Canadian Natural

Muskeg River Mine

Fluid Tailings Management Report

Approval 8512J, as amended

Submitted April 30, 2019

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

MRM CONCORDANCE TABLE

Description	Section
Directive 085, 6.2 – Fluid Tailings Volume Requirements	
Include a project site summary of all annual fluid tailings volumes, as per the accounting table in appendix 3.	Appendix B
Show in a figure the approved new and legacy profiles with the actual fluid tailings volume and the three thresholds (profile deviation, total volume, and total volume limit).	Appendix B
Describe if and how activities have deviated from the fluid tailings management plan and any modifications made to improve performance.	7.1.1
Identify the management level (as described in the TMF) that the operation's performance falls within.	2.2
If the operation is deemed level 2 or higher, describe the circumstances that led to the increased fluid accumulation and any actions that are being taken to improve fluid tailings management performance.	NA
Provide a site-wide water balance or provide the reference to another AER report and location where this information can be obtained.	Appendix B
Total volume of water at the beginning of the reporting period	7.1
Total volume of water at the end of the reporting period	7.1
Characterization of the quality of water	7.2
The volume and quality of water recovered from fluid tailings and runoff from RTR tailings	7.2
Quantity of fines in the ore processed during the reporting period	6.5
Quantity of fines in fluid tailings	6.6
Estimate the change in fluid tailings volume inventory as a result of settling and consolidation and provide an explanation if inconsistent with the predictions	6.7
Provide a status map of the current locations and sizes of all fluid tailings ponds and treated deposits for the project.	Appendix A
Provide tables indicating the volume and composition of each deposit containing fluid tailings (including the volume of fluid tailings, of treated and placed fluid tailings meeting RTR status, and of water).	6
Provide tonnage of ore processed and average composition (bitumen, water, solids) or provide the reference to another AER report and location where this information can be obtained.	6.5
Provide volume of fluid tailings treated and where they were placed	8
Provide chemical and physical properties of the treated fluid tailings and the water recovered from treatment	8
If the technology is not performing as predicted, provide mitigation measures to rectify performance (address any impacts on the deposit performance)	NA
Directive 085, 6.2 – Monitoring Reporting Data Requirements	
For each monitoring dataset required in the annual fluid tailings management report, - identify any uncertainties and - explain the dataset adequacy.	3.4
For each treated tailings deposit and fluid tailings ponds and their surrounding environment provide monitoring results, including the following: - a map and tabular data showing the survey locations of tailings deposits;	Appendix A

- representative cross-sections to illustrate the variation of tailings characteristics;	
For each deposit containing treated and placed fluid tailings, - the measured data on the chosen indicators and confirm performance against the chosen performance criteria; - for those fluid tailings deposits that have met RTR status, data to support that it is trending appropriately; and - confirmation that indicator and performance criteria are still appropriate or justify the need to modify them;	5
Verification that the tailings deposit is meeting the milestones in the fluid tailings management plan.	5
Directive 085, 6.2 – Inadequate Deposit Performance	NA
Directive 085, 6.2 – Technology: Continuous Improvement and Development	
Description of the treatment technologies' operation over the reporting period, including issues that were encountered and a summary of continuous improvement activities.	9 and Appendix D
Confirmation that technology development was implemented as proposed in the approved fluid tailings management plan by summarizing relevant activities in the reporting year. Confirm that technology development will continue to be implemented as stated in the approved fluid tailings management plan.	Appendix D
A technical report, within the constraints of proprietary information, on the progress of any pilots, prototypes, or demonstrations of fluid tailings technologies.	Appendix D
An assessment, within the constraints of proprietary information, of performance, successes, challenges, and implications for net environmental effects for all treatment technologies. The assessment may incorporate information references to other required reports, such as the tailings research report and groundwater monitoring report submitted under EPEA.	Appendix D
Directive 085, 6.2 – Environmental Monitoring Results	
To ascertain that environmental benefits and risk trade-offs anticipated by operators for their tailings technology justification continue to be accurate, and to assess operator performance in managing and minimizing environmental effects and implications associated with fluid tailings management activities, the annual management report must provide a summary of the results from environmental performance monitoring reports related to fluid tailings management activities.	10
Approval 8512J, Clause 46	
a progress update on the ongoing tailings technology selection project	Appendix D
a description of the Operator's ability to deliver on the amendment application	11
a description of how the Operator is ensuring that the centrifuge, thickened tailings or other technologies are achieving performance parity with other treatment technologies	8
the status of bitumen production expansion rates and implementation dates	NA
For each North Pool Deposit type, (i) provide a comparison of the results of the quarterly monitoring required by clause 45(a) with the operating targets identified in Table 1: WT/CST proportions relative to TT and TSRU in Application 1870302, (ii) provide the results of the quarterly monitoring required by clause 45(b) and (c);	8.2.2 and 8.2.3

