dominion Coal Company but after 1967 they were operated by the Cape Breton Development Corporation (CBDC), a Federal crown corporation. A summary of the salient characteristics of these mining operations is presented in Table 1.

Geological Setting:
The mines operated within a gently folded structure known as the Glace Bay Syncline and along the northward flanks of the Bridgeport Anticline (See Figure 1). The coal seams dip northward at a gradient ranging from 3 to 14 degrees. These seams are known to extend seaward under the Atlantic Ocean for at least 40 kilometres. Three major seams (Harbour, Phalen, Emery) were mined. Faulting did not seriously impact the operations. The major seams are separated by sedimentary sequences of rock, of Carboniferous age, ranging from 40 to 130 meters in thickness (See Figure 2). Inter-seam strata consist of mudstone, shale, siltstone, sandstone, and minor carbonaceous limestone, which are indicative of deposition in fluvial & lacustrine environments.

Geographic Location:
The working areas of No. 1B, No. 20, No. 26, Lingan and Phalen Collieries were predominantly submarine but all were connected to land directly or indirectly by a system of tunnels, slopes and shafts. Portions of these mines extend up to 8 kilometres northward under the Atlantic Ocean. No. 1A, No. 5, and No. 10 Collieries are located entirely under land; while No. 2 and No. 9 straddle both the submarine and land environments. It is noted that no major inflows of seawater were ever reported in these submarine mining operations. The working depth range of the mines extended from elevation 38 meters above sea level to 822 meters below sea level. Both depth and location are important factors that impact accessibility to several of these mines.

Mining Methods:
The methods of mining used by 1B Hydraulic System mines varied as technology developed over time. The earliest and shallowest mines were located under land and used the room and pillar mining method almost exclusively. This resulted in the extraction of 40 to 50 % of the coal seam with the remainder left in the ground as pillars to provide support for the mine roof. In many cases, these remnant pillars were subsequently removed leading to widespread collapse of roof strata and ground subsidence at the surface. No. 5 Colliery is a prime example of a colliery where the extensive extraction of remnant coal pillars took place. In such cases nearly 100% of the coal would have been removed over large areas. In submarine mines, room and pillar mining was employed at shallow depths to guard against seawater inflows, but full extraction longwall mining was generally favoured when depth exceeded 300 meters.

Method of mining had a significant impact on the development of post-mining residual void space (water storage volume), the creation of connections between the surface and adjacent mines and it also exerted a major influence on the chemistry of the mine water that eventually filled the mines.

Connections between Mines:
Mines within the 1B Hydraulic System are connected to one another by one or more openings consisting of boreholes, shafts, tunnels, drifts and mining-induced open fractures. A summary of the variety and locations of these connections is presented as Figure 3 (JWAL, 1993). Excellent connectivity exists between mines such as No. 1A and No. 1B Collieries by virtue of several dozen roadways in the mutually mined coal seam, whereas No. 2 and No. 1B Colliery are connected by a single roadway. In another case, Lingan Colliery is connected to No. 26 Colliery by one or more horizontal bed separation cavities that developed under the barrier pillar between the two mines. The picture is also complicated by the fact that some of the connections were sealed prior to mine abandonment, while others were not. In many cases, available records leave considerable doubt about the extent and adequacy of sealing. Furthermore, it is practically impossible to obtain confirmatory information regarding their current condition.

Knowledge of these mine connections is important when considering the quantity of water that must eventually be treated to produce a walk-away solution for the 1B Hydraulic System. This aspect will be dealt with in greater detail in Phase 2 of this project.

Flooding of the 1B Hydraulic System:
Flooding of the 1B System initially began when individual constituent mines ceased their operations. For several mines however (No. 1A, 1B and No. 5 Collieries) water level rise was controlled by pumping from the 1B Shaft. This was done to permit the safe mining of coal in adjacent or deeper mines. After the 1B Shaft pumps were shut down in 1985, flooding of the system continued at an accelerated rate. This history of flooding has been recorded by water level measurements taken in the 1B Shaft. The measurements were used to construct the hydrograph shown in Figure 4.

The hydrograph identifies several occasions where water rise had reversed in the system. These events can be related to the failure of mine seals in No. 2 and No. 26 Collieries and loss of water to Lingan and Phalen Collieries, which were operating at the time. A well-documented example of the latter occurred in 1992 (See Figure 4) when longwall mining at Phalen Colliery created horizontal bed separation cavities beneath the barrier pillar separating overlying Lingan and No. 26 collieries. These fractures provided conduits through which water from flooded No. 26 Colliery entered Lingan Colliery. In an effort to stop or reduce the water inflow, pumping at Lingan Colliery and the 1B Shaft was initiated and water discharged to the sea. The quality of the discharge proved to be unacceptable (high iron and TDS) and pumping had to be stopped (See Figure 5). Failure to control the flow of water eventually led to the closure of Lingan Colliery.

Following 1992, water continued to flow from No. 26 to Lingan Colliery and additional inflows were experienced at Phalen Colliery as its production longwall units extracted coal under flooded Harbour Seam workings. The loss of water to these mines, coupled with a fluctuating seasonal recharge rate produced the rise and fall character of the hydrograph between 1992 and 2002.

By early 2003, the water level in the 1B Hydraulic System had risen to a point where it would have discharged into the sea at the 1A Outfall. Emergency pumping at the hastily constructed Neville Street Wellfield and the establishment of a water treatment facility at the 1B Shaft prevented this from happening. At the present time, more than 95% of the mine workings in the 1B hydraulic System are flooded. The remaining 5% is not permitted to flood to guard against a mine water discharge to the sea. Mine pool water level is presently maintained between elevation -17 feet (-5.18 meters) and -19 feet (-5.80 meters) below sea level by pumping at the Neville Street Wellfield.

THE 1B MINE POOL

The 1B Mine Pool is the body of mine water occupying the workings of the ten mines making up the 1B Hydraulic System. (Note: In this report, the 1B Mine Pool will always be used to describe this water body. When water in individual collieries is discussed, it will be referred to by the mine name; for example, No. 5 Mine Pool is a sub pool of the 1B Mine Pool contained within No. 5 Colliery workings).

Source of Mine Water:
The 1B Mine Pool resulted from infiltration of surface water along a variety of pathways through the overburden and along connections within and between mine workings. Of special significance are pathways connected to the workings, which originated along the outcrop of the coal seams. Rainfall infiltration rates for the local area have been estimated to range from 15 to 18% (JWEL, 1993) but actual rates of infiltration to the workings have been modified by mining-induced fracturing of aquifers surrounding the mines. CRA believes that significant direct infiltration has taken place via shallow illegal bootleg mining operations and through sinkholes formed by collapse of shallow mine workings. Other direct sources include overflows of storm and sanitary sewers, direct sewage discharge into the mine workings, and abandoned shafts, tunnels and boreholes.

Little mine water inflow has been derived from connate sources. This is especially evident in the deep submarine mines where total inflow to the mines is less than 50 GPM (See Table 1). Sea water is also not believed to contribute in any substantial way to mine flooding however, some sea water leakage may still exist around the sea tunnel driven in 1903 to quench a mine fire in No. 1A Colliery, and 20 GPM of sea water was reported while driving one of the 1B Shafts. No major seawater inflows were ever reported while these mines were operating.

Water Inflow (Recharge) Rate
The rate of water inflow to the 1B Hydraulic System have been variously estimated on the basis of water balance studies (MGI, ADI, 2002) (JWEL, 1996) and rates of water level rise in the flooding mines. Predicted annual recharge rate estimates have ranged anywhere from 800 to 1900 USGPM and these values were expected to be exceeded during years of higher than normal precipitation. Peak inflow rates during fall and spring storm events were estimated to be in the 3000 to 6500 USGPM range depending on whether the year was particularly wet or dry.

On the basis of almost four years of pumping at the Neville Street Wellfield (March 1, 2003 to January 23, 2007), an average daily pumping rate of 1910 USGPM was needed to maintain water level within the water level maintenance zone (-5.18 to -5.80 m below sea level). During this period, daily average pumping rates ranged from a low of <100 USGPM during summer to a high of 5500 USGPM in the spring. Peak daily inflow rates were estimated to have exceeded 7000 USGPM on rare occasions when pumping was unable to handle the volume of recharge.

Elevation data from monitoring wells at No. 5, No. 1A, and No. 1B Collieries clearly show that water level rises and falls uniformly in response to inflow rate and pumping at the Neville Street Wellfield. This indicates that a high level of connectivity exists between these three mines even where roof strata have collapsed over full extraction mining zones. To reflect this open and permeable mine environment, a "bathtub" model has been adopted to describe the hydrology of the 1B Hydraulic System. Details of this model may be found in "Mine Water Assessment and Monitoring Program, No. 1B Hydraulic System, MGI Limited, and ADI Limited, 2004.

Volume of Water in the 1B Mine Pool:
The volume of water in the 1B Mine Pool is estimated to be approximately 20 billion gallons. This has been estimated on the basis of void space created during operation of its constituent mines. Void space volume or storage capacity had been previously calculated (JWEL, 1993) to depth of -305 meters below sea level. CRA has extended these calculations to include the volume of void space over the full extent of the mine workings. As one might expect, any endeavour to calculate void space in as complex a structure as an abandoned coal mine is frought with difficulties. This is due to the extensive age of the mines, the variety of mining methods used, the impact of local geology, extent of strata collapse associated with coal removal, and the accuracy of mine plans. All of these factors conspire to insure that any calculated volume is an educated guess at best.

The calculation method itself is straightforward and is based on measurement of mine area, coal thickness and percent coal extraction. The most subjective part involves estimating the residual void space left after roof strata has collapsed and compacted in areas where full extraction mining (longwall and pillar drawing) was carried out. For the 1B Hydraulic System, a residual void space factor of 30% was used for full extraction areas, and 42% was used for room and pillar areas. Using these factors, the volume of void space for each mine in the 1B Hydraulic System has been calculated. Volumes expressed in US gallons are provided in Table 1.

The quantity of mine pool water that must be treated to attain a walk-away solution is currently unknown and has been the subject of considerable speculation. The most conservative estimates are based on an assumption that only the poor quality water near the top of the mine pool in No. 1A Colliery must be treated. Utilizing this concept, the treated water would be released to the sea and its volume would be replaced by good quality water from the recharge zone. Mine water would thereafter discharge to the sea indefinitely at the recharge water quality. The volume of water to be treated under this model would range from a low of 830,000,000 US gallons (assuming half the volume of AMD-impacted water in No. 1A and No. 5 Mine Pools) to a high of 3,100,000,000 US gallons (assuming all of the water in No. 1A, No. 1B and No. 5 Colliery must be treated to depth of the 1B Shaft (approximately 180 meters below sea level). The major unknown with this scenario is whether or not acceptable water quality can be indefinitely maintained at the discharge despite the natural tendency for poor quality water to migrate (driven by ionic diffusion and convection) upward from deeper workings.

In appreciation of the possibility that upward migration of poor quality water could take place, a second model suggests that at least one complete volume of all water in the system must be treated to sustain a long-term acceptable water quality at discharge. This volume could range from a minimum of 4,500,000,000 US gallons (assuming that several mines will not contribute a significant quantity of water to the treatment process) to 20,000,000,000 if all water in the 1 B Mine Pool must eventually be treated.

The highest possible estimate of treatment volume is based on documented evidence (Younger, 2002) that 4 mine water volumes might have to be treated and replaced by good quality recharge water before an asymptotic contaminant concentration status is obtained. Under this scenario a minimum of 18,000,000,000 US gallons to as much as 80,000,000,000 US gallons could require treatment.

It is noted that the volume of water potentially requiring treatment will, to a large extent, be contingent on the final agreed upon marine discharge criteria, which have yet to be determined.

Mine Pool Water Quality:

The quantity and variety of water quality data collected from mines making up the 1B Mine Pool has varied considerably over time. Past flooding events at CBDC operated mines and the demands of new environmental regulations has seen the frequency of water sample acquisition increase dramatically over time. Following is a summary of three significant time periods during which the collection of water quality data is described. Information acquired during these periods provides the basis for our current understanding of mine pool quality.

Pre-1988 Period: For mines operating prior to 1988, relatively few water quality samples were collected and the parameters measured were limited in scope. Examples of the rather abbreviated water quality analyses are presented in Table 2. These analyses focused primarily on parameters such as pH, hardness, and sulphate which would help to assess scaling and corrosion potential, and whether or not the water could be used to cool machinery. They were collected while the mines were operating so they do not necessarily represent post flooding water quality. They can be used however to speculate on how water chemistry may have evolved in mines which are no longer accessible. For example, the low pH and the high sulphate and aluminum in waters at No. 2, No. 9, and No. 10 Collieries reflect the ability of these mines to generate considerable acidity. This kind of information can be used today to speculate on the how the chemistry of the mine pool may have been impacted as the workings flooded.

1988 to 2002: This period was ushered in by a water inflow event at Phalen Colliery. Water chemistry was used to assess the origin of the water and establish its relationship to the method of mining. Its success in this regard led to significant increase in the frequency of water sampling at all mines operated by CBDC. During the intervening years over 2900 water samples were collected and analyzed for inorganic, biological and isotopic parameters. This large quantify of data has been assessed in a number of post-graduate research papers and consultant studies.

The current value of these samples lies in their ability to provide a glimpse into the possible chemistry of water in workings that are no longer accessible. For example, in 1992 a major water inflow occurred at Lingan Colliery. Inorganic and isotope analyses of water entering the mine supported speculation that it had originated in No. 26 Colliery. These same water analyses can now be used to contemplate the quality of water currently occupying those mines. The second column in Table 3 shows the average analyses of water samples collected from the 1992 inflow; the inferior nature of the water is apparent. Since Lingan and No. 26 Collieries have not been flushed by better quality recharge water, there is little reason to suspect that water quality has changed in any substantial way since 1992. Now, considering that the No. 26 Colliery mine pool was derived from up dip workings of No. 1B Colliery, the former would also be expected to contain water of a similar poor quality. Samples collected from the discharge from 1B Shaft in 1992 verified that this assumption was true (See Table 3). Since water in No. 2 Colliery originated, to a large extent, from No. 1B Colliery, and No. 2 Colliery is connected to No. 20 Colliery then one might suspect that water in both these mines may also be inferior in quality.

Samples collected during this time period currently comprises the entire basis for estimating the quality of water in seven (No. 2, No. No. 9, No. 10, No. 20, No. 26, Lingan and Phalen Collieries) of the ten mines making up the 1B Mine Pool. Due to poor accessibility, water samples have not been collected from these mines since flooding was completed in 2003. The reliability of current water quality projections for these seven mines must therefore be considered in this context. Mine water within the other three mines (No. 1A, No. 1B, and No. 5 Collieries) has been sampled several times during the post-flooding period and will be described in the next section of this report.

2002 to Present:
In 2002, as the water level in the 1B Hydraulic System approached sea level, sampling of water in the near-surface mines was implemented to determine the potential quality of an impending discharge to the sea. A number of monitoring wells were drilled by CBDC and PWGSC (See Table 4) into workings at No. 1A, No. 3, No. 5, and No. 8 Collieries and water samples were collected. No. 8 and No. 3 Collieries were not believed to be connected to the 1B Mine Pool but were investigated to prove this independence and assess water quality in mines that had been flooded for decades.

Analyses of water from these wells clearly showed the poor quality of water in No. 1A Mine Pool and emphasized the need to prevent its discharge to the sea. Fortunately, the monitoring wells also identified better water quality in the No. 5 Colliery Mine Pool and presented an opportunity to stop water level rise by pumping from that southern part of the mine pool. Eight large diameter wells were subsequently constructed in 2003 and the Neville Street Wellfield became operational.

Since 2003, several sets of water samples have been collected from the monitoring and pumping wells. The analytical results from the 2005 set of samples are shown in Table 5 and contours of iron concentration found in those samples are illustrated in Figure 6. This original series of monitoring and pumping wells has not been sampled since 2005.

Sampling of discharge water at the Neville Street Wellfield however, has taken place continuously since it was first established in 2003. This information represents the most complete set of data available on Wellfield chemistry and it will be described in more detail as a subsequent task in this current project.

The most recent sampling of the mine pool was conducted in the fall of 2006 when five new pumping wells were installed at the Neville Street Wellfield. The results of this sampling will also be addressed when the Wellfield is discussed in a subsequent report.

As indicated above, information on the current quality of water in the 1B Mine Pool is based almost exclusively on data collected from the shallow mine workings of No. 1A and No. 5 Collieries, and the Neville Street Wellfield. The other mines in the Hydraulic System have not been directly investigated since flooding was completed. The contours shown in Figure 6 illustrate the magnitude and spatial variability of iron concentration across the shallow mine pool. Also evident is the relatively low density of data points upon which the contouring is based. Because of this, the contours must be viewed as portraying general chemical trends only.

Water chemistry variability is believed to be the product of a number of contributing factors including coal mining method, mine geometry, mine operational history, local geology, and chemistry of recharge mine water. A discussion of how these factors may have inter-twined to produce the current mine pool chemistry has been previously described in "Mine Water Assessment and Monitoring Program, No. 1B Hydraulic System, MGI Limited, and ADI Limited, 2004".

Sampling of the No. 1A Mine Pool between 2002 and 2005 has revealed little overall improvement in its quality. This is probably because flushing of contaminants from the workings by recharge water is not taking place. All recharge water is currently being removed by pumping from the Neville Street Wellfield. On the basis of discharge water sampling, a progressive deterioration in water quality is taking place at the Neville Street. This is believed to be due to southward movement of contaminants from the No. 1A Mine Pool during periods of heavy pumping, and possibly by ionic diffusion and temperature driven convection.

Summary of Current Status of the 1B Mine Pool

The current situation in the 1B Mine Pool, from a water quality and water management viewpoint, may be summarized as follows.

1. No monitoring wells have been installed in the 1B Hydraulic System since the fall of 2005. Three of the existing monitoring wells (B-171, B-188 and B-196) have been abandoned by CBDC because of concerns of extraneous water inflow to the mine pool.

2. Five new water production wells were constructed by CBDC at the Neville Street Wellfield during the fall of 2006 while five former production wells were abandoned due to poor water quality or insufficient water at the pumps. The pumping capacity at the Wellfield is currently estimated at 5700 USGPM.

3. The quality of water pumped from the Neville Street Wellfield has showed a slow but continuous trend of deterioration.

4. Post-flooding information on the quality of water in the 1B Mine Pool is confined to the shallowest workings of No. 1A and No. 5 Collieries and was last updated in 2005. These workings constitute <10% of the total volume of the 1B Mine Pool. For the remaining 90% of the Mine Pool post-flooding water sampling has not been carried out and its quality is therefore highly speculative. However, before embarking on a program of additional sampling the need for such information must be assessed in terms of the proposed treatment options.

5. The quantity of water in the 1 B Mine Pool is estimated at approximately 20,000,000,000 US gallons. The volume that must be treated to attain a walk-away solution is also highly speculative. It will vary depending on the number of mines that will ultimately contribute water to the treatment facility, the volume of recharge water that must flow through the workings to flush out the contaminants, and the criteria that will be used to determine the quality of the effluent discharge. This quality has yet to be determined. Because each mine pool is unique and its intricacies imperfectly known, it is probable that the a determination of treatment volume will only be obtained by beginning the treatment process, collecting monitoring data and conducting periodic assessments of developing trends.

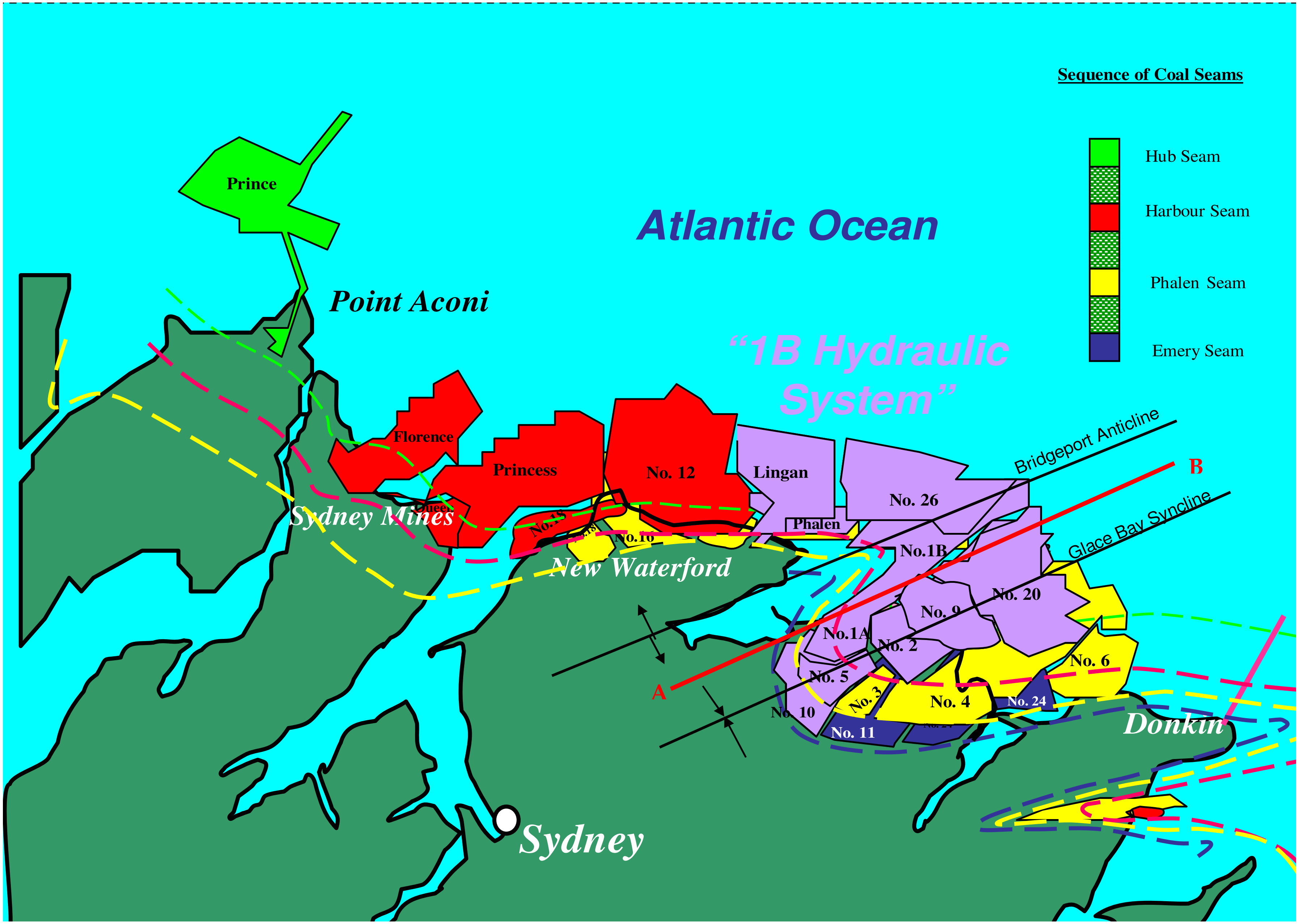
REFERENCES

Jacques-Whitford & Associates Ltd; Colliery Water Study, Sydney Coalfields, Cape Breton, Nova Scotia, Report to the Cape Breton Development Corporation, September 16, 1993.

Jacques-Whitford & Associates Ltd; Environmental Engineering Study, Update Status of Flooding Mines, Report to the Cape Breton Development Corporation, December 9, 1996.

MGI Ltd, ADI Ltd, Mine Water Assessment and Monitoring Program to September 5, 2003, 1B Hydraulic System, Report to Public Works & Government Services Canada, March, 2004.

Younger, P.L., Deep Mine Hydrogeology after Clsure: Insights from the UK, from Proc. Intl. Conf. Uranium Mining & Hydrogeol. III and Intl. Mine Water Assoc. Symposium, Freiberg, Germany, 15-21 September, 2002. Springer-Verlag, Berlin, pp 25-40.



Sequence of Coal Seams
Hub Seam
Harbour Seam
Phalen Seam
Emery Seam
Atlantic Ocean
"1B Hydraulic System"
Prince
Point Aconi
Florence
Princess
No. 12
Lingan
No. 26
Phalen
No.1B
Bridgeport Anticline
B
Glace Bay Syncline
Sydney Mines
New Waterford
No.16
No. 9
No. 20
No.1A
No. 2
No. 5
No. 6
No. 3
No. 4
No. 24
No. 10
No. 11
A
Donkin
Sydney

Figure 1

Stratigraphic Section Through Coal Seams Mined in the 1B Hydraulic System

(See Location of Section in Figure 1)

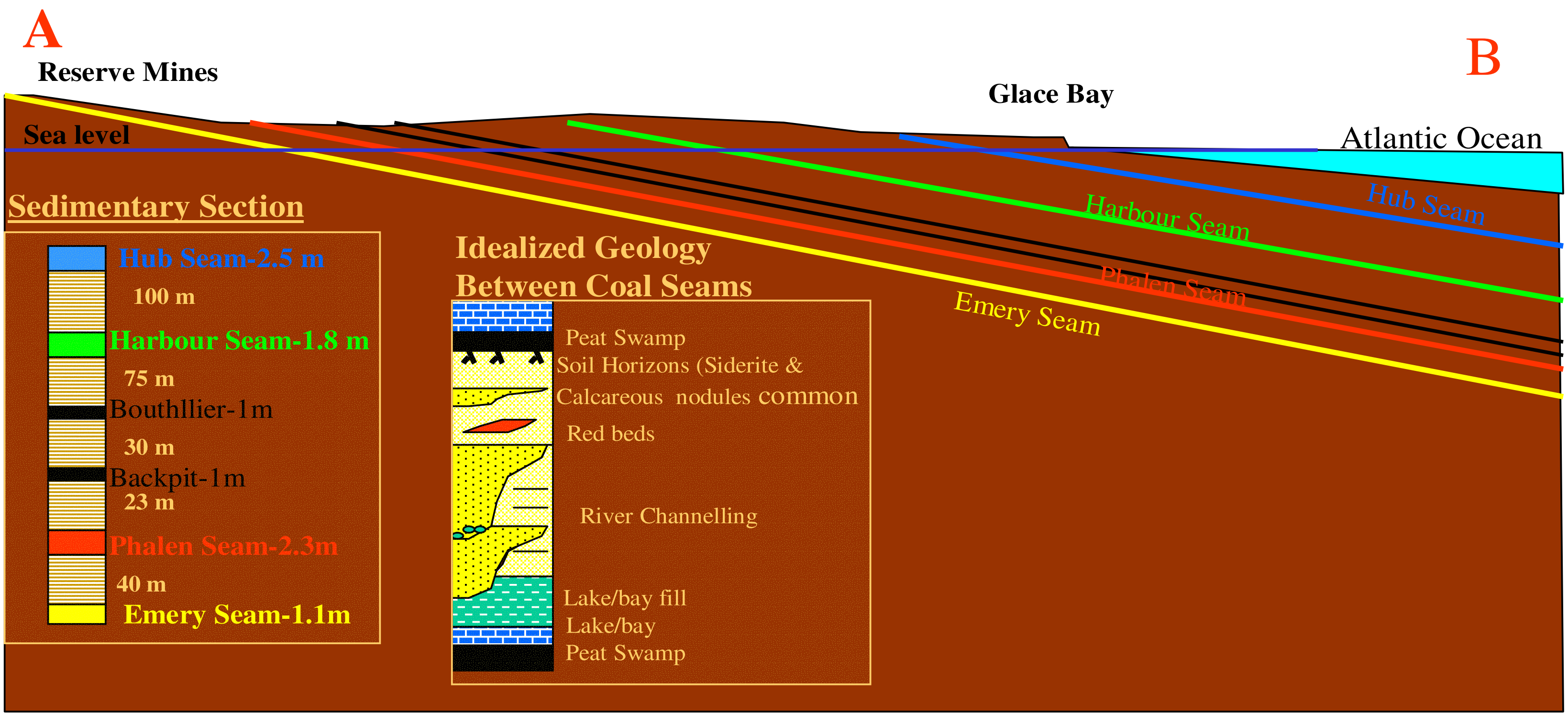
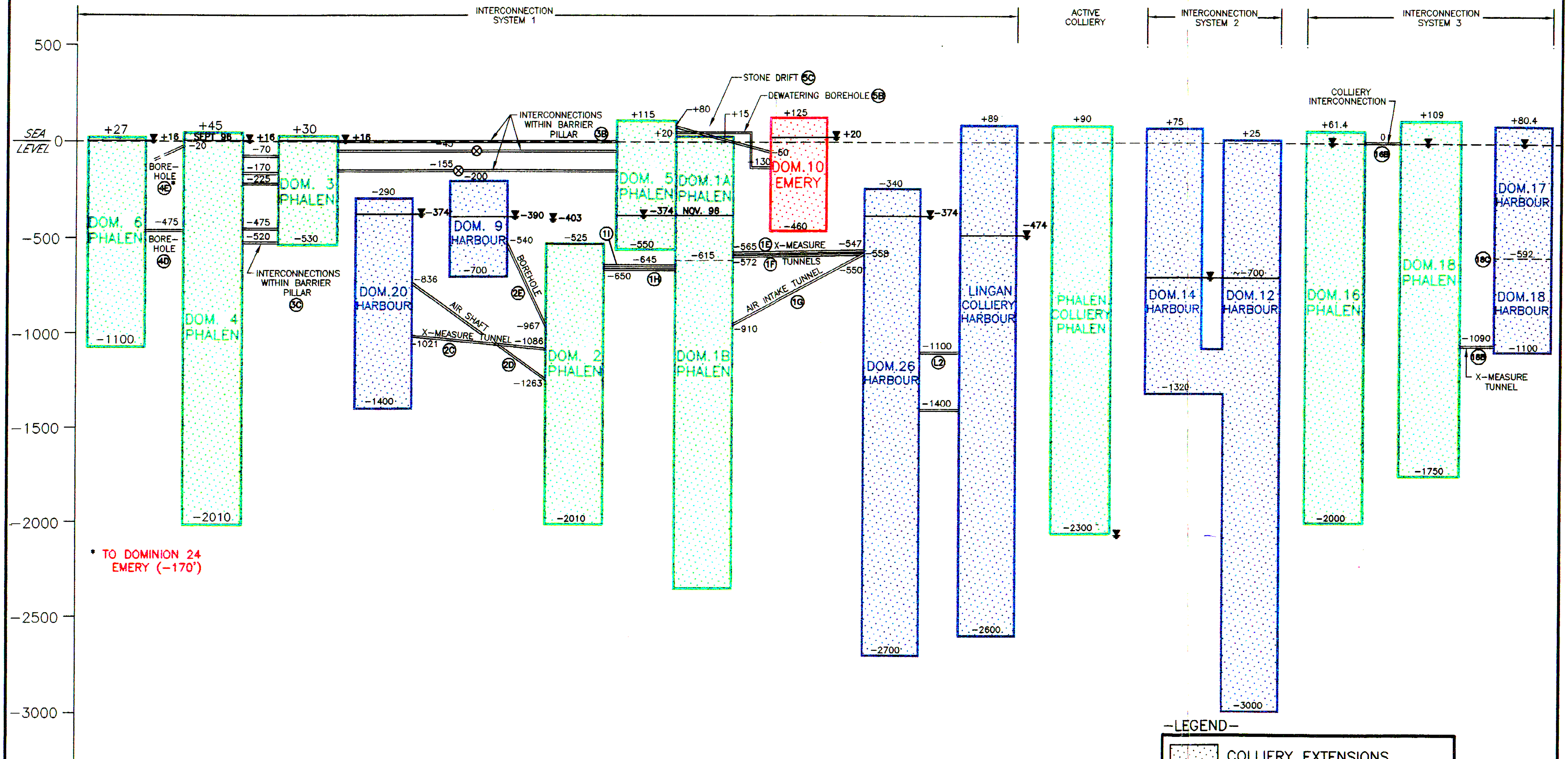


