8-A.2: Water Quality Monitoring and Management Plan for Dike Construction Dewatering

June 2016
Report No. 1541520

ADDENDUM

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NIRB Requirement:	Project Certificate No. 004	**Condition:** not applicable
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Section Change	**Specify: Update or New**	**Details** **(note – 'updates' are in red text a minor change to existing text, otherwise 'new' text in black)**
1	Update (first paragraph, last sentence)	Update provided in red text
	Update (last paragraph, last sentence)	Update provided in red text
4	New (new sentence after second paragraph)	New text provided in red text
4.1.4.2	New (includes general construction of Dikes)	New text provided in red text
4.2.1	New (new sentence after last paragraph)	New text provided in red text
4.2.2	New (new sentence after last sentence of section)	New text provided in red text
5.1	Updated (additions)	Update provided in red text
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5.2	Update (first bullet)	Update provided in red text
	Update (addition; second paragraph)	Update provided in red text
	Update (addition; third paragraph)	Update provided in red text

MEADOWBANK GOLD PROJECT

Water Quality Monitoring and Management Plan for Dike Construction and Dewatering

In Accordance with Water License 2AM-MEA0815

Prepared by:
Agnico-Eagle Mines Limited – Meadowbank Division

Version WT
June 2016

EXECUTIVE SUMMARY

The Nunavut Water Board (NWB) has issued Type A Water License 2AM-MEA0815 to Agnico-Eagle Mines Limited (AEM) for the Meadowbank Gold Project site authorizing the use of water and the disposal of waste required by mining and milling and associated uses.

This report documents the Water Quality Monitoring and Management Plan for Dike Construction and Dewatering specified under Water License 2AM-MEA0815 Part D, Item 11. Water quality monitoring includes several parameters (e.g., nutrients and metals), but TSS and turbidity (primarily as a surrogate for TSS) are the major drivers of management actions during construction and dewatering. The plan also includes the mitigation measures to control the releases of Total Suspended Solids (TSS) in the environment. The monitoring and management plans are detailed and should serve as operating procedures for real-time actions in the field.

IMPLEMENTATION SCHEDULE

As required by Water License 2AM-MEA0815, Part B, Item 16, the proposed implementation schedule for this Plan is outlined below.

This Plan will be immediately implemented (April 2010) subject to any modifications proposed by the NWB as a result of the review and approval process.

DISTRIBUTION LIST

AEM – Environment Superintendent

AEM – Environmental Coordinator

AEM – Environmental Technician

AEM - Dike Superintendent

AEM – Mine Manager

DOCUMENT CONTROL

Version	Date (YMD)	Section	Page	Revision
1	08/07/31			Comprehensive plan for Meadowbank Project
2	09/03/31	all		Overall revision of plan, incorporating license requirements and construction of Bay-Goose dike
3	09/11/15	Sections 4 & 5	7 - 21	Revisions to Water Quality Monitoring and TSS Management Plan for Dike Construction and Water Quality and Lake Level Monitoring and Management Plan For Dewatering; included discussions on construction and mitigation measures for Bay-Goose dike (Phase 2) and dewatering Water Treatment Plant
4	10/03/31	Sections 4 & 5 Figure 9 Figure 10 Figure 12	8-19	Incorporated intervener comments from version 3 review process. Addition of Section 4.4, Figure 13 and Appendix A.
4a	15/06/18	Section 5	18-20	Phaser Pit and BB Phaser Pit Addendum sent to NWB on June 18th, 2016 Version 4a (addendum) text is in Blue, pending Board approval
WT	16/06/30	Sections 1, 4, 5.1, 5.2 Figure 14		Incorporates details related to Whale Tail Pit.

Prepared by Golder Associates & Agnico Eagle Meadowbank Division - Environment Department

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

LIST OF FIGURES

SECTION 1 • INTRODUCTION

This plan provides details of water quality monitoring and management actions specifically related to the dike construction and dewatering activities at the Meadowbank mine. The plan does not cover complementary monitoring of limnological parameters in Second Portage Lake (as part of the Fish-Out Program) nor routine water quality monitoring of both Second and Third Portage lakes, or lakes in the Whale Tail Pit area (Mammoth Lake, Whale Tail Lake [South Basin]) (as these are part of the Aquatic Effects Management Program).

Water quality monitoring includes several parameters (e.g., nutrients and metals), but TSS (Total Suspended Sediments) and turbidity (primarily as a surrogate for TSS) are the major drivers of management actions during construction and dewatering. The plan also includes mitigation measures to control the releases of TSS in the environment. The TSS/turbidity focus allows for direct monitoring of the major potential stressor in "real time", thus allowing timely identification and mitigation of potential issues related to dike construction or dewatering.

This plan includes the following components:

- Review of TSS/turbidity effects and existing federal guidelines (**Section 2**);
- License requirements for the protection of fish and fish habitat at Meadowbank **(Section 3);**
- Water quality monitoring and management plan for dike construction (**Section 4**);
- Water quality and lake level monitoring and management plan for dewatering (**Section 5**); and
- References (**Section 6**).

The monitoring and management plans are detailed and should serve as operating procedures for real-time actions in the field. This plan has been revised to reflect discussions with regulatory agencies and the requirements of the Nunavut Water Board (NWB) Type A Water Licence (2AM-MEA1525) for the Meadowbank Gold Project.

SECTION 2 • REVIEW OF TSS / TURBIDITY AND EXISITING FEDERAL GUIDELINES

2.1 REVIEW OF TSS / TURBIDITY EFFECTS

Suspended sediments, and associated effects on water clarity, have the potential to affect fish and fish habitat in a variety of ways, including but not limited to:

- Smothering of deposited eggs or siltation of spawning habitats;
- Smothering of benthic invertebrate communities;
- Decreased primary productivity caused by reduced light penetration;
- Reduced visibility, which may decrease feeding efficiency and/or increase predator avoidance; and
- Clogging and abrasion of gills.

Fisheries and Oceans Canada (DFO) has produced a report on effects of sediment on fish and their habitat (DFO, 2000). That report is based primarily on a more detailed paper by Birtwell (1999). The review by Birtwell is in turn based on a few sources, the most recent and comprehensive of which was prepared by Caux et al. (1997). Azimuth Consulting Group conducted a literature review to find more recent articles specific to species of interest at the Meadowbank mine, but did not find any articles.

The general findings for effects of TSS on fish and fish habitat indicate the following:

- Effects of TSS depend on both the concentration of TSS and duration of exposure;
- Effects of TSS can also be influenced by the size and shape of suspended particles;
- Concentrations of TSS that are lethal to fish over acute exposures (i.e., hours) range from hundreds to hundreds of thousands of mg/L;
- Sublethal effects on fish (e.g., reduced growth, changes in blood chemistry, histological changes) associated with chronic (weeks to months) exposures tend to be exhibited at TSS concentrations ranging from the tens to hundreds of mg/L;
- There is considerable uncertainty about potential effects of low TSS concentrations (less than tens of mg/L) over long time periods;
- Overall, the most sensitive group of aquatic organisms to TSS appears to be salmonids, and guidelines are developed to protect this group;
- Adult salmonids are generally more sensitive to short duration, high concentrations of suspended sediments than juvenile salmonids. However, both juvenile and adult fish have the potential to avoid high concentrations of suspended sediments; and

- Low suspended sediment levels are known to cause egg mortality (40%) to rainbow trout at long durations (7 mg/L at 48 days). Guidelines for long-term exposure reflect these findings.

2.2 REVIEW OF EXISTING FEDERAL GUIDELINES

Based on the findings regarding effects of suspended sediment, guidelines for TSS as well as turbidity have been put forth by various federal agencies.

TSS

The Canadian Council of Ministers of the Environment (CCME) specifies separate guidelines for TSS for clear flow and high flow periods. The guidelines are derived primarily from Caux et al. 1997, with application intended mainly for British Columbia streams. In the case of application to the Meadowbank Project Lakes, the clear flow guidelines would be most relevant – even during freshet one would not expect to see large natural fluctuations in TSS except in localized areas for short periods.

The guidelines put forth by the CCME recognize that the severity of effects of suspended sediments is a function of both the concentration of suspended sediments and the duration of exposure. Guidelines are intended to protect the most sensitive taxonomic group (salmonids) and the most sensitive life history stages. The following table summarizes the available guidelines applicable to clear water (CCME) and to mine-related effluent discharges (MMER).

Table 2.1: Existing Federal TSS Guidelines

Source	Short-Term Exposure	Long-Term Exposure
CCME 1999	Anthropogenic activities should not increase suspended sediment concentrations by more than 25 mg/L over background levels during any short-term exposure period (e.g., 24-hr)	For longer term exposure (e.g., 30 days or more), average suspended sediment concentrations should not be increased by more than 5 mg/L over background levels
MMER 2002	Maximum authorized concentration in a composite effluent sample = 22.5 mg/L. Maximum authorized concentration in a grab sample of effluent = 30 mg/L.	Maximum authorized monthly mean effluent concentration = 15 mg/L [1].

The guidelines above are based on hundreds of studies in different environments (see Caux et al. 1997). Some of the studies may not be particularly relevant to the case of suspended sediment associated with dike construction and dewatering in a lake environment. Consequently, it is worth considering whether all aspects of existing guidelines are applicable to dike construction and monitoring at the Meadowbank mine. There are two particular aspects that warrant discussion.

First, in relation to short-term exposure guidelines, it is important to note that guidance is based on findings for adults and juveniles (which are more sensitive than eggs and larvae over short durations), and that the guidance is based primarily on reviews looking at application to stream environments. In

[2] For purposes of calculating monthly means, any values below detection limits are set at one-half of the detection limit.

a stream environment, compared to a lake environment, it is difficult for fish to swim away from suspended sediments because the high degree of mixing in the water column facilitates higher uniformity in TSS concentrations. In contrast, in lakes, in particular for sediment plumes associated with construction activities or discharges, high TSS concentrations would generally be expected to be localized, with dilution over distance. In a lake situation, adult and juvenile fish (the most sensitive life stages to short-term exposure) should readily be able to swim away from a sediment plume.

Second, in relation to long-term exposure guidelines, it is important to note that guidance is heavily influenced by findings indicating the sensitivity of eggs to low-level exposure to TSS over long durations. Consequently, the long-term exposure guidelines would be rather conservative if applied during times when eggs are not present, or in areas of a lake or stream that are not spawning habitat.

Turbidity

Turbidity guidelines put forth by the CCME (1999) are based on extrapolation from the TSS guidance above, adjusted by a factor of about 3:1 (a typical average ratio for TSS: turbidity). In the case of turbidity for clear water, CCME (1999) recommends a maximum increase of 8 NTUs from background levels for a short-term exposure (e.g., 24-h period), and a maximum average increase of 2 NTUs from background levels for a longer term exposure (e.g., 30-d period).

CCME (1999) notes that in some cases short-term resuspension of sediments and nutrients in the water column can augment primary productivity, and in other cases changes in light penetration may be inconsequential if a system is limited by other factors such as nutrients. The Caux et al. (1997) study considered effects of suspended sediment not only on fish but also on algae and zooplankton. In the end, the recommendations put forth by Caux et al. (1997) are based mainly on the most sensitive taxonomic group, which is salmonids.

However, research has shown that widespread, chronic turbidity can result in reduced light penetration and subsequent reductions of primary productivity (DFO, 2000; CCME, 1999; Lloyd et al., 1987). Consequently, water clarity is of concern at broader spatial scales and longer timeframes, such as the proposed dewatering activities.

It should be noted that DFO’s report on effects of sediment on fish and their habitat (DFO, 2000) endorses the guidelines for TSS put forth by the CCME (1999), but does not recommend following guidelines for turbidity. Rather, turbidity may be used as a surrogate for suspended sediment only when the relationship between the two parameters is established for a particular waterbody.

SECTION 3 • LICENSE REQUIREMENTS FOR THE PROTECTION OF FISH AND FISH HABITAT AT MEADOWBANK

During dike construction activities at Meadowbank, the following maximum monthly mean (MMM) and short term maximum (STM) TSS concentrations must be met, in accordance with the NWB Type A water license, Part D, Item 7.

Table 3.1: Maximum Allowable TSS Concentrations During Dike Construction

Parameter	Maximum Monthly Mean (mg/L)	Short Term Maximum (mg/L)
TSS in areas where there is spawning habitat and at times when eggs or larvae are expected to be present (applied at monitoring stations located closest to the high value shoal areas starting Sept 1, 2008)	6	25
TSS in all other areas and at times when eggs/larvae are not present	15	50
TSS in impounded areas (e.g. northwest arm of Second Portage Lake) at all times in all areas	15	50

During dewatering activities at Meadowbank, the maximum monthly mean and short term maximum concentrations presented in Table 3.2 must be met, in accordance with Part D, Item 8 of the NWB Type A water license.

Table 3.2: Maximum Allowable Water Quality Concentrations During Dewatering

Parameter	Maximum Monthly Mean	Short Term Maximum
Total Suspended Solids	15.0 mg/L	22.5 mg/L
Turbidity	15 NTU	30 NTU
pH	6.0 to 9.0	6.0 to 9.0
Total Aluminum	1.5 mg/L	3.0 mg/L

As stipulated in the water license, Part D, trigger values have been developed with corresponding management action plans; should TSS concentrations in the water body exceed the trigger values during either dike construction or dewatering, a management action plan consisting of a series of steps to be undertaken will be initiated. The trigger value for the short term maximum concentration is a single sample that exceeds the STM concentration. The trigger value for the maximum monthly mean is a 7-day moving average concentration that exceeds the MMM. The management action plans for the dike construction STM and MMM are discussed in detail in Section 4 and for dewatering in Section 5.

SECTION 4 • WATER QUALITY MONITORING AND TSS MANAGEMENT PLAN FOR DIKE CONSTRUCTION

During dike construction, both the dike material itself as well as the disturbed material on the lake floor (particularly in the deep areas of the lakes) will contribute to increases in concentrations of suspended sediments in the water column. In the absence of sediment control measures, suspended sediment plumes would be expected to migrate to the southeast with wind-driven (prevailing winds from the northwest) currents.

The key means for minimizing suspended sediment discharges from the dike construction zones during dike construction include the deployment of turbidity curtains and water treatment. The mitigation measures used during the construction of the East dike, South Camp dike, and Bay Goose dike (Phase 1) are described below. In addition, the proposed mitigation measures for the Bay Goose dike (Phase 2) are discussed.

Similar mitigation measures will be used during the construction of the Whale Tail Dike and Mammoth Dike and are also described in the Whale Tail Pit Water Management Plan.

4.1 TSS MANAGEMENT PLAN

4.1.1 East Dike Construction 2008

The turbidity curtains were placed as close as possible to the construction zone (except for the portion of the east curtain that was anchored to the small island) without risking direct incidental physical contact with construction materials (Figure 1), and allowing sufficient room for anchor placement on both sides of the curtains. Curtains were suspended off of the lake floor to allow some passage of water and to avoid resuspension of sediment associated with contact between the curtains and the bottom sediments.

During construction of the East dike, elevated concentrations of TSS were measured in the lake, bypassing the turbidity barriers and causing a downstream TSS plume. A full investigation and review of the cause(s) of the event took place in the fall of 2008. Based on that investigation, the mitigation measures for the Bay-Goose dike (Phase 1) were developed

4.1.2 South Camp Dike Construction 2009

The South Camp Dike was built in the winter of 2009. Ice-cover extended to the lakebed; therefore there was no exchange of water between the dike area and the lake during the construction period. Turbidity curtains were deployed on either side of the dike early in the spring following ice-melt to control for potential run-off from the construction area. No TSS plume was observed on either side of the dike outside of the turbidity curtains.

4.1.3 Bay-Goose Dike Phase 1 Construction 2009

Construction of the Bay-Goose dike was designed to be completed in two stages over two open water seasons. Similar to the construction of the East Dike in Second Portage Lake, turbidity barriers were the primary mitigation measure used to control the release of TSS from the construction area into

Third Portage Lake; other mitigation measures included the construction of South Camp dike first to control lake currents and the use of second bench rock material to reduce fines introduced into the lake. There were a number of differences in the method of turbidity curtain deployment between the two dike construction areas. Improving on the methods used for the East Dike construction, the modified deployment methods of the turbidity curtains at the Bay-Goose dike construction area included:

- two layers of turbidity curtains were installed around the Bay-Goose dike construction area, instead of just one layer;

- the curtains were installed to the bottom of the lake, instead of 1 m above the lakebed floor; and

- openings were left in the turbidity curtains to allow exchange of low turbidity level water between the enclosed construction areas and the remainder of Third Portage Lake. The concept for these openings was that during the period when the construction activities would occur at the northern portion of this dike, only the openings to the south would be active and the north openings would be closed. This would maximize the travel time for the entrained solids and provide additional opportunity for them to settle before leaving the area enclosed by the barriers. Similarly, during the period when the construction activities would occur at the southern portion of this dike, only the openings to the north would be active and the south openings would be closed.

Figure 2 shows the locations and configurations of the turbidity curtains deployed at the Bay-Goose dike (Phase 1) construction area in the spring of 2009.

Through regular inspections, it was noted that the turbidity curtain openings did not function as anticipated; therefore all of the openings were sealed. Also, highly turbid sediment plumes escaped beneath discrete sections of the silt curtains on the downwind side. Subsequent to this, a large storm event damaged many of the turbidity curtains and a TSS plume migrated into Third Portage Lake.

A full investigation and review of the cause(s) for the TSS release took place in the fall of 2009. Based on that investigation, and in consultation with regulators, the mitigation measures for the Bay-Goose dike (Phase 2) were developed.

4.1.4 Bay-Goose Dike Phase 2 Construction 2010

Similar to previous dikes construction, the deposited dike material and the fine lakebed sediments, especially in the deep areas of Third Portage Lake, are expected to be entrained into the water column during construction of Phase 2 of the Bay-Goose Dike. As it is best practice construction in waterbodies, turbidity curtains are still the main mitigation measures for the 2010 dike open-water construction season. However, experience from the 2008 East dike and 2009 Bay-Goose dike (Phase 1) construction was reviewed in detail to develop additional mitigation measures for TSS control. As a result, the following elements will be included in the Bay-Goose Dike (Phase 2) TSS management plan:

- Minimize water current out of the construction area to reduce potential for outflow of turbid water; this will be done by 1) slow-pace winter construction of a causeway about 25 m wide (the downstream portion of the dike), and 2) open-water installation of pumps in front of the rock platform deposition creating a no-current to inward-current zone inside the curtains. With the presence of the causeway, pumping water out from inside of the 'impoundment' should create an average negative pressure and will cause 'clean' water to move through the causeway into the impoundment.

- Provide a wind-breaker to protect turbidity curtains against the effects of high winds; this will be achieved by winter construction of the same causeway as mentioned above. Since the causeway is the downstream portion of the dike, it will be the same height as the dike. The concept of the causeway was developed based on observations from the 2009 wind storm event that the integrity of the inner curtain portion closer to the rock platform was not affected by wind activity.

- Reduce the height and length of the curtains as much as possible to make them less prone to breakage from wind action; this will be achieved by 1) installation of the inner turbidity curtains in small cell-like patterns along the causeway to prevent wholesale breakage of the curtain due to effect of high winds, and 2) installation of outer curtains, as much as possible, in depths of no more than 10 m to reduce the effects of high winds.

- Deploy turbidity curtains downstream from deep lake depressions to minimise escape of sediments below the curtains.

- Reduction of the TSS loading inside the turbidity curtains; this is achieved by 1) the above mentioned pumping of water in front of the rock platform construction, and 2) pumping of water from the trench (the water with the highest TSS concentrations), both to be treated at the dewatering water treatment plant.

In summary, the corner stone of this TSS management plan is the inclusion of the winter construction of a causeway to provide wind and water current protection. This causeway is in effect the downstream part of the Bay-Goose dike (Phase 2), and should be completed before turbidity curtain deployment. The construction of the causeway will require breaking the ice in front of the rock platform. This type of construction was done at Meadowbank in the spring of 2009 for the construction of 2 dewatering jetties in the northwest arm of Second Portage Lake; an efficient and safe ice breaking technique and a low turbidity rock deposition process were developed.

Additionally, AEM has developed a low-impact construction technique for the placement of the rock platform beginning with the rock selection process in the open pit. Rock containing more fines is not selected for construction. During the platform construction, to minimise the impact of material deposition, the rock is deposited on the platform and then pushed with a dozer into the lake. Given the quantity of material that needs to be deposited, these are the only mitigation measures that can be effectively implemented during the very short construction period to minimise suspended sediments in the lake environment.

In addition to the causeway, the other mitigation measures will be deployed during the open water season to 1) minimize sediment loading in the construction zone (installation of pumps in front of the rock platform during platform construction and in the trench excavation, and treatment) and 2) reduce the effects of high winds (installation of the outside curtain in an area where water depth is no more than 10 m, if possible).

Specific TSS management frameworks were developed for periods of ice-up (when the lake is ice-covered) and open water construction.

4.1.4.1 TSS Mitigation for Dike Construction During the Ice-up Period

Figure 3 shows the portion of the dike to be constructed from January to June 2010 that will act as the causeway. It will provide wind and water current protection for the dike construction zone and will be used as a base onto which the turbidity curtains in a cell-like pattern at the start of the open water construction season.