(iii) describe the engineering design and operation controls employed to form each North Pool Deposit type of tailings deposit during the reporting period; (iv)describe any actions required by clause 44 and their effectiveness;	
for each treated tailings deposit, monitoring data including representative cross-sections to illustrate the variation of the following: (i) sands to fine ratio; (ii) effective stress; (iii)deposit consolidation; (iv)pore water pressure; (v) clay type(s) and percentage; (vi) any other parameter considered relevant by the Operator; and (vii) any other parameter specified by the AER;	(i) Tables in Section 5 (ii) Figures 32-34 (iii) 5.4 (iv) Figures 32-34 (v) NA
the available storage capacity of each tailings deposit or pond that contains water or tailings at the end of the reporting period.	6.4
annual storage capacity and volume requirements for the five years following the end of the reporting period.	6.4
Approval 8512J, Clause 53 – Stakeholder Engagement	
(a) how the stakeholders and indigenous communities were identified for engagement; (b) a list of stakeholders and indigenous communities identified in (a); (c) objectives for engagement, including gathering input and feedback on the development of tailings management submissions from stakeholders and indigenous communities identified in (a); (d) the type of engagement activity that was undertaken and the tailings specific information that was provided to each stakeholder and indigenous community identified in (a); (e) the specific frequency and duration of the engagement with each stakeholder and indigenous community identified in (a); (f) what specific feedback was provided by each stakeholder and indigenous community identified in (a); (g) what specific feedback on this report was provided by each stakeholder and indigenous community identified in (a); (h) how the feedback and learnings from previous engagement will be incorporated into future engagement and into tailings management; (i) how the Operator addressed any outstanding concerns arising from engagement; and (j) outcomes from the annual forum.	Appendix C

1 INTRODUCTION

This report contains the information required for annual fluid tailings management reporting for Muskeg River Mine (MRM), and is prepared by Canadian Natural Upgrading Limited (Canadian Natural) in accordance with the October 12, 2017 edition of *Directive 085: Fluid Tailings Management for Oil Sands Mining (D085)*, provided under the *Oil Sands Conservation Act*. Data collected between January 1, and December 31, 2018 are presented and related to metrics and targets as approved under the MRM Fluid Tailings Management Plan (FTMP) (Commercial Scheme Approval No. 8512J). This data includes operational data, the results of the 2018 annual tailings investigation, and supplementary data related to specific tailings technologies in operation and development at MRM.

2 TAILINGS MANAGEMENT ACTIVITIES

Canadian Natural currently stores tailings in five locations at MRM. These include the External Tailings Facility (ETF), South Expansion Area (SEA), In-Pit Cell 1 (IPC1), In-Pit Cell 2 (IPC2), and In-Pit Cell 3 (IPC3), as illustrated in Figure 1 (Appendix A). This section provides a description of the tailings management activities that occurred in these areas during the reporting period.

2.1 AER Required Fluid Tailings Accounting

Fluid tailings (FT) volumes at MRM, as they relate to the approved requirements laid out in Approval No. 8512J, are included in Appendix B, both in tabular and graphical forms.

2.2 Management Level

Based on the measured FT volumes presented in Appendix B, Muskeg River Mine is currently operating under “Management Level 1”, as per Table 1 of D085. As such, the following managerial actions are being executed:

- A review of the interpretation of the annual tailings investigation is performed to ensure effective reporting and provide verification that targets are achieved.
- Trends in historic data are annually reviewed and used to calculate and refine parameters used for tailings modelling and planning purposes.
- An evaluation of annual investigation of tailings beaches is performed to optimize deposition strategy.
- Continued investment in treatment technology development is in place.
- All standard regulatory requirements continue to be fulfilled.