Figure 2



INTERCONNECTION SCHEMATIC OF COLLIERIES IN STUDY AREA

(FROM CBDC WATER STUDY, JWEL PROJECT NO. 8728, SEPT. 1993)

SCALE 1:20

—LEGEND—

- COLLIERY EXTENSIONS
- INTERCONNECTIONS
- SEALED INTERCONNECTIONS
- INTERCONNECTION REFERENCE NUMBER (REFER TO TABLE 8728–1 FOR DETAILS)
- +16 1996 WATER LEVELS

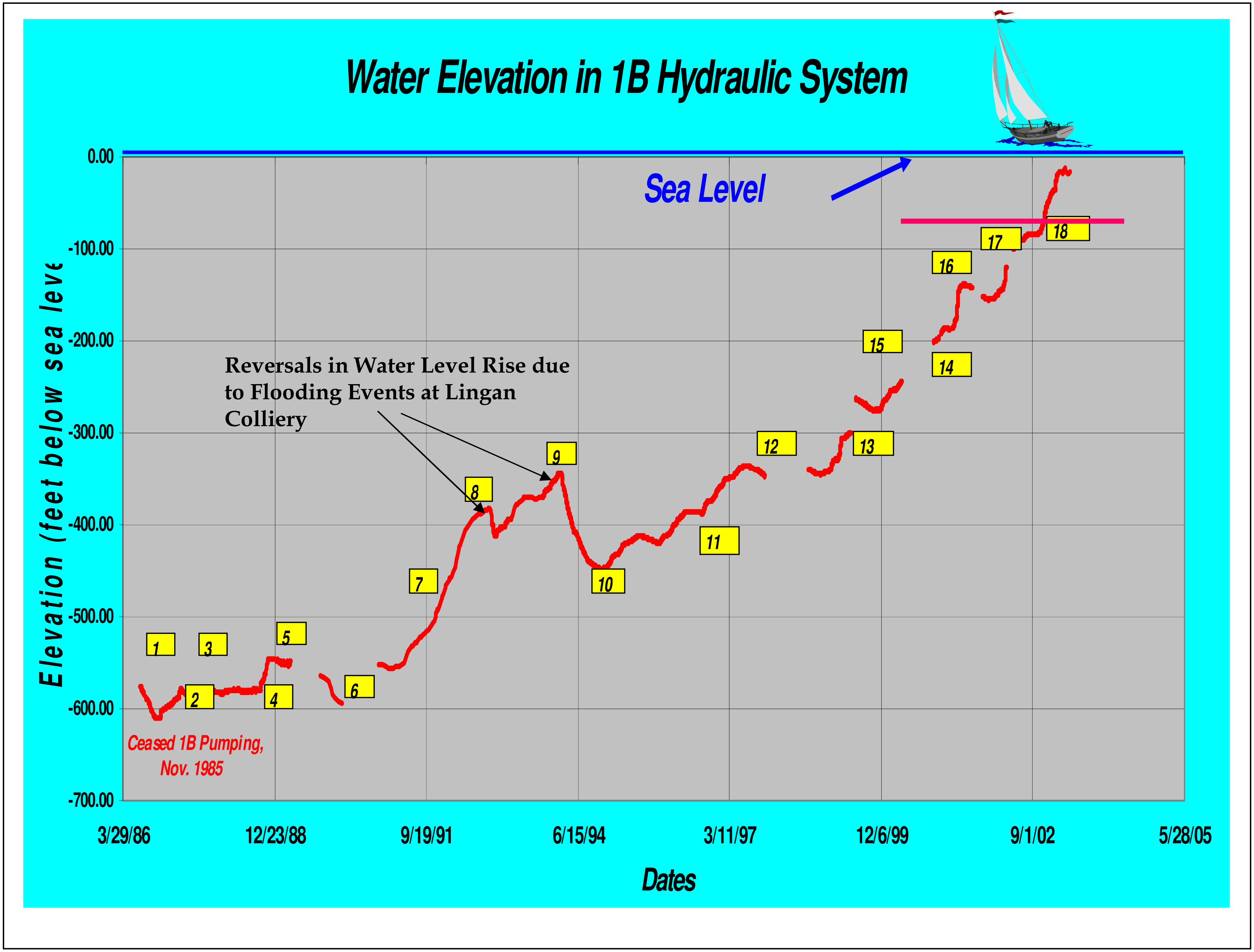
NOTE:

1/ ALL ELEVATIONS ARE IN FEET.

11545F21 96/12/06

11545

FIGURE 3



Water Elevation in 1B Hydraulic System
Sea Level
0.00
-100.00
-200.00
-300.00
-400.00
-500.00
-600.00
-700.00
Elevation (feet below sea leve
3/29/86
12/23/88
9/19/91
6/15/94
3/11/97
12/6/99
9/1/02
5/28/05
Dates
Reversals in Water Level Rise due to Flooding Events at Lingan Colliery
Ceased 1B Pumping, Nov. 1985
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

Figure 4

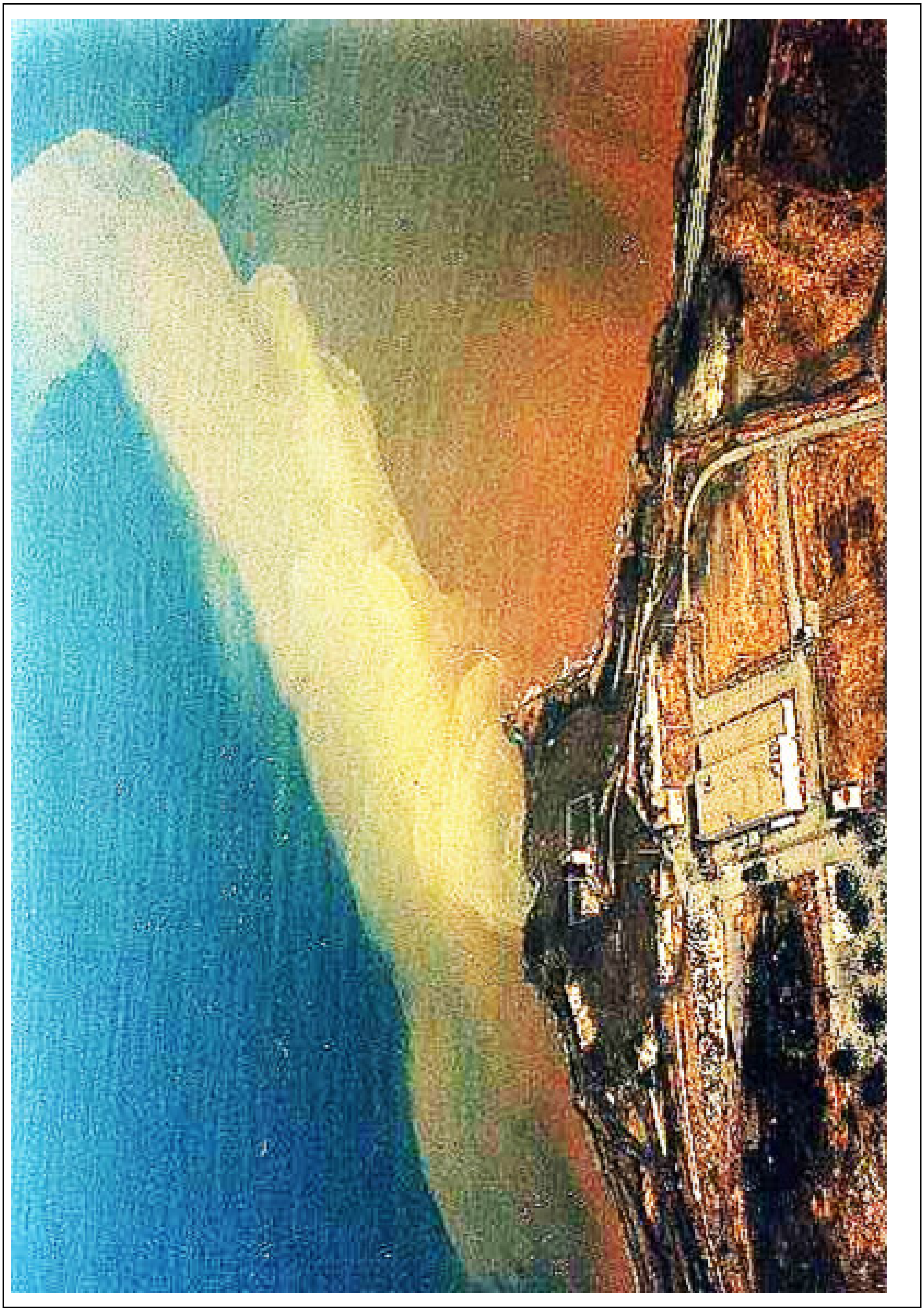
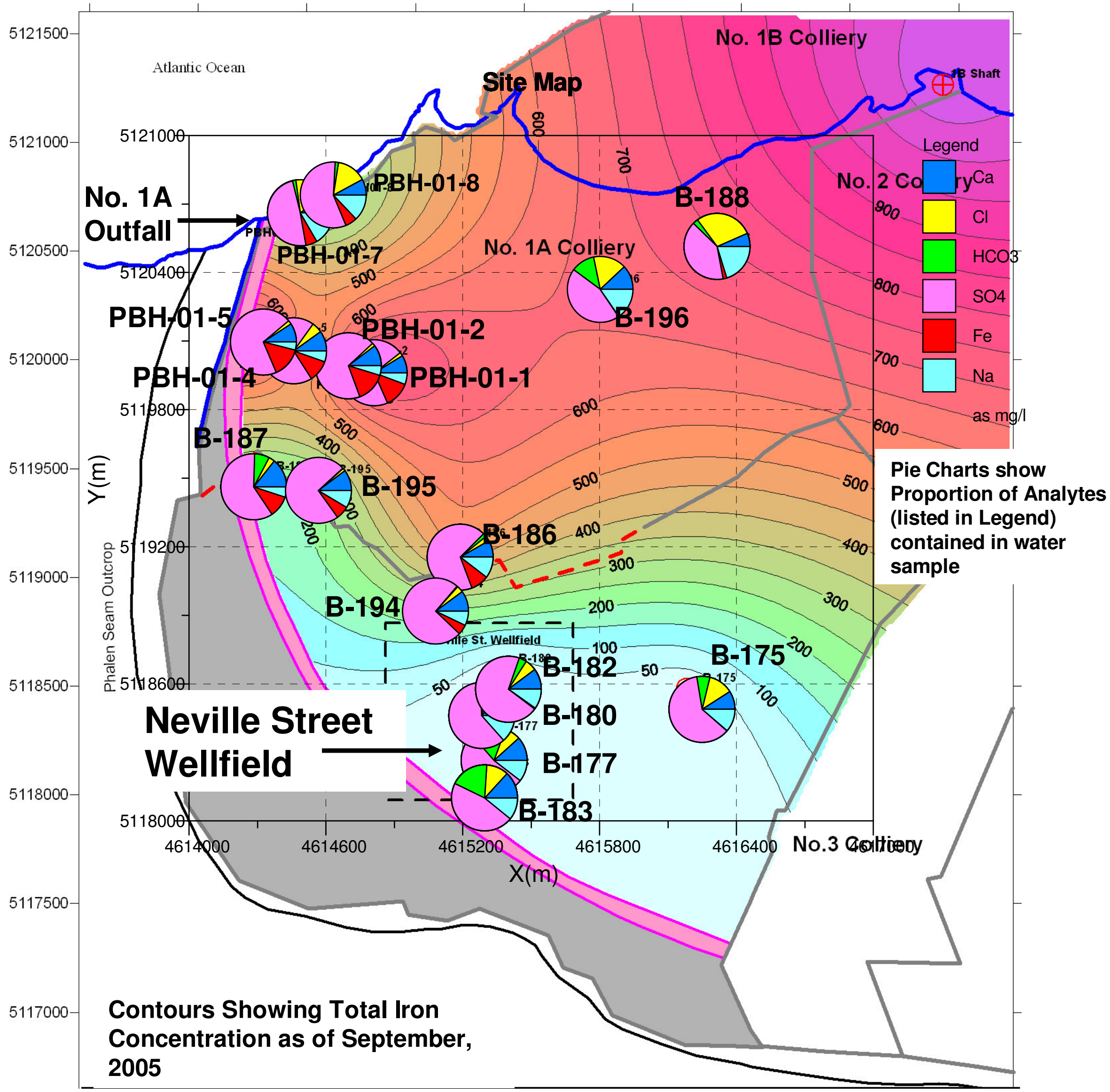


Figure 5



Site Map
Atlantic Ocean
No. 1B Colliery
1B Shaft
No. 2 Colliery
No. 1A Colliery
No.3 Colliery
No. 1A
Outfall
Neville Street
Wellfield
Neville St. Wellfield
Phalen Seam Outcrop
PBH-01-8
PBH-01-7
PBH-01-5
PBH-01-4
PBH-01-2
PBH-01-1
B-188
B-196
B-187
B-195
B-186
B-194
B-182
B-180
B-177
B-183
B-175
Legend
Ca
Cl
HCO3
SO4
Fe
Na
as mg/l
Pie Charts show
Proportion of Analytes
(listed in Legend)
contained in water
sample
Contours Showing Total Iron
Concentration as of September,
2005
Y(m)
X(m)
5121500
5121000
5120500
5120000
5119500
5119000
5118500
5118000
5117500
5117000
4614000
4614600
4615200
4615800
4616400

Figure 6

TABLE 1
Mines Within the 1B Hydraulic System

Mine Name	Year Opened	Year Closed	Seam Mined	Seam Thickness (m)	Workings Elevation Range (m)*	Location	Primary Mining Methods	Primary Mode of Access	Estimated Inflow Rate During Operations (GPM)	Estimated Volume of Water In Workings (US gallons)
No. 5 Colliery	1872	1938	Phalen	2.3	+35 to -168	Under land	R & P** & R & P with Pillar Extraction	Slopes from Outcrop & Shaft	400 (?)	803,000,000
No.1A Colliery	1893	1927	Phalen	2.1	+9 to -187	Under land	R & P** & R & P with Pillar Extraction	Shafts	550	863,000,000
No. 2 Colliery	1899	1949	Phalen	2.2	-160 to -613	Submarine & Under Land	R & P** & R & P with Pillar Extraction	Shafts	12	4,559,000,000
No. 9 Colliery	1899	1924	Harbour	1.9	-61 to -213	Submarine & Under Land	R & P** & R & P with Pillar Extraction	Shaft	900	1,315,800,000
No. 10 Colliery	1905	1942	Emery	1.1	+38 to -140	Under land	R & P** & Longwall	Slopes from Outcrop & Shaft	1750	748,770,000
No.1B Colliery	1924	1952	Phalen	2.1	-187 to -716	Submarine	R & P** & Longwall	Shafts	50	4,348,500,000
No. 20 Colliery	1939	1971	Harbour	1.6	-89 to -426	Submarine	R & P** & Longwall	Shaft & Cross Measure Tunnel	135	2,634,000,000
No. 26 Colliery	1943	1984	Harbour	1.8	-103 to -822	Submarine	R & P** & Longwall	Shaft & Cross Measure Tunnel	15	1,872,000,000
Lingan Colliery	1978	1993	Harbour	2.0	+26 to -817	Submarine	R & P** & Longwall	Slopes from Outcrop	+/-50 (prior to flooding event)	1,562,000,000
Phalen Colliery	1985	1999	Phalen	2.1	+27 to -750	Submarine	Longwall	Slopes from Outcrop	+/-50 (prior to flooding event)	1,573,500,000
							Estimated Total Water Volume In 1B Hydraulic System			**20,279,570,000**

*Elevations are relative to sea level
**Room and Pillar

TABLE 2

Typical Pre-1988 Water Quality Analyses For Various Collieries in the 1B Hydraulic System

Colliery	Sample Location	Sample Date	pH	Hardness (mg/L $CaCO_3$)	SO_4 (mg/L)	CL (mg/L NaCl)	Fe (mg/L)	Al (mg/L)	TDS (mg/L)
1B	Pit bottom	Oct 20 1970	6.4	294	na	na	na	na	na
No. 2	13 Lodgement	Nov 01 1932	2.3	na	1441	103700	na	na	na
No. 9	Deeps	Apr 17 1940	2.5	na	4042	16845	v. high	v. high	na
No. 10	na	Apr 17 1940	3.1	na	3325	2960	high	high	na

na = information not available
Data from Jacques Whitford and Associates Limited, Report: Colliery Water Study, Sydney Coalfields, Cape Breton, Nova Scotia, September, 1993.

TABLE 3

Water Quality Data for the 1992 Water Inflow at Lingan and Pumping from the 1B Shaft

	Location:	1B Shaft Discharge	Lingan Colliery 2E Bot. Level	
	Sample Date:	Nov 30 1992	Nov. 20, 1992 to Dec, 4, 1992	
Parameters	**Units**		Mean Value	# of Lingan samples
Sodium (Na)	mg/L	900	7839	12
Potassium (K)	mg/L	24	50	12
Calcium (Ca)	mg/L	225	1070	12
Magnesium (Mg)	mg/L	700	1060	12
Hardness (CaCO3)	mg/L	3444.4	7036.0	12
Alkalinity (as CaCO3)	mg/L	570.0	123.0	12
Sulphate (SO4)	mg/L	5519.9	5586.0	12
Chloride (Cl)	mg/L	1283	11569	12
Reactive Silica (SiO2)	mg/L	-	<0.5	2
O- Phosphorus	mg/L	-	<0.01	2
Nitrate + Nitrite	mg/L	<0.01	<0.5	12
Nitrogen (Ammonia Nitrogen)	mg/L	13.14	16.00	12
Colour	TCU	0	32	12
Turbidity	JTU	1.1	102.0	12
Conductivity	µS	14300	51842	12
pH	units	4.4	6.0	12
T.O.C.	mg/L	-	1	1
Iron (Fe)	mg/L	2000.0	1188.0	8
Manganese (Mn)	mg/L	-	53	2
Copper (Cu)	mg/L	-	0.03	2
Zinc (Zn)	mg/L	-	0.22	2
Lead (Pb)	mg/L	-	0.07	2
Aluminum (Al)	mg/L	-	0.5	2
Arsenic (As)	mg/L	-	0.05	1
Barium (Ba)	mg/L	-	0.03	2
Boron (B)	mg/L	-	0.1	2
Beryllium (Be)	mg/L	-	<0.005	2
Chromium (Cr)	mg/L	-	0.003	2
Cadmium (Cd)	mg/L	-	<0.005	2
Cobalt (Co)	mg/L	-	0.2	2
Nickel (Ni)	mg/L	-	0.33	2
Antimony (Sb)	mg/L	-	0.04	2
Selenium (Se)	mg/L	-	0.05	2
Strontium (Sr)	mg/L	2.5	101.6	7
Vanadium (V)	mg/L	-	0.25	2
TDS	Theor	13862	36820	12
Cation Sum	me/L	-	483	12
Anion Sum	me/L	-	471	12

Data from Jacques Whitford and Associates Limited, Report: Colliery Water Study, Sydney Coalfields, Cape Breton, Nova Scotia, September, 1993.

Table 4
Mine Water Monitoring and Production Wells - Status as of January, 2007
1B Hydraulic System

Well Designation	Year Drilled	Mine Intersected	Pumping Ability: Horsepower Rating	Pumping Ability: Capacity USGPM	Comments
Monitoring Wells (water sampling and level monitoring)					
B-170	2002	No. 8 Colliery, Glace Bay	No pump installed		Shallow well in No. 8 Colliery
B-171	2002	No. 5 Colliery, Wellfield	No pump installed		Well abandoned by CBDC in 2006; capped at top of casing and buried +/- 1 meter).
B-173	2002	No. 8 Colliery, Glace Bay	No pump installed		Deep well in No. 8 Colliery
B-174	2002	No. 3 Colliery, Paschendale	No pump installed		Well in No. 3 Colliery
B-175	2002	No. 5 Colliery, Phalen Road	1	<20	Well in No. 5 Colliery
B-181	2003	No. 1A Colliery, Dominion	No pump installed		Located in No. 1A Colliery
B-186	2003	No. 5 Colliery, Wellfield	0.5	<20	Located in No. 1A Colliery
B-187	2003	No. 1A Colliery, Dominion	0.5	<20	Located in No. 5 Colliery
B-194	2005	No. 5 Colliery, Neville St.	No pump installed		Located in No. 5 Colliery
B-195	2005	No. 1A Colliery, Dominion	No pump installed		Located in No. 1A Colliery
PBH-01-1	2001	No. 1A Colliery, Dominion	No pump installed		Located in No. 1A Colliery
PBH-01-2	2001	No. 1A Colliery, Dominion	0.5	<20	Located in No. 1A Colliery
PBH-01-4	2001	No. 1A Colliery, Dominion	No pump installed		Located in No. 1A Colliery
PBH-01-5	2001	No. 1A Colliery, Dominion	0.5	<20	Located in No. 1A Colliery
PBH-01-6	2001	No. 1A Colliery, Dominion	No pump installed		Located in No. 1A Colliery
PBH-01-7	2001	No. 1A Colliery, Dominion	0.5	<20	Located in No. 1A Colliery
PBH-01-8	-	No. 1A Colliery, Dominion	No pump installed		Located in No. 1A Colliery
Remote Water Level Measuring Stations					
B-172	2003	No. 5 Colliery, Wellfield	No pump installed		Equipped with pressure transducers to measure water level
PBH-01-3	2001	No. 1A Colliery, Dominion	No pump installed		Equipped with pressure transducers to measure water level
Former Monitoring Wells					
B-188	2003	No. 8 Colliery, Glace Bay	No pump installed		These wells abandoned by CBDC in fall 2005 to reduce water inflow to the mine pool.
B-196	2005	No. 1A Colliery, Dominion	No pump installed		They are completely sealed with cement grout.
Pumping Wells (for mine dewatering)					
B-176	2003	No. 5 Colliery, Wellfield	30	425	Well available for pumping
B-177	2003	No. 5 Colliery, Wellfield	30	540	Well available for pumping
B-183	2003	No. 5 Colliery, Wellfield	30	475	Well available for pumping
B-184	2003	No. 5 Colliery, Wellfield	30	520	Well available for pumping
B-185	2003	No. 5 Colliery, Wellfield	30	580	Well available for pumping
B-192	2004	No. 5 Colliery, Wellfield	30	511	Well available for pumping
B-193	-	No. 5 Colliery, Wellfield	30	440	Well available for pumping
B-198	2006	No. 5 Colliery, Wellfield	30	470	Well available for pumping
B-199	2006	No. 5 Colliery, Wellfield	30	470	Well available for pumping
B-200	2006	No. 5 Colliery, Wellfield	30	470	Well available for pumping
B-201	2006	No. 5 Colliery, Wellfield	30	470	Well available for pumping
B-202	2006	No. 5 Colliery, Wellfield	30	325	Well available for pumping
			Available total pumping capacity	**5696**	
Former Pumping Wells (for mine dewatering)					
B-179	2003	No. 5 Colliery, Wellfield	Pump Removed		Wells abandoned by CBDC in 2006 due to poor water quality; capped at top of casing and buried +/- 1 meter)
B-180	2003	No. 5 Colliery, Wellfield	Pump Removed		
B-182	2003	No. 5 Colliery, Wellfield	Pump Removed		
B-190	-	No. 5 Colliery, Wellfield	Pump Removed		Wells abandoned by CBDC in 2006 due to insufficient water at the pumps; wells were capped at top of casing and buried +/- 1 meter)
B-191	2004	No. 5 Colliery, Wellfield	Pump Removed		
Other wells					
B-178	2003	No. 5 Colliery, Wellfield	No pump installed		Well cannot be used for water sampling or water level monitoring (not in workings)
B-189	-	No. 1A Colliery. Dominion	No pump installed		Sealed, cored borehole; grouted upon completion
B-197	-	-	No pump installed		There is no well with this designation

Table 5
Monitoring Well Sample Analyses - Unfiltered
1B Hydraulic System - February, 2005