Since turbidity curtains cannot be deployed in the winter, other TSS mitigation measures were developed for the causeway construction. The first mitigation measure is to advance the rock platform at a very slow rate, approximately 2 400 tonnes per day (up to 10 times lower than the open water season). The rate of construction will be used to control the TSS loading. Given that the winter construction activities do not have the same time constraints as open water construction, a less productive method of rock deposition can be used. Secondly, sediment dispersion will be decreased during winter construction of the causeway, as ice-cover will eliminate wind-driven currents and allow sediment to settle. Lastly, a shovel will be used to deposit the rock through the ice openings. In combination, these mitigative measures should reduce the sediment resuspension and dispersion, especially in shallow water. Nevertheless, the possibility of sediment re-suspension and dispersion will be monitored as discussed below in Section 4.2.

4.1.4.2 TSS Mitigation for Dike Construction During the Open Water Period

Turbidity curtains are an integral part of the TSS management plan during the open water period. However, based on the experience gained during the 2008 and 2009 construction seasons, some changes to the turbidity curtain deployment strategy will be implemented to increase their effectiveness for Phase 2 of the Bay-Goose dike construction. The inner turbidity curtains will be deployed in short spans using the causeway as the initial and final anchor points, reducing the length of the curtains and the consequent effect of wind. The outer turbidity curtains will be located downstream of the deep depressions in the lake to minimise gravity induced slippage of sediments under the curtains. In addition, where feasible, the outer turbidity curtains will be deployed in areas with a maximum water depth of 10 m to minimize the effect of wind. An Effect Assessment Study (EAS) will be performed post construction, including this area between the silt curtains.

Figure 4 shows the location of the turbidity curtains that will be installed prior to the start of the open water dike construction. Based on experience from previous years, there is a 2-week open water window during which turbidity curtain installation can be done prior to the start of the construction. Approximately 4 km of curtains will be installed in that period. AEM may consider testing an underwater camera as an investigation tool to inspect the installation and condition of the curtains.

As a supplementary measure to protect the fish inside the Bay-Goose dike while the fishout is taking place, a turbidity curtain will be deployed concurrently with the start of the dike construction on the north side of the Bay-Goose dike. This should minimize the effect on the fish that will remain in the basin while the fishout takes place.

Finally, to protect the one high-value fish habitat that will lie within the outer curtains, a turbidity curtain will be deployed across the Eastern Bay concurrently with the start of the dike construction. Two curtains will also be placed between the causeway and the small island south of Goose Island to provide additional contingency. These additional curtains are shown in Figure 5.

In addition to the installation of turbidity curtains, the following mitigative measures will be applied during dike construction to minimize sediment loading in the construction zone (Figure 6):

- A pump will be installed in the water in front of the construction platform to neutralise the current created by the displacement of water from the deposition of rock in the lake. Based on the planned volume of rock deposition and two working fronts for the platform construction, two pumps (one for each front) will be installed each with a capacity of approximately 10 000 m^3 per day. This water will be pumped to the northwest arm of Second Portage Lake where it will be treated through the dewatering water treatment plant and discharged into Third Portage Lake (the same lake where the water originated but in the western basin of the lake instead of the eastern basin). This will require deployment of about 2.5 km of pipes between the Bay-Goose dike construction zone and Second Portage Lake.

- In addition to creating a ‘current neutral’ zone, pumping out water directly ahead of the rock platform will remove some sediment and reduce the loading in the construction zone.

- During the construction activities in the trench, a pump will be placed in the trench to first create a ‘current neutral’ zone, minimizing expulsion of the sediment laden water. The pump capacity will be approximately 10 000 m^3 per day. This water will be pumped to the northwest arm of Second Portage Lake where it will be treated using the dewatering water treatment plant and discharged into Third Portage Lake.

- In addition to creating a ‘current neutral’ zone in the trench, pumping out water will remove some sediment and reduce the loading in the construction zone.

With the combination of the three types of mitigation measures: causeway, turbidity curtains and pump and treat, AEM is confident that the construction of the Bay-Goose dike (Phase 2) will be constructed with the best available practices and that the TSS will be controlled within the license limits.

Table 4.1: Tentative Schedule of Whale Tail Site

Tentative Schedule of Work[a]	Activity
January to June 2018	Construction of the Causeway
May to July 2018	Preparation of turbidity curtains on land Laying down the pipes leading to the water treatment plant Preparing the pump installations on land
June to July 2018	Deployment of inner and outer turbidity curtains Excavation of Abutment
July 2018	Start of platform construction at both ends of the Whale Tail Dike If deemed necessary, pump water in front of the two rock platform advances
July to August 2018	Start of the trench excavation and filling If deemed necessary, pump water in the trench
July to August 2018	Planned completion of rock platform Rock platform pump shutdown
August to September 2018	Planned completion of backfilled trench Trench pump shutdown End of the TSS producing activities and start of the settling period
August to November 2018	Planned completion of compaction Start of cement and bentonite cut-off wall installation Casing installation for injection Drilling bedrock and injection Installation of instrumentation
September to October 2018	Construction of WRSF Dike Continuing into the dewatering phase in March 2019

4.2 WATER QUALITY MONITORING PLAN

Water quality monitoring includes several parameters (e.g., nutrients and metals), but TSS and turbidity (primarily as a surrogate for TSS) are the major drivers of management actions during construction. The TSS/turbidity focus allows for direct monitoring of the major potential stressor, thus allowing timely identification and mitigation of potential issues.

4.2.1 Monitoring Locations

The TSS management plan has been developed for lake ice-up and open water construction seasons. Different locations for routine monitoring have been developed for these two periods.

During the lake ice-up period,moving stations will be established around the deposition area as close as safety permits on either side of the causeway and in front of the causeway; these stations will move in conjunction with work development. Background levels were measured prior to construction in the fall of 2009 and this data will be used for reference. TSS will be sampled at all monitoring stations on a weekly basis. Figure 7 shows the general location of the moving stations that will be used for routine monitoring during the causeway construction period.

During the open water construction, stations for routine monitoring have been established at a distance of 50 to 100 m from the turbidity curtains. Figure 8 shows the stations that will be used for routine monitoring during the Bay Goose dike (Phase 2) construction period.

Consistent with previous monitoring, during open water construction of the Whale Tail Dike and Mammoth Dike, routine monitoring will be established at a distance of 50 to 100 m from the turbidity curtains as proposed in Figure 14.

4.2.2 Monitoring Plan

AEM is committed to proactive and effective response to any potential TSS problems; the monitoring program has been designed to provide quick feedback. This is not possible using TSS as a direct measure, because of the time required to analyze TSS in the field. Consequently, and consistent with the recommendations of the DFO (DFO, 2000), AEM has developed a relationship between turbidity and TSS, allowing the use of turbidity as a surrogate for TSS and obtaining real time results. The TSS-turbidity relationship was developed using paired data collected across a range of TSS sources and concentrations (more details can be found in the Azimuth memo TSS-Turbidity relationship Feb 2010 v3 (Appendix A). The resulting linear regression was as follows:

$$\log10(\text{turbidity}) = 0.62196 + (0.95619 * \log10(\text{TSS}))\ [p<0.001;\ r2\text{-adj} = 0.81]$$

where turbidity is measured in NTUs in the field using an Analite NEP 160 meter, and TSS is measured in the lab as mg/L.

A turbidity meter will be used to perform the analysis at each station. One or two times per day a vertical profile will be conducted at each station, at two meter intervals. All values are recorded but for compliances purposes only the maximum value in the profile is used. Raw turbidity data will be handled in the following manner to facilitate comparisons to the maximum allowable TSS concentrations:

<u>Comparisons to Short-Term Maximum (STM)</u>

1. Calculate the 24-hr station mean for turbidity for each station based on the measured maximum values over the past 24 hours.
2. Use the TSS-turbidity regression (using the site-specific TSS:Turbidity) to estimate 24-hr mean TSS.
3. Calculate the moving average of each stations.
4. Compare to appropriate STM value.

<u>Example</u>: Maximum turbidity values of 2.4, 3.0 and 1.2 NTUs were measured in depth profiles at Station Y over the last 24 hours, for a 24-hr mean of 2.2 NTU. Using the TSS:Turbidity relationship, the 24-hr mean TSS concentration would be 6.6 mg/L.

<u>Comparisons to Maximum Monthly Mean (MMM)</u>

1. Calculate the 30-day moving average of each stations (24-hr mean TSS values) for the previous 30 days.
2. Compare this to the appropriate MMM value.

Routine water quality will also be conducted on a weekly basis. Water quality sampling parameters shall include:

- Physical parameters: hardness, pH, total dissolved solids, total suspended solids;
- Anions and nutrients: ammonia, alkalinity – bicarbonate, alkalinity – carbonate, alkalinity – hydroxide, alkalinity – total; chloride, silicate, sulfate, nitrate, nitrite, total kjeldahl nitrogen, orthophosphate, total phosphate;
- Organic parameters: chlorophyll a, dissolved organic carbon, total organic carbon;
- Total and dissolved metals.

During summer, a broad survey for turbidity will be conducted once a week in Third Portage Lake, Second Portage Lake and Tehek Lake.

During summer, a broad survey for turbidity will be conducted once a week in Whale Tail Lake (South Basin) and Mammoth Lake.

4.3 STANDARD OPERATING PROCEDURES FOR MONITORING AND MANAGEMENT

The Standard Operating Procedure (SOP) for monitoring and management of total suspended sediments during dike construction is shown in Figures 9 and 10. Importantly, the SOP strives for proactive prevention and mitigation of problems. Monitoring will be conducted during daylight hours when conditions are safe for workers. For Phase 2 of the Bay-Goose dike construction, the causeway will be constructed during the winter and the dike in summer. The SOPs for monitoring and management of total suspended solids during ice-up conditions will be different than for summer conditions. Consequently, the two types of SOPs are detailed below. All monitoring results will be included in the Monthly Monitoring Program Summary Report.

SOP for Winter Construction of the Causeway of the Bay-Goose Dike (Phase 2)

The SOP contains the following key elements:

1. Given the slow pace of deposition, routine TSS and turbidity monitoring will be done once per day (weather/logistics permitting). Monitoring will be conducted through a hole in the ice at the monitoring locations shown in Figure 7. Each monitoring event will measure TSS/turbidity at one or more established stations. TSS will be sampled weekly at all monitoring stations at the maximum value.

2. Given that no turbidity curtain can be installed, the TSS trigger levels will be conservative. If during construction of the causeway, the TSS concentration (or turbidity as a surrogate) in a single sample exceeds 50% of the Short Term Maximum (after September 1), 25 ppm, the construction front will be moved to the other end of the causeway while the TSS settles at the original construction area. Construction will continue at the original construction area as soon as AEM has demonstrated that TSS levels are within 50% of the limit. In addition, an observation of the causeway construction sequence will be completed daily to determine if the rock deposition method is being conducted according to specifications; corrective actions will be taken if necessary.

3. If 50% of the 25 ppm trigger for TSS is exceeded on both ends of the causeway, construction will stop until AEM has demonstrated that TSS levels are within 50% of the limit.

4. Report all actions and findings to the regulators in a report no later than 7 days after the noted exceedance.

5. Sediment traps have been installed in the East Basin of Third Portage Lake for the winter. They will provide data on sedimentation effects, if any, from the winter construction. The traps will be removed and replaced prior to the start of the summer construction activities. The location of the sediment traps is shown on Figure 13.

SOP for Open Water Construction of the Bay-Goose Dike (Phase 2)

The SOP contains the following key elements:

1. Routine TSS monitoring will include two monitoring events per day (weather/logistics permitting), approximately every 8 hours during daylight. Each monitoring event will include (a) inspection of silt curtain integrity/deployment, and (b) measurement of TSS/turbidity at one or more established stations (see # 2 for more details). Figure 8 shows the locations of the routine TSS monitoring stations.

2. Stations for routine monitoring have been established 50 to 100 meters outside of the silt curtains. All stations will be sampled at every event.

3. If there is a silt curtain problem, it will be immediately fixed.

4. If TSS levels (or turbidity as a surrogate) in a single sample exceeds the Short Term Maximum, this will trigger a series of actions. First, the silt curtain will be inspected in more detail to identify any obvious problems. If there are no obvious problems, mitigative measures will be considered such as adjusting construction practices if possible (e.g., more careful placement of materials), modification of silt curtain deployment, or deployment of additional silt curtains. As an additional safeguard, visual inspections of the silt curtain and the turbidity of water will also be taken into account in construction decisions.

5. As monitoring continues, the 24-hour average TSS concentrations for each stations will be calculated. Should the 24-hour average exceed the Short Term Maximum at any sampling location, AEM will stop construction, advise the regulators and take the following actions:

    i. Verify the physical extent of the problem.

    ii. Verify that all mitigation measures are working according to best practices.

iii. Where deficiencies are noted, correct mitigation measures to established best practices and increase inspection frequency at areas of noted deficiencies for the rest of the construction period.

iv. Once best practices have been re-established and AEM has demonstrated TSS levels are within the limit, restart the construction activities.

v. Trigger the EAS.

vi. Report all actions and findings to the regulators in a report no later than 7 days after the noted exceedance.

6. If the 7-day moving average TSS concentration of at any sampling location exceeds the maximum monthly mean, this will trigger a series of actions:

   i. Advise regulators;

   ii. Verify the physical extent of the problem

   iii. Determine if the average has been heavily influenced by one or more events that have been addressed.

   iv. Verify the state of mitigation measures against best practice.

   v. Where deficiencies are noted, correct mitigation measures to established best practices and increase inspection frequency at areas of noted deficiencies for the rest of the construction period.

   vi. Report all actions and findings to the regulators in a report no later than 7 days after the noted triggering event.

7. Should the mean of the 30-day moving average for at any sampling location exceed the Maximum Monthly Mean, AEM will stop construction the regulators and take the following actions:

   i. Verify the physical extent of the problem.

   ii. Verify that all mitigation measures are working according to best practices.

   iii. Where deficiencies are noted, correct mitigation measures to established best practices and increase inspection frequency at areas of noted deficiencies for the rest of the construction period.

   iv. once best practices have been re-established and AEM has demonstrated TSS levels are within the limit, restart the construction activities.

   v. Trigger the EAS.

vi. Report all actions and findings to the regulators in a report no later than 7 days after the noted exceedance.

8. Follow-up monitoring of the benthic community will be conducted in the event of any exceedance. While it would be expected that any adverse effects from sediment deposition would not be permanent, plume deposition areas will be monitored in the year following construction (and the next year if significant adverse effects are found). A control-impact design will be used to test for differences in benthic community (e.g., abundance and diversity) between the deposition area and an area (similar depth and substrate characteristics) unaffected by construction activities.

9. High value habitat identified in close proximity to the construction areas will be subject to a higher level of protection (i.e., lower trigger values for TSS) than other areas during the fall spawning season; sediment deposition rates will also be monitored in the high value habitat areas using sediment traps. High value habitat areas will be determined prior to the start of construction. Results will be compared across monitoring points and to existing literature on effects of deposited sediment.

4.4 QA/QC FOR TURBIDITY MEASUREMENTS

The purpose of quality assurance and quality control (QA/QC) for turbidity measurements is to ensure that the field data collected are representative of the water sampled. Since turbidity will be used as a surrogate for Total Suspended Solids (TSS) there are two important objectives to ensure the turbidity measurements meet the QA/QC standard: ensure the turbidity meters are properly calibrated (i.e. their readings have high precision and accuracy) and collect TSS samples to complete a paired TSS-turbidity measurement comparison to the updated TSS-turbidity regression correlation. Furthermore, data quality is assured throughout the collection and analysis of samples using standard procedures, certified laboratories and by staffing with trained technicians.

The establishment of a site specific TSS-turbidity relationship at Meadowbank is based on rigorous statistical analysis of the turbidity data collected and paired with collected TSS water samples that were submitted to a certified laboratory (Azimuth, 2010). Data from Bay-goose dike construction provided the basis for the TSS-turbidity relationship using a McVan's Analite NEP160-3-05R portable turbidity meter/logger with a high sensitivity NEP260 90° probe. Accordingly the most updated TSS-turbidity regression correlation for dike construction monitoring is based on TSS being measured in a certified laboratory in mg/L and turbidity being measured in NTUs in the field using an Analite NEP 160 meter (Azimuth, 2010).

4.4.1 Turbidity Meter Calibration

To meet these objectives, turbidity will be measured using a McVan's Analite NEP160-3-05R portable turbidity meter/logger with a high sensitivity NEP260 90° probe. The meter will be calibrated and properly maintained following the manufacturers instructions. Turbidity meters will be calibrated before each sampling event (i.e. daily, in most cases), using the manufactured specified calibration solution.

4.4.2 Paired Turbidity-TSS Comparison to Established Turbidity-TSS Correlation

Weekly samples will be submitted for TSS analysis to an accredited laboratory. These laboratory TSS results will be paired with the field turbidity data and statistically compared (i.e. using ANCOVA) to the TSS-turbidity correlation regression to ensure that the turbidity data are representative of the current dike construction TSS inputs. The TSS sampling will follow a standard QA/QC program which is designed to evaluate sample variability and sample homogeneity; whereby duplicates are taken for 10% of the samples. Duplicate results will be assessed using the Relative Percent Difference (RPD); an RPD of 50% for TSS concentrations that exceed 10x the MDL is considered acceptable.

Together, the calibration and maintenance of the Analite NEP 160, the QA/QC for TSS sample analysis and a paired TSS-turbidity measurement comparison to the updated TSS-turbidity regression correlation will provide confidence that the turbidity measurements in the field are meeting actual TSS concentrations.

SECTION 5 • WATER QUALITY AND LAKE LEVEL MONITORING AND MANAGEMENT PLAN FOR DEWATERING

5.1 WATER QUALITY MONITORING AND MANAGEMENT DURING DEWATERING ACTIVITIES

During dewatering of the northwest arm of Second Portage Lake and Whale Tail Lake (North Basin), there is potential for sediments to become suspended as exposed substrates slump. Suspended sediments could then enter the water pipe(s) and be discharged to Third Portage Lake and/or Second Portage Lake and Mammoth Lake and/or Whale Tail Lake (South Basin). In addition, the discharge itself could disturb the bottom sediments in the lakes and lead to increased levels of suspended sediments. The following plans will mitigate against possible problems with suspended sediments and other key parameters (i.e., pH and aluminum) during dewatering:

- Intake pipe(s) will be located at a sufficient distance from shore (minimum 10 meters) and, to the extent possible, in areas with highest water depth. As dewatering progresses, intakes can only be located in deep basins.

- The discharge will be located in areas of Third Portage Lake and Second Portage Lake where there is deep, low-value habitat.

Monitoring during dewatering will be primarily focused at the water intake pumps or at the outlets of the water treatment plant, but will also include the receiving environment of Third Portage Lake and/or Second Portage Lake, and Mammoth Lake and/or Whale Tail Lake (South Basin). Unlike monitoring during dike construction, where turbidity was used solely as a real-time surrogate for estimating TSS (see Section 4), turbidity measurements will be used two- fold: as a surrogate for TSS (using an established site-specific relationship) and directly as an indicator of water clarity.

In the summer of 2016, Agnico Eagle plans to dewater Phaser Lake to allow for mining activities to occur in Phaser and BB Phaser pits. During dewatering activities, there is potential for sediments to become suspended as exposed substrates slump. Suspended sediments could then enter the water pipe(s) and be discharged to Wally Lake. In addition, the discharge itself could disturb the bottom sediments in the lakes and lead to increased levels of suspended sediments. The following plans will mitigate against possible problems with suspended sediments and other key parameters (i.e., pH and aluminum) during dewatering:

- Intake pipe(s) will be located at a sufficient distance from shore (minimum 10 meters) and, to the extent possible, in areas with highest water depth.

- The discharge will be located in areas of Wally Lake where there is deep, low-value habitat.

Monitoring during dewatering will be primarily focused at the water intake pumps or at the outlets of the water treatment plant, but will also include the receiving environment of Wally Lake. Unlike monitoring during dike construction, where turbidity was used solely as a real-time surrogate for estimating TSS (see Section 4), turbidity measurements will be used two-fold: as a surrogate for TSS (using an established site-specific relationship) and directly as an indicator of water clarity.

5.1.1 Dewatering Location

Two locations may be used to dewater the northwest arm of Second Portage Lake (see Figure 11). The first location is from the main basin of Second Portage Arm; this water will be discharged to Third Portage Lake. At this location two Water Treatment Plants (WTP) are installed to treat the discharge water if needed. The second location is from the south basin of Second Portage Arm, west of the East Dike; this water will be discharged to Second Portage Lake (on the east side of the dike). No WTP is installed at this location.

The WTP will be used when the water quality monitoring from the northwest arm of Second Portage Lake indicates the water does not meet the license criteria. The WTP will be bypassed when the water quality monitoring indicates the license criteria are being met; in this event water will be discharged directly to Third Portage and Second Portage Lakes.

Three locations will be used to dewater Phaser Lake (see Figure 1a). First of all, pumping will be conducted at location 1 to dewater basin 1. When the water level will reach elevation 138m, basins 2 and 3 will be separated from basin 1. Water intake will then be transferred to location 2 and pumping will continue in basin 2. At elevation 137.4m, basins 2 and 3 will be separated. Dewatering will finally be conducted at location 3 to complete dewatering of basin 3.

Water will be discharged to the Vault Attenuation Pond (Figure 2b). At this location a Water Treatment Plant (WTP) is installed to treat the water if needed. The WTP will be used when the water quality monitoring from Phaser Lake indicates the water does not meet the license criteria. The WTP will be bypassed when the water quality monitoring indicates the license criteria are being met; in this event water will be discharged directly to Wally Lake.