2.3 External Tailings Facility

The ETF has Coarse Sand Tailings (CST) output lines distributed around the facility that form conventional tailings beaches and historically were used for dyke cell construction. The discharge locations of the Low Temperature Tailings Solvent Recovery Unit (LT TSRU) output line and the Thickened Tailings (TT) output line were previously located along the eastern edge of the ETF. The combination of TT, Tailings Solvent Recovery Unit (TSRU) tailings, and CST deposition formed the North Pool Deposit (NPD); a mixed tailings deposit within the ETF. These lines have since been removed and currently only CST is deposited in the ETF. Fluid tailings are pumped from a strategically located dredging system in the northern portion of the ETF that transfers FT to IPC2 in the area previously called cell 2a. Coarse Sand Tailings is being deposited along the southern side of the pond to progress the beach northward. This deposition, in conjunction with the FT dredging, forms the ongoing “infilling phase” of the ETF.[1] The ETF water is transferred to IPC1 through a pumping system located in the reclaim pocket at the north end of the ETF. In addition, these systems manage fluid containment in the ETF and provide a source of process water to the plant.

Figure 2 provides a plan view of the ETF that includes the location of the fluid transfer systems and the historical Atmospheric Fines Drying (AFD) cells located on the ETF crest. No AFD material was poured in these cells during the reporting period.

[1] Refer to the *MRM ETF Overburden Capping Design Report* (Shell 2016) for more information on ETF infilling.

2.4 South Expansion Area

The SEA has a CST output line that forms conventional CST beaches and historically was used for dyke cell construction. Recovered FT and water are transferred from the SEA to the ETF using a dredge in the past and then pumps as the area was infilled. The SEA has been designed and utilized as a sand storage area. The seepage collection system (located on the perimeter of the facility) receives seepage water from the structure and any precipitation from the side slopes of the structure. This water is pumped to the SEA where it is then transferred to the ETF. The SEA is at its final stages of operation and is transitioning into the first stage of decommissioning. A plan view of the SEA is shown in Figure 3.

2.5 In-Pit Cell 1

In-Pit Cell 1 had a CST output line that has previously formed conventional CST beaches along the east side of the pond and was used for dyke cell construction; however no significant volumes of CST have been deposited in IPC1 during the reporting period (several hours of emergency deposition occurred as required by operations for line flushes and by-passes). No other tailings were deposited in IPC1 during the reporting period. There was previously a historical TSRU tailings output line from the High Temperature Tailings Solvent Recovery Unit (HT TSRU) that discharged into IPC1 from the southwest corner of the pond, but this line was moved to In-Pit Cell 3 (IPC3) in late 2016. In-Pit Cell 1 currently acts as a clarification pond by accepting water transfers from ETF, IPC2, and IPC3 before water is transferred to the Recycle Water Pond (RCW). Figure 4 provides a plan view of IPC1 and locations of the fluid transfer systems.

2.6 In-Pit Cell 2

In-Pit Cell 2A (IPC2A) and In-Pit Cell 2B (IPC2B) were previously independent; however, in late 2017 the ponds were hydraulically connected with a channel as shown in Figure 5. Prior to the channel, FT was transferred from the ETF barge system into IPC2A and containment was managed with a separate water transfer from IPC2A to IPC2B. Fluid tailings and TT are currently discharged into the now merged IPC2. Fluid tailings continue to be transferred into the location of the former IPC2A and TT is deposited into the location of the former IPC2B. In Q2 2018, Dyke2i between IPC2A and IPC2B was overtopped fully merging the ponds into IPC2. In-Pit Cell 2 water is managed through a transfer to IPC1. Figure 5 provides a plan view of IPC2 and locations of the fluid transfer systems.

2.7 In-Pit Cell 3

Tailings streams that discharged into IPC3 during the reporting period included CST, HT TSRU tailings, LT TSRU tailings, and TT. The TSRU tailings streams are discharged from the eastern side of the cell. Thickened Tailings is discharged to the north of the TSRU tailings. These lines, in combination with some CST deposition, form a mixed deposit in the southeast corner of the facility. The CST discharge line was also used for conventional beaching and dyke cell construction along the south and west sides of the cell. A barge in the northeast corner of the pond manages the pond level and transfers water to IPC1. Figure 6 provides a plan view of IPC3 and the location of the fluid transfer system.

3 ANNUAL TAILINGS INVESTIGATION PROGRAM

The 2018 annual tailings investigation program was conducted at MRM from May 21 to August 15, 2018. The investigation consisted of sampling locations, Cone Penetration Testing (CPT), mudline measurements, and drop soundings across the ETF, SEA, IPC1, IPC2, and IPC3 tailings ponds. Table 1 quantifies the testing activities performed in the 2018 annual tailings investigation. Figures 7 and 8 provide plan views of the testing locations for each MRM tailings pond.