	PARAMETERS	UNITS	OMOE[3]	CCME-FAL[1]	CCME-MAL[2]	B-188	PBH-01-8	PBH-01-7	PBH-01-5	PBH-01-4	PBH-01-2	PBH-01-1	B-195	B-196	B-187	B-186	B-182	B-180	B-177	B-183	B-175	Minimum Value	Maximum Value	Mean	Standard Deviation	Coefficient of Variation (%)
	MGI Sample Number					B-188	PBH-01-8	PBH-01-7	PBH-01-5	PBH-01-4	PBH-01-2	PBH-01-1	B-195	B-196	B-187	B-186	B-182	B-180	B-177	B-183	B-175					
	Date Collected					9-Feb-05	9-Feb-05	7-Feb-05	11-Feb-05	9-Feb-05	4-Feb-05	10-Feb-05	12-Sep-05	19-Sep-05	7-Feb-05	2-Feb-05	3-Feb-05	2-Feb-05	3-Feb-05	3-Feb-05	10-Feb-05					
	Maxxam Laboratory Number					9967930-05	9967930-01	9967886-03	9967962-01	9967930-03	9967878-01	9967952-01	I12876		9967886-01	9967837-01	9967857-03	9967837-03	9967857-05	9967857-01	9967952-03					
						Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered	Unfiltered					
Major Ions:	Sodium	mg/L	NG	NG	NG	1100	460	683	210	194	242	350	340	330	92	627	801	649	214	84	350	84	1100	420	281.39	66.9
	Potassium	mg/L	NG	NG	NG	9.7	17	17.6	18	18.8	16.2	23	32	18	13	18.8	18.7	24.5	22.6	12.3	28	9.7	32	19.3	5.72	29.7
	Calcium	mg/L	NG	NG	NG	110	290	438	520	359	501	530	380	220	350	504	751	754	310	130	750	110	754	431	203.88	47.3
	Magnesium	mg/L	NG	NG	NG	41.2	228	221	260	231	280	390	180	100	130	366	415	384	150	56	420	41.2	420	241	126.88	52.7
	Alkalinity (as CaCO3)	mg/L	NG	NG	NG	192	63	76	<1	<1.0	<1.0	<1.0	7	240	140	99	244	234	284	109	388	<1.0	388	173	109.50	63.3
	Sulphate	mg/L	NG	NG	NG	47	2110	2170	3970	2340	3330	4490	2700	930	1170	4030	3390	3160	1110	540	3350	47	4490	2427	1350.75	55.6
	Chloride	mg/L	NG	NG	NG	2010	540	750	104	173	75	112	46	340	59	146	364	381	207	94	1500	46	2010	431	559.67	129.8
	Silica	mg/L	NG	NG	NG	5.9	8.9	12.6	72.8	24.3	31.2	29.7	15	7.1	15.4	15.5	9.2	7.7	7.6	12.7	7.2	5.9	72.8	18	16.71	94.5
Nutrients:	Ortho-Phosphorus (as P)	mg/L	NG	NG	NG	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<20	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	NA	NA	NA
	Phosphorus	mg/L	NG	NG	NG	<0.10	0.78	0.61	1.19	0.8	1.01	0.97	<1	<0.1	0.68	0.8	0.62	0.68	0.43	0.15	0.88	<0.10	1.19	NA	NA	NA
	Nitrite+Nitrate (as N)	mg/L	NG	NG	NG	<0.6	<6	<3.0	0.21	<0.06	<0.06	<0.06	0.12	<3	<0.06	0.1	<0.06	<0.06	<0.06	0.38	<0.06	<0.06	0.38	NA	NA	NA
	Nitrate (as N)	mg/L	NG	2.9 [4]	3.6[4]	<0.06	0.07	**<3.0**	0.21	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	0.1	<0.06	<0.06	<0.06	0.38	<0.06	<0.06	0.38	NA	NA	NA
	Nitrite (as N)	mg/L	NG	0.06	NG	**<0.6**	**<6**	**<3.0**	<0.06	<0.06	<0.06	<0.06	**0.12**	**<3**	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	NA	NA	NA
	TKN	mg/L	NG	NG	NG	2.6	3.1	1.9	3.5	2.7	2.8	3.2	1.7	1.0	0.7	1.3	0.8	0.8	0.2	<0.1	0.9	<.01	3.5	NA	NA	NA
	Ammonia as (N)	mg/L	NG	Narrative	NG	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.02	<0.02	0.51	<0.1	<0.02	<0.1	<0.1	<0.1	<0.1	<0.02	<.01	<.1	NA	NA	NA
	Total Organic Carbon	mg/L	NG	NG	NG	1.6	6.4	4.7	3.4	3.9	4.9	6.3	2.8	<0.5	2	3.5	4.2	2.6	2	2.7	5.2	1.6	6.4	3.7	1.52	40.6
Physical Parameters:	Hardness (as CaCO3)	mg/L	NG	NG	NG	444.33	1663.03	2003.76	2369.12	1847.68	2404.04	2929.43	1700	920	1409.29	2765.68	3584.22	3464.05	1391.77	555.22	3602.31	444.33	3602.31	2065.87	1017.20	49.2
	Bicarbonate	mg/L	NG	NG	NG	190.54	62.99	75.98	1	1	1	1	7	241	139.95	98.99	243.85	233.72	283.46	108.89	387.41	1	387.41	129.86	121.14	93.3
	Carbonate	mg/L	NG	NG	NG	1.42	0.01	0.02	0	0	0	0	<1	<1	0.05	0.01	0.14	0.28	0.53	0.1	0.58	0	1.42	0.22	0.40	176.6
	Color	TCU	NG	Narrative	Narrative	42	258	>500	11	78	71	18	<5	<5	190	177	90	17	110	<5	113	<5	258	NA	NA	NA
	Turbidity	NTU	NG	Narrative	Narrative	16	44	51	0.7	6.3	6.2	1.4	46	26	51	78	9.3	1.9	12	2.4	9.4	0.7	78	22.6	23.81	105.4
	Conductivity	umhos/cm	NG	NG	NG	6180	4950	4830	5160	4530	4330	5720	4000	2800	2780	5440	5940	5530	3180	1380	7140	1380	7140	4618	1492.81	32.3
	pH	Units	NG	6.5 - 9.0	7.0-8.7+Narrative	7.9	**6.1**	**6.4**	**3.5**	**4.4**	**4.4**	**4.2**	**5.4**	7.2	6.6	**5.9**	6.8	7.1	7.3	7	7.2	3.5	7.9	6.1	1.33	21.8
	Acidity	mg/L	NG	NG	NG	8	620	440	1600	990	1200	1600	410	30	300	700	100	95	25	20	130	8	1600	517	555.68	107.5
Calculated Values:	TDS	mg/L	NG	NG	NG	3439.6	3697.7	4340.8	5155.61	3340.76	4476.06	5925.36	3710	2070	1913.46	5766.8	5895.36	5500.66	2237.66	994.78	7228.06	994.78	7228.06	4105.79	1746.09	42.5
	Cation Sum	meq/L	NG	NG	NG	57.12	53.68	82.7	96.35	64.07	58.99	113.78	48.7	32.4	32.51	83.05	106.94	98.08	40.6	15.17	116.1	15.17	116.1	68.77	31.55	45.9
	Anion Sum	meq/L	NG	NG	NG	61.02	60.52	67.94	87.44	54.21	72.22	97.35	58.2	34	28.7	89.98	85.03	80.52	33.79	16.01	118.55	16.01	118.55	65.34	27.80	42.5
	Ion Sum	meq/L	NG	NG	NG	118.14	126.04	150.64	183.79	118.28	166.09	211.13			71.42	200.49	194.51	180.67	74.39	31.18	234.65	31.18	234.65	147.24	59.66	40.5
	Ion Balance	%	NG	NG	NG	3.3	5.99	9.8	4.84	8.34	10.08	7.78	8.94	2.41	6.21	4	11.42	9.83	9.15	2.71	1.05	1.05	11.42	6.62	3.24	48.9
Biological Parameters:	Total Coliforms	MPN/100ml	NG	NG	NG	10	<10	<10	<10	<10	*no result	<10	<1	8	<10	no result*	0	0	0	3	0	0	10	NA	NA	NA
	Faecal Coliforms (E. coli)	MPN/100ml	NG	NG	NG	0	<10	<10	<10	<10	*no result	<10	<1	<1	<10	no result*	0	0	0	0	0	0	<10	NA	NA	NA
	COD	mg/L	NG	NG	NG	9.1	43	28	100	61	67	95	28	<5	<5	48	5.2	<5	<5	62	<5	<5	100	NA	NA	NA
	BOD	mg/L	NG	NG	NG	<5	10.5	11.8	13.3	6.8	39.3	6.1	<5	<5	<5	10.5	<5	<5	<5	<5	12.2	<5	39.3	NA	NA	NA
Metals:	Iron	mg/L	NG	0.300	NG	**<2.5**	**214.00**	**246**	**830**	**357**	**714**	**800**	**240**	**3.7**	**208**	**523**	**9.18**	**2.03**	**5.45**	**0.4**	**6.27**	0.4	830	277.27	304.00	109.6
	Ferrous Iron	mg/L	NG	NG	NG	<2.5	14.7	180	14.6	220	125	13.8	230	<1	8.7	12.8	7.5	<1	5	<1	6.3	<1	230	69.9	91.32	130.7
	Manganese	mg/L	NG	NG	NG	0.497	41.3	27.1	40	40.6	53	65	48	4.6	16.3	74	39	36.3	12	1.52	41	0.497	74	33.76	21.93	65.0
	Copper	mg/L	0.023	0.002 - 0.004	NG	**0.238**	**0.05**	**0.05**	**0.042**	**0.022**	**0.029**	**<0.020**	**<0.02**	<0.002	**0.008**	**0.094**	**0.14**	**0.099**	**0.053**	**0.016**	**<0.020**	0.008	0.238	0.070	0.07	93.4
	Zinc	mg/L	1.1	0.030	NG	0.007	**0.203**	**0.044**	**1.62**	**0.712**	**0.44**	**1.62**	**0.8**	0.004	**0.265**	**1.11**	**0.042**	**0.082**	0.018	**0.046**	0.026	0.004	1.62	0.440	0.57	129.2
	Aluminum	mg/L	NG	0.005 - 0.100	NG	<0.05	**2.22**	**0.423**	**56**	**20.7**	**57.2**	**69**	**5.5**	**<0.005**	**10.5**	**32.9**	**0.065**	**0.037**	**0.036**	**4.02**	**0.039**	0.036	69	18.474	24.90	134.8
	Antimony	mg/L	16	NG	NG	0.0197	<0.01	<0.0004	<0.020	<0.01	<0.0004	<0.020	<0.004	<0.0004	<0.0004	<0.0004	<0.0004	0.0008	<0.0004	<0.0004	<0.020	<0.0004	0.0197	NA	NA	NA
	Arsenic	mg/L	0.48	0.005	0.0125	**<0.015**	**0.0077**	0.0045	**0.0136**	**0.0135**	**0.0115**	**0.0315**	**<0.006**	0.00081	0.0028	0.0021	0.0029	0.0011	0.0008	<0.0006	0.0016	0.0008	0.0315	0.0073	0.01	120.0
	Barium	mg/L	23	NG	NG	5.88	0.03	0.0414	0.0122	0.0206	0.105	0.0113	0.02	0.068	0.0307	0.0204	0.0244	0.019	0.0174	0.0364	0.0144	0.0113	5.88	0.3970	1.46	368.4
	Beryllium	mg/L	0.053	NG	NG	<0.0005	0.0014	0.0005	0.0124	0.0054	0.0101	0.0134	<0.005	<0.0005	0.0024	0.0082	<0.0005	<0.0005	<0.0005	0.001	<0.0005	<0.0005	0.0134	NA	NA	NA
	Bismuth	mg/L	NG	NG	NG	<0.05	<0.05	<0.002	<0.020	<0.05	<0.002	<0.020	<0.02	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.020	<0.002	0	NA	NA	NA
	Boron	mg/L	50	NG	NG	<0.10	<0.10	<0.10	<0.1	<0.10	<0.10	<0.1	<1	<0.1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.1	<0.10	<0.10	NA	NA	NA
	Cadmium	mg/L	0.011	0.000017	0.00012	**<0.0004**	**<0.0004**	<0.000017	**0.0023**	**<0.0004**	**0.0006**	**0.0008**	**0.0047**	**0.000041**	**0.0005**	<0.000017	<0.000017	**0.0005**	**0.0003**	<0.000017	**0.000244**	<0.000017	0.0047	NA	NA	NA
	Chromium	mg/L	2	0.0089 - 0.001	.0015 - .056	**0.002**	**0.055**	**0.049**	**0.045**	**0.077**	**0.162**	**<0.020**	**0.025**	<0.001	**0.049**	**0.07**	**0.001**	<0.001	<0.001	<0.001	**<0.020**	<0.001	0.162	NA	NA	NA
	Cobalt	mg/L	0.1	NG	NG	0.002	0.243	0.182	0.64	0.364	0.533	0.96	0.28	0.01	0.225	0.6	0.055	0.034	0.018	0.016	0.026	0.002	0.96	0.262	0.29	109.8
	Lead	mg/L	0.032	0.001 - 0.007	NG	**<0.025**	**<0.025**	<0.001	**0.011**	**<0.025**	0.002	<0.005	**<0.01**	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.005	<0.001	0.011	NA	NA	NA
	Lithium	mg/L	NG	NG	NG	0.092	0.098	0.072	0.74	0.263	0.327	0.58	0.11	0.043	0.137	0.292	0.063	0.068	0.101	0.062	0.2	0.043	0.74	0.203	0.20	98.9
	Mercury	mg/L	0.00012	0.00026 [4]	0.00016 [4]	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00001	<0.00001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	NA	NA	NA
	Molybdenum	mg/L	7.3	0.073	NG	**<0.1**	**<0.1**	<0.004	<0.020	**<0.1**	<0.004	<0.020	<0.04	<0.004	<0.004	<0.004	<0.004	0.006	<0.004	<0.004	<0.020	<0.004	0.006	NA	NA	NA
	Nickel	mg/L	1.6	0.025 - 0.150	NG	<0.003	**0.326**	**0.228**	**0.804**	**0.627**	**0.887**	**1.34**	**0.35**	0.012	**0.28**	**0.942**	0.089	0.074	0.033	0.042	0.037	0.012	1.34	0.405	0.42	102.9
	Selenium	mg/L	0.050	0.001	NG	**<0.025**	**0.004**	**0.013**	**0.005**	<0.001	**0.003**	**0.01**	**<0.01**	**0.005**	**0.002**	**0.009**	**0.008**	**0.009**	**0.003**	**0.002**	**0.012**	<.001	0.013	NA	NA	NA
	Silver	mg/L	0.0012	0.0001	NG	**<0.0025**	**<0.0025**	<0.0001	**<0.002**	**<0.0025**	<0.0001	<0.0001	**<0.001**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<.0025	NA	NA	NA
	Strontium	mg/L	NG	NG	NG	5.42	3.12	4.95	4.38	2.04	1.78	4.71	4.2	3.3	3.81	2.31	9.53	8.64	4.58	1.78	7.89	1.78	9.53	4.53	2.37	52.5
	Sulfur	mg/L	NG	NG	NG	13.2	634	1220	1400	835	1820	1600	1100	240	1070	2230	1980	1800	888	357	1200	13.2	2230	1149.2	642.46	55.9
	Thallium	mg/L	0.4	0.0008	NG	**<0.02**	**<0.02**	<0.0008	**0.0038**	**<0.02**	**0.0009**	**0.0015**	**<0.008**	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	**<0.001**	<0.0008	0.0038	NA	NA	NA
	Tin	mg/L	NG	NG	NG	<0.5	<0.5	<0.02	<0.020	<0.5	<0.02	<0.020	<0.2	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.020	<0.020	<.5	NA	NA	NA
	Titanium	mg/L	NG	NG	NG	0.004	0.009	0.011	0.013	0.009	0.014	0.011	<0.03	<0.003	0.014	0.008	0.008	0.01	0.005	<0.003	0.017	<0.003	0.017	NA	NA	NA
	Uranium	mg/L	NG	NG	NG	<0.0038	<0.0038	0.00142	0.0012	<0.0038	0.00876	0.0021	<0.0015	0.00055	0.0093	0.0218	0.00669	0.001	0.00284	0.00051	0.0021	0.00051	0.0218	NA	NA	NA
	Vanadium	mg/L	0.2	NG	NG	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.02	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	NA	NA	NA
Field Measurements:	Temperature	°C	NG	Narrative	Narrative	11.7	12.7	12.46	13.2	14.48	14.54	15.87	13.20	12.73	13.13	12.29	8.99	9.41	8.97	8.44	11.02	8.44	15.87	12.07	2.19	18.1
	Dissolved Oxygen	%	NG	NG	NG	4.7	8.7	1.90	2.4	3	2.9	8.6	6.4	5.2	2.4	6.5	1.2	1.2	1.1	10.6	3.3	1.1	10.6	4.38	3.00	68.4
	Dissolved Oxygen	mg/L	NG	5.5 - 9.5	>8	**0.52**	**0.93**	**0.20**	**0.25**	**0.3**	**0.29**	**0.83**	**0.65**	**0.55**	**0.25**	**0.68**	**0.14**	**0.14**	**0.13**	**1.23**	**0.35**	0.13	1.23	0.47	0.32	69.9
	pH	units	NG	6.5 - 9.0	7.0-8.7+Narrative	7.45	**5.48**	**5.86**	**3.42**	**4.52**	**4.64**	**4.31**	**5.12**	6.87	**6.07**	**5.52**	**5.87**	**5.88**	**6.3**	**6.03**	**6.27**	3.42	7.45	5.60	1.01	18.1
	ORP	RmV	NG	NG	NG	-115.4	53.4	-8.10	231.6	99.8	70.6	129	103.7	-11.7	-26.8	44.1	93.8	110.4	64.6	193.2	41.3	-115.4	231.6	67.09	84.53	126.0
	TDS	mg/L	NG	NG	NG	4057	3278	3195	3366	2979	2802	3751	2174	1591	1883	3692	3927	3724	2094	909	4673	909	4673	3005.94	1024.35	34.1
	Conductivity	ms/cm	NG	NG	NG	4654	3855	3737	4014	3662	3529	4750	2591	1873	2240	4302	4197	4025	2235	956	5269	956	5269	3493.06	1184.18	33.9
	Specific Conductance	ms/cm	NG	NG	NG	6240	5040	4914	5180	4583	4410	5770	3351	2446	2898	5680	6035	5730	3221	1399	7199	1399	7199	4631	1575	34.0
	Static Water Level	m from TOP		-		26.51	16.68	15.2	33.94	33.7	37.59	46.67	42.76	16.92	33.25	36.68	40.81	42.17	41.15	42.6	49.9	15.2	49.9	34.78	10.77	31.0

Notes

1	Indicates Canadian Council of Ministers of the Environment (CCME) Canadian Environmental Quality Guidelines for Freshwater Aquatic Life - Update 2002
2	Indicates Canadian Council of Ministers of the Environment (CCME) Canadian Environmental Quality Guidelines for Marine Aquatic Life - Update 2002
3	OMOE refers to the Ontario Ministry of the Environment guidelines as contained in "Soil, Groundwater and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act" March 9, 2004
4	Indicates that the CCME value is based on the revisions in 2003.
NG	Indicates that there is no CCME guideline for this parameter.
Narrative	Indicates there is no numerical value; a narrative description is used.

Indicates an analyses that exceeds the CCME-FAL guideline value.

Indicates an analysis that may or may not exceed the CCME-FAL Guidelines. Doubt exists because of elevated reporting limits caused by elemental interferences associated with sample matrix.

TASK 2, PART 2 – REVIEW AND COMMENTS ON PUMPING STRATEGY AT THE NEVILLE STREET WELLFIELD.

BACKGROUND:

The Neville Street Wellfield was constructed in 2003 to provide an emergency water level control capability within the 1B Mine Pool and thereby prevent a discharge of AMD-impacted water to the local marine environment. It has achieved this goal by pumping water from No. 5 Colliery workings at a rate equivalent to mine pool recharge. Pumping is carried out by a series of 30 horsepower electrical submersible pumps installed in large diameter (20 centimetres), steel-cased production wells.

Initially, in 2003, eight wells were constructed to generate a pumping capacity of 3750 USGPM. The pumps were operated by portable electric power generators and water was discharged from several pumping locations into nearby Cadegan Brook. These pumps together with the 1500 USGPM capacity of the water treatment plant at 1B Shaft in Glace Bay were capable of handling the 2003 spring water run-off and prevent a mine water discharge. Water quality was monitored by sampling the pumping wells, the Wellfield discharge and also several stations above and below the discharge on Cadegan Brook.

Since the fall of 2003, pumping operations at the Wellfield have been managed by the Cape Breton Development Corporation (CBDC). The pumping arrangements have been streamlined with the provision of a permanent electrical power supply, installation of pumps and water mains below grade, and the construction of a central discharge for the water. Several new wells have been commissioned and others have been abandoned (See Table 1). Sampling of the Wellfield discharge has continued but sampling of Cadegan Brook was halted. Water level and pumping rates have been recorded daily and the measurements are maintained in an Excel spreadsheet. Currently, 12 production wells are available for pumping (See Table 1). When all wells are operating, a pumping capacity of approximately 5700 USGPM is achievable. The current configuration of wells at the Wellfield is shown in Figure 1.

PUMPING AND RECHARGE RATE:

Since its development in 2003, the Neville Street Wellfield has successfully controlled water level rise in the 1B Hydraulic System. The objective of pumping has been to maintain water level within a "maintenance zone", the range of which lies between elevations -5.18 and -5-80 meters below sea level. The success in achieving this goal is demonstrated by the graph in Figure 2. The graph was constructed from mine pool water elevations acquired daily from electronic measuring stations. In general, the water level has been kept within the maintenance zone. The water level has risen above the minimum elevation during periods of high recharge associated with elevated precipitation and snow melt in the spring of the year. Peak water inflow rates during the spring have exceeded 7000 USGPM and as such cannot be instantaneously handled by the Wellfield. Also shown on the graph is the period between October 2003 and February 2004 when the water level was lowered to create some additional storage capacity during the construction of the Wellfield discharge.

From the daily pumping data recorded by CBDC it is possible to estimate an average recharge rate for the 1B Hydraulic System. Since the water level has been maintained throughout each year within a rather narrow elevation range, pumping rate is for all practical purposes equivalent to the recharge rate. Pumping rates at the Wellfield are shown for the periods indicated in the table below.

Pumping Periods	Average Pumping Rate (USGPM)	Total Precipitation (mm)
March 1, 2003 to Feb. 29, 2004	1472	1528
March 1, 2004 to Feb. 28, 2005	1619	1250
March 1, 2005 to Feb. 28, 2006	2444	1430
Averages	**1845**	**1403**

It is noted that average pumping rate has increased yearly since 2003. This is an important observation because total precipitation does not follow the same increasing trend. The reason for this is not readily apparent but must be related to either a reduction in pumping efficiency over time or the addition of new sources of water to the mine pool. It is important that this apparent increase in pumping effort be investigated to insure that the capacity of the Wellfield is maintained. Since pump capacity and efficiency can be checked in a straightforward way, these parameters should be assessed before embarking on more involved investigations into potential new sources of water recharge.

NEVILLE STREET WELLFIELD DISCHARGE WATER QUALITY

Discharge water from the Neville Street Wellfield has been continuously monitored since the Wellfield was first established in 2003. Over this time, ninety-two samples have been collected and analyzed for a variety of physical and chemical parameters. For most of the samples, temperature, pH, and conductivity were also measured in the field at the time of collection. A tabulation of discharge sample analyses has been maintained by CBDC in an Excel spreadsheet. Table 2 was prepared using data from water samples collected between July and December 2006. The table provides a description of current discharge water quality and illustrates the variety of parameters used in the assessment.

CCME Fresh Water Aquatic guideline values are included in Table 2 and parameters that exceed those guidelines have been identified by shading. It is noted that guideline values are most frequently exceeded for iron, aluminum, zinc, and cadmium. Less frequent exceedances are identified for molybdenum and selenium. It is further noted that in several cases trace metal analyses were not analyzed to the CCME Freshwater Aquatic-compliant detection limit. In other cases, the filtered analyses exceed the unfiltered value on the same sample. Both of these results are due to analytical difficulties created by the complex mine water sample matrix. Where the CCME Freshwater Aquatic detection limit has not been attained the data cannot be used to determine if the CCME guideline values were exceeded.

Water Quality Trends:
To illustrate changes in Wellfield discharge chemistry over time, the entire set of 92 samples has been plotted for sulphate, aluminum, total iron, pH and temperature in Figure 3. The unfiltered sample values have been used and linear regression lines have been added to illustrate trends. These parameters were selected because they are most useful for tracking the level and trends of AMD impacted water at the Wellfield.

To interpret the information in these graphs however, it is important to know which wells were pumping at the time of sampling. The Wellfield may be considered to be made up of three groups of wells (See Table below and Figure 1) that tap the mine pool at different locations.

Well Grouping Name	Wells in Grouping
Northern Group	B-179, B-180, B-182
Southern Group	B-176, B-177, B-183, B-184, B-185, B-192, B-193
Western Group	B-198, B-199, B-200, B-201, B-202

The Southern Group of seven wells pumps the shallowest mine workings (53-62 m) and has consistently discharged the best quality water. The Northern Group consists of three wells that tap water from the deepest mine workings (68-82 m) and their water quality has been gradually deteriorating over time. Northern wells have only operated when high pumping capacity was needed in the spring and fall of the year. During the summer of 2005, the Northern wells were decommissioned and capped due to their poor water quality. The Western Group consists of five recently (during fall of 2006) constructed wells that replace the abandoned Northern wells and two others (B-190 & B-191) that had been abandoned in the Southern Group.

In the Figure 3, the red data point symbols identify samples collected when Northern Group wells were discharging water; the light-blue data point symbols indicate when the Western Group wells contributed water to the discharge. The dark blue data points indicate samples collected when only the Southern Group was pumping. Two graphs are shown for each of the five parameters. The graph on the left contains the complete data set; the graph on the right shows the same sampling period but does not include samples collected when the Northern and Western well groups were pumping. The companion graphs were created to illustrate how pumping various well groups have impacted discharge water chemistry.

All the graphs show a trend of deteriorating water quality over time. This trend is especially evident for iron and aluminum. Sulphate and pH have changed less dramatically but still support the trend to poorer quality water. The iron and sulphate graphs display a strong relationship between increasing concentration and periods of high volume pumping when Northern Group wells were operating. Since Northern Group wells are located closest to the highly AMD-impacted No. 1A Mine Pool, it is believed that pumping these wells has tended to draw the poor quality water to the Wellfield. This opinion is supported by the accompanying rise in discharge water temperature when the wells were pumping. Increasing temperature would be expected because the No. 1A Mine Pool tends to be 5 - 6 degrees warmer than the Wellfield.

The graphs also show a sharp rise in the concentrations of aluminum and iron when the Western Group of wells was pumping. Although aluminum concentration has tended to rise when the Northern Group of wells was pumping, that relationship is not as strong as for iron and sulphate. The peak concentrations of aluminum are actually associated with pumping of the Southern and Western Group wells. Why this should be is not readily apparent but it may be related to local conditions in No. 5 Colliery workings.

Comparison of Discharge Chemistry to CCME Guideline Values:
The concentration of iron and aluminum in the discharge samples is summarized in the table below. It shows the increasing concentration of these parameters over time and provides the basis for comparing them to the CCME (Canadian Conference of Ministers of the Environment) Freshwater Aquatic Guideline values.

Iron Concentration in the Neville Street Wellfield Discharge

	2003	2004	2005	2006
Minimum	<0.10	0.14	0.43	0.87
Maximum	0.50	16	12	12
Mean	0.36	0.40	3.03	4.40
CCME Guideline Value for Iron	0.3 mg/L	0.3 mg/L	0.3 mg/L	0.3 mg/L
Percentage of Samples that Exceed the Guideline Value	50%* 3 of 6 samples	63% 5 of 8 samples	100% 17 of 17 samples	100% 23 of 23 samples

* Only unfiltered samples that were analyzed to CCME detection limits are included.

Aluminum Concentration in the Neville Street Wellfield Discharge

	2003	2004	2005	2006
Minimum	0.02	0.013	0.05	0.13
Maximum	0.4	0.832	2.1	2.5
Mean	0.09	0.146	0.71	0.79
CCME Guideline Value for Aluminum	0.005 at pH<6.5 0.10 at pH>6.5	0.005 at pH<6.5 0.10 at pH>6.5	0.005 at pH<6.5 0.10 at pH>6.5	0.005 at pH<6.5 0.10 at pH>6.5
Percentage of Samples that Exceed the Guideline Value	21%* 3 of 14 samples	37% 7 of 19 samples	96% 24 of 25 samples	100% 26 of 26 samples

* Only unfiltered samples that were analyzed to CCME detection limits are included.

The CCME guideline values for these metals have always been exceeded whenever the Northern and Western Groups of wells were pumping. During 2006, the guideline values were continually exceeded even when the best quality water in the Southern Group wells was being pumped. The impact of pumping poor water quality became evident in the spring of 2006 when local residents reported accumulations of iron precipitate on the bed of Cadegan Brook. An examination of Cadegan Brook during May of 2006 (CRA, 2006) revealed that iron precipitate on the streambed for a distance of approximately 5 kilometres below the Wellfield discharge.