Figure 1a. Water intake locations for Phaser Lake Dewatering

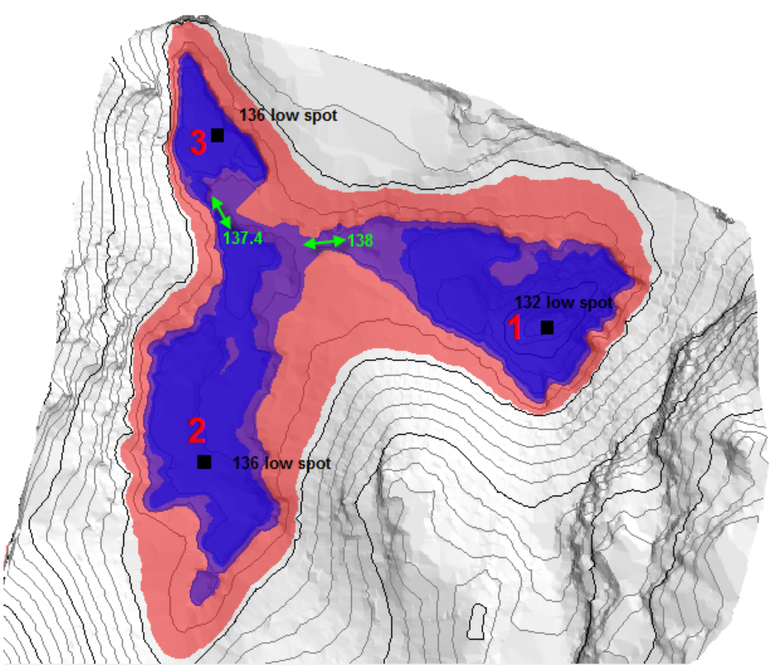
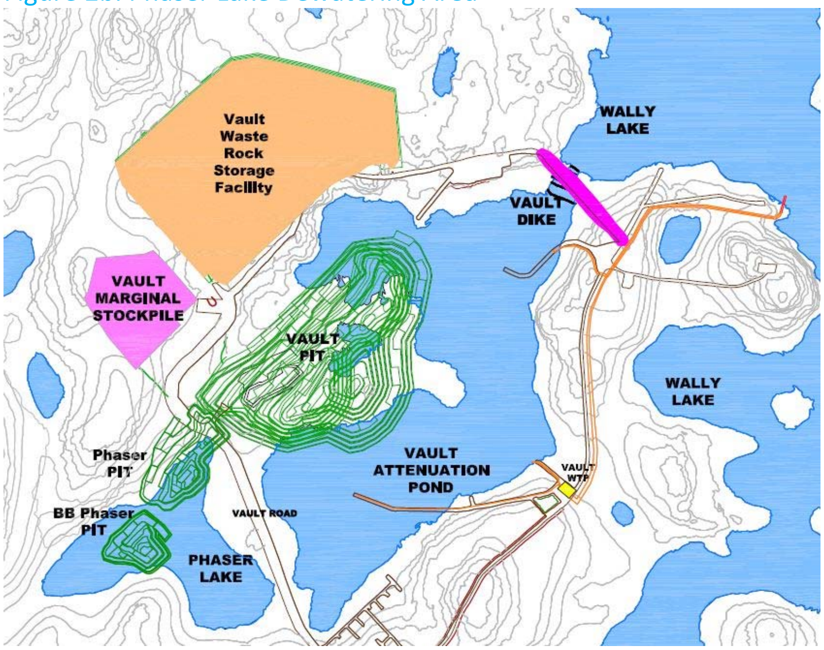


Figure 2b. Phaser Lake Dewatering Area



Two locations may be used to dewater Whale Tail Lake (North Basin). The first location will be Whale Tail Lake (South Basin) which will receive the first approximately 66% of the water volume (if it meets discharge criteria). The remaining 34% will be pumped to the water treatment plant (WTP) and then discharged to Mammoth Lake.

The WTP will be used when the water quality monitoring from Whale Tail Lake (North Basin) indicates the water does not meet license criteria. The WTP will be bypassed when the water quality monitoring indicates the license criteria are being met; in this event water will be discharged directly to Whale Tail Lake (South Basin).

5.1.2 Standard Operating Procedure for Monitoring And Management During Dewatering

The Standard Operating Procedure (SOP) for monitoring and management of suspended sediments and other key parameters during dewatering is shown in Figure 12 (version 4, March, 2010). Importantly, the SOP strives for proactive prevention and mitigation of problems. Monitoring will be conducted under direction of AEM's environmental supervisor on-site. All monitoring results will be included in the Monthly Monitoring Program Summary Report.

The SOP contains the following key elements:

1. Routine monitoring of TSS/turbidity at the WTP water outlets (when the WTP is in operation) or at the water intake pump(s) (when the WTP is not in use) will be conducted at a minimum of once each day; in addition, a visual inspection of the impounded area for sediment slumps and/or resulting plumes will be completed.
2. Water samples will be collected by opening a valve at the outlet of the WTP or at the water intake pump. Water samples from each monitoring station will be collected every day and sent to an accredited laboratory for Turbidity and TSS. In addition, a turbidity

reading will be taken in the field using a YSI turbidity meter.

3. Monitoring for other required parameters (i.e., pH and aluminum) will be completed once per week at the outlet of the WTP or at the water intake pump; water samples will be collected in the same manner as described above for the turbidity sample.

4. TSS/turbidity will be measured in the receiving environment on a weekly basis; monitoring will take place approximately 30 - 100 meters from end-of-pipe, dependent on stable ice conditions during ice-up.

5. If parameter levels in a single sample from the WTP outlet or intake pump exceed the STM, this will trigger a series of actions. First, visual inspections will try to identify any obvious source of slumping on the lake edges to determine if the source of sediment is likely to be short-term or more continuous. Second, mitigative measures will be considered, such as movement of the intake pipe(s) and/or putting the WTP in recirculation mode.

6. If the moving 24-hour average turbidity value exceeds the STM, then dewatering will shut down or the WTP will be put in recirculation mode while (a) mitigative measures are considered, (b) monitoring continues, (c) weather shifts (if weather is a factor), and (d) AEM provides an appropriate course of action to regulators. Dewatering will resume once the conditions that led to the elevated turbidity levels have been addressed.

7. If the 7-day moving average TSS or turbidity concentration at the WTP outlet or intake pump exceeds the MMM, this will trigger a series of actions. First, visual inspections will try to identify any obvious source of slumping on the lake edges to determine if the source of sediment is likely to be short-term or more continuous. Second, mitigative measures will be considered, such as movement of the intake pipe(s) and/or putting the WTP in recirculation mode.
8. If the 30-day moving average Maximum Monthly Mean is exceeded, then dewatering will shut down or the WTP will be put in recirculation mode while (a) mitigative measures are considered, (b) monitoring continues, and (c) AEM provides an appropriate course of action to regulators. Dewatering will resume once the conditions that led to the elevated TSS levels have been addressed.

5.2 LAKE LEVEL MONITORING DURING DEWATERING ACTIVITIES

In addition to the monitoring and management of suspended sediments, a hydraulic monitoring plan has been developed to monitor the following components:

- Water levels in Third Portage Lake and Second Portage Lake, Mammoth Lake and Whale Tail Lake (South Basin) will be monitored on a regular basis while dewatering activities are occurring;

- Water levels in Wally Lake will be monitored on a weekly basis while dewatering activities are occurring; and

- Outlet erosion inspections to monitor outlet stability, including potential erosion and/or ice damming within the outlets.

Third Portage Lake, Second Potage Lake, Wally Lake, Mammoth Lake, and Whale Tail Lake (South Basin) water levels will be surveyed at a location of sufficient distance from the outlets to limit potential lake level drawdown effects. Lake water levels will be monitored weekly during the freshet and ice-free period, and weekly during the ice-up period, dependent of the ice conditions and worker safety.

The central and eastern outlets and the outlet of the raised Whale Tail Lake (South Basin) and Mammoth Lake, will be visually inspected to confirm that no significant erosion of the channel bed or channel banks, or ice damming has occurred. Significant ice damming observed within the outlets will be removed as soon as possible in order to minimize potential reductions in channel capacity. The regular inspection program will occur during the freshet and ice free period at a minimum of once every two weeks.

SECTION 6 • REFERENCES

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Appendix A

TSS – Turbidity Relationship

Technical Memorandum:

Proposed Revision to the TSS-Turbidity Relationship Used of Dike Construction Monitoring and Dewatering (untreated water) Monitoring

February 5, 2010

Technical Memorandum

Date: February 5, 2010

To: Stéphane Robert (Agnico-Eagle Mines Ltd.)

From: Ryan Hill and Gary Mann (Azimuth Consulting Group Inc.)

RE: **Proposed revision to the TSS-turbidity relationship used for dike construction monitoring and dewatering (untreated water) monitoring**

Field measurements of turbidity are used as a surrogate for TSS during dike construction monitoring and dewatering monitoring. Prior to 2009, a limited data set was available, and was used to develop a single relationship that was applied to dike construction monitoring and to dewatering (of untreated water[1]) monitoring. Intensive sampling during 2009 has now provided a data set that could support development of distinct relationships for dike construction monitoring and dewatering monitoring – the relationships should be distinct in theory because conditions during dewatering are fundamentally different from conditions during dike construction.

Dike Construction Monitoring – The new proposed TSS-turbidity relationship for dike construction monitoring is:

$$\log_{10}(\text{turbidity}) = 0.62196 + (0.95619 * \log_{10}(\text{TSS})),$$

where TSS is measured in the lab in mg/L and turbidity is measured in NTUs in the field using an Analite NEP 160 meter[2].

This relationship is based on data from targeted TSS samples collected during construction of the Bay-Goose dike in 2009, as well as other relevant data collected in 2009 in Second and Third Portage Lakes (sampling associated with the AEMP, the Effects Assessment for the Bay-Goose dike construction, and weekly dike construction water quality). The 2008 data associated with the East Dike were not included because (a) the 2009 data set was very large and covered a range of conditions, and could therefore support derivation of a rigorous relationship without additional data; (b) there was some *a priori* expectation of differences between the two data sets because the nature of construction material used and the placement methods may have changed slightly in

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[1] All discussions herein regarding dewatering refer to untreated water and are not applicable to monitoring of treated water.

[2] Different turbidity probes often differ systematically in their NTU readings. Results from other meters could only be used with the reported TSS-turbidity relationships if they are first converted to Analite NEP 160 equivalence (i.e., by deriving the relationship between observed NTU values for both meter types).

2009; and (c) statistical analysis confirmed a significant difference between the 2008 and 2009 data sets.

Dewatering Monitoring (see footnote 1) – The new proposed TSS-turbidity relationship for dewatering monitoring is:

$$\log_{10}(\text{turbidity}) = 0.53276 + (0.99276 * \log_{10}(\text{TSS})),$$

where TSS is measured in the lab in mg/L and turbidity is measured in NTUs in the field using an Analite NEP 160 meter[1].

This is based on data from 2009 dewatering of the impounded arm of Second Portage Lake, as well as all of the data related to dike construction from 2008 and 2009. The dewatering data alone are insufficient because (a) they cover only a very limited range of turbidity and TSS values, and cannot be easily extrapolated to higher values; and (b) the data were collected during a narrow time window and their applicability to dewatering conditions in general is unknown. In future it may be possible to exclude the dike construction monitoring data and use only dewatering data, if additional dewatering data are collected across a higher range of turbidity values and at different times of year.

Details regarding the selection of data sets and statistical methods are provided in **Appendix A**.

APPENDIX A – DERIVATION OF TSS-TURBIDITY RELATIONSHIPS FOR DIKE CONSTRUCTION MONITORING AND DEWATERING MONITORING

1. INTRODUCTION

Turbidity is measured in the field during dike construction as a surrogate for total suspended solids (TSS). It is well known that the relationship between turbidity and TSS is site-specific, in part because of site-specific variation in the size, shape and other properties of the suspended particulates.

A TSS-turbidity relationship for dike construction monitoring and dewatering monitoring was developed prior to construction of the East Dike in 2008, based on limited available data. As additional and more relevant data became available, the relationship was updated during construction of the East Dike. The updated relationship was applied to construction of the Bay-Goose dike in 2009.

During 2009, a significant number of paired TSS-turbidity samples were collected, including targeted sampling as well as sampling conducted as part of routine weekly water quality monitoring, the AEMP, and the Effects Assessment Strategy.

This technical appendix develops an updated TSS-turbidity relationship that could be used for dike construction monitoring in 2010, and a second TSS-turbidity relationship that is more appropriate for dewatering monitoring (for untreated water only). **Section 2** reviews the general statistical framework used to analyze the TSS-turbidity relationship. **Section 3** reviews and selects the data to be used for each analysis. **Section 4** presents the new TSS-turbidity relationships.

2. GENERAL STATISTICAL FRAMEWORK

Federal guidance on the use of turbidity as a surrogate for TSS (CCME 1999) provides an example relationship, which has log-turbidity (in NTUs) as a function of log-TSS (in mg/L). The 2008 Meadowbank data set was well described by a similar relationship (i.e., log data), so we used the same type of simple linear regression at that time. In theory, it is suspended solids that cause turbidity, not the other way around, so it makes sense to use TSS as the independent (x) variable. On the other hand, we are measuring turbidity and using it to estimate TSS, so argument could be made to make turbidity the x-variable. For this analysis we use TSS as the x-variable, consistent with the example provided by CCME (1999).

One assumption of linear regression is that data points are independent. In our case, the data points come from distinct data sets. Since the nature of the TSS-turbidity relationship may vary somewhat among these data sets, the assumption of independence may be violated. In such cases, it may be preferable to either exclude certain data sets, or to incorporate multiple data sets using a mixed-effect modeling approach, or to combine multiple data sets in spite of the violation of independence. We provide rationale for our approaches in this regard in **Section 3**.

Finally, all analyses are conducted by excluding data points where TSS concentrations were below laboratory method detection limits (DLs). We had included those data in earlier analyses (using ½ of the DL) due to the limited number of data points. Now that we have more data, we exclude any data points where measured TSS was below laboratory detection limits. In a case where regression is based on log-values, the low values at or below detection limits have considerable influence on the predicted relationship. From a regulatory perspective, the range of TSS values that we need to characterize accurately does not include the low values around the detection limits, and error at those values has relatively little impact on estimated long-term average TSS levels. It would therefore be preferable to drop some of the data at low TSS concentrations (below DLs) in order to avoid bias at higher, more relevant TSS concentrations.

All statistical analyses reported in this technical memo were implemented using R software version 2.9.0, using methods outlined in Dalgaard (2008) and Venables and Ripley (2002).

3. REVIEW AND SELECTION OF DATA

3.1. General Considerations

This section reviews the available data sets and their relevance to dike construction. There are a few considerations that apply to all of the data sets:

1. *Probe Type* – All of the data sets were generated using the same model of turbidity probe, the Analite NEP 160. It is important that the data are either based on the same probe, or are corrected for differences among probes.
2. *Spatial Bias* – All of the data collected in Second and Third Portage Lakes during dike construction activities share a common limitation which can be expected to bias any derived TSS-turbidity relationship. Specifically, the data points with high TSS / high turbidity tend to be collected near the construction zones (including inside the turbidity barriers) where we expect proportionately more large suspended particles, while the data points with low TSS / low turbidity tend to be collected further away from the construction zone where we expect fewer large suspended particles (because they would have settled out). Particle size influences any TSS-turbidity relationship – TSS is more affected by heavy particles (e.g., sand), while turbidity is more affected by the presence of lots of small particles (e.g., clay)[3]. Therefore, any TSS-turbidity relationship that is derived has an inherent spatial element – the relationship works well if applied to high turbidity values near the construction zone and to low turbidity values away from the

[3] In addition, according to the EPA (1993), coarse particles that settle out rapidly are a source of interference for measurements of turbidity by nephelometry.

construction zone, but the opposite may not be true. Fortunately, the usual pattern is to see high TSS levels near the construction zone and lower TSS levels at a distance.

3. *Temporal Bias* – In addition, since large particles settle out over time, we would also expect data collected several weeks or months after the end of construction activities to consist of proportionately fewer large particles. Therefore, given the effect of particle size on the TSS-turbidity relationship, the relationship during construction would not necessarily be the same as the relationship long after construction, particularly at locations close to the construction zones.

3.2. Description of Available Data Sets

The available data sets are summarized as follows.

East Dike 2008 – These data were collected during the early part of east dike construction in 2008. Many of the samples were taken from inside the turbidity barriers in order to characterize the high end of the TSS-turbidity relationship. Data for the East Dike are shown in **Table 1**.

Bay-Goose Dike 2009 – These data were collected during construction of the Bay-Goose dike in 2009. The Bay-Goose data were collected from all around the dike, both inside and outside the curtains, as well as far out into Third and Second Portage Lakes. Collection of the Bay-Goose data spanned a long time frame, and included many samples of turbid water in areas away from the construction zone, after a major wind event dispersed turbid water beyond the construction zone. Data for the Bay-Goose Dike are also shown in **Table 1**.

Weekly Dike Construction Monitoring Data – During construction of the East Dike in 2008 and the Bay-Goose Dike in 2009, weekly water quality monitoring was conducted at stations close to and away from the construction zone. When vertical profiles existed in the water column, various depths were sometimes targeted. The data include collection of water samples (including for TSS) at a specified depth, plus vertical profiles of turbidity. The turbidity measured at the closest depth interval to the depth of water samples can be paired with the TSS data. Since there may be a time delay in the field (e.g., a couple of minutes) between evaluation of the turbidity profile and collection of the water samples, we can expect slightly more imprecision with these data than with the targeted TSS sampling, but there is no reason to expect bias. The weekly dike construction monitoring data are shown in **Table 2**.

AEMP Water Quality Data – AEMP data are similar to the weekly dike construction monitoring data, involving collection of water samples (including TSS) and vertical profiles of turbidity. Most of the AEMP data are not useful for a TSS-turbidity relationship since they occur at sites not affected by dike construction, and where TSS is often below detection limits. However, samples taken in Second Portage Lake during dike construction activities in 2008/2009, as well as samples taken in the east basin of Third Portage Lake in 2009 can be used. The relevant AEMP data are shown in **Table 2**.

EAS Water Quality Data – As part of the assessment of potential ecological effects of dike construction, limited water quality data have been collected in both 2008 and 2009 in Second

Portage Lake and the east basin of Third Portage Lake. These data are similar to the weekly dike construction monitoring data and the AEMP data described above. The relevant EAS data are shown in **Table 2**.

Dewatering Data 2009 – Dewatering of the impoundment in Second Portage Lake began in winter/spring 2009. Starting in the spring of 2009, data collection included field turbidity, lab turbidity and lab TSS. Field turbidity measurements were taken incorrectly[4] for the first few months, but methodology was corrected and field data on or after June 20th can be used. In addition, there is a strong correlation between field and lab turbidity, so lab data can be used to predict field turbidity for the earlier period June 9-19. Dewatering data are shown in **Table 3**, with the relationship between field and lab turbidity explained in the footnote. Only those records with simultaneous water collection for field and lab were used (i.e., the water samples for both were collected at the same time). Dewatering data collected over the winter (i.e., earlier in 2009; data not shown) had consistently low turbidity, generally in the range of 2 to 5 NTU. This indicates that most of the turbidity associated with dike construction had settled out by the winter. The higher turbidity over the June-July period shown in **Table 3** is therefore reflective of newly suspended sediments – one potential explanation is erosion of newly exposed banks during freshet, but other explanations are also possible.

AWPAR and Quarry Data – The AWPAR and Quarry data collected since 2007 come from locations around Meadowbank camp and along the road between Meadowbank camp and Baker Lake. The data primarily characterize sediment introduced from quarried construction material contacting water (i.e., either runoff flowing through the road and picking up fines or material placed within stream channels), or ponded water that occurs in quarries or other areas. The quarried construction material may be similar to material used for dike construction. However, the setting for the turbid water is not the same as a lake, occurring instead in ponded water or in streams or runoff areas. In addition, the effect of erosion or resuspension of lake bottom materials would not be captured at all by the AWPAR and Quarry data. The AWPAR and Quarry data are not shown, because they are not relevant to either dike construction or dewatering; there are sufficient other data to allow us to ignore the AWPAR and Quarry data.

3.3. Data Selection for Dike Construction

For the TSS-turbidity relationship for dike construction monitoring, it is appropriate to consider all data except for the dewatering data and the AWPAR & Quarry data (i.e., we initially consider all data in **Table 1** and **Table 2**). These data sets are inherently different from data collected in the lakes during dike construction.

The remaining data sets are all directly relevant to dike construction. The only variable which could potentially differentiate among the data sets is the year (2008 vs. 2009). For example, if construction materials used to build the two dikes were different, or if placement methods changed, the TSS-turbidity relationships may also be different.

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[4] Field crews stirred the water as they measured, which creates air bubbles that interfere with probe function.

The 2008 and 2009 data relevant to dike construction are shown together in **Figure 1** (excluding data points below lab detection limits as discussed above). Log values are used to spread out the data and facilitate visual interpretation. Due to differences in detection limits between 2008 and 2009, the earlier data set lacks values at the low end.

Next, we considered alternative data transformation that would facilitate linear modeling. We evaluated various log and root transformations for both TSS and turbidity (log base 10, natural log, square root, fourth root). In each case we (a) evaluated how effectively the transformation spread the data across each axis, (b) evaluated apparent normality based on plots of the residuals, and (c) tested for normality of the residuals using a Shapiro-Wilks normality test. Our judgment was that the log base 10 transformation (for both variables) performed best overall.