Testing Activity	Number Performed
Sampling Location	116
Cone Penetration Test	98
Drop Sounding*	451

*ConeTec CT09

Table 1: Activities Performed for Annual Tailings Investigation

3.1 Laboratory Testing

A laboratory testing program was conducted on samples collected during the 2018 annual tailings investigation to characterize the MRM tailings deposits. The laboratory testing included:

- Moisture Content (MC);
- Dean Stark (DS);
- 75 μm and 44 μm mineral solids fraction using wet sieve;
- Atterberg Limits (AL);
- Methylene Blue Index (MBI); and
- Total Suspended Solids (TSS) on Clear Water Zone (CWZ) samples.

A total of 2,105 samples from the 2018 annual tailings investigation were tested. All testing was conducted in accordance with Canadian Natural's standard laboratory testing procedures and American Society for Testing and Materials (ASTM) standards. Further information on Canadian Natural's tailings investigation standard working procedures is detailed in *Muskeg River Mine & Jackpine Mine Tailings Measurement Plan* (CNRL, 2018).

3.1.1 75 μm and 44 μm Mineral Solids Fraction using Wet Sieve

Previous annual tailings investigations utilized the Malvern Laser Diffraction (LD) instrument (MS2000) to determine the particle size distribution of all sampled tailings. This instrument is no longer commercially available so a study was undertaken to determine the best path forward. The study reviewed several commercially available laser diffraction instruments, as well as a wet sieve procedure currently utilized by Canadian Natural Horizon, designed to assess the 75 μm (No. 200 sieve) and 44 μm (No. 325 sieve) mineral solids fraction. The primary findings of this study are as follows:

- There was a notable variation in reported fines from one brand of LD instrument to another;
- Other LD machines would produce results that were not directly comparable to previously measured values with the Malvern MS2000;

- LD machines can produce more variable results than the wet sieve procedure in some high fines materials depending on the sample preparation;
- LD methodology uses <1 g of sample whereas wet sieve procedure uses 50-100 g of sample. The increased sample size will improve representative sampling as well as lower result deviations; and
- The wet sieve procedure returned a systematically higher 44 μm fines content, but with lower variability. The increase in reported fines has been attributed to better dispersion of agglomerated fines due to the sample preparation required for wet sieve, specifically the steps of boiling and soaking the sample in sodium hexametaphosphate.

A decision was made to move forward with the wet sieve procedure, as documented in the *Muskeg River Mine and Jackpine Mine Measurement Plan* (CNRL, 2018). This has caused a systematic increase in reported fines content for both fluid and treated tailings. The fines content measured using this methodology is seen as more representative because it relates to a fully dispersed condition that is not erroneously reporting agglomerated fines as coarser particles. The impact of this change in fines content has been investigated. The approach and resultant quantification of the impact of this laboratory procedure change are described in later sections of this report. Continued evaluation of this methodology will be performed as future data is collected to better understand the accuracy and precision of this methodology, and to better understand how it relates to historic LD data.

It should be noted the wet sieve methodology will not replace LD in all cases. There continue to be several benefits to LD making it the preferable index test in certain scenarios. In cases where the full particle size distribution (PSD) is required, LD remains the preferable index text. Future requirements for a broader understanding of the PSD may require an increase in LD testing in future investigations. The continued evaluation of the impact of the specific details of the laboratory methodology will be used to ensure any new data is appropriately related to any existing data.

3.2 Survey

As-built and Lidar surveys were used with pond measurements conducted during the time of the annual investigation to model the volumes of site tailings deposits. Original ground surveys were used to supplement the pond survey data as required. Further details of this process and the interpretation of the survey data for the reporting period are further outlined in the following sections.

3.3 Classification of Treated Tailings, Fluid Tailings, and Clear Water Zone

Canadian Natural generally classifies oil sand tailings into three main types: solid tailings, FT, and CWZ. Definitions of the tailings types, the different tailings zones, and the in situ measurement techniques used to delineate them are described in the glossary of terms (Section 15).

3.4 Methodology to Address Uncertainty in Data

There are several sources of uncertainty throughout the process of data collection and interpretation that lead to some variability in annual reported volumes. Critical points of uncertainty and the approach used to minimize that uncertainty are described below.