NEW PUMPING WELLS B-198, B-199, B-200, B-201 AND B-202

The Western Group of five new pumping wells was installed at the Wellfield during the fall of 2006. They replaced three wells of the Northern Group which had been abandoned due to poor quality water and two shallow wells in the Southern Group that were providing insufficient water at the pumps. The wells were located along the strike of the mine workings west of the Southern Group of wells. Well depth ranged from 59 to 61 meters. Their locations are shown in Figure 1. They were sampled on December 13, 2006 and the resulting water analyses are presented as Table 3.

The most significant findings in these new wells are the elevated concentrations of metals. The new wells all exceed CCME Guideline values for iron (16 – 130 times the guideline value) and zinc (2 – 16 times the guideline value), and all except B-198 exceeded the guideline values for aluminum (4.5 – 1500 times the guideline value) and cadmium (1 – 11 times the guideline value). Slight exceedances for arsenic were also evident in several of the wells while the guideline for nickel is exceeded only in B-201.

The impact of these wells on the iron and aluminum content at the Wellfield discharge can be seen in Figure 3. Note the sharp increase in the concentration of iron and aluminum (light blue data points) when these wells were pumping during November and December 2006.

WELLFIELD PUMPING STRATEGY

To optimize discharge water quality at the Wellfield, a strategy of always pumping the better water quality wells first, has been adopted. Poorer quality wells are added only when a demand for the additional pumping capacity was needed. Discharge water quality data for 2006 indicates that even when the best quality water from the Southern Group of wells was being pumped, CCME Guideline values for iron and aluminum could not be met. It is possible that CCME compliance might have been attained during periods of low recharge when only one or two Southern Group wells were operating however, this cannot be reliably assessed because (accept for B-177) discharge samples were collected when multiple wells were running, and samples from individual wells are not available.

The future success of pumping at the Wellfield will depend on the regulatory criteria that have to be met for compliant water discharge. Based on the 2006 discharge data it seems unlikely that compliance with CCME guideline values can be achieved if more than one or two wells in the Southern Group are pumped at the same time. This situation would be exacerbated even further during high recharge events in the spring and fall when the Western Group wells would have to be started.

Table 4 shows the estimated iron and aluminum concentrations in the Wellfield discharge when the Southern Group of wells are operating and how those metal concentrations might change as the Western Group wells are brought on line. (Note: A single concentration value for iron and aluminum has been used for all the Southern Group wells because individual well chemistries are not available. These concentrations were determined by critically assessing discharge water chemistry for output from different well combinations. It is possible that the metal concentration in individual wells may be less than this average while other may exceed it. The contribution of individual wells can only be determined by sampling).

Table 4 clearly shows that CCME guideline criteria cannot be met at the Neville Street Wellfield. At pumping rates up to 3500 USGPM, the Southern Wellfield can be expected to discharge iron and aluminum at average concentrations of about 1.6 mg/L (range: 0.8 – 2.9) and 0.7 mg/L (range: 0.05 – 2.5) respectively. If the compliant discharge criterion for iron is increased to 2.0 - 2.4 mg/L (based on a past qualitative risk assessment at Gardiner and Summit sites) then pumping at rates of up to 4000 USGPM should be possible. Pumping at rates in excess of 4000 USGPM however would necessitate operation of the remaining four wells in Western Group, and this would quickly result in iron concentrations that exceed 3 mg/L.

It is important to note that the validity of this conclusion can be significantly impacted by changes in the operational condition of the pumping wells. It was noted earlier that pumping effort to maintain water level has apparently increased significantly since 2003 without a notable increase in precipitation. It was also stated that this may be due to an increase in the groundwater recharge rate (failure of seals at No. 10 or No. 3 Collieries, new sinkhole developments, new storm sewer additions, leakage around monitoring wells, etc.), however, it might also have been caused by reduced pumping efficiency in the wells themselves, induced by incrustation in riser pipes, fouling of screens, etc. If incrustation or fouling is a problem, higher velocities may result in increased turbidity at the discharge, which could impact the chemistry of unfiltered samples. In addition, if pumping rates are less than those used in Table 4, then the capacity of the Wellfield may actually be lower than it appears.

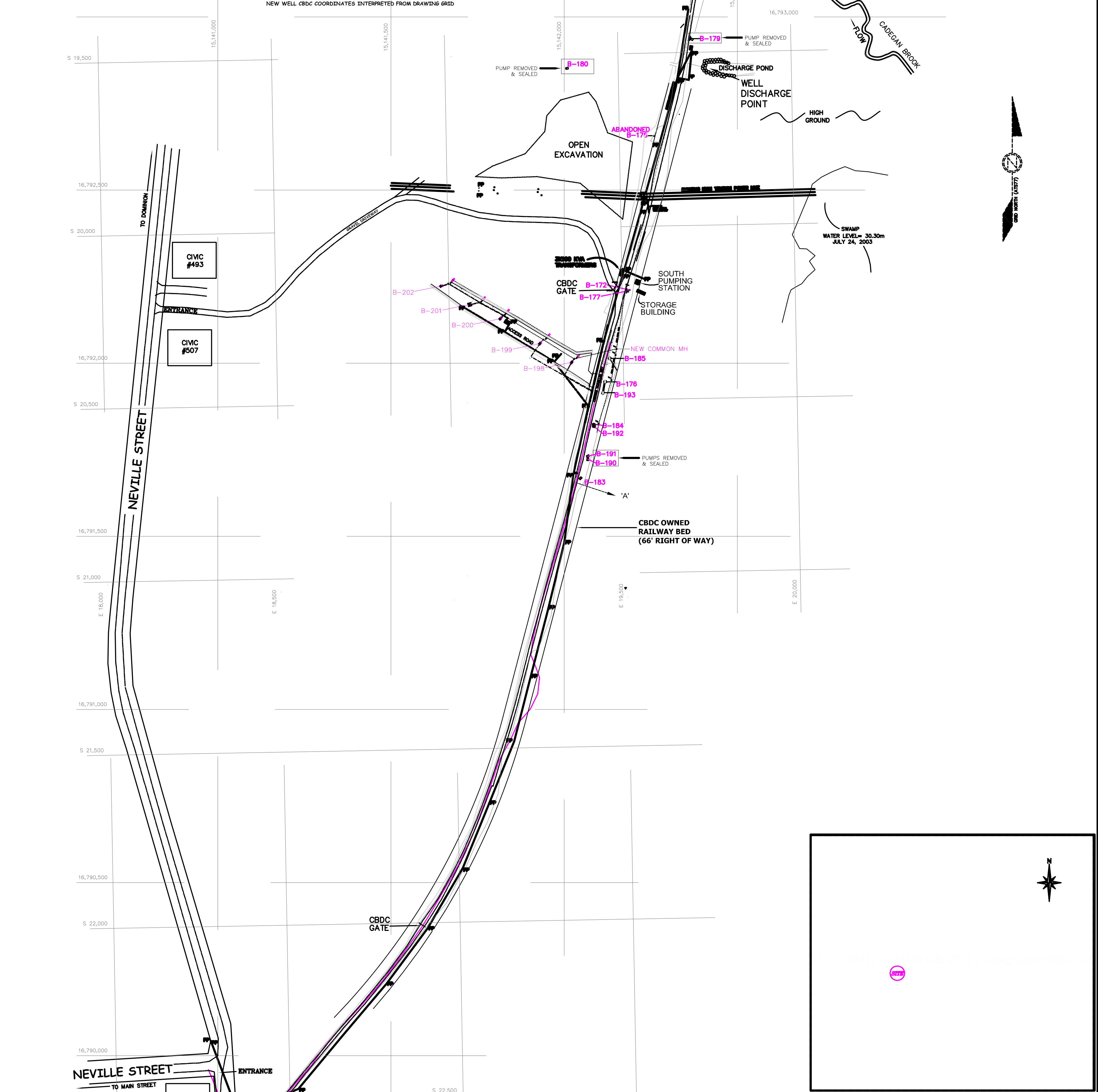
The source of this apparent increase in pumping should be thoroughly investigated so that the capacity of the Wellfield and discharge water quality can be reliably assessed. The first step in this investigation should involve the inspection of all pumping wells and a verification of flow rate measurements. This should be done before undertaking the more complicated assessment into potential new sources of water recharge.

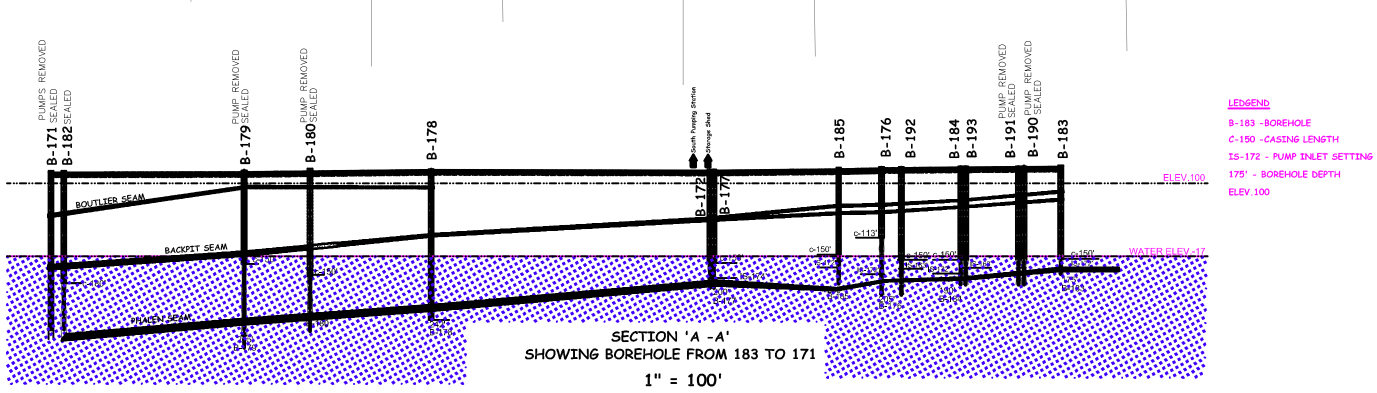
Nonetheless, if 4000 USGPM is the maximum allowable pumping rate for compliant discharge, and if the spring recharge rate exceeds 4000 USGPM, then water level control will be at risk unless additional pumping capacity is found. The following options might be considered to provide additional capacity.

1. New wells containing better quality water could be developed. The probability of finding better quality water is highest on the east side of the Southern Group of wells.
2. The Wellfield discharge water could be treated on site, prior to its release into Cadegan Brook and thereby allow the Western well capacity to be utilized.
3. Pumping and treatment of the mine pool from the 1B Shaft or from a new pumping/treatment facility at Dominion could be considered. This may slow down water quality deterioration at Neville Street and may even reverse the trend. At the very least, it would reduce the need for additional pumping capacity at the Wellfield in proportion to the rate of water treatment.
4. Different combinations of options 1 to 3 could be considered.
5. Await the results of the quantitative risk assessment currently being carried out by PWGSC and then re-examine the options in light of its findings.

BOREHOLE	PUMP SIZE	CASING SIZE	VOLUME I GPM	STATUS	POWER FROM	ELEVATION TOP OF PIPE	ELEVATION GROUND	DEVCO GRID - FEET NORTHING	DEVCO GRID - FEET EASTING	ATS77 GRID - FEET NORTHING	ATS77 GRID - FEET EASTING
B171	7.5 hp.	6"	N/A	INACTIVE	INACTIVE	120.67	117.2	N:-19151.15	E:19735.64	N: 16,793,247.19	E: 15,142,384.41
B172	7.5 hp.	6"	N/A	INACTIVE	INACTIVE	121.98	119.3	N:-20183.11	E:19521.78	N: 16,792,211.58	E: 15,142,189.00
B176	20 hp.	8"	425	ACTIVE	South Sta	118.76	123.4	N:-20447.50	E:19445.35	N: 16,791,945.87	E: 15,142,117.29
B177	30 hp.	8"	540	ACTIVE	South Sta	115.51	119.7	N:-20185.92	E:19515.97	N: 16,792,208.66	E: 15,142,183.23
B178	N/A	N/A	N/A	ABANDONED	N/A	121.43	120.7	N:-19739.79	E:19600.36	N: 16,792,656.23	E: 15,142,259.65
B179	30 hp.	8"	545	ACTIVE	North Sta	113.57	117.6	N:-19460.52	E:19711.84	N: 16,792,937.43	E: 15,142,366.14
B180	20 hp.	8"	430	ACTIVE	North Sta	119.26	122.3	N:-19540.16	E:19349.97	N: 16,792,851.35	E: 15,142,005.74
B182	30 hp.	8"	545	ACTIVE	North Sta	114.01	117.0	N:-19172.13	E:19737.76	N: 16,793,226.25	E: 15,142,386.91
B183	30 hp.	8"	475	ACTIVE	South Sta	120.62	125.4	N:-20724.95	E:19369.70	N: 16,791,667.13	E: 15,142,046.62
B184	30 hp.	8"	520	ACTIVE	South Sta	120.39	124.5	N:-20569.50	E:19410.02	N: 16,791,823.26	E: 15,142,084.15
B185	30 hp.	8"	580	ACTIVE	South Sta	117.9	121.8	N:-20379.92	E:19459.49	N: 16,792,013.68	E: 15,142,130.25
B190	30 hp.	8"	N/A	INACTIVE	INACTIVE	119.99	124.0	N:-20669.39	E:19392.62	N: 16,791,723.09	E: 15,142,068.70
B191	7.5 hp.	8"	N/A	INACTIVE	INACTIVE	120.35	124.8	N:-20661.16	E:19392.91	N: 16,791,731.43	E: 15,142,068.57
B192	30 hp.	8"	511	ACTIVE	South Sta	119.77	124.5	N:-20575.45	E:19411.80	N: 16,791,817.45	E: 15,142,086.06
B193	30 hp.	8"	440	ACTIVE	South Sta	119.0	123.0	N:-20478.78	E:19439.46	N: 16,791,914.50	E: 15,142,111.98
B198						--	122.90	N:-19389.10	E:19350.82	N: 16,792,002.59	E: 15,142,021.75
B199						120.93	124.63	N:-19333.90	E:19258.94	N: 16,792,056.14	E: 15,141,928.90
B200						122.30	126.04	N:-19260.09	E:19145.84	N: 16,792,127.92	E: 15,141,814.50
B201						125.03	128.64	N:-19217.43	E:19057.65	N: 16,792,169.00	E: 15,141,725.56
B202						129.03	132.48	N:-19162.53	E:18976.42	N: 16,792,222.44	E: 15,141,643.37

NEW WELL CBDC COORDINATES INTERPRETED FROM DRAWING GRID





CAPE BRETON DEVELOPMENT CORPORATION

SOCIÉTÉ DE DÉVELOPPEMENT DU CAP-BRETON

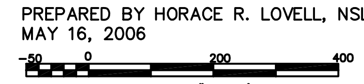
SITE PLAN FOR NEVILLE STREET WELL FIELD

RESERVE MINES
CAPE BRETON COUNTY
NOVA SCOTIA

Figure No. 1

REVISION No. 1 NOV 28,2006

PREPARED BY HORACE R. LOVELL, NSLS
MAY 16, 2006



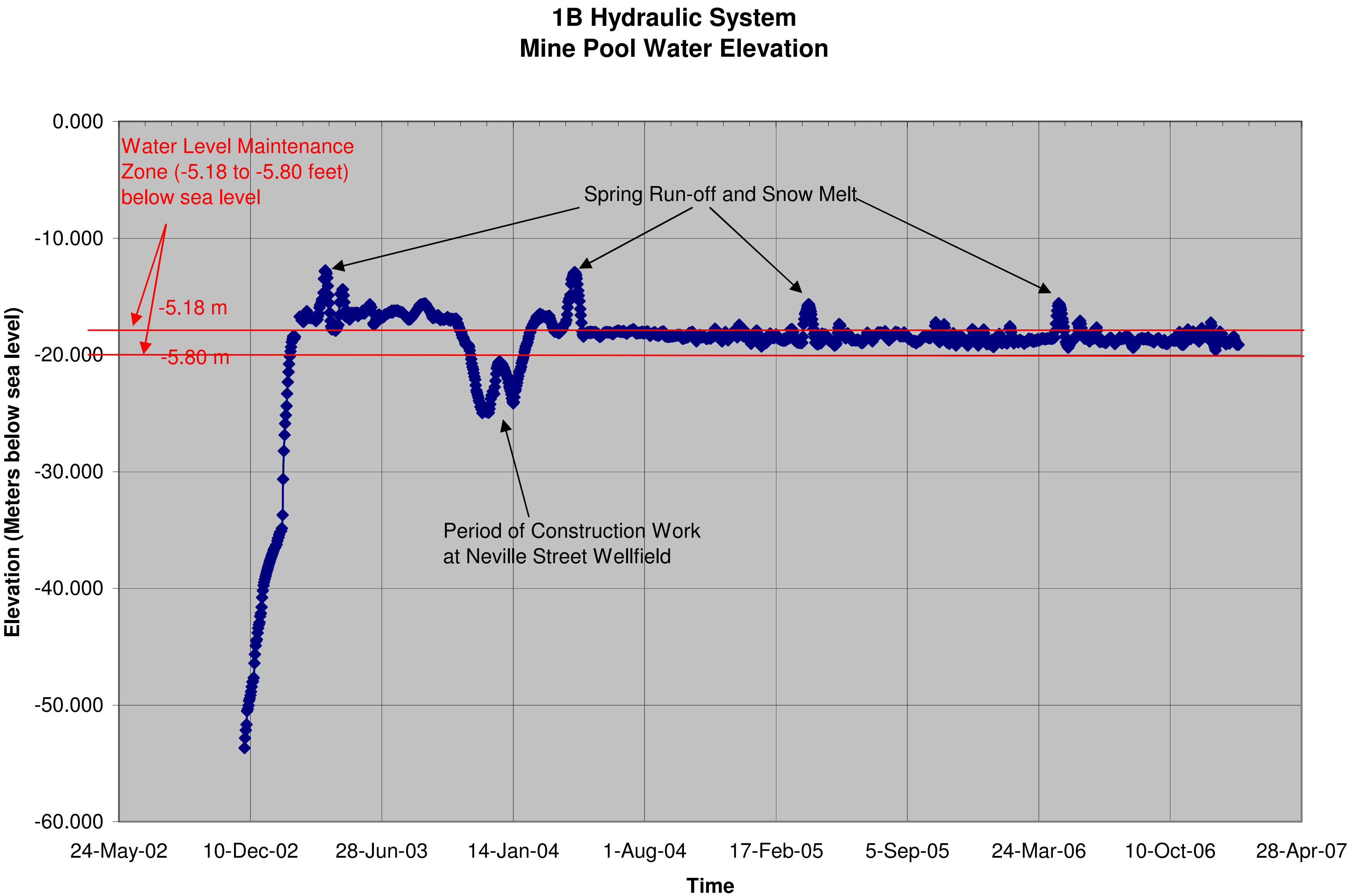
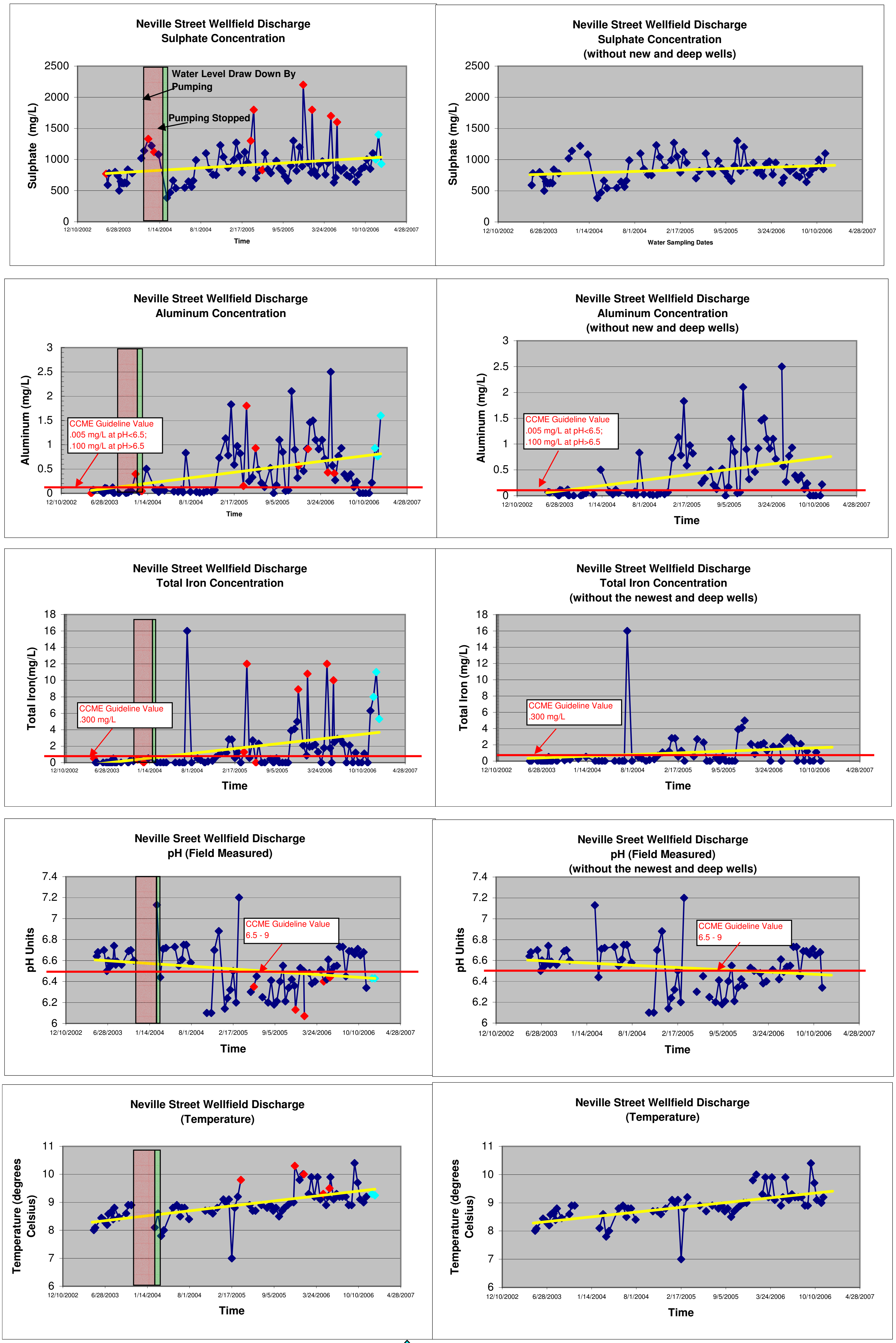

1B Hydraulic System
Mine Pool Water Elevation
Water Level Maintenance
Zone (-5.18 to -5.80 feet)
below sea level
-5.18 m
-5.80 m
Spring Run-off and Snow Melt
Period of Construction Work
at Neville Street Wellfield
0.000
-10.000
-20.000
-30.000
-40.000
-50.000
-60.000
Elevation (Meters below sea level)
24-May-02
10-Dec-02
28-Jun-03
14-Jan-04
1-Aug-04
17-Feb-05
5-Sep-05
24-Mar-06
10-Oct-06
28-Apr-07
Time

Figure 2



-Indicates that Northern Group wells were pumping -Indicates that Western Group wells were pumping

Figure 3

Indicates CCME Freshwater Aquatic Guideline value

Table 1
Mine Water Monitoring and Production Wells - Status as of January, 2007
1B Hydraulic System

Well Designation	Year Drilled	Mine Intersected	Pumping Ability		Comments
			Horsepower Rating	Capacity USGPM	
Monitoring Wells (water sampling and level monitoring)					
B-170	2002	No. 8 Colliery, Glace Bay	No pump installed		Shallow well in No. 8 Colliery
B-171	2002	No. 5 Colliery, Wellfield	No pump installed		Well abandoned by CBDC in 2006; capped at top of casing and buried +/- 1 meter).
B-173	2002	No. 8 Colliery, Glace Bay	No pump installed		Deep well in No. 8 Colliery
B-174	2002	No. 3 Colliery, Paschendale	No pump installed		Well in No. 3 Colliery
B-175	2002	No. 5 Colliery, Phalen Road	1	<20	Well in No. 5 Colliery
B-181	2003	No. 1A Colliery, Dominion	No pump installed		Located in No. 1A Colliery
B-186	2003	No. 5 Colliery, Wellfield	0.5	<20	Located in No. 1A Colliery
B-187	2003	No. 1A Colliery, Dominion	0.5	<20	Located in No. 5 Colliery
B-194	2005	No. 5 Colliery, Neville St.	No pump installed		Located in No. 5 Colliery
B-195	2005	No. 1A Colliery, Dominion	No pump installed		Located in No. 1A Colliery
PBH-01-1	2001	No. 1A Colliery, Dominion	No pump installed		Located in No. 1A Colliery
PBH-01-2	2001	No. 1A Colliery, Dominion	0.5	<20	Located in No. 1A Colliery
PBH-01-4	2001	No. 1A Colliery, Dominion	No pump installed		Located in No. 1A Colliery
PBH-01-5	2001	No. 1A Colliery, Dominion	0.5	<20	Located in No. 1A Colliery
PBH-01-6	2001	No. 1A Colliery, Dominion	No pump installed		Located in No. 1A Colliery
PBH-01-7	2001	No. 1A Colliery, Dominion	0.5	<20	Located in No. 1A Colliery
PBH-01-8	-	No. 1A Colliery, Dominion	No pump installed		Located in No. 1A Colliery
Remote Water Level Measuring Stations					
B-172	2003	No. 5 Colliery, Wellfield	No pump installed		Equipped with pressure transducers to measure water level
PBH-01-3	2001	No. 1A Colliery, Dominion	No pump installed		Equipped with pressure transducers to measure water level
Former Monitoring Wells					
B-188	2003	No. 8 Colliery, Glace Bay	No pump installed		These wells abandoned by CBDC in fall 2005 to reduce water inflow to the mine pool.
B-196	2005	No. 1A Colliery, Dominion	No pump installed		They are completely sealed with cement grout.
Pumping Wells (for mine dewatering)					
B-176	2003	No. 5 Colliery, Wellfield	30	425	Well available for pumping
B-177	2003	No. 5 Colliery, Wellfield	30	540	Well available for pumping
B-183	2003	No. 5 Colliery, Wellfield	30	475	Well available for pumping
B-184	2003	No. 5 Colliery, Wellfield	30	520	Well available for pumping
B-185	2003	No. 5 Colliery, Wellfield	30	580	Well available for pumping
B-192	2004	No. 5 Colliery, Wellfield	30	511	Well available for pumping
B-193	-	No. 5 Colliery, Wellfield	30	440	Well available for pumping
B-198	2006	No. 5 Colliery, Wellfield	30	470	Well available for pumping
B-199	2006	No. 5 Colliery, Wellfield	30	470	Well available for pumping
B-200	2006	No. 5 Colliery, Wellfield	30	470	Well available for pumping
B-201	2006	No. 5 Colliery, Wellfield	30	470	Well available for pumping
B-202	2006	No. 5 Colliery, Wellfield	30	325	Well available for pumping
			Available total pumping capacity	**5696**	
Former Pumping Wells (for mine dewatering)					
B-179	2003	No. 5 Colliery, Wellfield	Pump Removed		Wells abandoned by CBDC in 2006 due to poor water quality; capped at top of casing and buried +/- 1 meter)
B-180	2003	No. 5 Colliery, Wellfield	Pump Removed		
B-182	2003	No. 5 Colliery, Wellfield	Pump Removed		
B-190	-	No. 5 Colliery, Wellfield	Pump Removed		Wells abandoned by CBDC in 2006 due to insufficient water at the pumps; wells were capped at top of casing and buried +/- 1 meter)
B-191	2004	No. 5 Colliery, Wellfield	Pump Removed		
Other wells					
B-178	2003	No. 5 Colliery, Wellfield	No pump installed		Well cannot be used for water sampling or water level monitoring (not in workings)
B-189	-	No. 1A Colliery. Dominion	No pump installed		Sealed, cored borehole; grouted upon completion
B-197	-	-	No pump installed		There is no well with this designation

TABLE 2

Neville Street Wellfield Discharge Chemistry from July 26, 2006 to December 27, 2006