The log-log data shown in **Figure 1** appear to be linear over most of the range, except at low TSS values. Given the log-scale, a log value of 0.50 on the x-axis corresponds to TSS of 3.16 mg/L, so all data to the left of log-TSS of 0.50 are close to detection limits (the detection limit was 3 mg/L for most of the 2008 data, and 1 mg/L for most of the 2009 data). It is not surprising that there is considerably more variability about the relationship at these low values, given their proximity to detection limits (in fact, there hardly appears to be any slope to the data in that range). Rather than try to fit a non-linear relationship to the data, we dropped all of the data points where TSS was less than 3.16 mg/L. Data below that range are unimportant from a decision-making perspective, since the lowest management threshold is at 6 mg/L, and long-term average estimates of TSS levels are not strongly affected by imprecision in low numbers. This cropping of the data set allows more rigorous application of a linear model across the data range from 3.16 mg/L upwards, which should result in better characterization of the relationship at higher TSS levels.

We also deleted one obvious outlier in the 2009 data set, shown in the figure at a log-TSS of 1.15 and log-turbidity of 0.66. This data point is associated with sample BG-TSS-36. The lab-measured turbidity was more than 5-fold higher than field-measured turbidity, suggesting a measurement error in the field.

Finally, we tested for differences between the 2008 and 2009 data sets using Analysis of Covariance. Analysis of covariance indicated no difference in slopes between the two data sets ($p>0.10$), but there was a significant different in the intercepts ($p<0.01$). Visually, it does appear that the 2008 data are shifted slightly down relative to the 2009 data (keeping in mind that data below log TSS of 0.5 are not included). This could be explained by a difference in construction materials or construction practices between 2008 and 2009. Given that future dike construction monitoring is more likely to use materials and practices consistent with 2009 and not 2008, it is appropriate to drop the 2008 data.

In summary, the 2009 data in Second and Third Portage Lakes at TSS values above 3.16 mg/L were retained for derivation of the TSS-turbidity relationship for dike construction monitoring, with the exception of one outlier that was deleted.

3.4. Data Selection for Dewatering

The dewatering data (**Table 3 and Figure 2**) collected in the impoundment of Second Portage Lake are the only data that we know for certain are directly relevant to dewatering monitoring. However, the data have several limitations. First, they cover a narrow range of turbidity and TSS values, so any relationship derived solely on the dewatering data could not easily be extrapolated to higher turbidity levels. Second, they were collected during a relatively narrow time window (June-July 2009) so we do not know how applicable the data would be to the full range of dewatering conditions that may exist over time. Overall, our understanding of the applicability of the data to the full range of dewatering conditions is limited.

For these two reasons, it is appropriate to consider using the dike construction data to supplement the dewatering data. The dike construction data are somewhat relevant to dewatering since some residual East Dike construction material can be expected to be suspended in the impoundment, and because construction of other smaller dikes in the impoundment may overlap in time with dewatering. **Figure 3** shows the dewatering data together with the dike construction data. If we ignore data near the detection limits (i.e., data below log-TSS of 0.5, in accordance with the analysis in **Section 3.3**), the dewatering data appear relatively similar to the dike construction data over the narrow range of overlap. Nevertheless, analysis of covariance of the two data sets (ignoring the data below log-TSS of 0.5, and deleting the outlier point BG-TSS-36 as discussed in **Section 3.3**) indicates significant differences in slope and intercept ($p<0.01$). In spite of the results of the analysis of covariance, we retain all of the data because of the limitations in the dewatering data.

In summary, all dike construction and dewatering data at TSS values above 3.16 mg/L were retained for derivation of the TSS-turbidity relationship for dewatering monitoring (except for one outlier which was deleted). In future it may be possible to exclude the dike construction monitoring data if additional dewatering data are collected across a higher range of turbidity values and across longer time periods relevant to dewatering.

4. DERIVATION OF NEW RELATIONSHIPS

4.1. Dike Construction

Results of linear regression are shown in **Figure 4**. The precise model is:

$$\log_{10}(\text{turbidity}) = 0.62196 + (0.95619 * \log_{10}(\text{TSS})) \quad [p<0.001; \text{r2-adj} = 0.81]$$

where turbidity is measured in NTUs in the field using an Analite NEP 160 meter, and TSS is measured in the lab as mg/L.

4.2. Dewatering

Results of linear regression are shown in **Figure 5**. The precise model is:

$\log_{10}(\text{turbidity}) = 0.53276 + (0.99276 * \log_{10}(\text{TSS}))$ [$p<0.001$; r2-adj = 0.85]

where turbidity is measured in NTUs in the field using an Analite NEP 160 meter, and TSS is measured in the lab as mg/L.

5. REFERENCES

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Table 1. Targeted Turbidity-TSS Data for East Dike and Bay-Goose North Dike

2008 East Dike Data

Sample ID	Date	Turbidity (NTU)	TSS (mg/L)
DC1	July/Aug 08	17.9	5.8
DC10	July/Aug 08	230	89.8
DC11	July/Aug 08	157	59.8
DC12	July/Aug 08	223	88.4
DC13	July/Aug 08	430	181
DC14	July/Aug 08	178	69.1
DC15	July/Aug 08	59	22.4
DC16	July/Aug 08	66	19.8
DC17	July/Aug 08	5.3	<3
DC18	July/Aug 08	2.7	<3
DC19	July/Aug 08	3.3	<3
DC2	July/Aug 08	8.3	3.8
DC20	July/Aug 08	1.3	<3
DC21	July/Aug 08	4.2	<3
DC22	July/Aug 08	10.1	4.4
DC23	July/Aug 08	10.9	4.4
DC24	July/Aug 08	21	9.8
DC25	July/Aug 08	12.6	3.8
DC26	July/Aug 08	14	4.4
DC27	July/Aug 08	13.2	4.4
DC28	July/Aug 08	8.5	3.8
DC29	July/Aug 08	8.3	<3
DC3	July/Aug 08	7.5	4.4
DC30	July/Aug 08	7.6	<3
DC31	July/Aug 08	7.9	<3
DC32	July/Aug 08	8.8	3.1
DC33	July/Aug 08	20	7.8
DC34	July/Aug 08	11.9	3.8
DC4	July/Aug 08	36.7	15.8
DC5	July/Aug 08	41.5	15.8
DC6	July/Aug 08	53.5	19.1
DC7	July/Aug 08	32	11.8
DC8	July/Aug 08	19.5	<3
DC9	July/Aug 08	36.5	7.8

2009 Bay-Goose Dike Data

Sample ID	Date	Turbidity (NTU)	TSS (mg/L)
BG-TSS-1	30-Jul-09	95.9	35
BG-TSS-2	30-Jul-09	103.4	31
BG-TSS-3	30-Jul-09	49.5	12
BG-TSS-4	30-Jul-09	123.5	44
BG-TSS-5	30-Jul-09	160.4	53
BG-TSS-6	30-Jul-09	5.4	1
BG-TSS-7	30-Jul-09	1.3	<1
BG-TSS-8	30-Jul-09	12.4	2
BG-TSS-9	30-Jul-09	2.7	<1
BG-TSS-10	30-Jul-09	38.2	9
BG-TSS-11	1-Aug-09	56.1	14
BG-TSS-12	1-Aug-09	39.6	12
BG-TSS-13	1-Aug-09	17.4	12
BG-TSS-14	1-Aug-09	3.3	<1
BG-TSS-15	1-Aug-09	1.7	<1
BG-TSS-16	1-Aug-09	14.2	4
BG-TSS-17	1-Aug-09	58.0	26
BG-TSS-18	1-Aug-09	40.6	8
BG-TSS-19	1-Aug-09	38.1	10
BG-TSS-20	1-Aug-09	38.6	9
BG-TSS-21	3-Aug-09	20.4	5
BG-TSS-22	3-Aug-09	5.1	3
BG-TSS-23	3-Aug-09	35.4	8
BG-TSS-24	3-Aug-09	17.3	<1
BG-TSS-25	3-Aug-09	10.3	2
BG-TSS-26	3-Aug-09	71.5	18
BG-TSS-27	3-Aug-09	68.3	18
BG-TSS-28	3-Aug-09	65.9	19
BG-TSS-29	3-Aug-09	60.5	15
BG-TSS-30	3-Aug-09	69.5	16
BG-TSS-31	8/9/2009	10.2	4
BG-TSS-32	8/9/2009	40.5	16
BG-TSS-33	8/9/2009	1.3	2
BG-TSS-34	8/9/2009	35.2	12
BG-TSS-35	8/9/2009	1.35	<1
BG-TSS-36	8/9/2009	4.55	14
BG-TSS-37	8/9/2009	43.8	10
BG-TSS-38	8/9/2009	61.1	19
BG-TSS-39	8/9/2009	52.9	12
BG-TSS-40	8/9/2009	50.2	16
BG-TSS-41	8/9/2009	59.1	15
BG-TSS-42	8/9/2009	62.2	20
BG-TSS-43	8/9/2009	31.2	10
BG-TSS-44	8/9/2009	57.0	14
BG-TSS-45	8/9/2009	35.9	7
BG-TSS-46	8/9/2009	62.7	16
BG-TSS-47	8/9/2009	40.5	14
BG-TSS-48	8/9/2009	56.9	12
BG-TSS-49	8/9/2009	34.9	12
BG-TSS-50	8/9/2009	61.5	16
BG-TSS-51	8/9/2009	30.0	8
BG-TSS-52	8/9/2009	31.7	9
BG-TSS-53	8/9/2009	40.3	10
BG-TSS-54	8/9/2009	40.1	10
BG-TSS-55	8/9/2009	30.0	7
BG-TSS-56	8/9/2009	34.4	8
BG-TSS-57	8/9/2009	33.2	10
BG-TSS-58	8/9/2009	39.9	8
BG-TSS-59	8/9/2009	38.3	6
BG-TSS-60	8/9/2009	37.0	10
BG-TSS-61	9/9/2009	102.1	26
BG-TSS-62	9/9/2009	69.4	12
BG-TSS-63	9/9/2009	89.9	32
BG-TSS-64	9/9/2009	52.9	11
BG-TSS-65	9/9/2009	51.0	15
BG-TSS-66	9/9/2009	14.3	2
BG-TSS-67	9/9/2009	9.9	<1
BG-TSS-68	9/9/2009	34.3	5
BG-TSS-69	9/9/2009	0.9	2
BG-TSS-70	9/9/2009	20.6	3
SP-1	9/12/2009	4.7	3
Outlet 1	9/12/2009	42.7	13
Outlet 2	9/12/2009	28.5	8
SP-10	9/12/2009	0.8	<1
BGE-5	9/12/2009	33.7	8
BGE-3	9/12/2009	34.9	8
BGW-2	9/12/2009	29.5	8
DUP	9/12/2009	29.5	8

Table 2. Additional Turbidity-TSS Data Collected During Construction of the East Dike (2008) and Bay-Goose North Dike (2009)

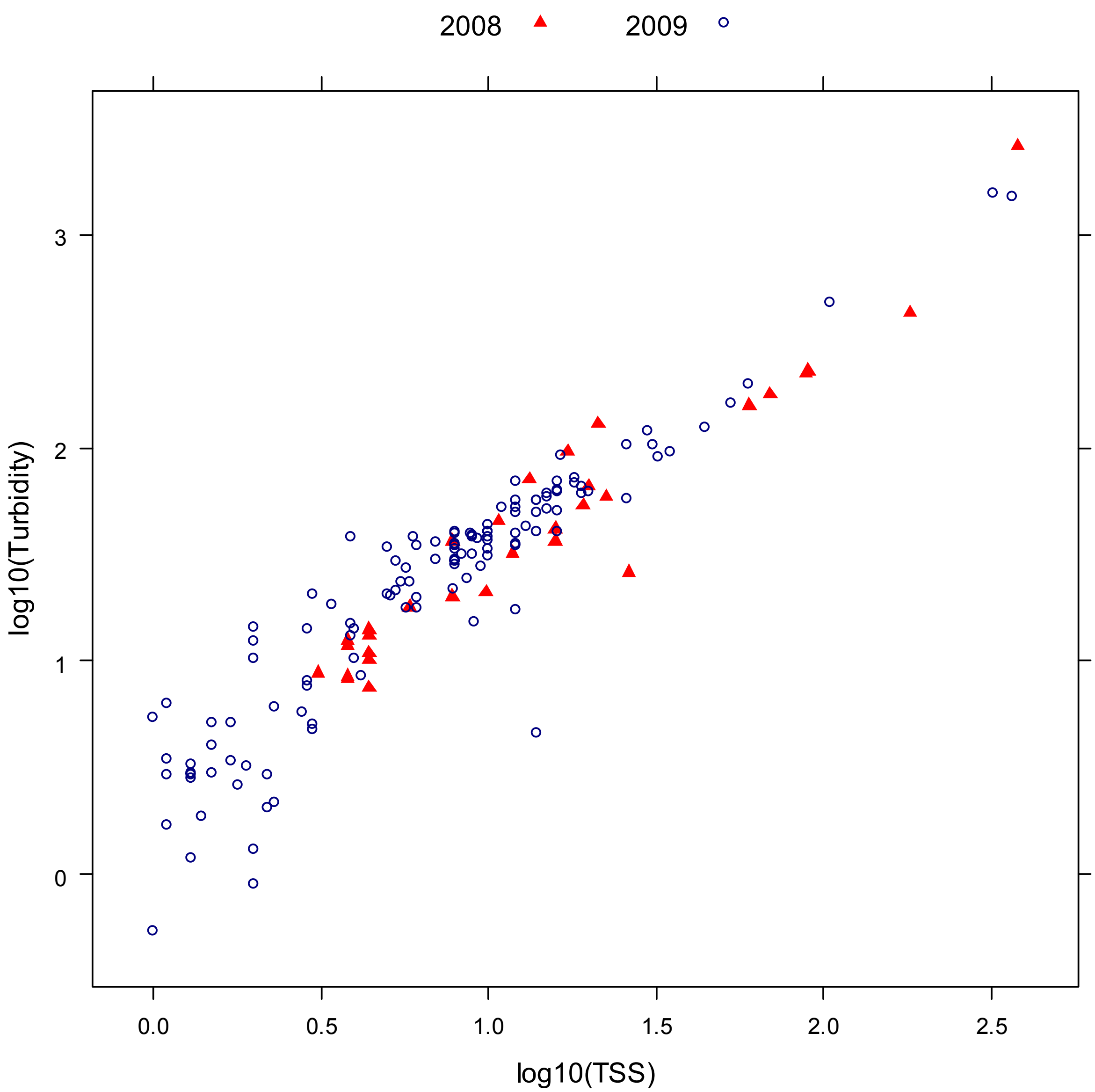
Program	Year	Date	Lake	Station ID/Rep	Field Turb (NTU)	Lab TSS (mg/L)	Lab Turb (NTU)
AEMP	2008	22-Aug-08	SPL	SP	45.5	11	NA
East Dike Construction Weekly Water Quality	2008	22-Aug-08	SPL	E214	96	17.2	NA
East Dike Construction Weekly Water Quality	2008	22-Aug-08	SPL	E214	2600	378	NA
East Dike Construction Weekly Water Quality	2008	22-Aug-08	SPL	A3	71	13.2	NA
East Dike Construction Weekly Water Quality	2008	22-Aug-08	SPL	A3	129	21.2	NA
East Dike Construction Weekly Water Quality	2008	12-Sep-08	SPL	SE2	26	26.2	NA
AEMP	2009	16-Aug-09	TPL	TPE-7	2.16	2.3	0.98
AEMP	2009	11-Sep-09	TPL	TPE-10	23.2	5.5	11
AEMP	2009	11-Sep-09	TPL	TPE-8	27.1	5.7	12.2
AEMP	2009	11-Sep-09	TPL	TPE-9	21.5	5.3	11.1
AEMP	2009	12-Aug-09	SPL	SP-7	0.54	1.00	0.52
AEMP	2009	15-Sep-09	SPL	SP-10	2.91	1.10	2.57
AEMP	2009	15-Sep-09	SPL	SP-8	2.80	1.30	2.15
Bay-Goose Dike Construction Weekly Water Quality	2009	31-Jul-09	TPL	DC-WQ-BGE1	1.2	1.3	0.76
Bay-Goose Dike Construction Weekly Water Quality	2009	31-Jul-09	TPL	DC-WQ-BGW1	17.8	5.7	10.3
Bay-Goose Dike Construction Weekly Water Quality	2009	31-Jul-09	TPL	DC-WQ-BGW2	17.7	6.1	8.54
Bay-Goose Dike Construction Weekly Water Quality	2009	31-Jul-09	TPL	DC-WQ-HVH4	1.71	1.1	1.2
Bay-Goose Dike Construction Weekly Water Quality	2009	08-Aug-09	TPL	DC-WQ-BGE1	8.47	4.2	3.13
Bay-Goose Dike Construction Weekly Water Quality	2009	08-Aug-09	TPL	DC-WQ-BGE3	18.3	3.4	4.22
Bay-Goose Dike Construction Weekly Water Quality	2009	08-Aug-09	TPL	DC-WQ-BGE5	1.85	1.4	1.66
Bay-Goose Dike Construction Weekly Water Quality	2009	08-Aug-09	TPL	DC-WQ-BGW2	5.78	2.8	2.16
Bay-Goose Dike Construction Weekly Water Quality	2009	08-Aug-09	TPL	DC-WQ-HVH2	2.04	2.2	1.36
Bay-Goose Dike Construction Weekly Water Quality	2009	08-Aug-09	TPL	DC-WQ-HVH4	2.92	2.2	1.71
Bay-Goose Dike Construction Weekly Water Quality	2009	16-Aug-09	TPL	DC-WQ-BGE1	14.2	2.9	8.83
Bay-Goose Dike Construction Weekly Water Quality	2009	16-Aug-09	TPL	DC-WQ-BGE3	6.03	2.3	5.8
Bay-Goose Dike Construction Weekly Water Quality	2009	16-Aug-09	TPL	DC-WQ-BGE5	4.05	1.5	3.32
Bay-Goose Dike Construction Weekly Water Quality	2009	16-Aug-09	TPL	DC-WQ-BGW3	3.49	1.1	3.75
Bay-Goose Dike Construction Weekly Water Quality	2009	16-Aug-09	TPL	DC-WQ-HVH2	3.4	1.7	3.46
Bay-Goose Dike Construction Weekly Water Quality	2009	16-Aug-09	TPL	DC-WQ-HVH4	5.11	1.7	3.93
Bay-Goose Dike Construction Weekly Water Quality	2009	21-Aug-09	TPL	DC-WQ-BGE2	1560	320	469
Bay-Goose Dike Construction Weekly Water Quality	2009	22-Aug-09	TPL	DC-WQ-BGE1	37.8	3.9	28
Bay-Goose Dike Construction Weekly Water Quality	2009	22-Aug-09	TPL	DC-WQ-BGW3	8.1	2.9	3.01
Bay-Goose Dike Construction Weekly Water Quality	2009	22-Aug-09	TPL	DC-WQ-HVH4	29.1	5.3	12.4
Bay-Goose Dike Construction Weekly Water Quality	2009	29-Aug-09	TPL	DC-WQ-BGE1	19.6	6.1	9.91
Bay-Goose Dike Construction Weekly Water Quality	2009	29-Aug-09	TPL	DC-WQ-BGE2	1511	367	260
Bay-Goose Dike Construction Weekly Water Quality	2009	29-Aug-09	TPL	DC-WQ-BGE3	200	59.5	86
Bay-Goose Dike Construction Weekly Water Quality	2009	29-Aug-09	TPL	DC-WQ-BGW2	480	105	206
Bay-Goose Dike Construction Weekly Water Quality	2009	29-Aug-09	TPL	DC-WQ-BGW3	6.3	1.1	3.7
Bay-Goose Dike Construction Weekly Water Quality	2009	29-Aug-09	TPL	DC-WQ-HVH4	14.9	3.9	6.3
Bay-Goose Dike Construction Weekly Water Quality	2009	04-Sep-09	TPL	DC-WQ-BGE2	92.1	16.5	32.6
Bay-Goose Dike Construction Weekly Water Quality	2009	04-Sep-09	TPL	DC-WQ-BGE5	39.5	8.9	18.4
Bay-Goose Dike Construction Weekly Water Quality	2009	04-Sep-09	TPL	DC-WQ-BGW2	120	29.7	53
Bay-Goose Dike Construction Weekly Water Quality	2009	04-Sep-09	TPL	DC-WQ-HVH5	34.5	6.1	19.7
Bay-Goose Dike Construction Weekly Water Quality	2009	11-Sep-09	TPL	DC-WQ-BGE3	49.5	13.9	27.6
Bay-Goose Dike Construction Weekly Water Quality	2009	11-Sep-09	TPL	DC-WQ-BGE5	37.7	9.3	23.7
Bay-Goose Dike Construction Weekly Water Quality	2009	11-Sep-09	TPL	DC-WQ-BGW2	20.2	5.1	13.2
Bay-Goose Dike Construction Weekly Water Quality	2009	11-Sep-09	TPL	DC-WQ-HVH5	31.5	8.3	22.8
Bay-Goose Dike Construction Weekly Water Quality	2009	04-Sep-09	TPE	DC-WQ-TPE6	27.5	9.5	21.3
Bay-Goose Dike Construction Weekly Water Quality	2009	21-Aug-09	SPL	DC-WQ-SP8	5.1	1.5	4.99
Bay-Goose Dike Construction Weekly Water Quality	2009	29-Aug-09	SPL	DC-WQ-SP6	2.93	1.3	1.89
Bay-Goose Dike Construction Weekly Water Quality	2009	29-Aug-09	SPL	DC-WQ-SP8	13.1	3.9	5.16
Bay-Goose Dike Construction Weekly Water Quality	2009	04-Sep-09	SPL	DC-WQ-SP6	3.00	1.5	5.03
Bay-Goose Dike Construction Weekly Water Quality	2009	11-Sep-09	SPL	DC-WQ-SP1	3.2	1.9	1.95
Bay-Goose Dike Construction Weekly Water Quality	2009	11-Sep-09	SPL	DC-WQ-SP6	3.27	1.3	3.09
Bay-Goose Dike Construction Weekly Water Quality	2009	11-Sep-09	SPL	DC-WQ-SP8	7.6	2.9	4.27
Bay-Goose Dike Effects Assessment	2009	18-Sep-09	TPL	EAS-BGW-1	23.5	5.8	9.47
Bay-Goose Dike Effects Assessment	2009	18-Sep-09	TPL	EAS-BGE-1	24.1	8.6	12.5
Bay-Goose Dike Effects Assessment	2009	24-Sep-09	TPL	EAS-BGW-1	15.1	9.1	11.2
Bay-Goose Dike Effects Assessment	2009	26-Sep-09	TPL	EAS-BGE-1	21.9	7.9	16.3
Bay-Goose Dike Effects Assessment	2009	19-Sep-09	SPL	EAS-SPC-1	2.6	1.8	2.06
Bay-Goose Dike Effects Assessment	2009	26-Sep-09	SPL	EAS-SPC-1	2.97	1.3	2.7