3.4.1 44 µm Mineral Solids Fraction using Wet Sieve

As described in Section 3.1.1, the 2018 annual tailings investigation relied upon a wet sieve procedure to determine 44 µm fines content. This was a change in procedure from 2017 and resulted in a stepwise change in both the characteristic fines content of FT as well as the estimated mass of fines in the FT. A correction that was developed to relate 2018 data to historic data is described in later sections of this report; however any measurement calculated as a function of the comparison of fines content in 2017 and 2018 will contain a higher level of uncertainty this year than is normally expected. This primarily includes annual fines capture and annual increase in the mass of FT fines, but can also impact other measurements such as settlement and consolidation. This source of uncertainty is not expected to be an issue going forward, as all future tailings data will be consistently collected as per the procedures documented in the *Muskeg River Mine and Jackpine Mine Measurement Plan* (CNRL, 2018). The accuracy and precision of the results of the new laboratory methodology will continue to be evaluated using 2019 data.

3.4.2 Pond Surfaces

A single recorded pond elevation may not be adequate for the purposes of quantifying the amount of FT in ponds where solids are present at the surface of the pond; Lidar survey is used to determine the top surface of the pond in this case. This is currently the case for the ETF because the date of the Lidar survey may not align with the nominal date of the pond investigation.

The data is reviewed on a case-by-case basis to minimize potential sources of error. Lidar measurements of the pond surface, taken close to the date of the survey, are compared to the monitored pond level and the surface elevations taken during the survey. The Lidar is then used to describe the pond surface if there is no significant difference in the elevations. The Lidar can be adjusted, or a simplified pond surface can be constructed from the surveyed pond elevations taken at the time of the CT09 soundings, if the elevations are significantly different. The Lidar surface is the preferable measurement option because the result of surveyed pond elevations can potentially be at a lower resolution surface.

3.4.3 Date Reconciliation

As pond investigations can take up to a month in larger ponds, average nominal survey dates are determined for each pond. This date is then used to linearly interpolate back or project forward to a nominal overall survey date. The adjusted values are then summed to determine the total reconciled volume. In cases where significant FT transfers have occurred; monitoring data is used instead of simple linear interpolation. The following points should be noted:

- The volumes presented in this report are generally the actual volumes surveyed, not the reconciled volumes, because the actual measured volumes are considered more accurate. The date reconciliation step is considered as a check to ensure that the duration of the investigation has minimally impacted the total volume. In cases where the timing of the survey has made a significant impact on the total volume and a reconciled volume is more accurate, the reconciled volume will be presented and it will be specifically noted that it has been adjusted from the surveyed value.
- The projected end-of-year volumes are calculated based on planning models. The actual surveyed volume is used to calibrate the model to the correct volume for each pond on the nominal date of the survey conducted in each pond.

- Fluid tailings transfers are monitored based on flow density; and reconciling for dilution at the source pond and settling at the destination pond can be challenging.

3.4.4 Transitional Materials

Soft materials with strengths on the boundary between soil behaviour and fluid behaviour have been identified on the Beach Below Water (BBW) face of several deposits. The specific instances of these materials and how they are interpreted are described in Section 4.1. In order to address uncertainty driven by the presence of this material, a conservative approach is taken. The following points should be noted:

- The transitional materials are classified as a separate material for the purposes of characterization and monitoring, but within this report they are considered a fluid.
- Pond bottom is derived from CPT where possible, as CT09 may encounter refusal prematurely. Additional CPTs are planned wherever this material is expected.
- The material properties are estimated within an independent domain in the block model, separate from other pond FT.

4 MODELLING

The data obtained from the annual tailings investigation was used to generate the pond bottom surface and mudline surface definitions, as well as to create a three-dimensional classification of treated tailings, FT, and CWZ for each pond. Figures 9 to 13 illustrate the most recent pond bottom contours and mudlines for the ETF, SEA, IPC1, IPC2, and IPC3, respectively. The sections of the different tailings zones for the five tailings ponds that were investigated are shown on Figures 14 through 19.

Block models were generated using the surface definitions mentioned above and individual block properties were subsequently estimated using laboratory test results. The block models were then used to quantify the mass of fines in the FT. The results were used to compare to growth estimates that were generated by tailings planning models. This comparison was used to support the annual tracking of fines in each tailings deposit and the determination of the amount of fines in treated tailings and FT. Sections are generated from the block models that show the variability in both solids content and fines content. These are provided on Figures 20 through 31.