			Sample Event No.	92		91		90		89		88		87		86		85		84		83		82		81	
			Date sampled	Dec 27 2006		Dec 13 2006		Nov 30 2006		Nov 16 2006		Nov 03 2006		Oct 18 2006		Oct 06 2006		Sep 21 2006		Sep 07 2006		Aug 25 2006		Aug 10 2006		Jul 26 2006	
	PARAMETERS	UNITS	CCME FWAL	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered
Major Ions:	SODIUM	mg/L	NG	170	200	210	230	160	170	180	190	180	170	240	200	190	170	190	190	150	160	120	120	150	150	160	150
	POTASSIUM	mg/L	NG	21	22	31	23	25	21	22	22	24	25	39	26	28	26	26	26	21	23	19	18	22	22	22	21
	CALCIUM	mg/L	NG	220	210	370	270	240	240	240	250	230	240	320	260	290	250	280	270	210	210	170	170	230	210	200	190
	MAGNESIUM	mg/L	NG	100	96	190	140	110	120	110	120	96	88	140	120	110	110	110	95	88	87	74	81	99	94	88	87
	ALKALINITY (as CaCO3)	mg/L	NG	NA	170	NA	160	NA	160	NA	180	NA	230	NA	250	NA	240	NA	250	NA	210	NA	200	NA	190	NA	200
	SULFATE	mg/L	NG	NA	930	NA	1400	NA	1000	NA	1100	NA	850	NA	1000	NA	880	NA	850	NA	760	NA	640	NA	830	NA	720
	CHLORIDE	mg/L	NG	NA	120	NA	190	NA	110	NA	140	NA	130	NA	140	NA	130	NA	140	NA	120	NA	110	NA	130	NA	110
	SILICA	mg/L	NG	NA	5.9	NA	17	NA	8.3	NA	6.6	NA	4.2	NA	4.8	NA	4.6	NA	3.7	NA	4.7	NA	4.3	NA	4.9	NA	4.8
Nutrients:	ORTHO-PHOSPHOROUS(as P)	mg/L	NG	NA	<0.3	NA	<0.3	NA	<0.3	NA	<0.3	NA	<0.3	NA	<0.3	NA	<0.3	NA	<0.3	NA	<0.3	NA	<0.3	NA	<0.3	NA	<0.3
	PHOSPHOROUS	mg/L	NG	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.1	<1	<0.1	<1	<1
	NITRITE+NITRATE (as N)	mg/L	NG	NA	<3	NA	<3	NA	<3	NA	<3	NA	<3	NA	<3	NA	<3	NA	<0.06	NA	<0.06	NA	0.06	NA	<2	NA	0.11
	NITRATE (as N)	mg/L	CCME Narrative	NA	0.1	NA	0.06	NA	0.08	NA	0.14	NA	<0.06	NA	<0.06	NA	<0.06	NA	<0.06	NA	<0.06	NA	0.06	NA	0.07	NA	0.11
	NITRITE (as N)	mg/L	0.06	NA	<3	NA	<3	NA	<3	NA	<3	NA	<3	NA	<3	NA	<3	NA	<0.06	NA	<0.06	NA	<0.06	NA	<2	NA	<0.06
	TKN	mg/L	NG	NA	N/A	NA	0.66	NA	0.46	NA	0.5	NA	0.5	NA	0.4	NA	0.3	NA	0.2	NA	0.2	NA	NA	NA	NA	NA	NA
	AMMONIA as (N)	mg/L	CCME Narrative	NA	0.2	NA	0.38	NA	0.3	NA	0.25	NA	0.12	NA	0.21	NA	0.15	NA	0.1	NA	0.14	NA	0.06	NA	0.06	NA	0.13
	TOTAL ORGANIC CARBON	mg/L	NG	NA	0.6	NA	0.5	NA	0.6	NA	<0.5	NA	0.6	NA	<0.5	NA	<0.5	NA	0.9	NA	0.9	NA	0.7	NA	<0.5	NA	0.8
Physical Parameter	HARDNESS(as CaCO3)	mg/L	NG	NA	930	NA	1300	NA	1100	NA	1100	NA	960	NA	1100	NA	1000	NA	1100	NA	880	NA	760	NA	920	NA	840
	BICARBONATE	mg/L	NG	NA	171	NA	153	NA	160	NA	178	NA	230	NA	253	NA	241	NA	251	NA	211	NA	199	NA	188	NA	198
	CARBONATE	mg/L	NG	NA	<1	NA	4	NA	<1	NA	<1	NA	<1	NA	<1	NA	1	NA	<1	NA	<1	NA	<1	NA	<1	NA	<1
	COLOR	TCU	CCME Narrative	NA	10	NA	<5	NA	5	NA	8	NA	<5	NA	<5	NA	<5	NA	<5	NA	<5	NA	<5	NA	7	NA	<5
	TURBIDITY	NTU	CCME Narrative	NA	39	NA	45	NA	38	NA	28	NA	5.2	NA	8.1	NA	12	NA	2.4	NA	12	NA	3.4	NA	23	NA	5.3
	CONDUCTIVITY	umhos/cm	NG	NA	2200	NA	2800	NA	2200	NA	2500	NA	2100	NA	2500	NA	2300	NA	2400	NA	2000	NA	1800	NA	2100	NA	1900
	pH	Units	6.5 - 9.0	NA	6.9	NA	8.4	NA	7	NA	6.9	NA	7.1	NA	7.2	NA	7.7	NA	7.1	NA	7.1	NA	7	NA	7.2	NA	7.6
	ACIDITY	mg/L	NG	NA	51	NA	135	NA	169	NA	120	NA	59	NA	67	NA	37	NA	80	NA	52	NA	19	NA	51	NA	43
Calculated Values:	TDS	mg/L	NG	NA	1710	NA	2400	NA	1820	NA	1940	NA	1650	NA	1940	NA	1720	NA	1720	NA	1490	NA	1260	NA	1570	NA	1420
	CATION SUM	meq/L	NG	NA	28.2	NA	36.2	NA	30.2	NA	31	NA	27.3	NA	31.8	NA	28.8	NA	29.9	NA	25.1	NA	20.8	NA	25.6	NA	23.8
	ANION SUM	meq/L	NG	NA	26	NA	37.7	NA	27.6	NA	30.3	NA	25.9	NA	30.6	NA	26.9	NA	26.6	NA	23.4	NA	20.3	NA	24.8	NA	22.2
	ION SUM	meq/L	NG	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	41.1	NA		NA	
	ION BALANCE	%	NG	NA	4.06	NA	2.08	NA	4.46	NA	1.22	NA	2.54	NA	1.96	NA	3.46	NA	5.88	NA	3.51	NA	1.22	NA	1.71	NA	3.52
Biological Para-meters	TOTAL COLIFORMS	MPN/100ml		NA	1	NA		NA	<1	NA	66	NA	3	NA	<1	NA	2	NA	<1	NA	1	NA	1	NA	<1	NA	1
	FECAL COLIFORMS (E. coli)	MPN/100ml		NA	<1	NA		NA	<1	NA	2	NA	<1	NA	<1	NA	<1	NA	<1	NA	<1	NA	<1	NA	<1	NA	<1
	COD	mg/L		NA	<5	NA	<5	NA	<5	NA	<5	NA	<5	NA	<5	NA	<5	NA	<5	NA	<5	NA	<5	NA	13	NA	<5
	BOD	mg/L		NA	<5	NA	<5	NA	<5	NA	<5	NA	<5	NA	<5	NA	<5	NA	7	NA	<5	NA	<5	NA	6	NA	<5
Metals:	IRON	mg/L	0.3	**5.3**	**7.6**	<1	**13**	**8**	**8.6**	**6.3**	**5.2**	<1	<1	**1.1**	<1	<1	**1**	<1	<1	**1.2**	**1.1**	<1	**0.52**	**2.1**	**2.2**	<1	<1
	FERROUS IRON	mg/L	NG	6	6	11	12	10	10		5	<1	<1	<1	1	2	2	<1	<1	1	1	<1	<1	3	3	<1	<1
	MANGANESE	mg/L	NG	9.1	12	24	21	15	14	14	12	5.7	6.3	9.5	7.8	5.7	7.5	8	6.9	7.9	5.7	5.3	3.4	6.4	7.1	8.8	6.4
	COPPER	mg/L	0.002 - 0.004*	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.002	<0.002	<0.002	<0.02	<0.02
	ZINC	mg/L	0.03	**0.1**	**0.053**	**0.14**	**0.056**	**0.17**	**0.14**	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.033	0.056	<0.02	<0.02	<0.02	<0.02	<0.02	0.013	0.021	0.024	<0.02	<0.02
	ALUMINUM	mg/L	0.005 - 0.1*	**1.6**	**0.15**	**0.76**	**0.64**	**0.93**	**0.64**	**0.22**	**0.11**	<0.05	**0.11**	<0.05	<0.05	<0.05	<0.05	<0.05	**0.31**	**0.24**	**0.13**	**0.13**	0.028	**0.39**	**0.25**	**0.31**	**0.16**
	ANTIMONY	mg/L	NG	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.0004	<0.0004	<0.0004	<0.004	<0.004
	ARSENIC	mg/L	0.005	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.00073	<0.0006	<0.0006	<0.006	<0.006
	BARIUM	mg/L	NG	0.015	0.019	0.02	0.021	0.014	0.017	0.022	0.018	0.017	0.018	0.016	0.013	0.015	0.013	0.017	0.013	0.017	0.015	0.021	0.015	0.016	0.015	0.024	0.016
	BERYLLIUM	mg/L	NG	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.005	<0.005
	BISMUTH	mg/L	NG	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.002	<0.002	<0.002	<0.02	<0.02
	BORON	mg/L	NG	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.1	<0.1	<0.1	<1	<1
	CADMIUM Guideline			0.00023	0.00023	0.00030	0.00030		0.00026		0.00026		0.00023		0.00026		0.00024		0.00026		0.00021		0.00019		0.00022		0.00021
	CADMIUM	mg/L	0.000017*	**0.00036**	**0.0014**	<0.00017	**0.0014**	<0.00017	<0.00017	<0.00017	<0.00017	<0.00017	**0.0017**	**0.0014**	**0.0018**	**0.00028**	<0.00017	**0.0012**	**0.0003**	**0.00078**	**0.0017**	**0.0018**	**0.00024**	0.00018	0.00016	**0.0032**	**0.0011**
	CHROMIUM	mg/L	0.0089	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.001	<0.001	<0.001	<0.01	<0.01
	COBALT	mg/L	NG	0.027	0.028	0.044	0.039	0.034	0.036	0.025	0.021	<0.01	<0.01	0.011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.0062	0.012	0.011	0.015	<0.01
	LEAD	mg/L	0.001 - 0.007*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.001	<0.001	<0.001	<0.01	<0.01
	LITHIUM	mg/L	NG	0.07	0.081	0.069	0.088	0.058	0.07	0.074	0.073	0.074	0.088	0.078	0.06	0.064	0.06	0.094	0.048	0.063	0.064	0.053	0.053	0.065	0.067	0.06	0.065
	MERCURY	mg/L	0.0001		N/A																						
	MOLYBDENUM	mg/L	0.073	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	**0.087**	<0.04	<0.04	<0.04	<0.04	<0.04	0.078	<0.04	<0.04	<0.04	<0.004	<0.004	0.005	<0.04	<0.04
	NICKEL	mg/L	0.025 - 0.150*	0.05	0.059	0.073	0.064	0.059	0.063	0.039	0.033	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.015	0.025	0.021	0.038	<0.03
	SELENIUM	mg/L	0.001	<0.01	<0.01	**0.019**	<0.01	<0.01	**0.02**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**0.035**	<0.01	<0.001	**0.0017**	<0.001	<0.01	<0.01
	SILVER	mg/L	0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.0001	<0.001	<0.001
	STRONTIUM	mg/L	NG	2.7	3.1	3.8	4.2	3.4	2.7	3.3	3	2.7	3.3	3.5	2.9	2.3	2.9	3.4	3	2.6	2.2	2.4	1.9	2.2	2.2	3	2.5
	SULFUR	mg/L	NG	400	420	730	630	450	450	470	490	410	540	3800	420	320	360	480	370	370	330	270	190	340	380	290	290
	THALLIUM	mg/L	0.0008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.0008	<0.0008	<0.0008	<0.008	<0.008
	TIN	mg/L	NG	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	<0.2	<0.2
	TITANIUM	mg/L	NG	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.085	<0.03	<0.03	<0.03	<0.03	0.076	<0.03	<0.03	<0.03	<0.003	0.0071	0.003	0.068	<0.03
	URANIUM	mg/L	NG	<0.0015	0.0024	<0.0015	0.0025	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	0.0016	0.0016	0.0035	<0.00015	0.00026	0.0002	<0.0015	<0.0015
	VANADIUM	mg/L	NG	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.002	<0.002	<0.002	<0.02	<0.02
Field Measurements:	TEMPERATURE	°C	Narrative	NA	9.2	NA	9.3	NA	NA	NA	9.2	NA	9	NA	9.1	NA	9.7	NA	10.4	NA	8.9	NA	8.9	NA	9.2	NA	9.2
	DISSOLVED OXYGEN	%	NG	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	DISSOLVED OXYGEN	mg/L	5.5 - 9.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	pH	units	6.5 - 9.0	NA	**6.43**	NA	**6.43**	NA	NA	NA	**6.34**	NA	6.68	NA	6.65	NA	6.71	NA	6.66	NA	6.69	NA	6.69	NA	**6.45**	NA	6.73
	ORP	RmV	NG	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	TDS	mg/L	NG	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	CONDUCTIVITY	ms/cm	NG	NA	2190	NA	3400	NA	NA	NA	2330	NA	2120	NA	2540	NA	2700	NA	2290	NA	1810	NA	1810	NA	1624	NA	2400
	SPECIFIC CONDUCTANCE	ms/cm	NG	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	FLOW RATE	USGPM	-	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

5 Shaded cell with bold underlined text indicates an exceedance of CCME-FWAL guidelines.

CCME -FWAL = Canadian Council of Ministers of the Environment, Canadian Environmental Quality Guidelines for Freshwater Aquatic life, July 2006

* Guideline details:

Copper: 2 µg/L at $[CaCO^3]$ = 0-120 mg/L; 3 µg/L at $[CaCO^3]$ = 120-180 mg/L; 4 µg/L at $[CaCO^3]$ > 180 mg/L.

Aluminum: 5 µg/L at pH<6.5; or 100 µg/L at pH≥6.5.

Cadmium: $10E\{0.86[\log(\text{hardness})]^{-3.2}\}$

Lead: 1 µg/L at [CaCO3] = 0-60 mg/L; 2 µg/L at [CaCO3] = 60-120 mg/L; 4 µg/L at [CaCO3] = 120-180 mg/L; 7 µg/L at [CaCO3] = 180 mg/L.

Nickel: 25 ug/L at [CaCO3] = 0-60 mg/l; 65 ug/L at [CaCO3] = 60-120 mg/l; 110 ug/L at [CaCO3] = 120-180 mg/l; 150 ug/L at [CaCO3] = 180 mg/L.

TABLE 3
Neville St Well Field
Water Chemistry for Wells B198, B199, B200, B201, B202

Test Group	Analysis ID	CCME FWAL	EQL	Units	B198		B199		B200		B201		B202	
				Date Sampled:	Dec 13 2006		Dec 13 2006		Dec 13 2006		Dec 13 2006		Dec 13 2006	
				Client Sample ID:	B198(UF)	B198(F)	B199(UF)	B199(F)	B200(UF)	B200(F)	B201(UF)	B201(F)	B202(UF)	B202(F)
				ESL ID:	Q10518	Q10519	Q10520	Q10521	Q10522	Q10523	Q10524	Q10525	Q10530	Q10531
Major Ions	Sodium (Na)	NG	1	mg/l	380	420	300	350	230	230	95	99	75	81
	Potassium (K)	NG	5	mg/l	39	30	32	27	27	24	16	15	19	17
	Calcium (Ca)	NG	0.1	mg/l	500	360	450	350	400	320	220	180	230	190
	Magnesium (Mg)	NG	0.1	mg/l	270	220	220	230	190	200	110	120	110	120
	Alkalinity (Total as CaCO3)	NG	1	mg/l		260		180		54		<1		11
	Sulphate (SO4)	NG	2	mg/l		2000		2000		2000		1000		1100
	Chloride (Cl)	NG	1	mg/l		310		210		120		50		32
	Silica (SiO2)	NG	0.1	mg/l		15		17		27		35		32
Nutrients	Orthophosphate (P)	NG	0.3	mg/l		<0.3		<0.3		<0.3		<0.3		<0.3
	Phosphorus (P)	NG	0.1	mg/l	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Nitrite + Nitrate	NG	0.06	mg/l		<3		<3		<0.06		0.08		<0.06
	Nitrate (N)	CCME-Narrative	0.06	mg/l		<0.06		<0.06		<0.06		0.08		<0.06
	Nitrite (N)	0.06	0.06	mg/l		<3		<3		<0.06		<0.06		<0.06
	Total Kjeldahl Nitrogen	NG		mg/l		0.69		0.81		1.06		0.56		0.75
	Nitrogen (Ammonia Nitrogen)	CCME-Narrative	0.05	mg/l		0.47		0.57		0.81		0.37		0.53
	Organic Carbon (C)	NG	0.5	mg/l		<0.5		<0.5		0.9		0.8		0.7
Physical Parameters	Hardness (CaCO3)	NG	1	mg/L		1800		1800		1600		940		950
	Bicarb. Alkalinity (as CaCO3)	NG	1	mg/L		261		175		54		<1		11
	Carb. Alkalinity (as CaCO3)	NG	1	mg/L		<1		<1		<1		<1		<1
	Colour	CCME-Narrative	5	TCU		<5		<5		12		<5		5
	TURBIDITY	CCME-Narrative	0.1	NTU		24		59		46		24		25
	Conductivity	NG	1	umho/cm		4000		3500		3200		1800		1700
	pH	6.5-9.0	N/A	pH Units		7.4		7.2		6.5		**4.1**		**6**
	Acidity (CaCO3)	NG		mg/l		144		154		260		150		210
Calculated Values	Calculated TDS	NG	1			3530		3320		3090		1570		1620
	Cation Sum	NG	N/A	meq/L		55.3		52.5		45.2		24.3		24.3
	Anion Sum	NG	N/A	meq/L		55.4		50.7		46.7		22.8		23.5
	no parameter code	NG		meq/L										
	Ion Balance (% Difference)	NG	N/A	%		0.0994		1.74		1.61		3.18		1.59
Biological Parameters	Total Coliforms			MPN/100ml										
	Escherichia coli			MPN/100ml										
	Chemical Oxygen Demand		5	mg/l		<5		<5		<20		<5		<5
	Biochem Oxygen Demand		5	mg/l		<5		<5		<5		<5		<5
Metals	Iron (Fe)	0.3	0.1	mg/l	**4.9**	**5**	**15**	**19**	**39**	**52**	**20**	**21**	**33**	**34**
	Iron (ferrous)	NG	1	mg/l	4	4	16	16	43	45	21	21	34	34
	Manganese (Mn)	NG	0.004	mg/l	24	24	31	36	39	48	23	23	29	28
	Copper (Cu)*	0.002-0.004	0.002	mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	Zinc (Zn)	0.03	0.002	mg/l	**0.25**	**0.2**	**0.1**	**0.066**	**0.28**	**0.29**	**0.27**	**0.21**	**0.5**	**0.14**
	Aluminum (Al)*	0.005-0.1	0.005	mg/l	0.056	<0.05	**0.45**	**0.21**	**0.39**	**0.16**	**7.5**	**6.3**	**2**	**2.2**
	Antimony (Sb)	NG	0.0004	mg/l	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Arsenic (As)	0.005	0.0006	mg/l	<0.006	**0.0067**	<0.006	**0.0065**	**0.0085**	**0.0092**	<0.006	**0.0063**	**0.0077**	**0.0088**
	Barium (Ba)	NG	0.0004	mg/l	0.024	0.027	0.017	0.02	0.017	0.023	0.016	0.018	0.016	0.018
	Beryllium (Be)	NG	0.0005	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
	Bismuth (Bi)	NG	0.002	mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	Boron (B)	NG	0.1	mg/l	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Cadmium guideline					0.00040		0.00040		0.00036		0.00023		0.00023
	Cadmium (Cd)*	CCME-Narrative	0.000017	mg/l	0.002	0.0016	**0.0021**	**0.0013**	**0.0017**	**0.0013**	**0.0026**	**0.0018**	**0.002**	**0.0015**
	Chromium (Cr)	0.0089	0.001	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Cobalt (Co)	NG	0.001	mg/l	0.03	0.036	0.048	0.056	0.071	0.096	0.09	0.091	0.087	0.094
	Lead (Pb)*	0.001 - 0.007	0.001	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Lithium (Li)	NG	0.001	mg/l	0.073	0.1	0.091	0.1	0.11	0.13	0.1	0.1	0.11	0.11
	Molybdenum (Mo)	0.073	0.004	mg/l	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
	Nickel (Ni)*	0.025-0.150	0.003	mg/l	0.053	0.059	0.079	0.088	0.094	0.13	**0.17**	**0.17**	0.14	0.15
	Selenium (Se)	0.001	0.001	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Silver (Ag)	0.0001	0.0001	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Strontium (Sr)	NG	0.002	mg/l	6.9	6.5	6.1	6.5	5.2	5.9	2.2	2.4	2.5	2.8
	Sulphur (S)	NG	37	mg/l	900	980	810	910	770	970	440	420	450	460
	Thallium (Tl)	0.0008	0.0008	mg/l	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
	Tin (Sn)	NG	0.02	mg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	Titanium (Ti)	NG	0.003	mg/l	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
	Uranium (U)	NG	0.00015	mg/l	<0.0015	0.0029	<0.0015	0.0026	<0.0015	0.0025	<0.0015	0.0028	<0.0015	0.0024
	Vanadium (V)	NG	0.002	mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

5 Shaded cell with bold underlined text indicates an exceedance of CCME-FWAL guidelines.

CCME -FWAL = Canadian Council of Ministers of the Environment, Canadian Environmental Quality Guidelines for Freshwater Aquatic life, July 2006

* Guideline details:

Copper: 2 µg/L at $[CaCO^3]$ = 0-120 mg/L; 3 µg/L at $[CaCO^3]$ = 120-180 mg/L; 4 µg/L at $[CaCO^3]$ > 180 mg/L.

Aluminum: 5 µg/L at pH<6.5; or 100 µg/L at pH≥6.5.

Cadmium: $10E\{0.86[\log(hardness)]^{-3.2}\}$

Lead: 1 µg/L at [CaCO3] = 0-60 mg/L; 2 µg/L at [CaCO3] = 60-120 mg/L; 4 µg/L at [CaCO3] = 120-180 mg/L; 7 µg/L at [CaCO3] = 180 mg/L.

Nickel: 25 ug/L at [CaCO3] = 0-60 mg/l; 65 ug/L at [CaCO3] = 60-120 mg/l; 110 ug/L at [CaCO3] = 120-180 mg/l; 150 ug/L at [CaCO3] = 180 mg/L.

Table 4

Concentration of Iron & Aluminum in Wellfield Discharge as Well Outputs are Combined

Well Group	Pumping Wells	Estimated Pumping Capacity (USGPM)	Pump Turned on or off ("1"on; "0" off)	Concentration **Iron** in Well/Wells (mg/L)	Concentration **Aluminum** in Well/Wells (mg/L)	Cumulative Discharge Rate	Concentration **Iron** in Discharge (mg/L)	Concentration **Aluminum** in Discharge (mg/L)
Southern Group**	B-176	425	1	1.6	0.7	425	1.6	0.7
	B-177	540	1	1.6	0.7	965	1.6	0.7
	B-183	475	1	1.6	0.7	1440	1.6	0.7
	B-184	520	1	1.6	0.7	1960	1.6	0.7
	B-185	580	1	1.6	0.7	2540	1.6	0.7
	B-192	511	1	1.6	0.7	3051	1.6	0.7
	B-193	440	1	1.6	0.7	3491	1.6	0.7
Western Group	B-198	470	1	4.9	0.056	3961	2.0	0.6
	B-199	470	1	15	0.45	4431	3.4	0.6
	B-200	470	1	39	0.39	4901	6.8	0.6
	B-201	470	1	20	7.5	5371	7.9	1.2
	B-202	325	1	33	2	5696	9.4	1.2

****The concentration of iron and aluminum used for the Southern well group is an average derived from discharge chemistry when these wells were pumping. It is possible that concentrations in individual wells will be lower than the average while others may be higher than the average. The future contribution by each well can only be determined by sampling.**

CCME -FWAL = Canadian Council of Ministers of the Environment, Canadian Environmental Quality Guidelines for Freshwater Aquatic life, July 2006

* Guideline details:

Aluminum: 0.005 mg/L at pH<6.5; or 0.1 mg/L at pH≥6.5. Iron: 0.3 mg/L

Forgeron, Steve

From: Paul Younger [Paul.Younger@newcastle.ac.uk]
Sent: Sunday, February 25, 2007 8:12 AM
To: Forgeron, Steve
Cc: Graeme Young
Subject: Task 2, Part 1 and Task 2, Part 2

Importance: High

pyconhyd1.pdf
(409 KB)

Dear Steve

I am conscious I owe you comments on these two documents, which I have now reviewed. This took me only two hours. They are very well written and clear, and I have few comments to offer.

Task 2, Part 1:

5th page, first para under 'Volume of Water in the 1B Mine Pool':
- "in a complex structure" should read "in as complex a structure"
- "is wrought with difficulties" should read "is fraught with difficulties"

6th Page - penultimate paragraph in the section entitled 'Volume of Water in the 1B Mine Pool': the reference to Younger (2002) - I notice you don't have a reference list at the end of the document, but I've a feeling the paper you are alludding to was the one published in 2000 (attached). Also, it was something more than a 'suggestion', as it was based on plenty of data from real systems, but the story has since been modified a little by the 'partial first flush' paper which I sent to you last time.

8th Page - para at top of page: "the questionable need for the information" - I'd say the need is not questionable any more; but I agree it would still be very expensive.

Task 2, Part 2:

I have only one comment to make on this document, and it isn't a proposed edit. It is just an expression of dismay that the reorientation of the wellfield, so that almost all wells were disposed along strike and should thus all be intercepting relatively fresh recharge water, has not been the success we originally hoped. The elevated Fe and Al in the new wells indicates that there is active pyrite oxidation occurring very close to these wells (Al in particular tends to be associated with aerated shallow workings and surface deposits of spoil, because you need very low pH to make the water aggressive enough to clay minerals to leach Al from them. This then partly neutralised the acidity - or at least raises the pH - until the Al hydrolyses and releases three protons per mole of Al^{3+}). Is the saturated thickness in the new wells less than in the older wells along strike (I can't see why it should be, unless there's a partial barrier oriented roughly down-dip between them). If not, then unless there's an abrupt increase in pyrite content along strike (not impossible, but surprising if this were of sufficient magnitude to explain this degree of variability), then some other control on oxygen ingress must be responsible for accelerated leaching up-dip from the new line of wells.
It would be worth evaluating these sorts of factors before planning more new wells in the apparently 'safer' on the east side of the Southern Group (option 1 as listed on the final page of text).

****

Finally, I have been making progress with the marine review, though as anticipated the answer is that there is very little info out there. I will summarise what is known in report form asap, though I suspect I may need a few days' grace beyond 28th Feb, as I have had a few unanticipated deadlines thrust upon me in the course of my mainstream duties. I hope you can live with waiting, say, a further week?

Best wishes

Paul Y

Paul L Younger C.Geol. C.Eng.
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e-mail: paul.younger@ncl.ac.uk
http://www.ncl.ac.uk/environment/research/HEROGroup.htm

Comments on
Managing Mine Water Quality and Flow in the 1A Mine Pool –Phase 1
Jeff Skousen
West Virginia University

TASK 2 PART 1 – CHARACTERIZATION OF THE 1B MINE POOL

Task 2 Part 1 of Phase 1 report provided a history of mining and closure of 10 underground mines and the subsequent development of the 1B Mine Pool. An understanding of this 129-year history of mining is helpful because it identifies the mining methods and extraction amounts which allow an estimate of the void volumes within the underground workings. Closure of each mine and approximate flooding scenarios were also provided in this report.