Table 3. Turbidity-TSS Data for 2009 Dewatering of the Impounded Arm of Second Portage Lake [1]

Sample ID	Date	Time	Measured Field Turbidity	Predicted Field Turbidity	Time	Lab Turbidity	Lab TSS (mg/L)
Intake Unit 1	6/10/2009	8:30	22.40	15.42	8:30	11.00	2
Intake Unit 2	6/10/2009	8:30	22.20	16.80	8:30	12.80	2
Intake Unit 3	6/10/2009	8:30	20.50	15.58	8:30	11.20	1
Intake Unit 4	6/10/2009	8:30	21.50	37.67	8:30	40.10	3
Intake Unit 5	6/10/2009	8:30	17.94	14.89	8:30	10.30	2
Intake Unit 6	6/10/2009	8:30	17.82	14.89	8:30	10.30	2
Intake Unit 1	6/11/2009	8:00	27.10	17.79	8:00	14.10	5
Intake Unit 2	6/11/2009	8:00	27.50	17.41	8:00	13.60	4
Intake Unit 3	6/11/2009	8:00	26.70	16.95	8:00	13.00	4
Intake Unit 4	6/11/2009	8:00	26.70	18.48	8:00	15.00	5
Intake Unit 5	6/11/2009	8:00	20.50	16.03	8:00	11.80	2
Intake Unit 6	6/11/2009	8:00	21.10	15.73	8:00	11.40	3
Intake Unit 1	6/12/2009	7:00	25.10	18.48	7:00	15.00	4
Intake Unit 2	6/12/2009	7:00	23.70	18.10	7:00	14.50	4
Intake Unit 3	6/12/2009	7:00	24.20	17.26	7:00	13.40	4
Intake Unit 4	6/12/2009	7:00	23.70	15.81	7:00	11.50	5
Intake Unit 5	6/12/2009	7:00	22.40	16.95	7:00	13.00	3
Intake Unit 6	6/12/2009	7:00	22.50	16.03	7:00	11.80	3
Intake Unit 5	6/19/2009	17:00	29.90	18.94	17:00	15.60	6
Intake Unit 6	6/19/2009	17:00	32.50	18.79	17:00	15.40	4
Intake Unit 1	6/21/2009	17:30	22.10		17:30	19.80	10
Intake Unit 2	6/21/2009	17:30	21.80		17:30	19.30	10
Intake Unit 3	6/21/2009	17:30	21.30		17:30	21.60	10
Intake Unit 4	6/21/2009	17:30	22.30		17:30	19.60	9
Intake Unit 5	6/21/2009	17:30	17.28		17:30	16.36	7
Intake Unit 6	6/21/2009	17:30	19.01		17:30	17.30	7
Intake Unit 1	6/22/2009	6:30	23.20		6:30	20.40	9
Intake Unit 2	6/22/2009	6:30	21.80		6:30	18.70	9
Intake Unit 3	6/22/2009	6:30	21.40		6:30	17.90	8
Intake Unit 4	6/22/2009	6:30	21.90		6:30	18.90	9
Intake Unit 5	6/22/2009	6:30	16.74		6:30	15.50	6
Intake Unit 6	6/22/2009	6:30	18.18		6:30	15.60	7
Intake Unit 1	6/23/2009	6:30	23.90		6:30	25.60	7
Intake Unit 2	6/23/2009	6:30	20.50		6:30	20.40	5
Intake Unit 3	6/23/2009	6:30	19.52		6:30	20.80	8
Intake Unit 4	6/23/2009	6:30	20.10		6:30	21.00	7
Intake Unit 5	6/23/2009	6:30	22.00		6:30	22.50	7
Intake Unit 6	6/23/2009	6:30	22.10		6:30	22.30	6
Intake Unit 1	6/24/2009	17:30	23.90		17:30	20.30	8
Intake Unit 2	6/24/2009	17:30	23.40		17:30	16.90	7
Intake Unit 3	6/24/2009	17:30	23.80		17:30	17.40	7
Intake Unit 4	6/24/2009	17:30	22.80		17:30	16.60	8
Intake Unit 5	6/24/2009	17:30	18.75		17:30	16.90	7
Intake Unit 6	6/24/2009	17:30	19.07		17:30	17.50	8
Intake Unit 1	6/25/2009	6:30	24.90		6:30	20.70	8
Intake Unit 2	6/25/2009	6:30	22.50		6:30	17.10	8
Intake Unit 3	6/25/2009	6:30	24.50		6:30	17.90	8
Intake Unit 4	6/25/2009	6:30	25.10		6:30	18.80	10
Intake Unit 5	6/25/2009	6:30	20.80		6:30	15.70	7
Intake Unit 6	6/25/2009	6:30	21.90		6:30	17.90	7
Intake Unit 1	6/25/2009	17:30	23.80		17:30	21.20	8
Intake Unit 2	6/25/2009	17:30	22.50		17:30	21.10	6
Intake Unit 3	6/25/2009	17:30	20.10		17:30	19.60	6
Intake Unit 4	6/25/2009	17:30	21.10		17:30	19.80	6
Intake Unit 5	6/25/2009	17:30	17.30		17:30	16.10	4
Intake Unit 6	6/25/2009	17:30	24.40		17:30	24.80	6
Intake Unit 1	6/28/2009	17:30	27.30		17:30	24.00	8
Intake Unit 2	6/28/2009	17:30	24.20		17:30	19.20	7
Intake Unit 3	6/28/2009	17:30	22.60		17:30	19.80	8
Intake Unit 4	6/28/2009	17:30	22.90		17:30	21.40	6
Intake Unit 5	6/28/2009	17:30	17.37		17:30	16.50	6
Intake Unit 6	6/28/2009	17:30	35.10		17:30	35.10	13
Intake Unit 1	7/5/2009	17:30	23.00		17:30	18.30	8
Intake Unit 2	7/5/2009	17:30	22.90		17:30	17.70	8
Intake Unit 6	7/5/2009	17:30	11.97		17:30	10.30	5
Intake Unit 1	7/6/2009	7:00	21.00		7:00	16.30	7
Intake Unit 2	7/6/2009	7:00	17.24		7:00	14.30	8
Intake Unit 6	7/6/2009	7:00	13.16		7:00	12.00	7
Intake Unit 1	7/7/2009	18:00	23.90		18:00	21.50	7
Intake Unit 2	7/7/2009	18:00	24.40		18:00	21.90	9
Intake Unit 1	7/8/2009	18:00	22.60		18:00	16.90	7
Intake Unit 2	7/8/2009	18:00	22.20		18:00	19.80	6
Intake Unit 1	7/9/2009	6:40	22.30		6:40	21.40	8
Intake Unit 2	7/9/2009	6:40	22.80		6:40	22.30	8

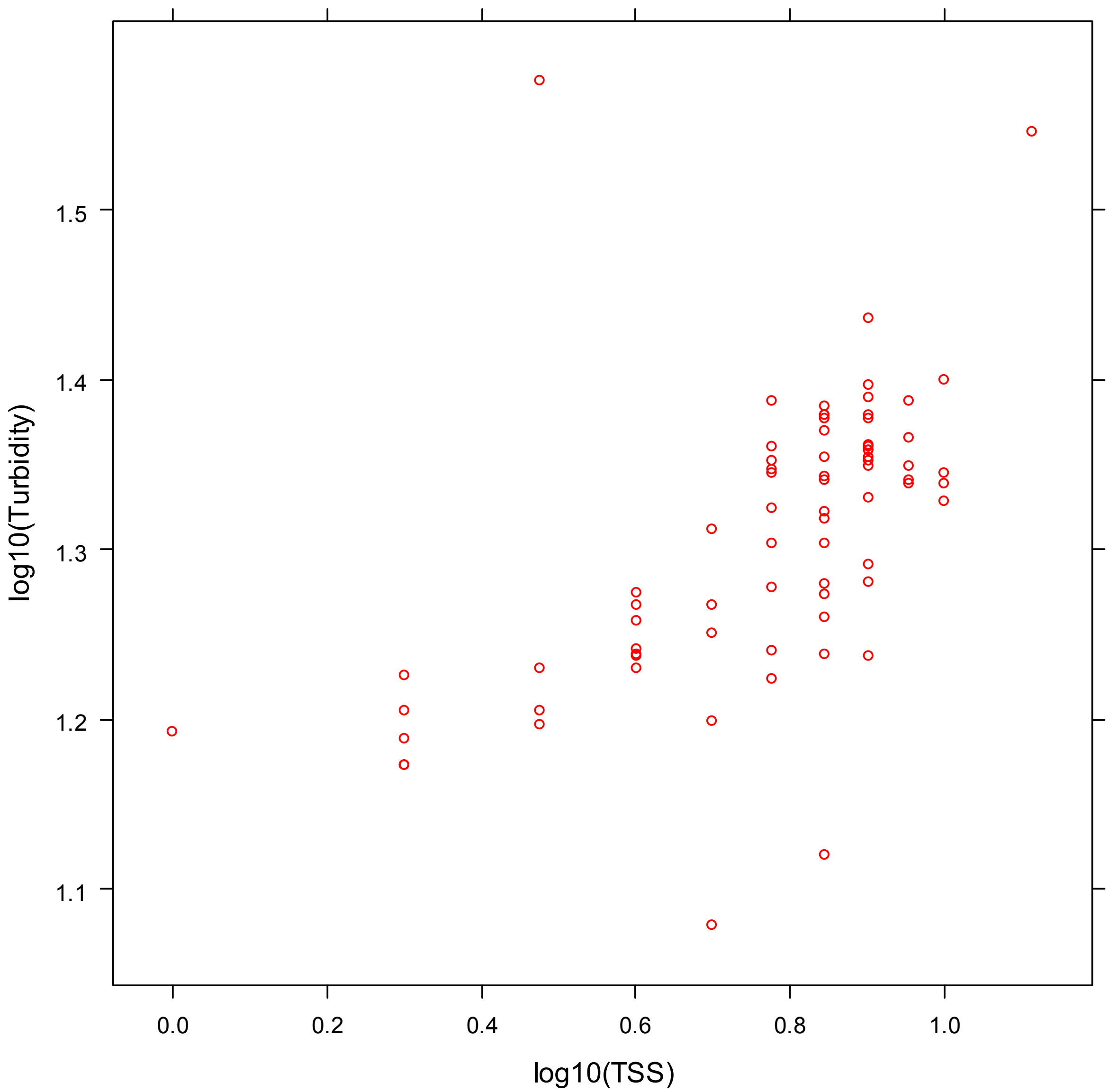
[1] For grey-shaded cells, field turbidity was measured incorrectly so predicted field turbidity is used. Predictions are based on the relationship between field and lab turbidity for other data points (Field=7.014+(0.7645*lab); $p<0.001$; $r2 = 0.66$)

Figure 1. All paired TSS-turbidity data relevant to dike construction monitoring[5] (2008 and 2009)



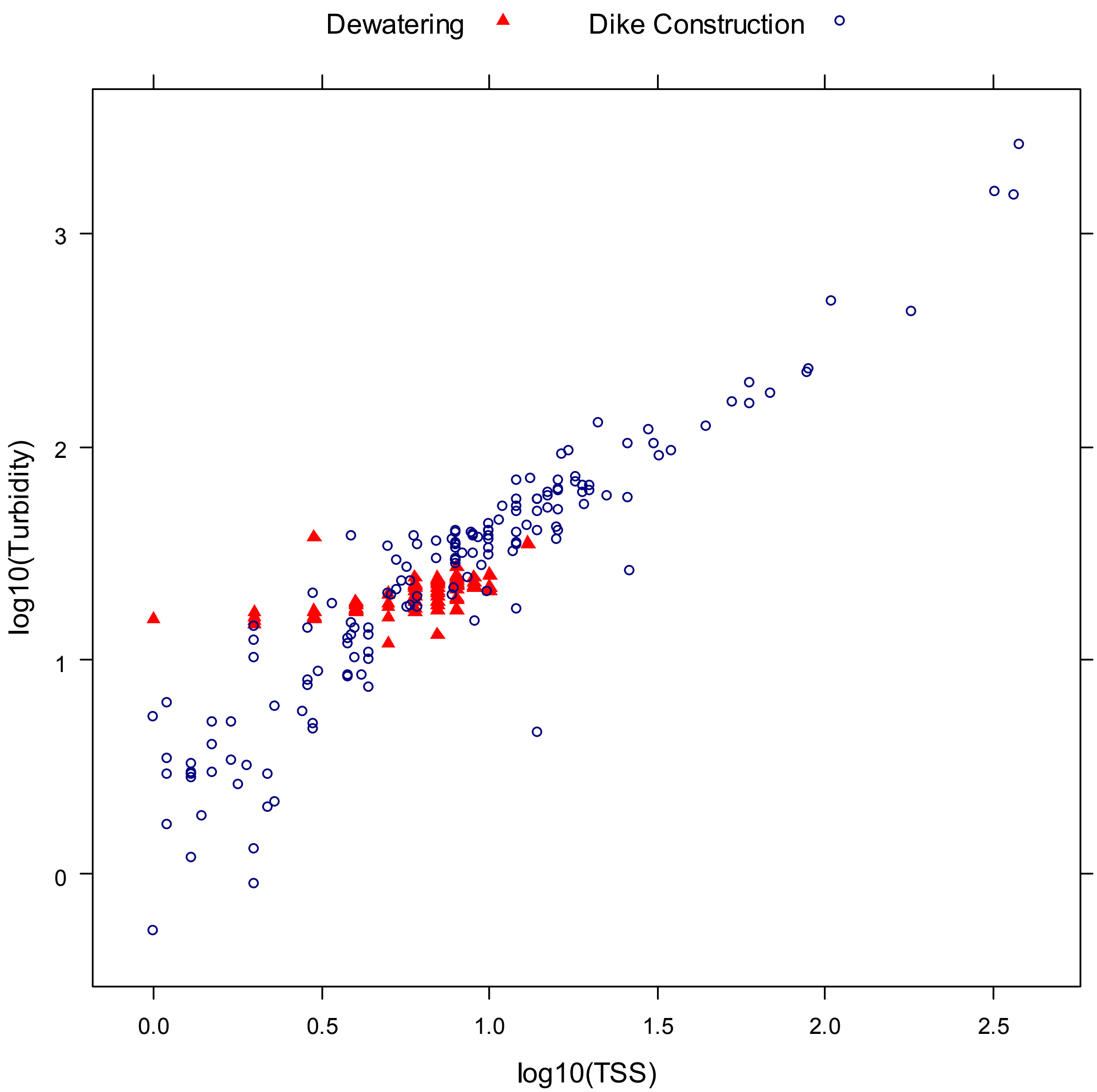
[5] This figure shows all data contained in Tables 1 and 2, except for data below detection limits.

Figure 2. Paired TSS-turbidity data for dewatering of the impoundment[6].



[6] This figure shows all data contained in Table 3, except for data below detection limits

Figure 3. All paired TSS-turbidity data for dewatering and dike construction[7].



[7] This figure shows all data contained in Tables 1 to 3, except for data below detection limits

Figure 4. Final data set and recommended TSS-turbidity relationship for dike construction monitoring