4.1 Pond Bottom and Mudline Interpretation

Fluid tailings volumes were calculated based on Canadian Natural's tailings measurement guidelines which are consistent with those outlined in the G*uideline for Determining Oil Sands Fluid Tailings Volumes* (COSIA, 2015) and Section 5 of the *Muskeg River Mine and Jackpine Mine Measurement Plan* (CNRL, 2018). Pond bottom surfaces were modelled and reviewed against previous surveys, laboratory sampling, satellite imagery, and any additional available data in an effort to produce a representative fluid inventory. Commentaries relating to the interpretation of the available data are outlined below.

4.1.1 External Tailings Facility TSRU Tailings Mats

Early refusals during the investigation of the ETF indicated the presence of TSRU tailings mats suspended in the pond. Many of the same locations are investigated annually and the refusal depth has changed on a yearly basis. This may be due to the fact that the TSRU tailings mats have migrated to lower elevations or farther out into the pond. The 2018 investigation of the ETF had an increased CT09 density in the northern portion of the ETF near the dredging operation compared to previous years. An increased frequency of refusal in this area, compared to previous years, suggests that these mats are likely mobile and are being pulled towards the dredging operation in the north end of the pond.

The extent of the TSRU tailings mats are re-evaluated annually based on the most recent investigation due to their mobile nature; however no quantitative estimates can be made. The mats suspended within the FT are included in the fluid volume. No new mats are expected to be created along the NPD because TSRU tailings deposition has been relocated to IPC3. Some mats appear to be settling to the pond floor and are expected to be consumed into the BBW during infilling. Other mats are being broken up during dredging and have not been observed to reform as mats after being transferred to IPC2.

4.1.2 ETF North Pool Deposit Beach Below Water

As mentioned, TSRU tailings and TT deposition have been relocated to IPC3. No significant growth was expected or seen over the reporting period since the cessation of tailings deposition onto the NPD.

The ETF NPD BBW is composed of a material with strengths clearly indicating soil behaviour that is overlain by a softer material. This softer material has strengths in a range that can produce inconsistent results with the CT09 tool. Cone Penetration Testing is used to determine the bottom of this soft material, and it is classified as a fluid for the purposes of reporting. For monitoring purposes, this material is classified and modelled as a separate material referred to as the Transition Zone (TZ), as initially identified in 2015. It is suspected that a significant portion of the TZ may be subject to mixing and entrainment into the infilled CST material. The TZ will continue to be monitored until it is determined that the properties meet Ready-to-Reclaim (RTR) criteria.

The ETF NPD BBW continues to be investigated with extra sampling and CPT locations to characterize the BBW and delineate the submerged TSRU tailings mats. The 2019 investigation will see a reduction in the number of CT09 measurements because the deposit no longer receives NPD composition of materials and is having CST placed over the deposit, but the high frequency of CPT and sampling to monitor the strength and solids content gain of the TZ will continue.

4.1.3 In-Pit Cell 1 TSRU Tailings Beach

It was observed during interpretation of the 2014 annual tailings investigation results that there was FT located under the toe of the IPC1 TSRU tailings beach, as illustrated in Figure 17. Several locations were added to this area in an effort to further investigate this material. The addition of historical CST deposition onto the TSRU tailings deposit produced beach growth both above and below the TSRU tailings. This resulted in the need for more investigation to resolve the geometry of this deposit. Increased investigation frequency continues to support the interpretation of the geometry and behaviour of this deposit. As noted above in 2.5, the IPC1 is the primary clarification pond that receives clear water zone water from the other ponds, before the water is recycled back into the plant.

4.1.4 In-Pit Cell 3 Mixed Deposit

The tailings strategy for IPC3 is to produce a similar mixed deposit to what exists in the NPD. This beach should be investigated in a similar way to the NPD for the purposes of interpretation and modelling. The current composition and geometry has the following subtle similarities and differences from the NPD.

- No significant transition zone currently exists; however, if a significant enough amount of this material is formed, it will be included in this material category in IPC3, similar to the NPD.
- The geometry of current beach is such that the eastern side is being formed as a mixed deposit; however, no treated material is being directly deposited along the western side. This means that the west side of the beach is compositionally and behaviourally similar to a typical CST beach but as the beach reaches out from west to east it will start to mix. A boundary is provided separating what is forming as CST beach and what is forming as mixed deposit (see Figure 6); however, additional data will be collected in 2019 to refine this boundary. This boundary may be subject to change in future reporting.