I found this report to be well-written and explained the development of the mine pool very well. The report also recounts when mines were closed, barrier breakages, changes in water levels in several of the mines, and actions taken when the mine pool eventually threatened to spill out into the ocean. Water quality of the 1B Mine Pool for various time periods are also detailed. Recharge into the 1B Mine Pool varies during the year because of rainfall and inflow to the mine (800 to 6000 gpm), but averages about 1900 gpm, which is the year-round pumping rate to maintain water levels within the mine to not allow overflow into the ocean. It provides ranges of water volumes in the mine pool (including estimates for each subpool or mine) and a chronology of water quality.

However, many questions are raised about the mine pool and how it is changing over time, especially in relationship to the pumping at the Neville Street Wellfield. The goal is to find a walk-away solution, where the water coming from the flooded underground workings can be discharged without treatment. The water initially pumped from the Wellfield in 2003 after construction was suitable for discharge without treatment, however, the water quality is deteriorating.

One scenario mentioned the pumping of the entire mine pool, or at least a substantial portion of the mine pool, and treating it for discharge. This pumping would allow recharge water to enter the mine and dilute the contaminants so that the water could overflow into the ocean. Another scenario mentioned that perhaps as many as 4 mine pool volumes would have to be pumped out before the contaminants would be removed sufficiently for the water to overflow without treatment. The amount of pumping and the number of turnover volumes to achieve an quality of water suitable for discharge are indeed difficult questions with few answers, and as mentioned, the effectiveness of the pump and treat concept and the subsequent water quality changes in the 1B Mine Pool could only be evaluated after the actual pumping operated for some time.

TASK 2 PART 2 – PUMPING STRATEGY AT THE NEVILLE STREET WELLFIELD

Task 2 Part 2 describes the pumping situation at the Neville Street Wellfield and gives pumping volumes as well as water quality of pumped water. With the current 12 wells, about 5700 gpm can be pumped from the mine pool.

The report brought up several disturbing trends.

1) The amount of water pumped from the mine pool to maintain the water level has increased by 60% from 2004 to 2006. A concurrent precipitation increase has not been noted to account for the increased water inflow to the mine. Therefore, as noted, either the pumping efficiency has decreased or additional water is being introduced into the mine pool from other sources.

2) Water quality has deteriorated rapidly over this same two year period. Initially the water was suitable for discharge and met effluent standards, but during the past two years, the effluent has increased in iron and aluminum concentrations that now exceed effluent standards for discharge. The increase in metal concentrations could be related to 1) filtered versus unfiltered samples (sampling and analytical issues), 2) the removal of accumulated precipitates by the new wells (this turbidity should decline over time as the wells become established), and 3) the movement of poor quality water from deeper areas within the mine pool to the pumping area.

The strategy for pumping and the sequence of wells makes good sense in that the pumps withdrawing the best quality water in the mine pool are run first. Then as additional capacity is required, the wells with the next to best water quality areas within the mine are run, then finally the wells that pump the poorest quality water are run last.

Several options are given to increase pumping capacity including developing new wells in the mine pool area with good water quality, pumping and treating at the 1B shaft, and pumping and treating at other current wells with poor water quality. Depending on how the abandoned wells were left, one could consider re-opening these wells to increase pump capacity. If the abandoned wells were filled with concrete or completely removed, then re-opening is not feasible and new wells would have to be drilled.

Comments on Managing Mine Water Quality and Flow in the 1A Mine Pool – Phase 1, Task 2

by

Syd S. Peng

Since Task 2 is a review and summary of past works and data collected, all of my comments and questions below probably can be resolved by citing references in which detailed analyses had been performed.

Task 2, Part 1

1. Figure 3 –
    a. In 1A mine, it has "Nov. 1996", but at the bottom of this figure, it says "from CBDC -----, Sept. 1993."
    b. There are no Mines 14 and 17 in Figure 1 showing where those two mines were located
2. Figure 4 – what do the numbers in yellow squares mean?
3. **Flooding of the 1B Hydarulic System – 3rd paragraph, 2nd from the last sentence " additional inflow were experience at Phalen Colliery as its production longwall units extracted coal under flooded Harbor Seam workings."**
   Wasn't it true that water in Phalen was mainly from the sandstone between Phalen and Harbor seam, it was not sea water ?
4. Figure 5 – no legend to indicate what the readers are looking at..
5. **Volume of Water in the 1B mine Pool –**
    a. **2nd paragraph -**How did you estimate the residual void space?
    b. **4th and 5th paragraphs –** In the 4th paragraph, I understood how did you get the 20 billion gallons, but in the 5th paragraph, I did not get where the 80 billion gallon came from?
6. **Mine Pool Quality – 2002 to present**
   Where was No. 8C colliery located in Figure 1?

Task 2, Part 2

1. Neville Street Wellfield – the depths of the three groups of wells are different. Are they measured from well surface to water surface? Were all the samplings from the water surface, or different depths below the water surface?

Managing Mine Water Quality and
Flow in the 1A Mine Pool – Phase 1

TASK 3 – MINE WATER DISCHARGE CRITERIA

INTRODUCTION

The following report by Conestoga-Rovers and Associates (CRA) constitutes Task 3 - Phase 1 of investigations into the Water Treatment Program 1A Mine Pool, Town of Dominion, Cape Breton County, Nova Scotia. Phase 1 of the program involved four tasks: 1) the preparation of a report on our initial nine options review, (2) mine pool characterization and Neville Street pumping strategy (3) mine water discharge criteria development and (4) the creation of an external advisory committee to review project reports. It is noted that tasks 1, 2, and 4 have already been completed.

Task 3 of the Phase 1 investigation was to determine if criteria for the discharge of treated mine water exists for other jurisdictions. This investigation involved the three following work activities:

- Activity 1: conduct a literature review and consultation to explore discharge criteria used internationally for discharge of mine water to marine environments.
- Activity 2: investigate how mine water discharges are being dealt with locally (Nova Scotia and Atlantic Canada); and
- Activity 3: evaluate water chemistry data from the outfalls in the Sydney Coalfield to determine how these waters have naturally evolved since mine closure and how this mine water chemistry compares to the existing water quality criteria established in Activities 1 and 2, above.

International Review of Mine Water Discharge Practices and Criteria

Activity 1 was carried out by Dr. Paul Younger, an internationally renowned practitioner in the area of mine water issues. The following text represents a summary of Dr. Younger's report. The full report is included in this document as Attachment A.

In preparing his report, Dr. Younger identified and consulted a number of relevant sources, as follows:

- direct mailings to professionals known to be engaged in environmental management of coastal mining operations worldwide;
- the entire database of Proceedings of Symposia and Congresses of the International Mine Water Association, dating back to 1979;
- the entire contents of the journal "Mine Water and the Environment", back to 1998;

- Science Citation Index, and through it several hundred electronic journals including "Marine Pollution Bulletin", "Journal of Experimental Marine Biology and Ecology", and "Ocean & Coastal Management"; and
- The web site www.metalsriskassessment.org (maintained by the International Council on Mining and Metals) and
- Open searching of the Internet as a whole.

Dr. Younger addresses the following specific subjects in his report:

- issues involved with mine water discharges to marine environments;
- the irrelevance of freshwater standards for marine environments;
- issues truly relevant to marine environment discharges; and
- collation of international experiences/practices, including known cases; non-coal mines and coal mines.

Based on the literature review and his experience, Dr. Younger concludes that there are only two real concerns associated with the discharge of mine waters to marine environments. These are (1) the negative visual impacts of stained water plumes, and (2) the localized impacts these discharges might have on seafood resources. Dr. Younger further concludes, "In all real cases for which information has been forthcoming that the visual impacts of stained water plumes has proved the only real issue in practice".

In the "Summary" section of his report, the author includes Table 1 to summarize key findings, from the reviewed case studies, and to illuminate key issues in consent limit-setting and loading thresholds. The table reveals that for the cases reviewed, there are no known cases in which Fe (Iron) loading of less than 200 kg/day has given rise to an unsightly ochreous plume in the sea around a mine water discharge. The table also indicates that consents for iron concentration in marine discharges of mine waters range from an extreme low of 0.1 mg/L (which is not achievable or justified, amenity or ecological) to a maximum of 100 mg/l, with most permits lying in the 10 to 15 mg/L range.

With respect to site-specific criteria for mine water discharge to marine environments, the report evaluates the case studies presented and concludes that in order to prevent unsightly ochreous plumes; the threshold of iron loading should be less than 200 kg Fe/day. The author also presents a formula to calculate a target maximum iron concentration to avoid discharging at this threshold value. He concludes that if a mine has a total average flow rate of 116 L/s (approx. 1845 USGPM), which is the annual mean pumping rate at Neville Street needed to maintain the mine water level in the 1B Hydraulic system, then for discharge to the sea with certainty of not causing a visible plume, the operator would target a post-treatment iron concentration of less than 20 mg/L. He further states that in wetter periods a lower target iron concentration might be needed to maintain iron loading at less than 200 kg Fe/day. At the estimated maximum mine water discharge rate of 6000 USGPM (approximately 377 L/s), this would equate to an iron concentration of approximately 6.1 mg/L).

Dr. Younger recommends that a dialogue be established with regulators to take this and related concepts forward as the options for dealing with the mine water in the 1B Hydraulic system proceeds.

Local Experience of Mine Water Discharges

Activity 2 investigated how mine water discharges are being dealt with locally (Nova Scotia and Atlantic Canada) and has determined that there are no coal mine water discharge criteria for marine waters available in Atlantic Canada. This investigation also determined that if such criteria were to be developed, they would be subject to Sections 35 and 36 of the Fisheries Act administrated by the Fisheries and Oceans Canada (DFO).

Mine Water Chemistry Evaluation

When coal mines in the Sydney Coalfield ceased operations, the workings were permitted to flood and discharge mine water to the local environment. Because of geographic location, most mines discharged directly into the Atlantic Ocean. Unfortunately, no compliance monitoring or environmental effects monitoring programs were undertaken or required by provincial regulators at the time. Only a few detailed records of these discharges are available. However, following serious mine water inflows at Lingan and Phalen Collieries in 1988, greater attention was paid to the composition of mine waters across the breadth of the Sydney Coalfield, and in some cases systematic sampling of mine discharges was undertaken.

Available mine water discharge information has been compiled and consolidated in a single database. The following sources of information were used in this compilation.

- Cape Breton Development Corporation (from former mining operations files).
- Cape Breton Development Corporation (from current CBDC web site)
- LaPierre, A. B., 1999, Characterization of Discharges from Abandoned Mines of the Sydney Coalfield, Nova Scotia, Thesis for Master of Applied Science, Dalhousie University.
- Neill and Gunter, February, 2005; Former Mine Water Discharge Points, 8 Locations in Glace Bay, Nova Scotia; Report to PWGSC Environmental Services.
- Neill and Gunter, 2006; Surface Water Sampling Program on CBDC sites; Report to PWGSC Environmental Services.

The goal of establishing this database is to provide information to assist in the development of water quality criteria for future discharges of mine water into the marine environment. These discharges may be in the form of treatment plant effluents or direct flows from flooded coal mines.

Table 1 contains the complete data set for 63 water chemistry samples collected from 15 mine water outfall sites across the Sydney Coalfield. Table 2 contains a summary of Table 1 data and includes the average pH and sulphate concentration, as well as maximum concentrations of iron and aluminum. The results of fish toxicity (96 hour LC_{50}) testing are presented where available. The iron analyses were used to calculate total iron loading values on a kg/day basis. Numbers or comments in Table 2, which are shown in bold font, indicate that iron staining and iron plume observations were made at the time of sampling and are therefore the most reliable data. In all other cases, the iron loading value is based on flow rates and iron concentrations recorded on separate occasions; these values should be treated as rough estimates of iron loading.

In Activity 1 of this report Paul Younger is referenced as noting that the primary concern associated with discharging mine water to the marine environment is the development of unsightly iron plumes around the points of discharge. This concern is based more on aesthetics than any real negative impact these plumes pose to the marine ecosystem. Through documented international examples, Younger has shown that a threshold value of 200 kg of iron per day is needed to generate an iron plume. Iron loading rates calculated for the Sydney Coalfield discharges listed in Table 2 are all below this threshold level. In those cases where reliable observations are available for the Sydney outfalls, no plumes have been observed. This lends considerable credibility for the application of Younger's suggested threshold value at the local level. For comparison purposes, data from the 1B Shaft pumping event in 1992 have been added to the last row of Table 2. Pumping of mine water from 1B Colliery during this event produced an extensive iron plume along the coast of Glace Bay. The iron-loading rate calculated for this event (38,368 kg/day) exceeds, by far, the 200 kg/day threshold value.

RECOMMENDATIONS

CRA recommends that a dialogue be established with regulators to discuss the concept of using iron loading as a criterion for permitting the discharge of mine waters into the marine environment. This dialogue would include the documentation of international experience provided by Dr. Younger. With respect to the discharge of coal mine water discharge to the marine environment, our review of the past and current practice in Atlantic Canada has identified that the responsible regulator is the Fisheries and Oceans Canada and therefore the dialog should involve DFO regarding Sections 34 to 36 of the Fisheries Act.

Consideration should also be given to continuing compliance monitoring of existing mine water outfalls to the marine environment on a regular basis. The monitoring should include a standard set of chemical parameters, a determination of outfall flow rate and visual observations regarding the presence or absence of an iron plume.

Table 1 - Metals and General Chemistry Analytical Results
From Mine Water Outfalls
Sydney Coalfield, Sydney Nova Scotia

						Sample Location Name	Gowrie Water Level			Blockhouse Water Level	No. 21 Colliery	No. 22 Colliery (1)	No. 22 Colliery (2)	Beaver Nicholson slope				No. 8 Colliery Bridgeport						Old Lingan
						Sample ID:	GOOF-02SW-01-01	GOOF-02SW-01-02	GOOF-02SW-01-03	PMFM-06SW-01-01	21WI-06SW-01-01	MLSA-05SW-01-01	22WI-06SW-01-01	BNMS-02SW-01-01	BNMS-02SW-01-02	BNMS-05SW-05-01	BNMS-06SW-14-01	BPOF-97SW-01-01	BPOF-97SW-01-02	BPOF-02SW-01-01	BPOF-02SW-01-02	BPOF-02SW-01-03	BPOF-06SW-01-01	OLOF-88SW-01-01
						Maxxam-Sydney Laboratory ID:	9952117-01	9952385-02	9955011-03	O99737	P15305	NA	P15307	9951941-06	9955011-04	G55805	O90243	na	na	9952096-02	9952368-01	9954956-02	P13331	na
						Date Sampled:	Jan 30 2002	Feb 27 2002	Aug 22 2002	Oct 18 2006	Oct 25 2006	Jul 05 2005	Oct 25 2006	Jan 15 2002	Aug 22 2002	Jun 09 2005	Oct 11 2006	Mar 09 1997	Jun 04 1997	Jan 29 2002	Feb 26 2002	Aug 20 2002	Oct 24 2006	Nov 15 1988
	Parameters	RDL	*MMER*	CCME FWAL	CCME MAL	Units																		
INORGANICS	Alkalinity (as CaCO3)	5		NG	NG	mg/L	<1	<1	<1.0	55.0	5.0	50.0	31.0	72.0	61.0	52.0	73.0	181.6	179.0	190.0	187.0	202.0	14.0	2.0
	Chloride (Cl)	1		NG	NG	mg/L	26	23	19	38	23	16	18	37	30	28	39	84	48	67	59	55	60	51
	Colour	5		NG	NG	TCU	39	86	46	<5	<5	<5	<5	19	18	NA	<5	5	<5	17	8	<5	6	7
	Hardness (CaCO3)	1		NG	NG	mg/L	114	147	126	110	65	93	94	NA	NA	57	67	615	644				50	197
	Nitrate (N)	0.05		13	16	mg/L				<0.05	0.22	<0.06	0.08	NA	NA	<0.06	<0.05						<0.05	
	Nitrate + Nitrite	0.05		NG	NG	mg/L	0.12	0.26	<0.06	<0.05	0.22		0.08	<0.06	<0.06	<0.06	<0.05	0.32	0.34	0.36	0.36	0.21	<0.05	
	Nitrite (N)	0.01		0.06	NG	mg/L				<0.01	<0.01	<0.06	<0.01	NA	NA	<0.06	<0.01						<0.01	0.23
	Nitrogen (Ammonia Nitrogen)	0.05		-	-	mg/L	<0.1	0.20	<0.1	<0.05	0.07	<0.02	0.12	<0.1	<0.1	<0.05	0.05	0.07	0.05	<0.1	<0.1	<0.1	<0.05	0.05
	Organic Carbon (C)	0.5		NG	NG	mg/L	2.1	1.5	2.0	<0.5	2.9	0.8	<0.5				<0.5	1.7	2.5				2.5	1.6
	Orthophosphate (P)	0.01		NG	NG	mg/L	<0.3	<0.3	<0.3	<0.01	<0.01	<0.3	<0.01	<0.1	<0.3	<0.3	<0.01	<0.03	<0.01	<0.3	<0.3	<0.3	<0.01	
	pH	N/A	6.0 - 9.5	6.5-9.0	7.0 - 8.7	pH	***3.60***	***4.10***	***4.10***	6.91	***5.70***	6.80	7.05	7.70	7.70	7.83	7.66	7.60	7.60	7.80	7.70	7.80	7.13	***4.08***
	Reactive Silica (SiO2)	0.5		-		mg/L	16.2	15.7	16.7	6.9	10.0	11.0	7.7	5.7	5.2	5.4	5.7	5.9	5.9	6.6	7.7	5.7	5.6	14.0
	Sulphate (SO4)	2.0		-		mg/L	150.0	227.0	192.0	64.0	67.0	81.0	65.0	13.7	13.6	12.0	12.0	384.5	400.0	500.0	463.0	441.0	27.0	182.0
	Turbidity	0.1		1.0		NTU	**12.0**	**15.0**	**12.0**	**49.0**	**34.0**	**37.0**	**59.0**	**4.2**	**5.9**	1.0	**7.1**	**1.5**	0.3	**2.3**	**1.7**	**3.4**	0.7	**1.7**
	Conductivity	1		-		uS/cm	441	497	508	360	220	330	250	273	238	220	290	1294	1186	1401	1220	1260	300	680
	Ferrous	1				mg/L												<1	<1					
	Ferric	N/A				mg/L																		
RCAP CALCULATIONS	Anion Sum	N/A		-		me/L				3.5	2.2	3.1	2.5	NA	NA	2.1	2.8						2.5	
	Bicarb. Alkalinity (calc. as CaCO3)	1		-		mg/L				55	5	50	31	NA	NA	52	73						14	
	Calculated TDS	1		-		mg/L				211	151	211	163	NA	NA	122	159						154	
	Carb. Alkalinity (calc. as CaCO3)	1		-		mg/L				<1	<1	<1	<1	NA	NA	<1	<1						<1	
	Cation Sum	N/A		-		me/L				3.5	2.2	3.3	2.6	NA	NA	2.2	2.8						2.5	
	Ion Balance (% Difference)	N/A		-		%				0.014	1.910	2.010	1.960	NA	NA	3.440	0.934						0.178	
	Langelier Index (@ 20C)	N/A		-		N/A				-1.290	-3.770	-1.500	-1.450	NA	NA	-0.548	-0.447						-2.100	
	Langelier Index (@ 4C)	N/A		-		N/A				-1.540	-4.020	-1.750	-1.700	NA	NA	-0.799	-0.698						-2.350	
	Saturation pH (@ 20C)	N/A		-		N/A				8.20	9.47	8.30	8.50	NA	NA	8.38	8.11						9.23	
	Saturation pH (@ 4C)	N/A		-		N/A				8.45	9.72	8.55	8.75	NA	NA	8.63	8.36						9.48	
	Cadmium Calculated Guideline*	N/A	see individual sample			N/A	0.037	0.046	0.040	0.036	0.023	0.031	0.031	0.017	0.017	0.020	0.023	0.158	0.164	0.017	0.017	0.017	0.018	0.059
Total	**Elements (ICP-MS)**																							
	Aluminum (Al)	5	-	5-100	-	ug/L	**1260**	**1000**	**770**	32	**965**	**200**	<5.0	<20	<20	<5	<5.0	<10.0	<10.0	<20	**190**	<20	31	**1300**
	Antimony (Sb)	2	-	-	-	ug/L	0.8	<0.4	<0.4	<2.0	<2.0	6.6	<2.0	<0.4	<0.4	<0.4	<2.0	<0.02	<0.02	1.5	0.7	<0.4	<2.0	50
	Arsenic (As)	2	1000	5	12.5	ug/L	0.90	1.90	1.20	<2.0	2.80	<6	<2.0	1.50	0.70	1.10	2.50	3.00	0.10	<0.6	1.30	<0.6	<2.0	
	Barium (Ba)	5	-	-	-	ug/L	20.0	20.4	15.4	35.6	36.1	14.0	20.2	146.0	81.1	92.0	148.0	20.0	20.0	13.7	14.9	11.0	31.1	20.0
	Beryllium (Be)	2	-	-	-	ug/L	0.7	0.5	0.5	<2.0	<2.0	<5	<2.0	<0.5	<0.5	<0.5	<2.0	<10.0	<10.0	<0.5	<0.5	<0.5	<2.0	5.0
	Bismuth (Bi)	2	-	-	-	ug/L				<2.0	<2.0	<20	<2.0	NA	NA	<2	<2.0						<2.0	
	Boron (B)	5	-	-	-	ug/L	<10	<100	<100	19.6	13.6	<1000	19.9	<100	<100	<100	23.5	20.0	30.0	<100	<100	<100	21.2	20.0
	Cadmium (Cd)	0.017		see calc.*	0.12	ug/L	**0.600**	<0.3	**0.400**	0.032	**0.070**	**0.850**	<0.017	<0.3	<0.3	<0.02	<0.017	<10.0	<10.0	<0.3	<0.3	<0.3	<0.017	**10.000**
	Chromium (Cr)	2		8.9	56.0	ug/L	<2	<2	<2	<2.0	<2.0	<10	<2.0	<2.0	<2.0	<1	<2.0	<10.0	<10.0	<2	<2	<2	<2.0	**10.0**
	Cobalt (Co)	0.4		-		ug/L	9.0	9.0	7.0	6.8	5.3	<10	4.7	<1.0	<1.0	<1	<0.40	<10.0	<10.0	<1	<1	<1	<0.40	10.0
	Copper (Cu)	2	600	2-4	-	ug/L	**7.0**	**5.0**	**7.0**	<2.0	<2.0	<2	<2.0	<2.0	**3.0**	<2	<2.0	<10.0	<10.0	2.0	**3.0**	**4.0**	<2.0	**10.0**
	Iron (Fe)	50	-	300	-	ug/L	**10700**	**21900**	**18300**	**5030**	**8350**	**22000**	**2500**	**400**	<100	<100	**1510**	120	130	<100	**1430**	<100	<50	**1800**
	Lead (Pb)	0.5	400	1-7	-	ug/L	2.0	<1	<1	<0.50	0.6	<10	<0.50	<1.0	<1.0	<1	<0.50	<50	<50	<1	2.0	<1	<0.50	**50.0**
	Manganese (Mn)	2	-	-	-	ug/L	630	900	773	658	474	700	446	117	84	58	177	100	80	96	166	102	3	1500
	Molybdenum (Mo)	2	-	73	-	ug/L	<4	<4	<4	<2.0	<2.0	<40	<2.0	<4.0	<4.0	<4	<2.0	<20	<20	<4	<4	<4	<2.0	
	Nickel (Ni)	2	1000	25-150	-	ug/L	18	19	9	15	11	<30	5	<3.0	<3.0	<3	<2.0	30	<10.0	<3	3	<3	<2.0	30
	Selenium (Se)	1	-	1	-	ug/L	<1	<1	<1	<1.0	<1.0	<10	<1.0	<1.0	<1.0	<1	<1.0	**2**	<1	1	1	**2**	<1.0	**10**
	Silver (Ag)	0.1	-	0.1	-	ug/L	<2	<2	<2	<0.10	<0.10	<1	<0.10	<0.2	<0.2	<0.1	<0.10			<0.2	<0.2	<0.2	<0.10	
	Strontium (Sr)	5	-	-	-	ug/L	377	572	477	233	221	430	410	424	361	340	459	1240	1270	1350	1350	1290	58	35
	Thallium (Tl)	0.1	-	0.8	-	ug/L	<0.8	<0.8	<0.8	<0.10	<0.10	<8	<0.10	<0.8	<0.8	<0.8	<0.10	<20.0	<20.0	<0.8	**13.4**	<0.8	<0.10	
	Tin (Sn)	2	-	-	-	ug/L	<20	<20	<20	<2.0	<2.0	<200	<2.0	<20	<20	<20	<2.0	90.0	<20.0	<20	<20	<20	<2.0	30.0
	Titanium (Ti)	2	-	-	-	ug/L				<2.0	<2.0	<30	<2.0	NA	NA	<3	<2.0						<2.0	
	Uranium (U)	0.1	-	-	-	ug/L	<0.15	<0.15	<0.15	<0.10	<0.10	<1.5	<0.10	<0.15	<0.15	<0.15	<0.10	<50	<50	0.61	0.70	0.41	<0.10	
	Vanadium (V)	2	-	-	-	ug/L	<2	<2	<2	<2.0	<2.0	<20	<2.0	<2.0	<2.0	<2	<2.0	30.00	<10.0	<2	<2	<2	<2.0	10.00
	Zinc (Zn)	5	1000	30	-	ug/L	**98.0**	**76.0**	**54.0**	17.1	**52.3**	13 F	7.8	2.0	2.0	<2	6.5	<10.0	10.0	3.0	8.0	<2	<5.0	**50.0**
	Elements (ICP-OES)																							
	Calcium (Ca)	0.1	-	-	-	mg/L	27.9	37.6	33.2	28.0	15.0	25.0	24.0	22.1	19.6	18[a]	25.0	173.0	188.0	212.0	191.0	172.0	10.0	47.0
	Magnesium (Mg)	0.1	-	-	-	mg/L	10.8	13.0	10.5	13.0	6.7	7.6 F	8.3	2.6	2.4	2.7a	3.1	44.4	42.3	51.4	48.7	39.3	6.1	19.0
	Phosphorus (P)	0.1	-	-	-	mg/L				<0.1	<0.1	<1	<0.1	NA	NA	<0.1	<0.1						<0.1	
	Potassium (K)	0.1	-	-	-	mg/L	5.7	7.5	7.4	6.1	3.3	8.2 F	7.3	1.8	1.6	1.2[a]	2.0	9.7	9.5	10.7	9.8	9.4	2.4	2.4
	Sodium (Na)	0.2	-	-	-	mg/L	17.2	17.9	14.0	17.0	12.0	9.6 F	9.8	27.0	21.7	24[a]	26.0	47.4	26.7	42.7	37.5	32.2	34.0	24.0
	Total Mercury (Hg)	0.01		0.026	0.016	ug/L	**0.20**	<0.1	**0.10**	<0.01	<0.01	<0.05	<0.01	<0.1	**0.10**	<0.1	<0.01			<0.1	**0.40**	<0.1	<0.01	
Field Parameters	DO (%)									14.4	30.4		93.7				13.4						108	
	DO (mg/L)									1.75	3.61		10.87				1.59						12.1	
	Cond. (us)									229.3	160.7		183.7				195.4						205.3	
	S. Cond. (us)									351.6	241.1		270.2				296.9						283.5	
	Salinity (ppt)									0.2	0.1		0.1				0.1						0.1	
	pH									6.6	5.55		7.36				6.73						7.19	
	Temp (oC)									6.8	7.6		9				7.2						10.4	
	REDOX (mV)									168.3	130.4		73.9				51.8						143.5	
	Alkalinity (mg/L)									56.8	11.6		40.8				72.4						18.8	
	Ferrous Iron (mg/L)									3	3.2		2.7				0.6						0	
	Toxicity % Mort. After 96hr					%																		

Notes: RDL = Reportable Detection Limit; **NG** = No Guideline value; **F** = Dissolved (Filtered)

CCME = Canadian Council of Ministers of the Environment, Canadian Environmental Quality Guidelines , July 2006. **FWAL** = Freshwater Aquatic Life; **MAL** = Marine Aquatic Life

MMER = Metal Mining Effluent Regulations

Exceedances identifiers: Italics = MMER; bold & underline = FWAL; shaded cell = MAL

Aluminum CCME Guideline: 5 µg/L at pH<6.5; **or** 100 µg/L at pH≥6.5.