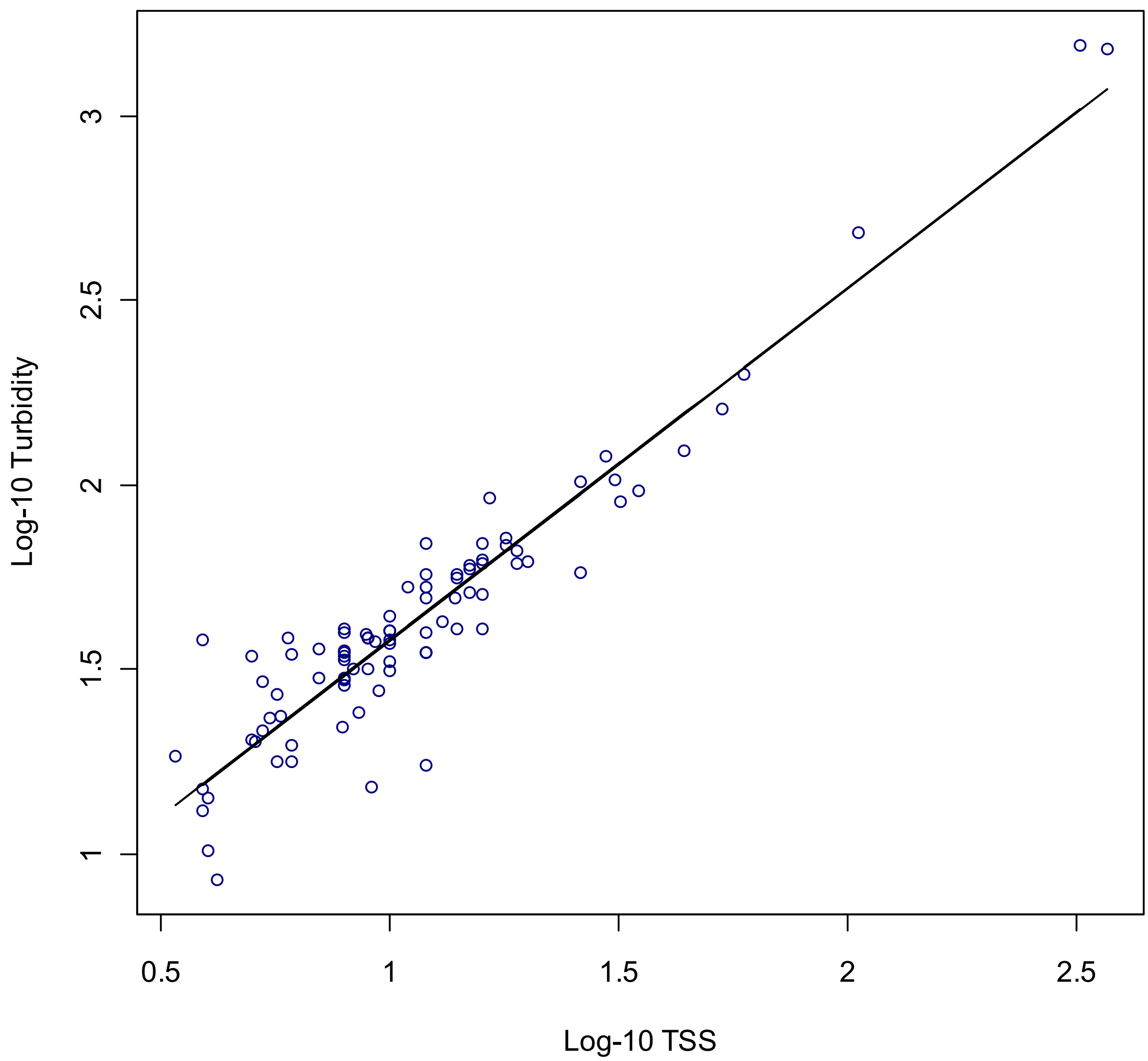
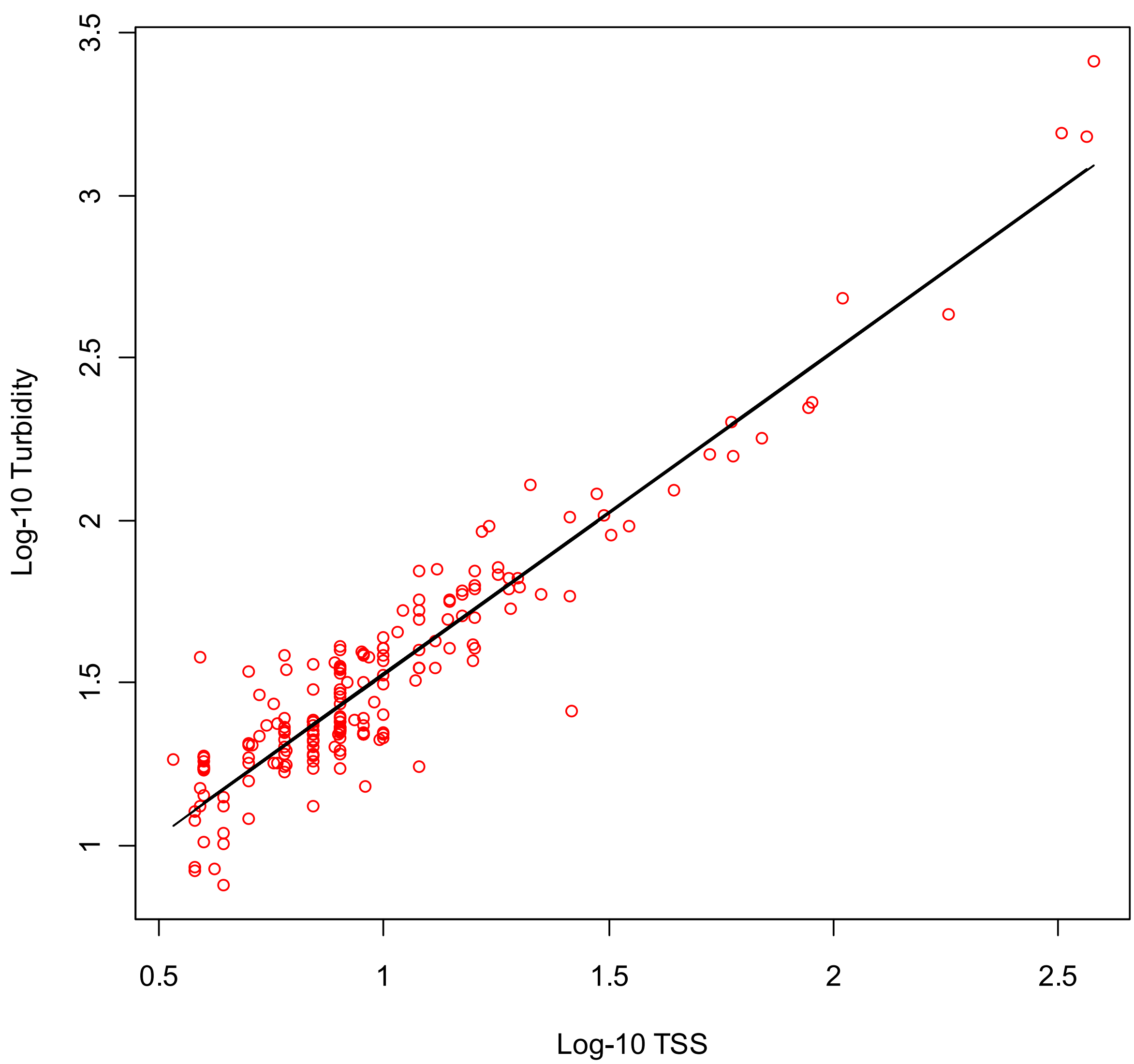
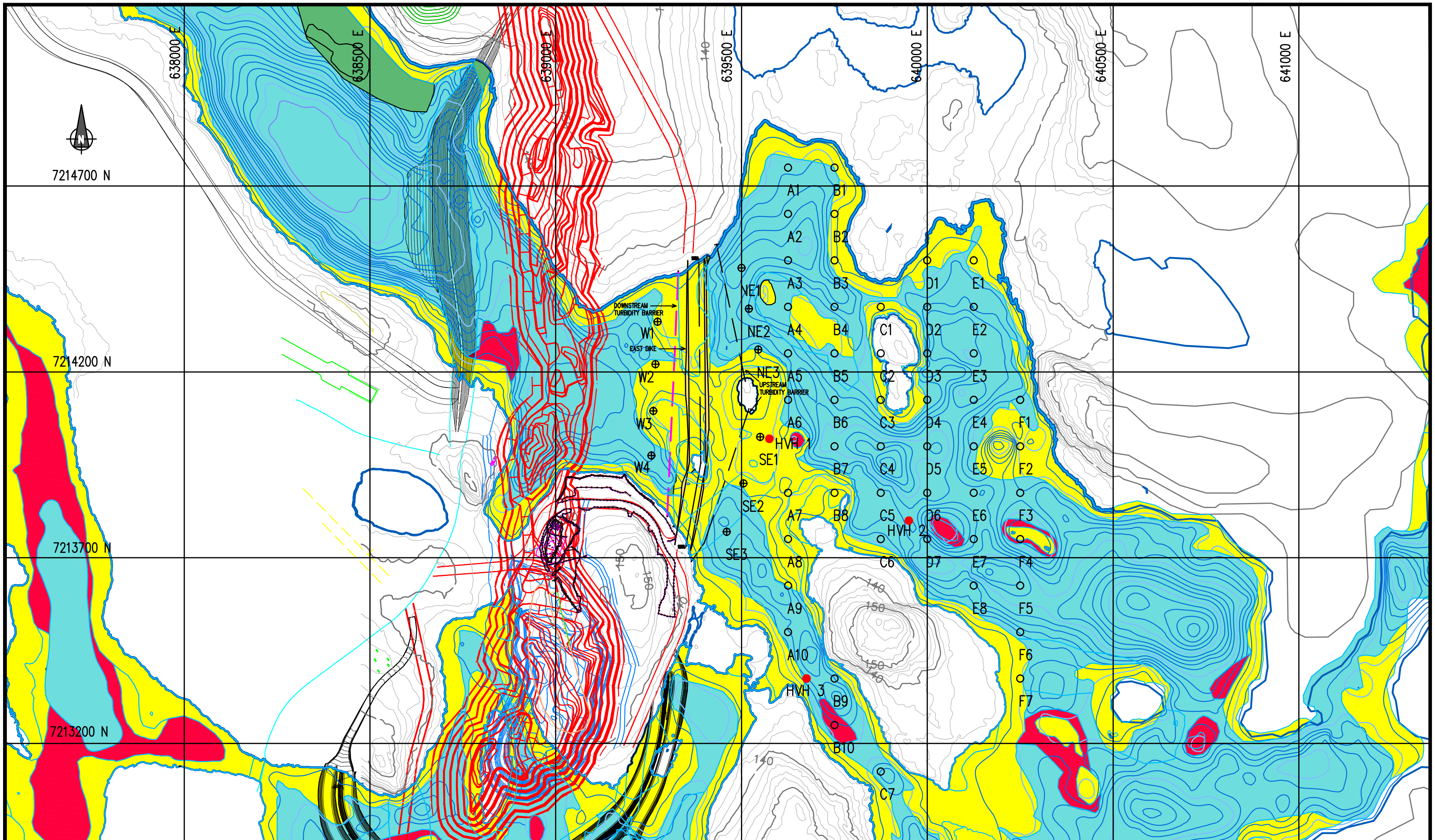


Figure 5. Final data set and recommended TSS-turbidity relationship for dewatering monitoring





TITRE / TITLE	# DWG	REV	DESCRIPTION		
DESSINS EN RÉFÉRENCE / REFERENCE DRAWINGS		REVISIONS			

AGNICO-EAGLE
DIVISION MEADOWBANK

DESSINÉ PAR / DRAWN BY	JMARSTON	DATE	
VÉRIFIÉ PAR / CHECKED BY			
APPROUVÉ PAR / APPROVED BY			
No. PROJET / PROJECT NO.			
DATE	16-JULY-08		

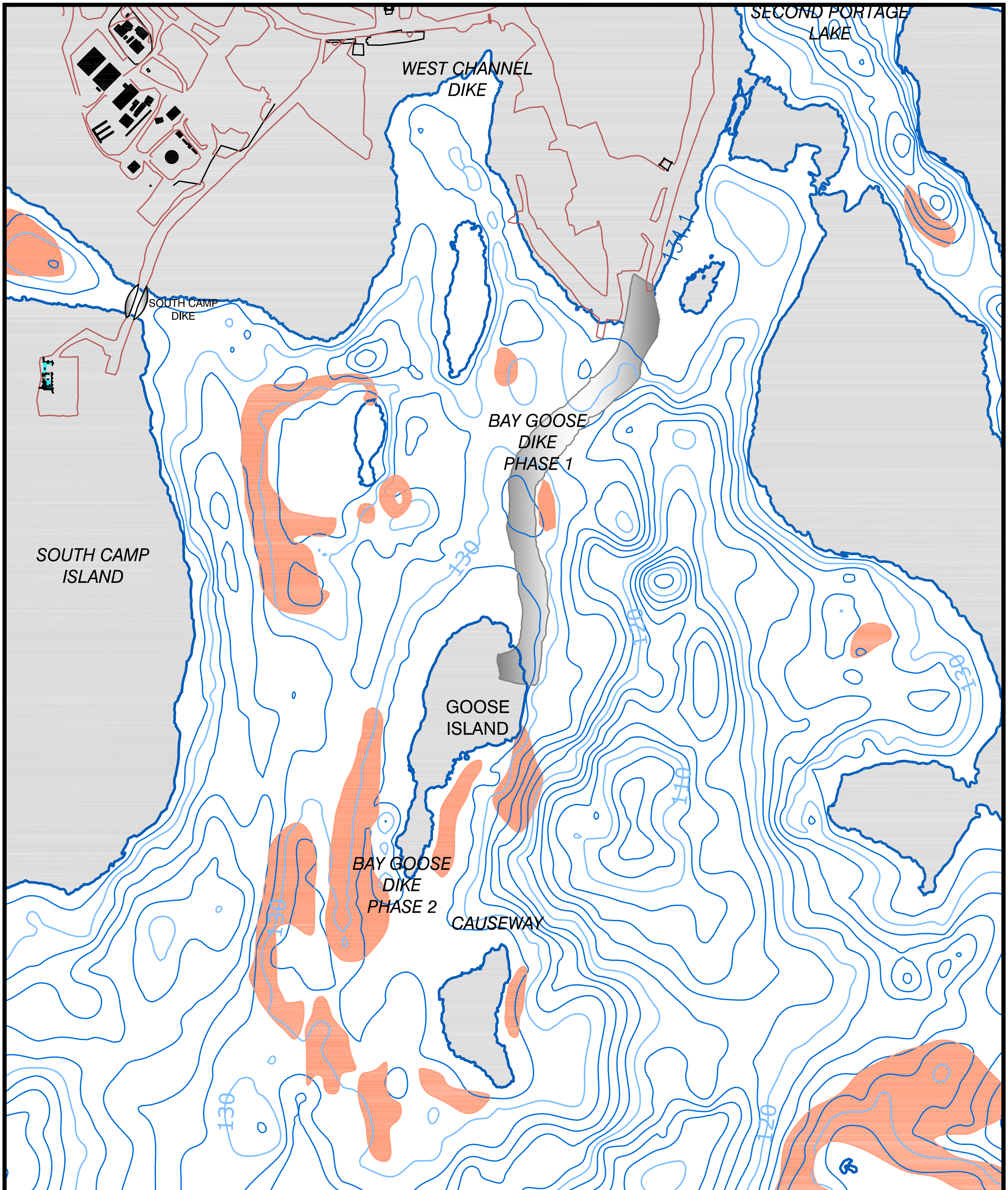
TITRE / TITLE

MEADOWBANK_GOLD_PROJECT
EAST_DIKE_CONTSTRUCTION
MONITORING_LOCATIONS

ÉCHELLE/ SCALE	1:10000	FICHIER FILE	FCH_DESSIN
FIGURE 1		REVISION	FEUILLE/SHT PAGE/PAGES

AE-CART-ANSI B

FORMAT ANSI A – PORTRAIT



LEGEND

HIGH VALUE HABITAT

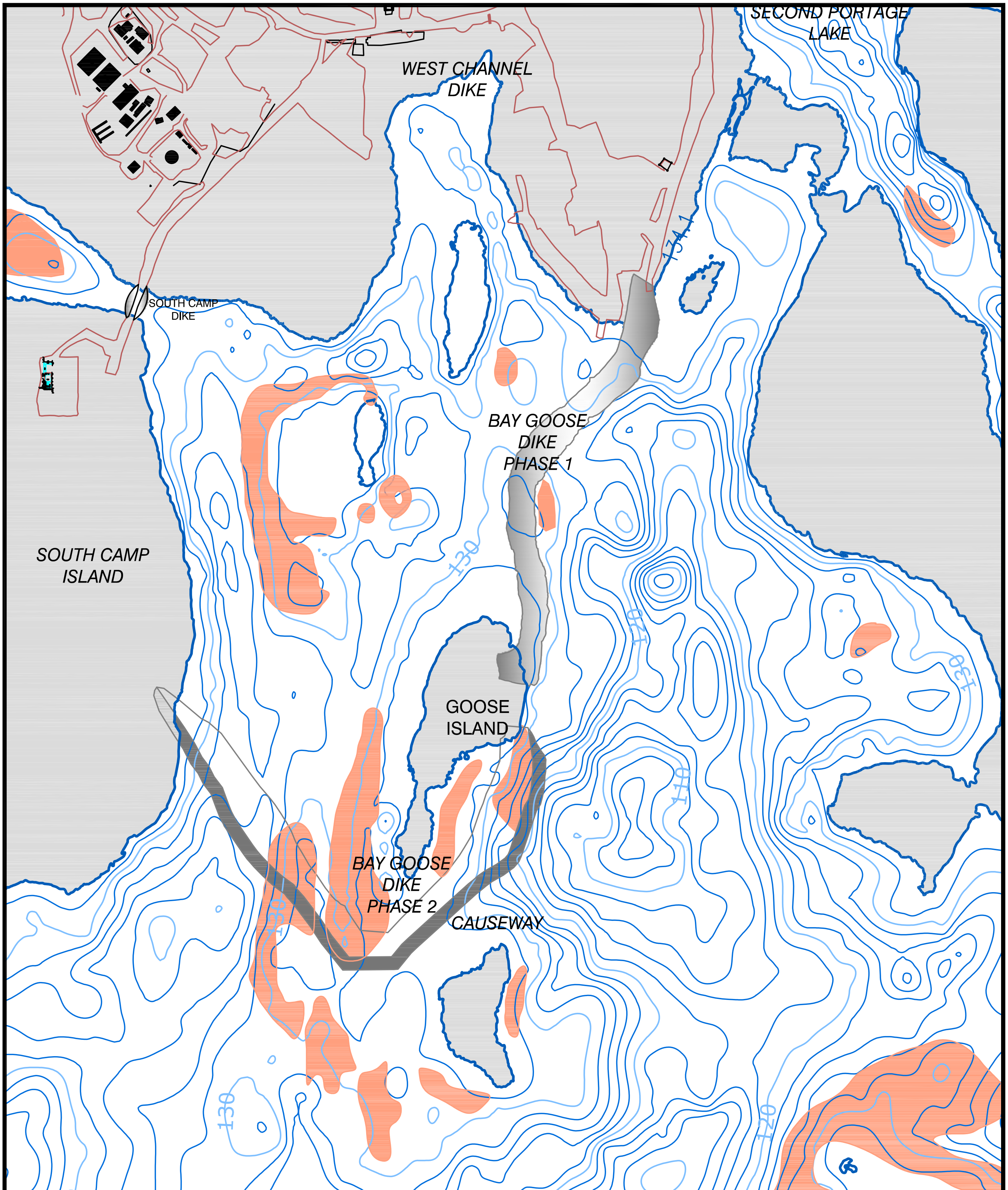
AGNICO-EAGLE

TITLE AGNICO–EAGLE – MEADOWBANK DIVISION			
FIGURE 2			
PROJECT No.	DATE NOV. 16 , 2009		
DRAWN BY P. DAUDELIN		SHEET 1 / 1	
APPROVED BY			
DRAWING NO.		REVISION	

N:\Drawings\TSS MANAGEMENT PLAN 2010.dwg, 24 Nov 2009

FILE NO. FIGURE 2

FORMAT ANSI A — PORTRAIT



LEGEND

HIGH VALUE HABITAT

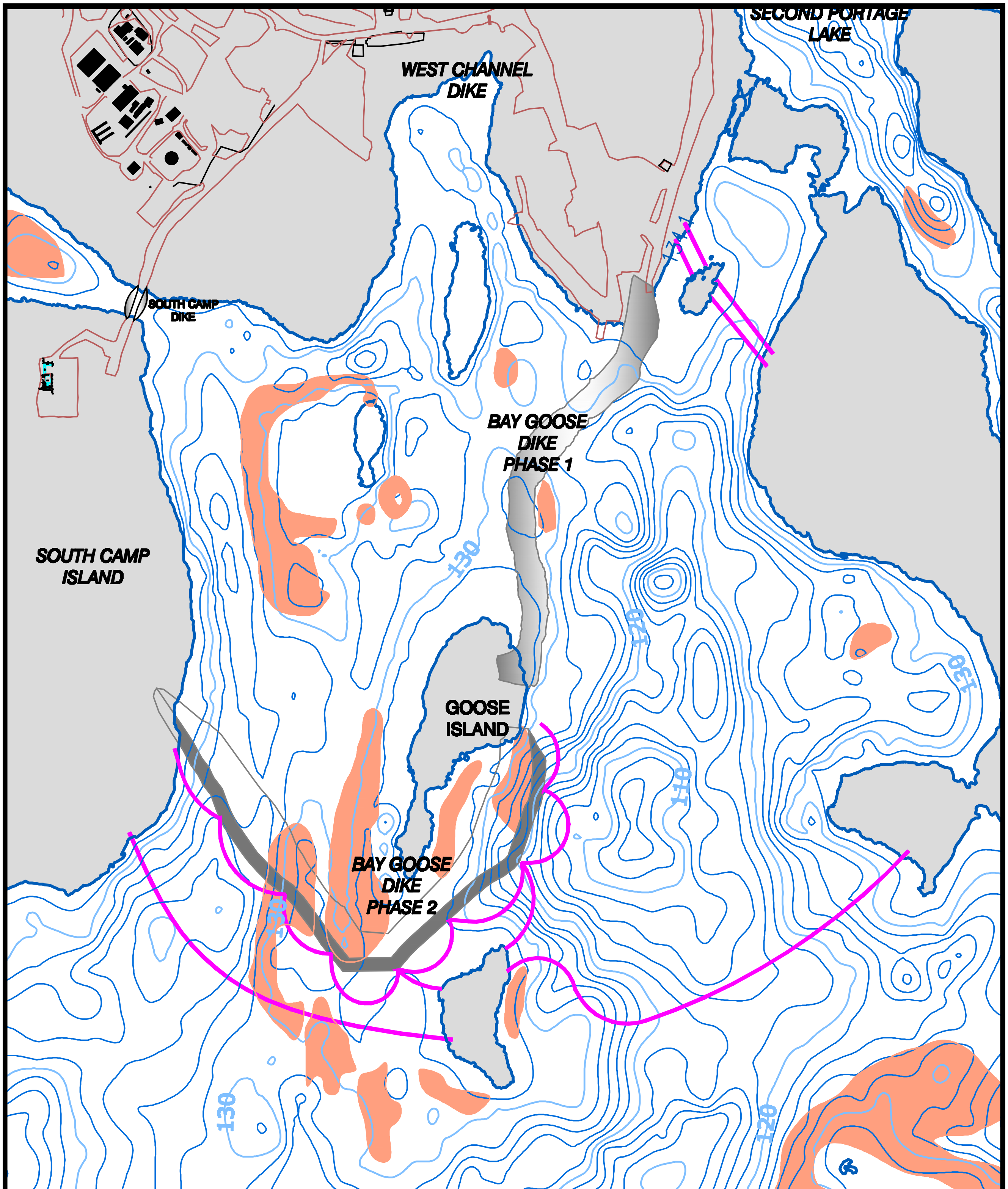
AGNICO-EAGLE

TITLE	AGNICO—EAGLE — MEADOWBANK DIVISION FIGURE 3		
PROJECT No.		DATE	NOV. 16 , 2009
DRAWN BY	P. DAUDELIN		SHEET 1 / 1
APPROVED BY			
DRAWING NO.			REVISION