- The overall behavior of the mixed deposit is a function of the distribution of TSRU tailings and TT within the deposit. 2018 and 2019 data will be used to assess the similarities and differences in mixing between the NPD and IPC3, to better understand the impact on overall deposit performance and to inform optimization efforts.

4.2 Mass of Fines Modeling Process

The mass of fines within the fluid bodies and the treated tailings deposits are determined based on an estimation produced through the creation of block models using Maptek's "Vulcan" engineering software. This section outlines areas of special interest encountered during the process of calculating the mass of fines across the site.

4.2.1 North Pool Deposit Beach Below Water

The estimation of the mass of fines in the FT is performed assuming that the tailings have settled into essentially uniform horizontal layers. Review of the data in the BBW surrounding the NPD indicates that the TZ, despite its low strength and fluid-like behaviour, does not form uniform horizontal layers. As a result, the mass of fines in the TZ has been estimated separately from the FT.

4.2.2 Mass of Fines Correction

As described in Section 3.1.1, a decision was made to move to an alternate procedure for determining 44 µm fines content of tailings samples. The procedure is described in the *Muskeg River Mine and Jackpine Mine Measurement Plan* (CNRL, 2018); a higher fines content than previously reported is due to an increase in dispersion of the fines. A fines capture correlation was developed in order to quantify the impact of the change in procedure to the calculated mass of fines.

The correlation developed to relate historic fines data to fines data collected using the new methodology was developed using 92 re-tested samples. The samples were selected from retained 2018 samples and were selected to provide a broad spectrum of properties. For example, samples were selected with low to high solids contents, low to high 44 µm fines contents, low to high 75 µm fines contents, and low to high bitumen contents. The selected samples were then re-tested at the laboratory that was responsible for LD testing of the 2017 annual tailings investigation. The re-testing involved re-sub-sampling, re-running DS, and then testing the mineral solids left from DS in the exact Malvern MS2000 machine that was used for 2017 testing. The results were then used to formulate a multi-linear regression to allow the calculation of estimated fines content as if it was measured using the LD machine and the 2017 methodology ($LD44_{estimated}$), based on the 2018 methodology results. A sensitivity was performed and the best fitting multi-linear regression was a function of wet sieve 44 µm fines content (WS44), wet sieve 75 µm fines content (WS75), and geotechnical solids content (bitumen plus mineral solids). The correlation fits well ($R^2 = 0.917$) for samples that would have had a LD44 less than about 85%. Any sample with an LD44 of greater than 85% returns an $LD44_{estimated}$ of about 85% because all those samples have a WS44 of 100% and WS44 is the most significant factor in the regression. The majority of the tailings contained an LD44 of well below 85% in the larger ponds, so the correlation was seen as adequate to estimate the overall impact of the change in procedure.

A set of estimated fines contents were used in the block modelling process based on the developed correlation. This allows for the calculation of a total mass of fines in any unit of the block model based on $LD44_{estimated}$ and WS44. Section 6.4 presents masses calculated by each method. The mass based on $LD44_{estimated}$ is presented for the purpose of comparison with previously reported data. The mass based on WS44 is considered the more accurate volume and all future reporting will be compared to these values.

5 TAILINGS DEPOSITS

5.1 Beaching Operations

Coarse Sand Tailings continued to be deposited site-wide during the reporting period with a focus on ETF infilling, SEA infilling, and IPC3 beaching. Cell construction was utilized where applicable to continue dyke raises and maintain containment. Design beach lengths were monitored and maintained as specified in the individual dyke designs. Details regarding the geotechnical performance of the beaches are outlined in the 2018 Annual Construction Performance Reports (ACPR) that are submitted to the AER for each associated dyke structure.

Infilling operations are underway in the MRM ETF and SEA using progressive CST beaching to displace the FT in an effort to move into the next stage of reclamation of the facility. This deposition methodology in the ETF has resulted in some fines capture. Investigation frequency in this material has been increased to better understand the impact of ETF infilling and CST beaching in general.

The TSRU tailings are a by-product of both MRM and Jackpine Mine (JPM) extraction plant operations. The tailings feed that is treated in the TSRU process consists of Low Temperature Froth Tailings (LTFT) and High Temperature Froth Tailings (HTFT) from the MRM and JPM extraction plants. The resulting tailings (HT TSRU and LT TSRU tailings) streams were historically deposited into the ETF (NPD) and IPC1 and are currently both being deposited into IPC3 to form a mixed deposit. No isolated beaching of TSRU tailings is currently being performed.