*** Cadmium CCME Guideline:** $10^{\{0.86[\log(\text{hardness})]-3.2\}}$ = 0.005 ug/L.

Copper CCME Guideline: 2 µg/L at [CaCO^3] = 0-120 mg/L; 3 µg/L at [CaCO^3] = 120-180 mg/L; 4 µg/L at [CaCO^3] > 180 mg/L.

Lead CCME Guideline: 1 µg/L at [CaCO^3] = 0-60 mg/L; 2 µg/L at [CaCO3] = 60-120 mg/L; 4 µg/L at [CaCO3] = 120-180 mg/L; 7 µg/L at [CaCO3] = 180 mg/L.

Nickel CCME Guideline: 25 ug/L at [CaCO^3] = 0-60 mg/l; 65 ug/L at [CaCO3] = 60-120 mg/l; 110 ug/L at [CaCO3] = 120-180 mg/l; 150 ug/L at [CaCO3] = 180 mg/L.

Table 1 - Metals and General Chemistry Analytical Results
From Mine Water Outfalls
Sydney Coalfield, Sydney Nova Scotia

	Sample Location Name						No.1A Colliery Outfall									No. 7 Colliery (Hay St.)								Glace Bay Harbour Outfall						
	Sample ID:						1AOF-94SW-01-01	1AOF-95SW-01-01	1AOF-97SW-01-01	1AOF-97SW-01-02	1AOF-02SW-01-01	1AOF-02SW-01-02	1AOF-02SW-01-03	1AOF-05SW-01-01	1AOF-06SW-01-01	HSOF-97SW-01-01	HSOF-97SW-01-02	HSOF-02SW-01-01	HSOF-02SW-01-02	HSOF-02SW-01-03	HSOF-05SW-01-01	HSOF-06SW-01-01	HSOF-06SW-01-01-DUP01	HBOF-02-SW-01-01	HBOF-02-SW-01-02	HBOF-02-SW-01-03	HBOF-05SW-01-01	HBOF-05SW-01-Dup01	HBOF-06SW-01-01	HBOF-06SW-01-01-DUP01
	Maxxam-Sydney Laboratory ID:										9951941-01	9952368-02	9954956-01	9967707-06	P13330	na	na	9951941-02	9952368-07	9954956-03	9967707-05	O97877	O97878	9952096-01	9952368-06	9954956-04	9967707-03	9967707-04	O97840	O97844
	Date Sampled:						Sep 13 1994	Jan 16 1995	Mar 09 1997	Sep 26 1997	Jan 15 2002	Feb 26 2002	Aug 20 2002	Jan 20 2005	Oct 24 2006	Mar 09 1997	Jun 04 1997	Jan 15 2002	Feb 26 2002	Aug 20 2002	Jan 20 2005	Oct 17 2006	Oct 17 2006	Jan 29 2002	Feb 26 2002	Aug 20 2002	Jan 20 2005	Jan 20 2005	Oct 17 2006	Oct 17 2006
	Parameters	**RDL**	*MMER*	**CCME FWAL**	**CCME MAL**	**Units**																								
INORGANICS	Alkalinity (as CaCO3)	5		NG	NG	mg/L	6.6	12.8	50.2	24.7	22.0	21.0	24.0	12	11.0	7.1	2.9	15.0	14.0	27.0	6.4	20.0	19.0	282.0	287.0	288.0	263.0	265.0	270.0	280.0
	Chloride (Cl)	1		NG	NG	mg/L	67	47	86	97	70	105	97	82	73	161	135	194	219	153	173	120	120	152	171	171	146	146	180	190
	Colour	5		NG	NG	TCU	15	6	40	20	19	52	59	48	<5	5	<5	126	24	108	30	<5	<5	89	103	107	31	54	<5	<5
	Hardness (CaCO3)	1		NG	NG	mg/L	357	262	428	324					270	231	204					220	220						720	730
	Nitrate (N)	0.05		13	16	mg/L									0.4							<0.05	<0.05						<0.05	<0.05
	Nitrate + Nitrite	0.05		NG	NG	mg/L	0.83	0.80	0.02	0.04	0.57	0.49	0.23	0.96	0.40	0.09	0.07	<0.06	0.08	<0.06	0.18	<0.05	<0.05	<0.06	<0.06	<0.06	1.20	0.52	<0.05	<0.05
	Nitrite (N)	0.01		0.06	NG	mg/L									<0.01							<0.01	<0.01						<0.01	<0.01
	Nitrogen (Ammonia Nitrogen)	0.05		-	-	mg/L	0.31	0.12	0.68	0.23	<.1	<0.1	<0.1	0.05	<0.05	0.14	0.14	<0.1	<0.1	<0.1	0.09	0.12	0.11	<0.1	0.30	<0.1	0.33	0.38	0.34	0.34
	Organic Carbon (C)	0.5		NG	NG	mg/L	3.4	3.0	3.8	<0.05					1.7	2.2	1.3					0.8	0.6						<0.5	<0.5
	Orthophosphate (P)	0.01		NG	NG	mg/L	0.02	0.02	<0.01	0.01	<0.1	<0.3	<0.3	<0.3	<0.01	0.03	<0.01	<0.1	<0.3	<0.3	<0.3	<0.01	<0.01	<0.8	<0.3	<0.3	<0.3	<0.3	<0.01	<0.01
	pH	N/A	6.0 - 9.5	6.5-9.0	7.0 - 8.7	pH	***5.00***	**6.20**	**6.40**	***5.80***	**6.40**	**6.20**	**6.40**	6.8	6.55	***5.50***	***5.10***	**6.30**	**6.10**	6.60	***5.90***	**6.25**	**6.40**	7.60	7.60	7.60	7.60	7.60	7.78	7.63
	Reactive Silica (SiO2)	0.5		-		mg/L	0.5	11.8	10.9	10.5	9.0	11.0	12.0	11.8	11.0	10.4	10.6	12.8	12.3	11.2	12.8	13.0	13.0	8.2	9.1	6.0	8.3	8.5	7.5	7.4
	Sulphate (SO4)	2.0		-		mg/L	439.8	228.2	335.0	256.0	167.0	213.0	248.0	249	220.0	168.0	164.0	221.0	191.0	227.0	215	190.0	190.0	393.0	427.0	317.0	362.0	364.0	340.0	340.0
	Turbidity	0.1		1.0		NTU	**44.0**	**2.0**	**27.0**	**20.0**	**40.0**	**9.7**	**10.3**	**12**	**55.0**	**17.0**	**1.4**	**50.0**	**8.9**	**27.0**	**7.0**	**62.0**	**69.0**	**20.0**	**23.0**	**24.0**	**11.0**	**13.0**	**21.0**	**21.0**
	Conductivity	1		-		uS/cm	754	662	1066	836	572	728	841	747	710	923	857	1150	1050	1000	968	850	840	1690	1620	1570	1620	1610	1600	1600
	Ferrous	1				mg/L			20.0					<1		<1	<1				<1						2.0	<1		
	Ferric	N/A				mg/L								<1							3.5						<1	<1		
RCAP CALCULATIONS	Anion Sum	N/A		-		me/L									6.8							7.9	7.8						17.5	17.8
	Bicarb. Alkalinity (calc. as CaCO3)	1		-		mg/L									11							20	19						267	276
	Calculated TDS	1		-		mg/L									448							506	479						1020	1050
	Carb. Alkalinity (calc. as CaCO3)	1		-		mg/L									<1							<1	<1						2	1
	Cation Sum	N/A		-		me/L									7.1							7.9	6.8						17.2	18.0
	Ion Balance (% Difference)	N/A		-		%									2.020							0.089	7.270						1.070	0.530
	Langelier Index (@ 20C)	N/A		-		N/A									-1.960							-2.120	-2.040						0.932	0.814
	Langelier Index (@ 4C)	N/A		-		N/A									-2.210							-2.370	-2.290						0.687	0.568
	Saturation pH (@ 20C)	N/A		-		N/A									8.51							8.37	8.44						6.85	6.82
	Saturation pH (@ 4C)	N/A		-		N/A									8.76							8.62	8.69						7.09	7.06
	Cadmium Calculated Guideline*	N/A	see individual sample			N/A	0.099	0.076	0.116	0.091	0.017	0.017	0.017	0.017	0.078	0.068	0.061	0.017	0.017	0.017	0.017	0.065	0.065	0.017	0.017	0.017	0.017	0.017	0.181	0.183
Total	**Elements (ICP-MS)**																													
	Aluminum (Al)	5	-	5-100	-	ug/L	**400**	**350**	**130**	<10.0	**110**	**200**	**70**	**497**	80	**300**	**800**	**170**	**610**	**140**	**326**	**166**	**139**	<20	<20	<20	43	<5	<50	<50
	Antimony (Sb)	2	-	-	-	ug/L	10	10	<20.0	<20.0	<0.4	0.4	<0.4	<0.4	<2.0	<20	<20	<0.4	<0.4	<0.4	<0.4	<2.0	<2.0	0.17	<0.4	<0.4	<0.4	<0.4	<20	<20
	Arsenic (As)	2	1000	5	12.5	ug/L			**10.00**	**9.00**	0.75	**5.90**	**5.40**	3.10	<2.0	1.30	1.70	3.00	2.20	1.30	3.40	3.40	2.80	2.40	2.50	2.60	2.90	1.60	<20	<20
	Barium (Ba)	5	-	-	-	ug/L	30.0	20.0	20.0	90.0	24.2	24.2	18.2	25.4	22.2	10.0	10.0	16.1	16.8	9.0	17.4	13.2	11.2	18.2	18.0	14.1	27.4	36.7	<50	<50
	Beryllium (Be)	2	-	-	-	ug/L	10.0	10.0	<10.0	<10.0	<0.5	<0.5	<0.5	<0.5	<2.0	<10	<10	<0.5	<0.5	<0.5	<0.5	<2.0	<2.0	<0.5	<0.5	<0.5	<0.5	<0.5	<20	<20
	Bismuth (Bi)	2	-	-	-	ug/L									<2.0							<2.0	<2.0						<20	<20
	Boron (B)	5	-	-	-	ug/L	40.0	40.0	60.0	70.0	<100	<100	<100	<100	33.7	10.0	30.0	<100	<100	<100	<100	29.1	24.1	<100	<100	<100	<100	<100	<50	50.0
	Cadmium (Cd)	0.017		see calc.*	0.12	ug/L	**10.000**	**10.000**	<10.0	<10.0	<0.3	<0.3	<0.3	<0.017	0.053	<10	<10	<0.3	<0.3	<0.3	<0.017	**0.080**	0.047	<0.3	<0.3	<0.3	<0.017	<0.017	<0.17	<0.17
	Chromium (Cr)	2		8.9	56.0	ug/L	**10.0**	**10.0**	<10.0	<10.0	<2	<2	<2	<1	<2.0	<10	<10	<2	<2	<2	1.0	<2.0	<2.0	<2	<2	<2	2.0	2.0	<20	<20
	Cobalt (Co)	0.4		-		ug/L	10.0	10.0	30.0	<10.0	2.0	4.0	4.0	6.0	4.1	<10	<10	4.0	6.0	5.0	5.0	5.4	4.5	<1	<1	<1	<1	<1	<4.0	<4.0
	Copper (Cu)	2	600	2-4	-	ug/L	**10.0**	**10.0**	<10.0	<10.0	**3.0**	**3.0**	**6.0**	<2.0	<2.0	<10	<10	**8.0**	**7.0**	**11.0**	<2.0	<2.0	<2.0	**4.0**	**3.0**	**10.0**	<2.0	<2.0	<20	<20
	Iron (Fe)	50	-	300	-	ug/L	**5850 F**	**1310 F**	**33300**	**210 F**	**3780**	**2670**	**2030**	**940**	<50	**2360**	**760**	**7440**	**1190**	**6510**	**3520**	**7430**	**6170**	**2530**	**3790**	**1400**	**1960**	<100	**2050**	**1900**
	Lead (Pb)	0.5	400	1-7	-	ug/L	**50.0**	**50.0**	<50.0	**50.0**	<1	<1	<1	<1	<0.50	<50	<50	<1	<1	<1	<1	<0.50	<0.50	<1	<1	<1	<1	<1	<5.0	<5.0
	Manganese (Mn)	2	-	-	-	ug/L			1320		376	541	615	479	319	2550	2440	2750	2300	3010	2230	2710	2240	678	783	629	683	721	716	752
	Molybdenum (Mo)	2	-	73	-	ug/L			<20.0	<20.0	<4	<4	<4	<4	<2.0	<20	<20	<4	<4	<4	<4	<2.0	<2.0	<4	<4	<4	<4	<4	<20	<20
	Nickel (Ni)	2	1000	25-150	-	ug/L	20	20	60	<10.0	9	11	<3	15	14	40	<10	9	13	<3	11	10	8	<3	<3	<3	<3	<3	<20	<20
	Selenium (Se)	1	-	1	-	ug/L	1	1	**2**	<1.0	<1	<1	1	<1	<1.0	<1.0	<1.0	<1	<1	<1	<1	<2.0	<1.0	1	<1	**2**	1	1	<10	<10
	Silver (Ag)	0.1	-	0.1	-	ug/L					<0.2	<2	<2	<0.10	<0.10			<0.2	<0.2	<0.2	<0.10	<0.10	<0.10	<2	<2	<2	<0.10	<0.10	<1.0	<1.0
	Strontium (Sr)	5	-	-	-	ug/L	1710		470	630	302	408	428	427	378	290	250	284	262	308	309	276	231	1990	1890	1430	1770	1920	1570	1670
	Thallium (Tl)	0.1	-	0.8	-	ug/L			<20.0	<20.0	<0.8	**1.1**	<0.8	<0.8	0.3	<20	<20	<0.8	<0.8	<0.8	<0.8	<0.10	<0.10	<0.8	<0.8	<0.8	<0.8	<0.8	<1.0	<1.0
	Tin (Sn)	2	-	-	-	ug/L	10.0	40.0	30.0	60.0	<20	<20	<20	<20	<2.0	60.0	<20	<20	<20	<20	<20	<2.0	<2.0	<20	<20	<20	<20	<20	<20	<20
	Titanium (Ti)	2	-	-	-	ug/L									3.4							3.5	2.8						<20	<20
	Uranium (U)	0.1	-	-	-	ug/L			<50.0	<50.0	<0.15	<0.15	<0.15	<0.15	<0.10	50.00	<50	<0.15	<0.15	<0.15	<0.15	<0.10	<0.10	0.35	0.39	0.26	0.41	<0.15	<1.0	<1.0
	Vanadium (V)	2	-	-	-	ug/L	10.00	10.00	20.00	<10.0	<2	<2	<2	<2	<2.0	<0.03	<10	<2	<2	<2	<2	<2.0	<2.0	<2	<2	<2	3.00	4.00	<20	<20
	Zinc (Zn)	5	1000	30	-	ug/L	30.0	**50.0**	**40.0**	**50.0**	22.0	26.0	9.0	12.0	29.3	30.0	**90.0**	20.0	28.0	12.0	4.0	22.4	19.5	4.0	4.0	<2	<2	<2	<50	<50
	Elements (ICP-OES)																													
	Calcium (Ca)	0.1	-	-	-	mg/L	101.0	73.9	132.0	93.4	63.0	80.4	94.0	94.5	78.0	65.5	58.3	77.6	69.2	77.9	79.1	64.0	55.0	245.0	238.0	201.0	196.0	199.0	190.0	200.0
	Magnesium (Mg)	0.1	-	-	-	mg/L	25.5	18.7	23.9	22.1	11.6	17.0	12.6	17.5	17.0	16.4	14.1	14.4	15.4	15.6	15.5	16.0	14.0	49.0	48.6	41.2	44.5	44.2	45.0	47.0
	Phosphorus (P)	0.1	-	-	-	mg/L									<0.1							<0.1	<0.1						<0.1	<0.1
	Potassium (K)	0.1	-	-	-	mg/L	6.6	6.5	4.1	5.5	3.1	3.9	3.6	3.5	3.5	3.7	3.5	3.8	3.7	3.5	3.8	3.9	3.3	21.7	22.1	15.3	12.0	14.9	18.0	19.0
	Sodium (Na)	0.2	-	-	-	mg/L	115.0	30.0	39.2	43.2	31.4	48.4	43.9	42.4	38.0	86.6	79.9	123.0	125.0	79.1	114.0	70.0	59.0	75.2	75.0	70.1	85.4	85.4	80.0	84.0
	Total Mercury (Hg)	0.01		0.026	0.016	ug/L					<0.1	**0.30**	<0.1	<0.05	<0.01			<0.1	**0.30**	**0.20**	<0.05	<0.01	<0.01	0.01	**0.03**	0.02	<0.05	<0.05	<0.01	<0.01
Field Parameters	DO (%)													77.9	77.1						48.5	38.7					34.5		58.9	
	DO (mg/L)													10.21	8.57						6.21	4.54					4.52		6.56	
	Cond. (us)													775	509						1004	577					1660		1159	
	S. Cond. (us)													491	700						607	855					1167		1613	
	Salinity (ppt)													0.4	0.3						0.5	0.4					0.8		0.8	
	pH													6.15	6.02						5.62	6.11					6.78		7.18	
	Temp (oC)													7.1	10.8						5.5	8					9.1		10.3	
	REDOX (mV)														225.7							122							61.7	
	Alkalinity (mg/L)														16.8							39.6							265.2	
	Ferrous Iron (mg/L)														0							4							0.6	
	Toxicity % Mort. After 96hr					%								0							0						0			

Notes: **RDL** = Reportable Detection Limit; **NG** = No Guideline value; **F** = Dissolved (Filtered)
CCME = Canadian Council of Ministers of the Environment, Canadian Environmental Quality Guidelines , July 2006. **FWAL** = Freshwater Aquatic Life; **MAL** = Marine Aquatic Life
MMER = Metal Mining Effluent Regulations
Exceedances identifiers: Italics = MMER; bold & underline = FWAL; shaded cell = MAL
Aluminum CCME Guideline: 5 µg/L at pH<6.5; **or** 100 µg/L at pH≥6.5.
* **Cadmium CCME Guideline:** $10^{\{0.86[\log(\text{hardness})]-3.2\}}$ = 0.005 ug/L.
Copper CCME Guideline: 2 µg/L at $[CaCO^3]$ = 0-120 mg/L; 3 µg/L at $[CaCO^3]$ = 120-180 mg/L; 4 µg/L at $[CaCO^3]$ > 180 mg/L.
Lead CCME Guideline: 1 µg/L at $[CaCO^3]$ = 0-60 mg/L; 2 µg/L at [CaCO3] = 60-120 mg/L; 4 µg/L at [CaCO3] = 120-180 mg/L; 7 µg/L at [CaCO3] = 180 mg/L.
Nickel CCME Guideline: 25 ug/L at $[CaCO^3]$ = 0-60 mg/l; 65 ug/L at [CaCO3] = 60-120 mg/l; 110 ug/L at [CaCO3] = 120-180 mg/l; 150 ug/L at [CaCO3] = 180 mg/L.

Table 1 - Metals and General Chemistry Analytical Results
From Mine Water Outfalls
Sydney Coalfield, Sydney Nova Scotia

	Sample Location Name						No. 11 Colliery							No. 4 Colliery		Clyde Mine Donkin						Franklyn Mine		Greener Mine Sydney Mines				Morrisons Pond
	Sample ID:						DM11-97SW-01-01	DM11-02SW-01-01	DM11-02SW-01-02	DM11-02SW-01-03	DM11-02SW-01-04	DM11-04SW-03-01	DM11-06SW-05-01	04WI-97SW-01-01	04WI-06SW-01-01	PCD1-97-SW-01-01	PCD1-02-SW-01-01	PCD1-02-SW-01-02	PCD1-02-SW-01-03	PCD1-05SW-01-01	PCD1-06SW-01-01	FRBD-02SW-01-01	FRBD-02SW-01-02	GROF-02SW-01-01	GROF-02SW-01-02	GROF-05SW-01-01	GROF-06SW-01-01	MRPD
	Maxxam-Sydney Laboratory ID:							9951941-04	9952368-03	9952650-04	9954956-05	9967048-12	P13324	na	P13329	na	9951941-05	9952385-03	9955011-02	9967707-02	P13332	9952073-05	9952353-01	9952117-02	9952353-02	9967707-01	P10419	na
	Date Sampled:						Jun 05 1997	Jan 15 2002	Feb 26 2002	Mar 20 2002	Aug 20 2002	Nov 30 2004	Oct 24 2006	Jun 03 1997	Oct 24 2006	Aug 31 1997	Jan 15 2002	Feb 27 2002	Aug 22 2002	Jan 20 2005	Oct 24 2006	Jan 28 2002	Feb 25 2002	Jan 30 2002	Feb 25 2002	Jan 19 2005	Oct 20 2006	Aug 31 1997
	Parameters	RDL	MMER	CCME FWAL	CCME MAL	Units																						
INORGANICS	Alkalinity (as CaCO3)	5		NG	NG	mg/L	<0.4	<1.0	<1.0	<1.0	<1.0	<1.0	<5	27.9	7.0	64.5	78.0	59.0	75.0	37.0	59.0	<1.0	<1.0	152.0	140.0	122.0	160.0	<0.4
	Chloride (Cl)	1		NG	NG	mg/L	29	40	39	39	43	35	46	10	17	60	67	64	62	60	62	8	8	33	35	38	42	55
	Colour	5		NG	NG	TCU	<5	8	5	<5	<5	11	<5	15	12	60	198	268	218	367	<5	62	7	94	342	53	<5	
	Hardness (CaCO3)	1		NG	NG	mg/L	125	124	138	135	117		150	44	40	426					320						490	183
	Nitrate (N)	0.05		13	16	mg/L							0.77		0.06						0.34						<0.05	
	Nitrate + Nitrite	0.05		NG	NG	mg/L	0.31	0.25	0.28	0.34	0.33	0.16	0.77	0.06	0.06	0.12	0.25	0.27	0.10	0.60	0.34	0.12	0.12	0.34	0.08	0.17	<0.05	<0.02
	Nitrite (N)	0.01		0.06	NG	mg/L							<0.01		<0.01						<0.01						<0.01	
	Nitrogen (Ammonia Nitrogen)	0.05		-	-	mg/L	0.06	<0.1	<0.1	<0.1	<0.1	<0.02	<0.05	0.08	<0.05	0.33	<0.1	0.20	<0.1	0.60	0.23	<0.1	<0.1	<0.1	<0.1	0.18	0.22	0.17
	Organic Carbon (C)	0.5		NG	NG	mg/L	<2.5	0.9	0.9	1.2	0.9	1.4	<0.5	5.0	1.9	3.0					1.0	<0.5	0.9				0.8	
	Orthophosphate (P)	0.01		NG	NG	mg/L	<0.01	<0.1	<0.3	<0.3	<0.3		<0.01	0.01	<0.01	<0.01	<0.1	<0.3	<0.3	<0.3	<0.01	<0.3	<0.3	<0.3	<0.3	<0.3	<0.01	<0.01
	pH	N/A	6.0 - 9.5	6.5-9.0	7.0 - 8.7	pH	***4.10***	***3.90***	***3.90***	***4.00***	***4.00***	***4.30***	***4.03***	6.60	6.62	6.20	6.90	6.70	6.90	6.60	6.90	***3.60***	***3.50***	7.30	7.50	7.30	8.07	***2.90***
	Reactive Silica (SiO2)	0.5		-		mg/L	12.5	15.0	15.0	14.1	10.1	13.2	14.0	7.0	7.9	14.4	16.8	15.2	16.4	15.5	16.0	16.6	16.8	8.0	8.7	8.4	7.1	21.0
	Sulphate (SO4)	2.0		-		mg/L	130.0	150.0	148.0	149.0	143.0	120.0	150.0	22.6	24.0	414.0	282.0	261.0	268.0	242.0	270.0	141.0	143.0	482.0	485.0	380.0	370.0	442.0
	Turbidity	0.1		1.0		NTU	**39.0**	**15.0**	<1	<1	**3.9**	0.9	0.6	**3.9**	**4.5**	**57.0**	**68.0**	**55.0**	**6.7**	**22.0**	**79.0**	**15.0**	**2.7**	**18.0**	**44.0**	**12.0**	**45.0**	**22.0**
	Conductivity	1		-		uS/cm	433	474	446	456	464	402	500	148	130	856	843	689	844	710	840	360	387	1130	1130	1020	1000	1201
	Ferrous	1				mg/L					<1			2.0						4.0						3.6		
	Ferric	N/A				mg/L														2.2						<1		
RCAP CALCULATIONS	Anion Sum	N/A		-		me/L							4.4		1.1						8.6						11.9	
	Bicarb. Alkalinity (calc. as CaCO3)	1		-		mg/L							<1		7						59						153	
	Calculated TDS	1		-		mg/L							295		80						559						753	
	Carb. Alkalinity (calc. as CaCO3)	1		-		mg/L							<1		<1						<1						2	
	Cation Sum	N/A		-		me/L							4.5		1.3						8.7						12.1	
	Ion Balance (% Difference)	N/A		-		%							0.259		4.800						0.637						0.749	
	Langelier Index (@ 20C)	N/A		-		N/A							NC		-2.840						-0.786						0.963	
	Langelier Index (@ 4C)	N/A		-		N/A							NC		-3.090						-1.030						0.716	
	Saturation pH (@ 20C)	N/A		-		N/A							NC		9.46						7.69						7.11	
	Saturation pH (@ 4C)	N/A		-		N/A							NC		9.71						7.93						7.35	
	Cadmium Calculated Guideline*	N/A	see individual sample			N/A	0.040	0.040	0.044	0.043	0.038	0.017	0.047	0.016	0.015	0.115	0.017	0.017	0.017	0.017	0.090	0.017	0.017	0.017	0.017	0.017	0.130	0.056
Total	**Elements (ICP-MS)**																											
	Aluminum (Al)	5	-	5-100	-	ug/L	**2490**	**2310**	**2310**	**3310**	**1470**	**1140**	**2210**	20	52	**60**	**320**	**630**	80	**809**	18	**4480**	**5360**	<20	40	76	<50	**11400**
	Antimony (Sb)	2	-	-	-	ug/L	<20	<0.4	<0.4	<0.4	<0.4	0.7	<2.0	<20	<2.0	<20	<0.4	<0.4	<0.4	<0.4	<2.0	0.8	<0.4	0.7	<0.4	<0.4	<20	<20
	Arsenic (As)	2	1000	5	12.5	ug/L	<0.1	<0.6	<0.6	<0.6	<0.6	<0.6	<2.0	1.00	<2.0	1.20	**17.00**	**14.00**	**11.60**	**9.30**	<2.0	<0.6	<0.6	1.20	1.60	2.10	<20	4.50
	Barium (Ba)	5	-	-	-	ug/L	30.0	26.8	26.2	24.6	17.3	32.1	27.5	70.0	83.7	40.0	64.5	48.2	34.7	52.8	36.7	23.2	20.0	15.5	15.5	21.5	<50	<10
	Beryllium (Be)	2	-	-	-	ug/L	<10	1.2	1.2	1.7	0.8	1.0	<2.0	<10	<2.0	<10	<0.5	<0.5	<0.5	<0.5	<2.0	0.9	1.0	<0.5	<0.5	<0.5	<20	<10
	Bismuth (Bi)	2	-	-	-	ug/L							<2.0		<2.0					0.0	<2.0					0.0	<20	
	Boron (B)	5	-	-	-	ug/L	20.0	<100	<100	<100	<100	<100	42.1	20.0	10.8	<10	<100	<100	<100	<100	24.1	<100	<100	<100	<100	<100	<50	140.0
	Cadmium (Cd)	0.017		see calc.*	0.12	ug/L	<10	<0.3	<0.3	<0.3	<0.3	**0.071**	**0.125**	<10	<0.017	<10	<0.3	<0.3	<0.3	<0.017	0.041	<0.3	**0.400**	<0.3	<0.3	<0.017	<0.17	<10
	Chromium (Cr)	2		8.9	56.0	ug/L	<10	<2.0	<2.0	<2.0	<2.0	<1.0	<2.0	<10	<2.0	<10	<2	<2	<2	2.0	<2.0	<2	3.0	<2	<2	1.0	<20	<10
	Cobalt (Co)	0.4		-		ug/L	<10	24.0	28.0	29.0	19.0	20.0	28.6	<10	<0.40	<10	3.0	5.0	3.0	6.0	5.3	17.0	24.0	5.0	5.0	4.0	4.3	60.0
	Copper (Cu)	2	600	2-4	-	ug/L	<10	**6.0**	**6.0**	**9.0**	**7.0**	**4.0**	**6.6**	<10	<2.0	<10	**3.0**	**4.0**	**6.0**	2.0	<2.0	**74.0**	**10.0**	**3.0**	**3.0**	<2	<20	**20.0**
	Iron (Fe)	50	-	300	-	ug/L	**630**	250	**380**	170	110	**320**	190	**5660**	**1050**	<10 F	**11600**	**10900**	**8370**	**6180**	<200	**1790**	**3070**	**4740**	**6400**	**3960**	**5720**	**49000**
	Lead (Pb)	0.5	400	1-7	-	ug/L	<50	1.0	1.0	1.0	<1.0	1.0	1.0	<50	<0.50	<50	<1	<1	<1	<1	<0.50	3.0	4.0	<1	<1	<1	<5.0	<50
	Manganese (Mn)	2	-	-	-	ug/L	1023	1070	1140	1080	855	821	1150	3180	273		815	735	719	723	781	784	801	1020	1070	879	1160	
	Molybdenum (Mo)	2	-	73	-	ug/L	<20	<4.0	<4.0	<4.0	<4.0	<4.0	<2.0	<20	<2.0	<20	<4	<4	<4	<4	<2.0	<4	<4	<4	<4	<4	<20	<20
	Nickel (Ni)	2	1000	25-150	-	ug/L	90	57	65	71	20	49	68	20	<2.0	10	8	12	<3	12	11	41	52	7	10	8	<20	**210**
	Selenium (Se)	1	-	1	-	ug/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1	<1.0	<1	<1	1	1	1	<1.0	<1	<1	1	<1	1	<10	<1
	Silver (Ag)	0.1	-	0.1	-	ug/L		<0.2	<2.0	na	<2.0	<0.10	<0.10		<0.10		<0.2	<2	<2	<0.10	<0.10	<2	<2	<0.2	<0.2	<0.10	<1.0	
	Strontium (Sr)	5	-	-	-	ug/L	490	516	561	489	432	525	510	60	54	700	581	531	545	504	558	117	108	781	840	713	695	180
	Thallium (Tl)	0.1	-	0.8	-	ug/L	<20	<0.8	<0.8	<0.8	<0.8	<0.8	0.2	<20	<0.10	<20	<0.8	<0.8	<0.8	<0.8	<0.10	<0.8	<0.8	<0.8	<0.8	<0.8	<1.0	<20
	Tin (Sn)	2	-	-	-	ug/L	<20	<20	<20	<20	<20	<20	<2.0	<20	<2.0	<20	<20	<20	<20	<20	<2.0	<20	<20	<20	<20	<20	<20	<40
	Titanium (Ti)	2	-	-	-	ug/L							2.9		<2.0						4.3						<20	
	Uranium (U)	0.1	-	-	-	ug/L	<50	0.15	0.17	0.20	<0.15	0.20	0.15	<50	<0.10	<50	<0.15	<0.15	<0.15	<0.15	<0.10	0.20	0.32	0.29	0.32	0.26	<1.0	50.00
	Vanadium (V)	2	-	-	-	ug/L	<10	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<10	<2.0	40.00	<2	<2	<2	<2	<2.0	<2	<2	<2	<2	<2	<20	<40
	Zinc (Zn)	5	1000	30	-	ug/L	<90	**50.0**	**56.0**	**59.0**	**35.0**	**98.0**	**61.9**	**50.0**	11.9	30.0	13.0	20.0	8.0	5.0	22.0	**84.0**	**135.0**	6.0	9.0	<2	<50	**640.0**
	Elements (ICP-OES)																											
	Calcium (Ca)	0.1	-	-	-	mg/L	27.6	28.4	31.0	28.1	26.4	28.7	33.0	12.0	11.0	143.0	110.0	96.4	104.0	93.8	110.0	23.9	22.6	214.0	207.0	189.0	170.0	43.4
	Magnesium (Mg)	0.1	-	-	-	mg/L	13.5	13.0	14.6	15.8	12.5	11.6	17.0	3.5	3.2	16.7	12.4	12.5	12.4	11.9	15.0	8.3	8.3	19.6	17.8	14.8	15.0	18.1
	Phosphorus (P)	0.1	-	-	-	mg/L							<0.1		<0.1						<0.1						<0.1	
	Potassium (K)	0.1	-	-	-	mg/L	5.3	6.3	6.7	5.8	5.4	4.9	6.5	1.3	1.8	5.8	4.5	4.2	4.4	3.8	4.6	2.7	2.5	6.5	6.4	5.5	6.1	1.5
	Sodium (Na)	0.2	-	-	-	mg/L	16.4	21.0	22.5	25.3	20.8	19.9	26.0	7.0	8.7	53.1	48.9	48.6	52.8	43.2	47.0	8.0	7.6	55.4	55.0	59.7	51.0	56.6
	Total Mercury (Hg)	0.01		0.026	0.016	ug/L		<0.1	**0.20**	<0.1	<0.2	<0.05	<0.01		<0.01		<0.01	<0.01	0.01	<0.05	<0.01	**0.10**	**0.10**	**0.10**	<0.01	<0.05	<0.01	
Field Parameters	DO (%)												32.4		71.6					29.7	32.9					46.5	44.9	
	DO (mg/L)						6						3.77		7.84					3.59	3.91					5.62	5.28	
	Cond. (us)						395					223.4	335.4		99.2					741	576					1062	717	
	S. Cond. (us)												497.4		135.4					486	865					691	1069	
	Salinity (ppt)												0.2		0.1					0.4	0.4					0.5	0.5	
	pH						3.84					3.68	4.08		6.88					6.05	6.23					7.09	7.02	
	Temp (oC)						8.3					4.18	8		11					8	7.8					6.6	7.7	
	REDOX (mV)												234.6		167.2						94.7						64.4	
	Alkalinity (mg/L)												19.6		11.2						80.8						199.2	
	Ferrous Iron (mg/L)												0		0.5						2.6						3	
	Toxicity % Mort. After 96hr					%														0						0		