N:\Drawings\TSS MANAGEMENT PLAN 2010.dwg, 24 Nov 2009

FILE NO. FIGURE 2

FORMAT ANSI A – PORTRAIT



LEGEND

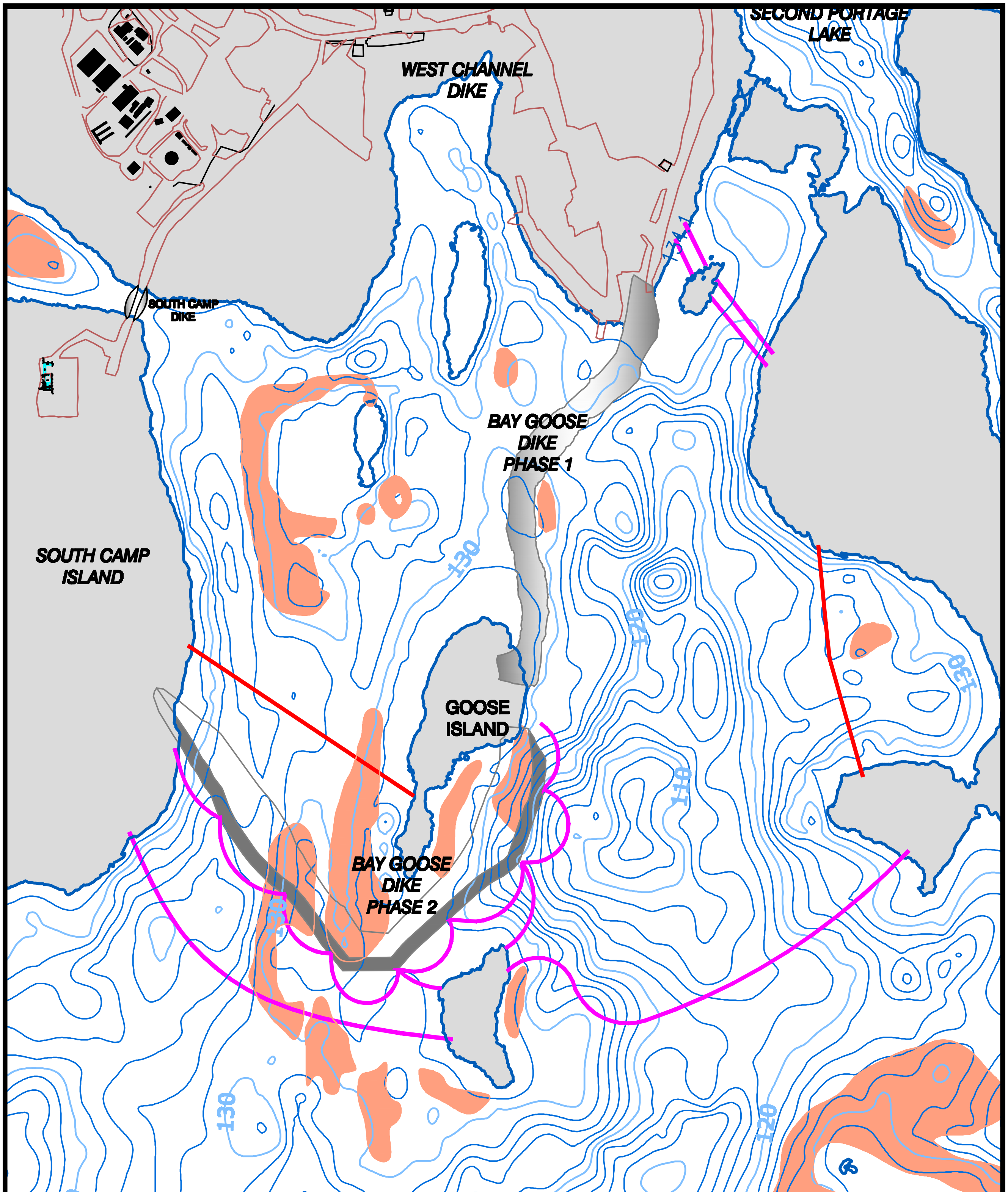
- CURTAIN
- HIGH VALUE HABITAT

AGNICO-EAGLE

TITLE	AGNICO–EAGLE – MEADOWBANK DIVISION FIGURE 4
PROJECT No.	DATE NOV. 16 , 2009
DRAWN BY P. DAUDELIN	SHEET 1 / 1
APPROVED BY	
DRAWING NO.	REVISION

N:\10 – DRAWINGS\Environment\TSS MANAGEMENT PLAN 2010.dwg, 27 Apr 2010

FILE NO. FIGURE 2

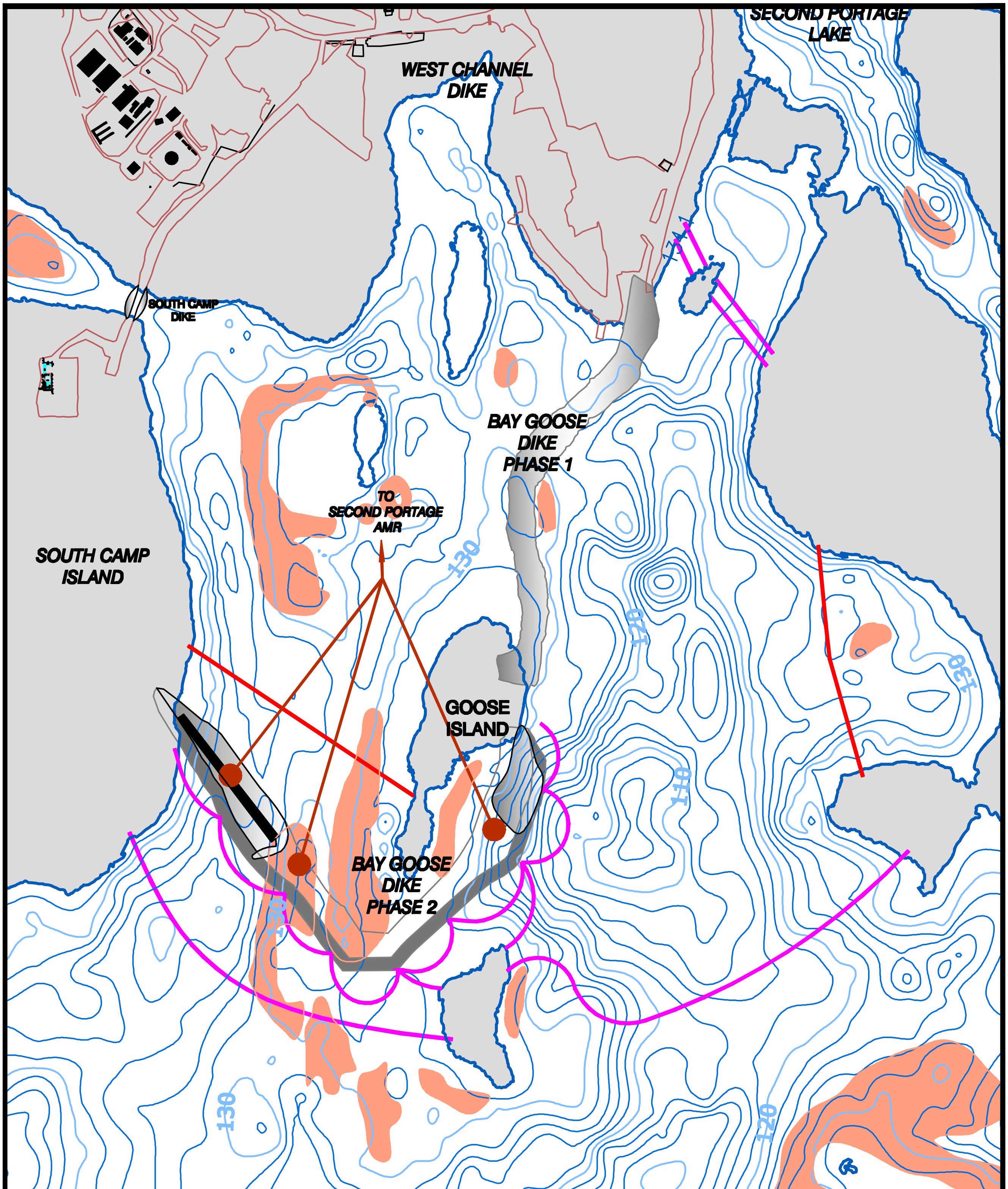


LEGEND

- CURTAIN (magenta)
- CURTAIN (red)
- HIGH VALUE HABITAT

TITLE	AGNICO–EAGLE – MEADOWBANK DIVISION FIGURE 5
PROJECT No.	DATE: NOV. 16, 2009
DRAWN BY: P. DAUDELIN	SHEET: 1 / 1
APPROVED BY	
DRAWING NO.	REVISION

FORMAT ANSI A – PORTRAIT



LEGEND

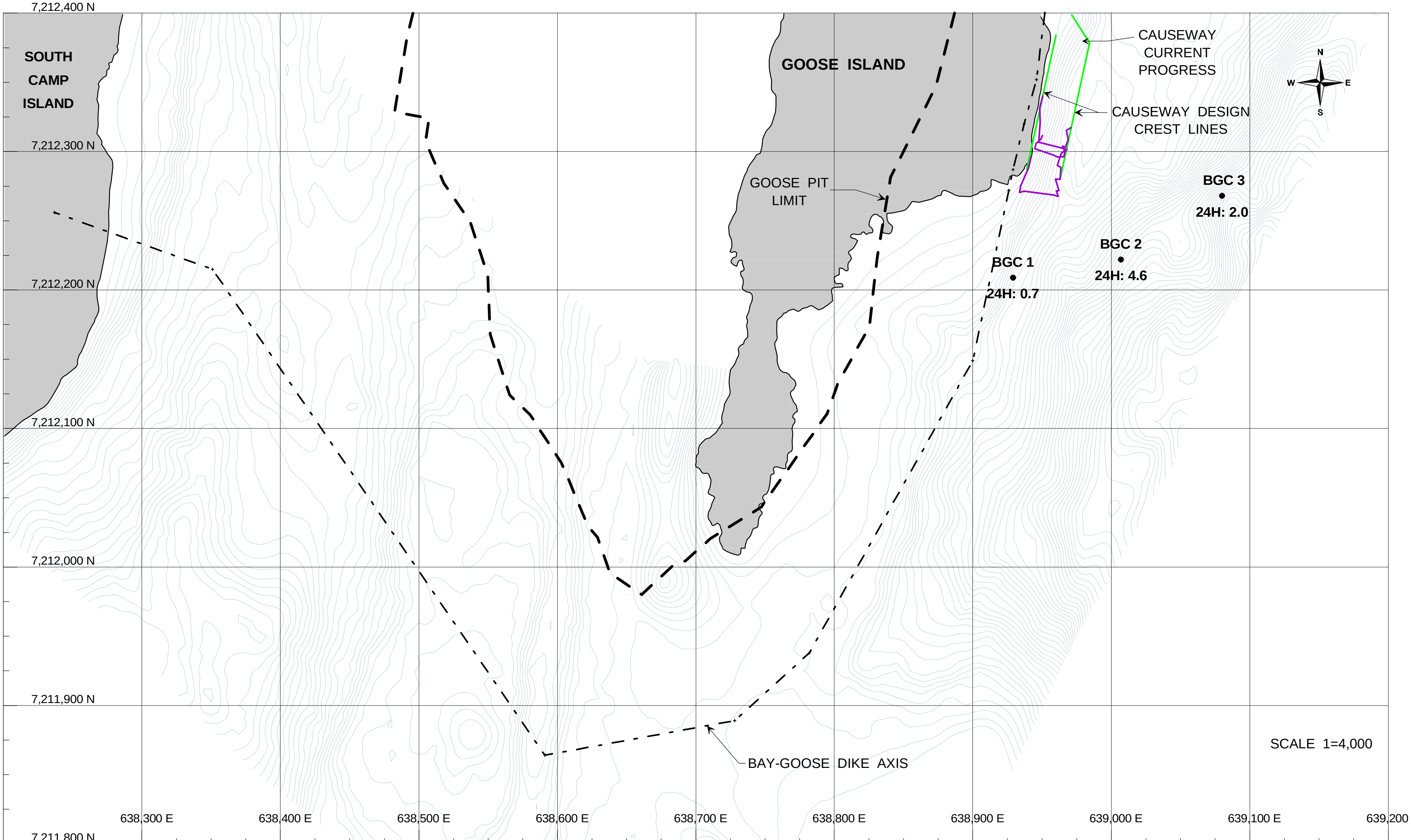
- PUMP AND PIPELIN
- CURTAIN
- CURTAIN
- HIGH VALUE HABITAT

AGNICO-EAGLE

TITLE	AGNICO–EAGLE – MEADOWBANK DIVISION FIGURE 6
PROJECT No.	DATE NOV. 16 , 2009
DRAWN BY P. DAUDELIN	SHEET 1 / 1
APPROVED BY	
DRAWING NO.	REVISION

N:\10 – DRAWINGS\Environment\TSS MANAGEMENT PLAN 2010.dwg, 27 Apr 2010

FILE NO. FIGURE 2



AGNICO-EAGLE MINES LIMITED - MEADOWBANK DIVISION

BAY-GOOSE DIKE CONSTRUCTION

TSS MONITORING DURING CAUSEWAY CONSTRUCTION

LATEST READINGS DATE : 27-Feb-2010

FIGURE 7

NOTES:

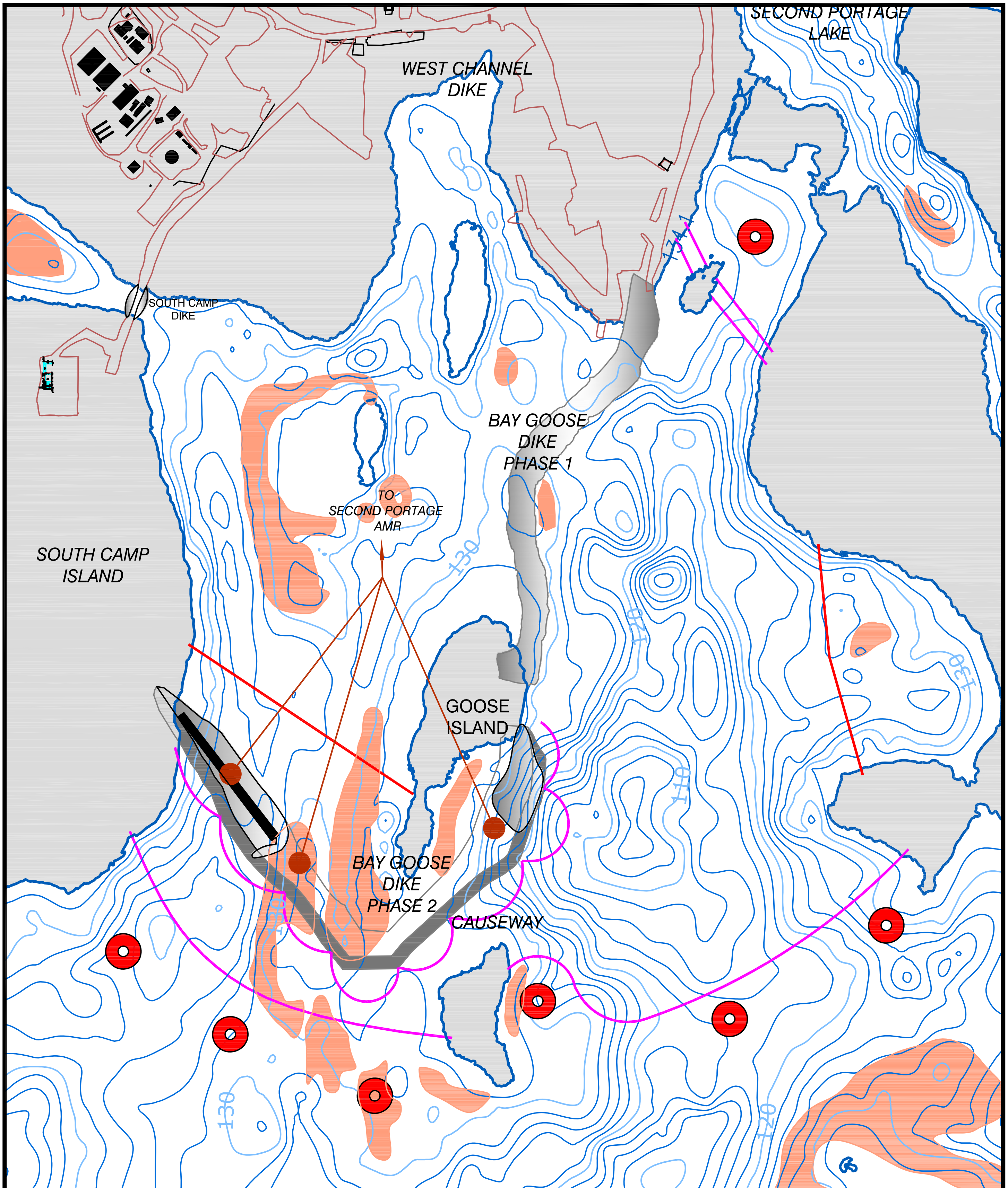
FIELD READINGS BY AEM

REPORTED TSS IS THE MAXIMUM VALUE ALONG THE PROFILE

LIMIT 24 HOURS : 25MG/L

TURBIDITY MONITORING CAUSEWAY.GRF

FORMAT ANSI A – PORTRAIT



LEGEND

- PUMP AND PIPELIN
- MONITORING STATION
- CURTAIN
- CURTAIN
- HIGH VALUE HABITAT

AGNICO-EAGLE

TITLE
AGNICO–EAGLE – MEADOWBANK DIVISION

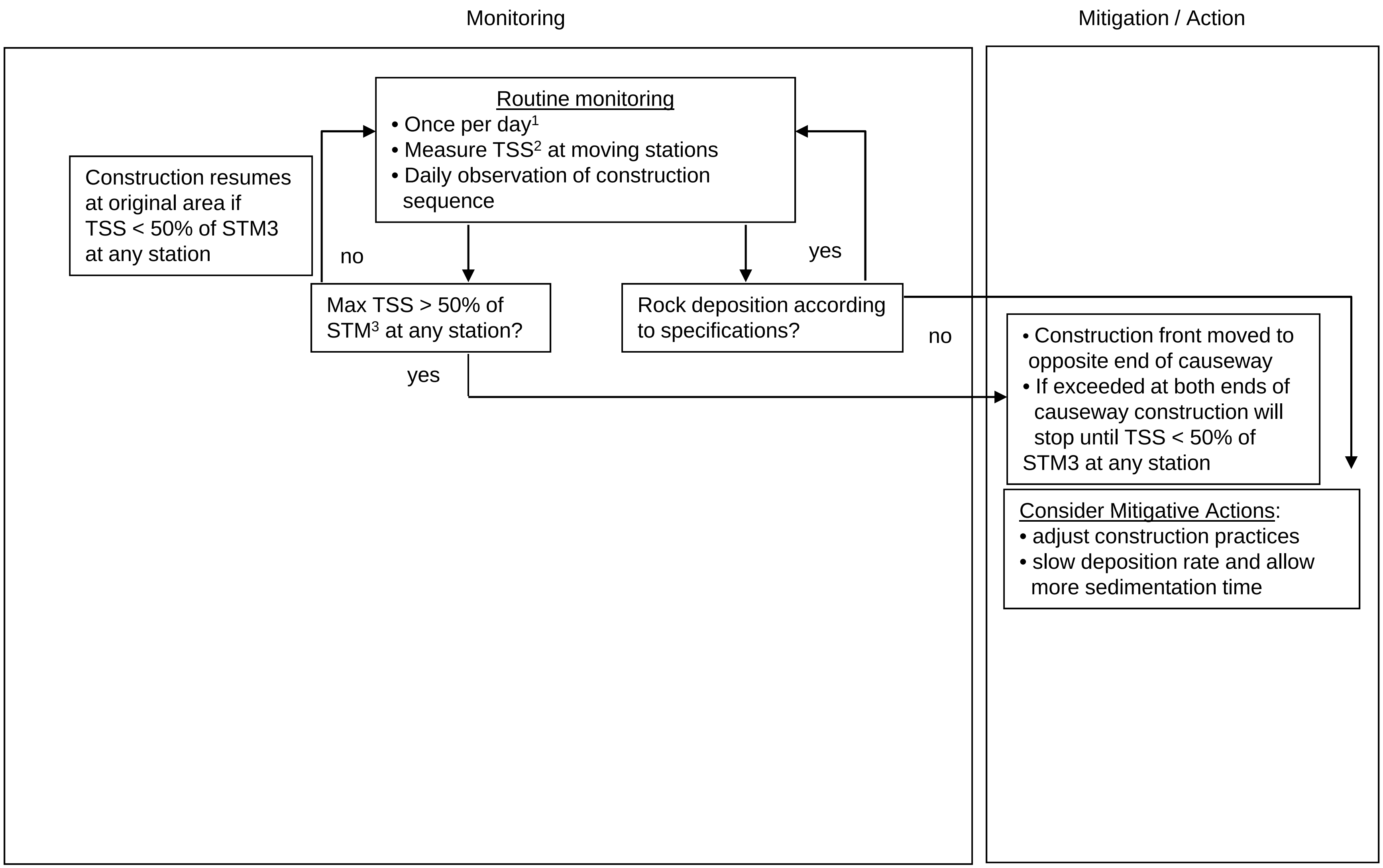
FIGURE 8

PROJECT No.	DATE NOV. 16, 2009
DRAWN BY P. DAUDELIN	SHEET 1 / 1
APPROVED BY	
DRAWING NO.	REVISION

N:\Drawings\TSS MANAGEMENT PLAN 2010.dwg, 24 Nov 2009

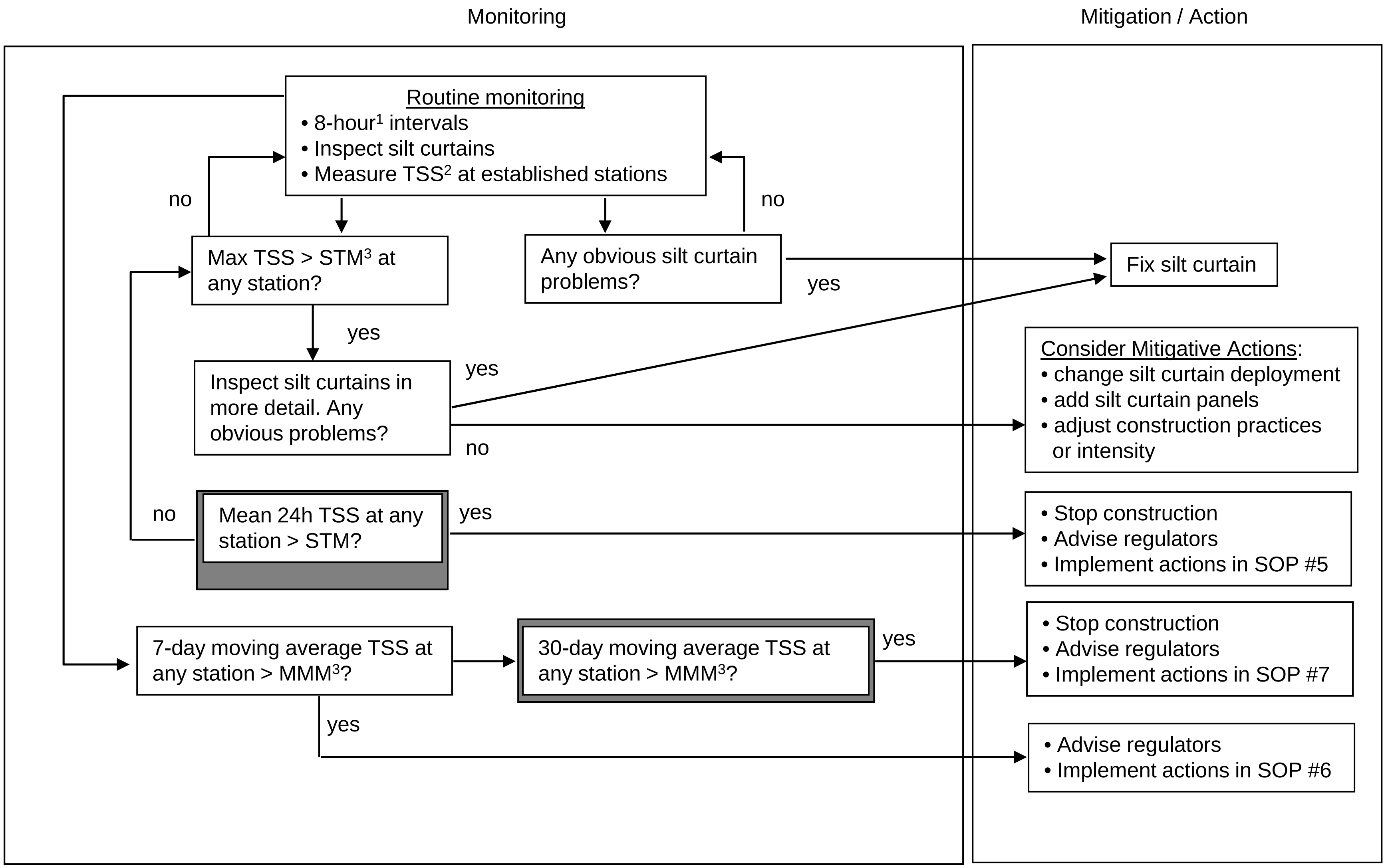
FILE NO. .DWG

Figure 9: Standard Operating Procedures for Suspended Sediment Monitoring and Management During Winter Dike Construction