Notes: **RDL** = Reportable Detection Limit; **NG** = No Guideline value; **F** = Dissolved (Filtered)

CCME = Canadian Council of Ministers of the Environment, Canadian Environmental Quality Guidelines , July 2006. **FWAL** = Freshwater Aquatic Life; **MAL** = Marine Aquatic Life

MMER = Metal Mining Effluent Regulations

Exceedances identifiers: Italics = MMER; bold & underline = FWAL; shaded cell = MAL

Aluminum CCME Guideline: 5 µg/L at pH<6.5; **or** 100 µg/L at pH≥6.5.

*** Cadmium CCME Guideline:** $10^{\{0.86[\log(hardness)]-3.2\}}$ = 0.005 ug/L.

Copper CCME Guideline: 2 µg/L at $[CaCO^3]$ = 0-120 mg/L; 3 µg/L at $[CaCO^3]$ = 120-180 mg/L; 4 µg/L at $[CaCO^3]$ > 180 mg/L.

Lead CCME Guideline: 1 µg/L at $[CaCO^3]$ = 0-60 mg/L; 2 µg/L at [CaCO3] = 60-120 mg/L; 4 µg/L at [CaCO3] = 120-180 mg/L; 7 µg/L at [CaCO3] = 180 mg/L.

Nickel CCME Guideline: 25 ug/L at $[CaCO^3]$ = 0-60 mg/l; 65 ug/L at [CaCO3] = 60-120 mg/l; 110 ug/L at [CaCO3] = 120-180 mg/l; 150 ug/L at [CaCO3] = 180 mg/L.

TABLE 2

Mine Water Discharge Summary, Sydney Coalfield

Mine Name	# of Samples (n)	Year Mine Closed	Years Since Closure	pH (average)	Sulphate mg/L (average)	Aluminum mg/L (maximum)	Iron (mg/L) (maximum)	Estimated Flow Rate (L/min)	Iron Loading (kg/day)	Receiving Water Body	Iron Plume Observed	Surface Staining Observed	Fish Toxicity (96 hr)
No. 7 Colliery	8	1918	89	6.2	207	0.800	6.4	1,977	**18.2**	Ocean	**Slight[4]**	**Yes[2]**	**Pass[2]**
No. 8 Colliery	6	1914	93	7.6	369	0.190	1.4	1,720	3.5	Ocean	No Observation Recorded	No Observation Recorded	No Sample
No. 1A Water Level	9	1927	80	6.1	263	0.500	33.3	132	**6.3**	Ocean	**No[2]**	**Yes[2]**	**Pass[2]**
Old Lingan	1	?	?	4.1	182	1.300	1.8	189	0.5	Ocean	No Observation Recorded	Yes[3]	No Sample
Franklyn Mine	2	1957	50	3.6	142	4.500	3.07	38	0.2	FW Pond[1]	No Observation Recorded	Yes[3]	No Sample
Greener Pit	4	1963	44	7.5	429	0.076	6.4	1,977	**18.2**	FW Pond[1]	**No Observation Recorded**	**Yes[2]**	**Pass[2]**
Morrison Pond	1	pre-1900	?	2.9	442	11.4	49	?	**?**	Ocean	No Observation Recorded	No Observation Recorded	No Sample
Beaver/Nicholson	4	1961	46	7.7	13	<.02	1.5	76	0.2	Stream	No[3]	Yes[3]	No Sample
Gowrie Outfall	3	1898	109	3.9	190	1.300	21.9	1,036	32.7	Ocean	No[3]	Yes[3]	No Sample
Clyde Mine	6	1892	115	6.7	290	0.809	11.6	599	**10.0**	Ocean	**No Observation Recorded (high surf)**	**Yes[2]**	**Pass[2]**
No. 4 Colliery	2	1961	46	6.6	23	0.052	5.7	38	0.3	Estuary	No[3]	Yes[3]	No Sample
No. 11 Colliery	7	1949	58	4.0	141	3.300	0.6	832	0.7	Stream	No[3]	Yes[3]	No Sample
No. 21 Colliery	1	1925	82	5.7	67	0.965	8.4	2,268	27.4	Stream	No Observation Recorded	Yes[3]	No Sample
No. 22 Colliery 1	1	1930	77	6.8	81	0.200	22		0.0	FW Pond[1]	No[3]	Yes[3]	No Sample
No. 22 Colliery 2	1	1930	77	7.1	65	<.005	2.5		0.0	FW Pond[1]	No[3]	Yes[3]	No Sample
Blockhouse	1	1888	119	6.9	64	0.032	5	756	5.4	Ocean	No[3]	Yes[3]	No Sample
Sterling Mine (?)	7	?	NA	7.6	369	0.043	3.8	3,415	**18.7**	Ocean	**No[2]**	**Yes[3]**	**Pass[2]**
Pumping No.1B Shaft November, 1992	1	NA	NA	4.3	5,551	NA	1,602	16,632	**38,368**	Ocean	**Yes[3]**	**Yes[3]**	**No Sample**

1 Fresh Water Pond
2 N&G Report, Feb. 9. 2005
3 CRA personnel observation
4 Slight plume probably derived from agitation of sea bottom precipitate by rough sea state at time of observation (personal conversation with Brent MacDonald, N&G)

Note Bold font entries identify observations of iron staining, plume development, and discharge flow rate that were made at the time of sampling

Review of criteria for discharging mine water into marine environments

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1. Scope of report

This review has been prepared at the request of Conestoga-Rovers Associates to contribute to the development of appropriate criteria for discharge of mine waters to marine environments, which is likely to be necessary as part of developing a long-term strategy for mine water management in the 1B Hydraulic System on Cape Breton Island, Nova Scotia.

2. Sources consulted

The following sources were consulted in the preparation of this review:

- Direct mailings to professionals known to be engaged in environmental management of coastal mining operations worldwide
- The entire database of Proceedings of Symposia and Congresses of the International Mine Water Association, dating back to 1979.
- The entire contents of the journal *Mine Water and the Environment* back to 1998.
- Science Citation Index, and through it several hundred electronic journals including *Marine Pollution Bulletin*, *Journal of Experimental Marine Biology and Ecology*, and *Ocean & Coastal Management*.
- The web-site www.metalsriskassessment.org (maintained by the International Council on Mining and Metals) and open searching of the internet as a whole

3. Findings

3.1. Issues with mine water discharge to marine environments

3.1.1. The irrelevance of freshwater standards

The regulation of mine water discharges to freshwater systems is far more widely practised than discharge to marine environments, not least because relatively few major mining operations are located precisely on the coastlines of the world. Given that experience with mine water management in freshwater systems far exceeds that in marine systems, there is a great temptation to attempt to transfer criteria for discharge from the freshwater to marine environments. Indeed, a very recent report of the 'MERAG' (Metals Risk Assessment Guidance) initiative specifically addresses ' use of freshwater data for the derivation of ecotoxicity thresholds for marine species'. One of the principal conclusions of that study is that:

> "it should be acknowledged that the physico-chemical characteristics of saltwater environments show important differences compared to freshwater environments. For example, seawater is characterized by a higher ionic strength and the observed gradients in abiotic factors such as chlorine content have important consequences on [*sic*] composition, behaviour, physiology, reproductive strategies of species on one [*sic*] hand and could have consequences for the speciation and bioavailability of metals on the other

hand. Consequently, marine risk assessments should use, where possible, data relevant to the marine environment that is considered". (MERAG 2007).

Herein lies the rub: data relevant to *any* marine environment are remarkably scarce, so that there is great temptation to attempt some extrapolation from the more abundant (but hardly prolific) data for freshwater systems. MERAG (2007) tentatively suggest how this might be done, at least for notoriously ecotoxic metals such as Cu, Cd and Zn by means of a fudge factor (known euphemistically as an 'assessment factor'). Given the rarity of Cu, Cd, Zn and other such metals in coal mine drainage, these tentative recommendations are of limited relevance to coal mine waters, in which the principal contaminants of concern are the far less toxic Fe (the freshwater toxicity of which was reviewed by Younger 2000) and Al (which simply precipitates as innocuous $Al(OH)_3$ as soon as pH exceeds 4.5 – which it inevitably does with even modest mixing of acidic waters with sea water, which is very well buffered). Indeed, the limited data available are consistent with the conclusion that direct toxicity effects of Fe and Al in marine waters are likely to be negligible for all but the most extreme loadings (cf Gnandi *et al.* 2006). Indeed, far from being regarded as a toxicant in marine ecosystems, Fe is in fact a limiting nutrient: introduction of excess Fe actually *stimulates* primary production. This is exactly why major experiments in iron dosing of the southern ocean have been undertaken (http://lgmacweb.env.uea.ac.uk/soiree), with a view to stimulating algal growth to remove CO_2 from the atmosphere.

However, it is important to note that direct toxicity is not a key issue for Fe in freshwater systems either (Younger 2000). Rather, for both Fe and Al, a key ecological impact process in freshwater ecosystems is benthic smothering, in which bed sediments (the principal focus of photosynthetic primary production by attached algae) are so cloaked with opaque ochres and / or alums that light cannot penetrate to the algae, so that primary production is prevented. The knock-on effects up the food chain explain impoverishment of invertebrate and fish communities (Jarvis and Younger 1997). Benthic smothering principally arises from accretion of ochres / alums by hydrolysis of sorbed Fe^{3+} / Al^{3+}, rather than by settlement of hydroxides from the water column as freshly precipitated hydroxides of these two metals are of very low density and thus tend to remain in the suspended load save under conditions of very low flow rates, as in settlement lagoons).

Benthic smothering is not a major concern in marine systems. This is because mine water (being generally fresh or brackish) is almost always significantly less dense than marine waters, so that it marine water released to the sea progrades on top of the dense marine water column. Mine water does not proceed along the sea bed, and therefore ochre accretion cannot occur in the way it does in freshwater systems. Normally, hydroxides formed in the prograding mine water will gradually flocculate and fall out to the sea bed over a very wide area (Younger *et al.* 2005), not leading to significant accumulation of a blanket of ochre on the benthos.

In summary, then, Fe and Al, as the principal contaminants of concern in coal mine waters, are not anticipated to be particularly problematic in marine ecosystems, due to their inability to give rise to benthic smothering and to the non-toxicity of the dispersed hydroxides into which they are both rapidly converted upon buffering by sea waters. What, then, *are* the real issues with coal mine discharge to marine environments?

3.1.2. Issues truly relevant to marine environments

Review of the literature suggests only two real concerns with mine water discharge to marine environments:

(i) Visual impacts of stained water plumes. The progradation of less dense, ferruginous mine waters above denser marine waters means that plumes containing highly visible ochre particles can extend over large areas of coastal waters around discharge points. Although such plumes have been found not to give rise to any ecological impacts (Younger *et al.* 2005), they are very unsightly, and negatively impact upon public perceptions of the wholesomeness of the local marine environment – with potentially negative effects on income from tourism and from sales of locally-obtained marine produce.

(ii) Localised impacts on seafood resources. Extreme concentrations of Fe in near-shore marine waters can be expected to lead to bioaccumulation of Fe in fish and crustaceans to levels in excess of human consumption guidelines (cf Gnandi *et al.* 2006). It is stressed that no such cases have been reported in practice in relation to coal mine discharges. However, it is conceivable that issues might arise if:

1. the mine water contained 100s of mg/l of Fe, and
2. the mine water were run into the sea across the beach (as opposed to being introduced from a pipeline below the low-tide line).

Even then, it would only be an issue in the immediate intertidal zone, so as long as the mine water was not directed to enter an active seafood collection area there would be no wider issues.

In all real cases for which information has been forthcoming, (i) above has proved the only real issue in practice. In the following section, brief summaries of these cases are collated.

3.2. Collation of international experiences / practices

3.2.1. Known cases – non-coal mines

(i) Wheal Jane, UK. By far the best documented case is that of the Wheal Jane Sn/Zn mine in Cornwall, UK (see Younger *et al.* 2005 and extensive literature cited therein). Wheal Jane mine does not actually discharge to the sea directly, but does discharge to a river only a short distance above its tidal limit, and at times when the discharge to the river contained very high iron concentrations this resulted in a plume of discoloured water prograding into the marine system of the Fal Estuary. Extensive monitoring and modelling established that (in this particular hydrodynamic setting) a discoloured plume was only visible when the loading of Fe entering the Fal Estuary exceeded a threshold of around 3000 kg Fe/d. Because the Environment Agency ended up owning the discharge consent for the Wheal Jane mine, however, they felt they had to limit themselves to a much lower consent than this to avoid being vulnerable to challenge on the grounds that they imposed stricter limits on others. Thus the discharge consent criteria eventually adopted for the treatment plant at Wheal Jane amounted to a maximum iron loading of 151 kg Fe/d (corresponds to a maximum pumping rate of 350 l/s at a maximum concentration of 10 mg/l Fe). The concentration limit adopted for Al was 10 mg/l, corresponding to a maximum permitted loading of 300 kg/d.

(ii) Skinningrove, UK. The untreated discharges totalling 46 l/s from the Loftus and Carlin How Ironstone Mines at Skinningrove (Cleveland, UK) also enter a freshwater system (the Kilton Beck) a short distance from its confluence with the sea. In the 1970s, when iron loadings were still on the order of 600 kg/d, a plume was visible over an estimated 3000 m^2 of the ocean surface around the mouth of the Kilton Beck. Iron concentrations in these discharges have decreased substantially from their early post-mine-flooding values, and with Fe concentrations currently averaging 17 mg/l, the total loading to the sea is only 67 kg Fe/d, and the mines no longer result in a significant plume in the sea (albeit ochre staining in the freshwater course of the Kilton Beck remains severe).

(iii) Stratoni, Greece. This underground gold mine generally yields very little mine water, but after block-caving intercepted an ephemeral surface watercourse some years ago, measures had to be taken to prevent rapid ingress of storm runoff to the mine. At times, these measures have been overwhelmed by the quantity of flow in the wake of convective storms, and the result has been occasional outflows from the mine with loadings of iron peaking at an estimated 60,000 kg/d. Such an outflow in December 2002 gave rise to a highly visible ochre plume in the Mediterranean. Generally, the mine water treatment plant at the mine treats up to 70 l/s to maintain iron concentrations below the consented discharge limit of 15 mg/l, such that the Fe loading to the Mediterranean does not exceed 90 kg Fe / d.

(iv) Britannia Mine, British Columbia. This site has recently been the subject of a major tendering exercise for construction of a mine water treatment plant. The principal concerns at that site relate to Cu in the mine water, which has been shown to have negatively affected growth of phytoplankton, invertebrates in the near shore zone of the Howe Sound (Levings *et al.* 2004; 2005), with knock-on effects for availability of safe food resources for salmonid fish. The Britannia Mine Water Treatment Plant was required to meet the following discharge consent criteria:

Al 1.0 mg/l
Cu 0.1 mg/l
Fe 0.1 mg/l
Zn 0.2 mg/l
Mn 0.4 mg/l
Cd 0.01 mg/l
Suspended solids 30 mg/l

It is notable that the permit concentration for Fe is lower than that for Zn – a completely nonsensical provision from any ecological perspective, given the powerful toxicity of Zn and the low toxicity of Fe. By contrast, the Al concentration is surprisingly lax, as it is known to be ecotoxic at such concentrations; however, in achieving 0.1 mg/l Fe, it is virtually impossible Al could still exceed 0.1 mg/l having passed through the same treatment plant.

3.2.2. Known cases – coal mines

(i) East Fife Coalfield, Scotland. During active mining in the East Fife coalfield, which definitively ended with the cessation of pumping in 1995, ferruginous mine water was pumped directly into the sea (without prior treatment) from two shafts:
- Michael Shaft: 278 l/s at an average of 34 mg/l Fe, corresponding to a loading of 816 kg Fe/d.
- Frances Shaft: 104 l/s at an average of 12 mg/l Fe, corresponding to a loading of 108 kg Fe/d.
The Michael discharge gave rise to a visible plume over an area of some 4000m^2, whereas the Frances discharge caused no visible plume.

After rebound of mine water in the East Fife Coalfield, pumping was restarted from the Frances Shaft. Water quality had deteriorated dramatically in the interim (Nuttall and Younger 2004) and intensive treatment was required before the mine water could be released. At present, no final consent limit has been set for this site, as trials with the treatment system continue. However, it is believed that a limit of 10 mg/l Fe is likely to be agreed, as this level can readily be attained by the current treatment plant. At current pumping rates (averaging 83 l/s) this equates to a maximum Fe loading of 72 kg / d – which would be erring very much on the side of caution given the lack of any plume associated with the former loading of 924 kg Fe/d released without treatment from the Frances and Michael shafts during the period of active mining.

<u>(ii) Bates Colliery, Northumberland (England).</u> This pump-and-treat system controls water in most of the now-abandoned Northumberland Coalfield. The consent specifies a total flow rate of up to 200 l/s at up to 10 mg/l Fe (equivalent to a loading of 173 kg Fe/d). In meeting this consent, no plume is visible in the receiving marine water.

<u>(ii) Horden Colliery, County Durham (England).</u> This pump-and-treat system controls water in most of eastern portion of the now-abandoned Durham Coalfield. The consent specifies a total flow rate of up to 116 l/s at up to 10 mg/l Fe (equivalent to a loading of 100 kg Fe/d). In meeting this consent, no plume is visible in the receiving marine water. On a number of short-live occasions in which discharge occurred without treatment, a loading of up to 400 kg Fe /d was locally entering the sea, though this caused only a highly localised visible plume in the sea.

<u>(iv) Gardanne Coal Basin, Provence (France).</u> Agreement has been reached to discharge the entire post-rebound water make of this coalfield to the sea without treatment, via a long outfall debouching up to 160 l/s of untreated mine water more than 300m beyond the low-tide line. With peak iron concentrations anticipated to reach as much as 100 mg/l, the permit envisages a peak loading of 1400 kg Fe/d. At such a high loading localised discolouration of sea water is accepted to be inevitable, though this will be located too far from the shore to be an eyesore from that vantage point.

3.2.3. Other information

It is notable that in all of the coal mine cases mentioned above, discharge consents specify only total Fe, pH (6 – 8.5) and suspended solids: none of them set specific limits on Al or any other metals.

It should also be noted that the non-coal mine cases are principally regulated in relation to Cu, Zn and other ecotoxic metals. As in the coal mine cases, the regulation of Fe is approached solely from the point of view of visible nuisance (except in the case of the extremely low concentration specified at Britannia, which is indefensible on ecological grounds).

Finally, it is noted that consultations with colleagues in Australia revealed that there are no specific criteria in use for managing mine water discharges to the sea in that country. Criteria used for (partly analogous) acid sulphate soil drainage systems do exist, but these refer only to the chemical content of sediments, not dissolved matter.

3.2.4. Summary

Table 1 below summarises the key findings from the reviewed case studies, arranged in order to illuminate key issues in consent limit-setting and loadings thresholds. As the Table reveals, there are no known cases in which an Fe loading less than 200 kg Fe/d has given rise to an unsightly ochreous plume in the sea around a mine water discharge. Consent limits for iron in marine discharges of mine waters range from an extreme low of 0.1 mg/l (which is not defensible on any grounds, either amenity or ecological) to a very liberal 100 mg/l, with most permits lying around 10 – 15 mg/l.

Table 1 – Summary of consent limits for Fe from case studies of discharges of mine water to the sea

Mine	Location	Type of mine	Consent limit for Fe (mg/l)	Permitted loading of Fe to sea (kg/d)	Loading of Fe to sea (kg/d) known to have caused a plume at this site	Comments
Wheal Jane	Cornwall (UK)	Tin / Zinc	10	151	3000	
Skinningrove	Cleveland (UK)	Iron	17*	70*	600	* no formal permits in force at this site
Stratoni	Greece	Gold	15	90	60,000	
Britannia	Canada (BC)	Copper	0.1	n/a	n/a	
Frances	Fife (UK)	Coal	10*	72*	816	* not yet finalised
Bates	Northumberland (UK)	Coal	10	173	400*	* imprecise estimate
Hordon	County Durham (UK)	Coal	10	100	400*	* imprecise estimate
Gardanne	Near Marseille (France)	Coal	100	1400	1400*	* tracer tests in container port harbour

4. Towards site-specific criteria for mine water discharge to marine environments

It is generally accepted that, to be meaningful and effective, discharge consent criteria for marine systems need to site-specific and season-specific (e.g. Johnston and Keough 2005). For mine effluent disposal to marine ecosystems, relevant issue include the vigour of marine dispersion, and metal toxicity (Fe, Al) towards 'model' marine species appropriate to the region (Marín-Guirao *et al.* 2005). Evaluations also need to take into account societal acceptability (e.g. Osborn and Datta 2006), particularly in relation to unsightly plumes of ochre which are actually innocuous in strict ecological terms (Younger *et al.* 2005). Development of site-specific criteria for the 1B Hydraulic System will therefore require consideration of a range of factors. However, the predominance of avoiding visual intrusion by unsightly plumes emerges as the principal driver in the vast majority of cases worldwide.

With regard to avoiding unsightly ochreous plumes, it is clear from the case studies summarised above that there exists a threshold of iron loading below which no visible plume would be expected (even where the mine water is discharged to relatively calm, barely tidal seas such as the Mediterranean). This threshold appears (from scrutiny of Table 1) to approximate to about 200 kg Fe/d.

Given that the quantity of water yielded by a given body of workings is generally beyond control (at least once reasonable steps have been taken to limit excessive indirect recharge), maintenance of iron loadings beyond this critical threshold can be applied by calculating a target maximum iron concentration (post-treatment, where necessary) using the following formula:

$$Fe_{MAX} = 2314.8 \,/\, Q_{MAX}$$

Where:
Fe_{MAX} is the maximum iron concentration to be permitted in the final effluent to the sea, and
Q_{MAX} is the maximum anticipated flow rate (either to be pumped or anticipated gravity flow rate from an adit)

Hence if a mine water has a total flow rate of 116 l/s (≈ 1845 US gpm, which equals the mean pumping rate at Neville Street needed to arrest water level rise in the 1B Hydraulic System), then for discharge to the sea with surety of not causing a visible plume, one would estimate a target post-treatment iron concentration of 2314.8/116 = 20 mg/l. (Obviously, in wetter periods, a lower target iron concentration might well be needed if the Fe loading to the sea were not to exceed 200 kg Fe/d).

It is recommended that a dialogue is established with regulators to take this and related concepts forward as the analysis of options for the 1B Hydraulic System proceeds.

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