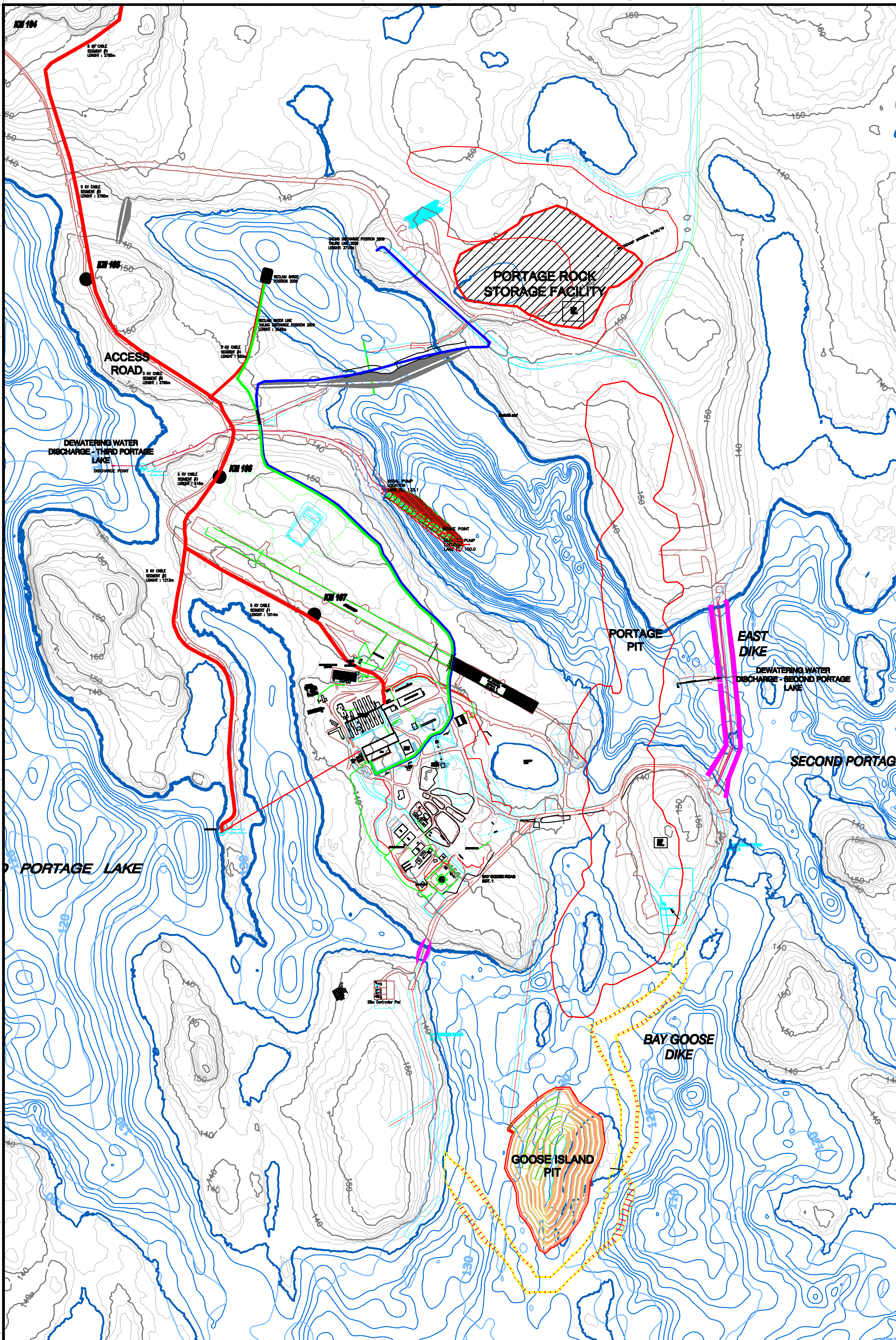
Notes: 1. During daylight hours and/or weather/logistics permitting. 2. TSS will be measured using turbidity as a surrogate 3. STM = short term maximum concentration of TSS. MMM = maximum monthly mean TSS concentration.

Figure 10: Standard Operating Procedures for Suspended Sediment Monitoring and Management During Summer Dike Construction



Notes: 1. During daylight hours and/or weather/logistics permitting. 2. TSS will be measured using turbidity as a surrogate 3. STM = short term maximum concentration of TSS. MMM = maximum monthly mean TSS concentration.

FORMAT ANSI B-PORTRAIT



REV	DESCRIPTION	DATE	BY

REVISIONS

AGNICO-EAGLE

DRAWN BY	G. LEA	DATE 22/06/2009
CHECKED BY		
APPROVED BY		
PROJECT NO.		
DATE		

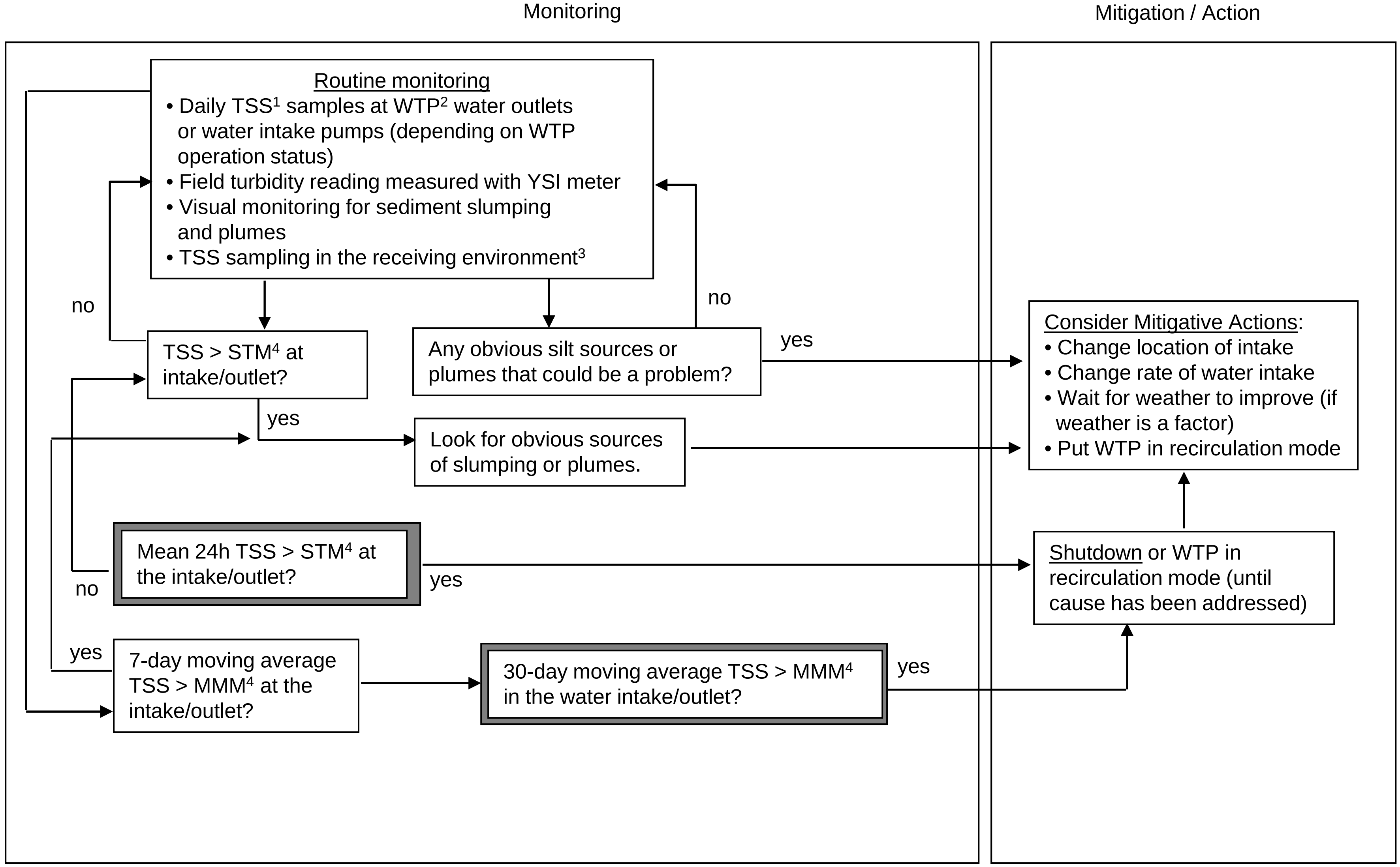
TITLE AGNICO–EAGLE – MEADOWBANK DIVISION

MEADOWBANK DEWATERING REGIONS

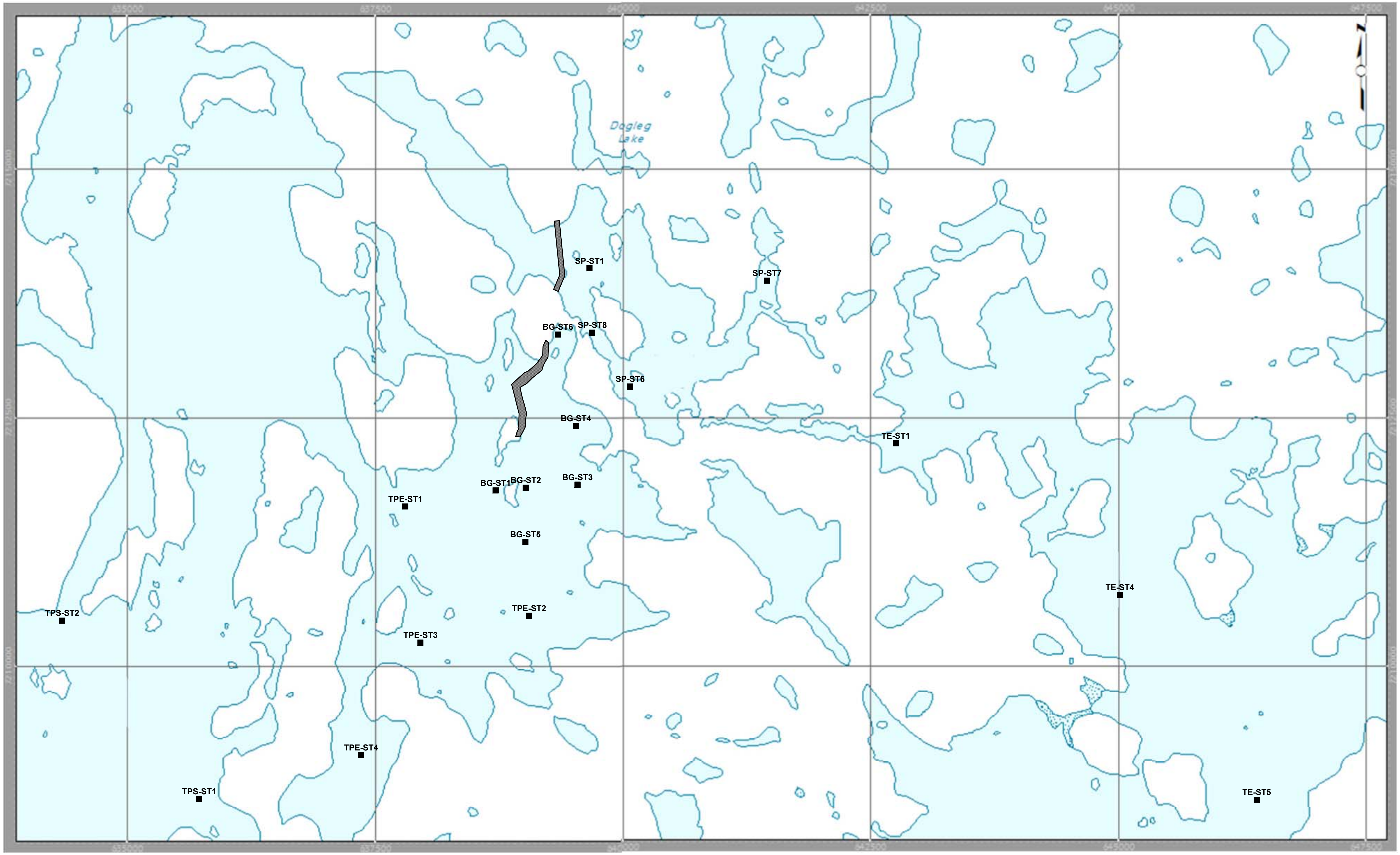
SCALE	FILE		
N.T.S.	.DWG		
DRAWING NO.		REVISION	SHEET 1 / 1

N:\Coop Work\Garner Lea\Garner_Working\drafting\MEADOWBANK PLANNING.dwg, 22 Jun 2009

Figure 12: Standard Operating Procedures for Suspended Sediment Monitoring and Management During Lake Dewatering



Notes: 1. TSS will be measured using turbidity as a surrogate 2. WTP = Water Treatment Plant 3. Monitoring on a weekly basis 4. STM = short term maximum concentration of TSS; MMM = maximum monthly mean TSS concentration



Legend

- ▲ Broad Survey Stns
- ● BG Routine Stns
- ○ BG HVH Stns
- ■ TE Sed Trap Stns

BG = Bay-Goose Routine Stations
HVH = High Value Habitat Stations

n/a = data do not cover full duration
blank = no data available

TSS Trigger Values (mg/L)

Station	24-hr	30-day
Routine	50	15
HVH_a	50	15
HVH_b	25	6
a = prior to Sept 1		
b = after Sept 1		

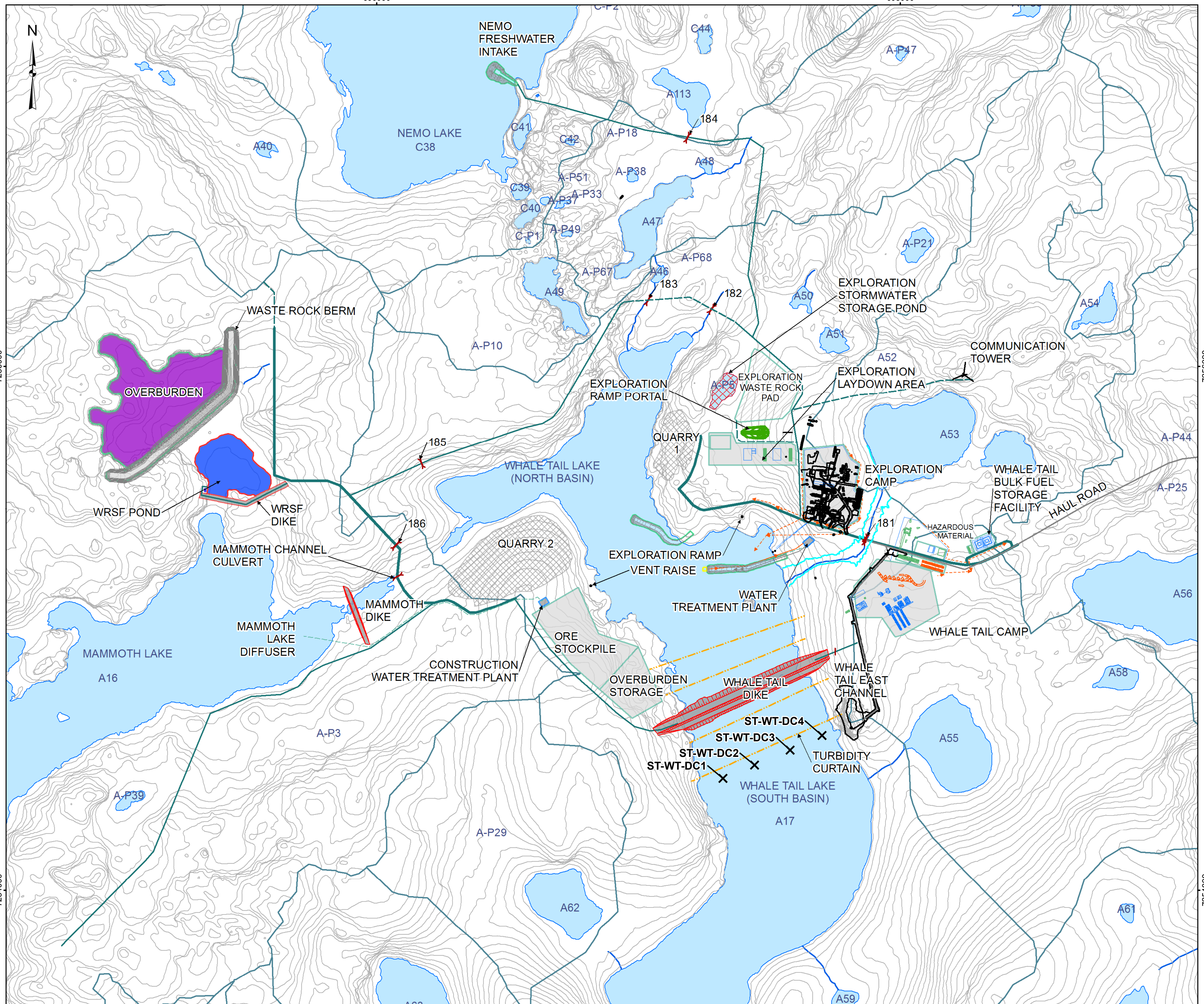
AZIMUTH

Azimuth Consulting Group Inc.

MEADOWBANK GOLD PROJECT
BAY-GOOSE DIKE CONSTRUCTION MONITORING

SEDIMENT TRAP LOCATIONS
WINTER 2009-10

BAY-GOOSE BROAD MAP.GRF



LEGEND

- ✕ TURBIDITY MONITORING STATION
- ROAD
- TEMPORARY ROAD
- COLLECTION CHANNEL
- CULVERT
- CONTACT WATER PUPE
- FRESHWATER PIPE
- TURBIDITY CURTAIN
- DIKE
- OVERBURDEN
- QUARRY
- STORM WATER STORAGE POND
- NATURAL WATERSHED
- POND/SUMP
- WATERBODY
- WATERCOURSE

REFERENCE

1. INFRASTRUCTURE OBTAINED FROM AGNICO EAGLE MINES LIMITED FROM 6108-600-210-001_R2(2018)s.dwg.
2. WATERCOURSE AND WATERBODY DATA OBTAINED FROM PHOTOSAT

DATUM: NAD 83 CSRS PROJECTION: UTM ZONE 14

300 0 300
METRES

PROJECT

AGNICO EAGLE

AGNICO EAGLE MINES LIMITED: MEADOWBANK DIVISION WHALE TAIL PIT PROJECT

TITLE

TURBIDITY MONITORING STATIONS DURING DIKE CONSTRUCTION

Golder Associates

PROJECT		1541520	FILE No.	
DESIGN	CP	16 May 2016	SCALE AS SHOWN	REV. 0
GIS	MH	16 May 2016		
CHECK	JR	21 Jun. 2016	**FIGURE 14**	
REVIEW	CP	21 Jun. 2016		

\\golder.gds\gal\burnaby\CAD-GIS\Client\Agnico_Eagle_Mines_Ltd\Whale_Tail\99_PROJECTS\1541520_FEIS\02_PRODUCTION\FEIS\MXD\2300_Water_Quality\Report\1541520_FIG_14_TURBIDITY_MONITORING_STATION.mxd