The beaching of CST and isolated TSRU tailings are generally considered to be reclaimable and are therefore not monitored for performance against RTR criteria. As per stipulation 37 of Approval No. 8512J, engineering analysis and consolidation modeling is being prepared for the TSRU tailings beach in IPC1 and will be submitted to the AER by September 30, 2020.

5.2 Mixed Deposits

Mixed deposits (“NPD type deposits”, as per Approval No. 8512J) are formed via the combined deposition of CST, TSRU tailings, and TT. The ETF NPD was the primary site for mixed deposition until the end of 2016. IPC3 has subsequently become the primary in-pit facility for mixed deposition within the reporting period. No mixed deposits were formed in NPD or IPC1 during the reporting period. Mixed deposits are subject to the monitoring guidelines laid out in D085 and the following sections present details of the operations and summaries of the performance of these deposits against the RTR criteria stated in *Muskeg River Mine Fluid Tailings Management Plan* (SCE, 2016b) and the subsequent approval conditions.

5.2.1 ETF North Pool Deposit Operation and Ready-to-Reclaim Performance

The ETF NPD is located in the northeast corner of the ETF. The ETF NPD is bounded by the dykes of the ETF to the north and east, and as a result, deposition flowed south and west advancing the toe of the BBW. The location of the ETF NPD is provided in Figure 2.

As indicated earlier, the ETF NPD is composed primarily of material from three tailings streams: CST, TT, and TSRU tailings. These streams were discharged on the ETF NPD along its eastern edge. Whole Tailings (WT) were also intermittently deposited onto the ETF NPD. The TSRU tailings line was relocated in October of 2016, the TT was relocated in March of 2017; and deposition of mixed deposit tailings onto the ETF NPD has ceased as a result.

Trafficability studies have been performed on the surface of the ETF NPD and indicate that some areas of the Beach Above Water (BAW) surface are trafficable with light equipment. Plans remain to continue to infill the area with a hydraulically cap of CST as described in *Muskeg River Mine External Tailings Facility Overburden Capping Design Report* (SCE, 2016a). Hydraulic placement of sand on the ETF NPD is scheduled to commence in 2019.

The ETF NPD received multiple tailings streams, forming a mixed deposit between 2005 and 2016. This deposit, as per D085, is subject to monitoring and reporting against the RTR criteria stated in Canadian Natural's FTMP submission and approval. These values are presented below in Table 2. Tailings deposited prior to 2005 in the NPD were deposited into different areas in the pond. These tailings are composed of TT and TSRU tailings and have been categorized as 'Legacy Deposit' to simplify NPD RTR performance because it has already met the RTR criteria for mixed deposits.

Additional data, including observed undrained shear strengths, pore pressures, and effective stress for a representative section are displayed in the section provided in Figure 32.

Treatment System	Deposition Date	Material Age (years)	Nominal Elevation (masl)	Estimated Deposit Volume (MCM)	Average Solids Content† (%)	Average SFR	RTR Status
Legacy Deposit	2002 - Jul. 2005*	13-16	286-298	17.3	78.5	2.37	NA
Mixed Deposit	Jul. 2005* - Jul., 2013	5-13	298-334	64.4	74.8	2.24	Achieved RTR Final Criteria **
Mixed Deposit	Jul. 2013 - Jul. 2015	3-5	334-336.8	8.2	74.8	2.21	Achieved RTR Final Criteria **
Mixed Deposit	Jul. 2015 - Jun. 26, 2017	1-3	336.8-337	4.6	75.4	2.23	Achieved RTR Final Criteria **
Mixed Deposit	Jun. 26, 2017- Aug. 15, 2018	0-1	-	0	NA	NA	NA
Total				**94.5**	**-**	**2.26‡**	**-**

* Mixed Deposition in the NPD from 2005. Any tailings deposited below El. 298 m are considered Legacy Deposit.

**Based on Approval No. 8512J Table 1 Appendix C for "North Pool Deposit type deposits".

†Geotechnical solids content including bitumen.

± Average calculated based on weighted average of fines content.

Table 2: NPD Mixed Deposit Performance

As presented in Table 2, the ETF NPD has achieved sub objective 1 RTR criteria for the entire deposit. Based on the process presented in the *Muskeg River Mine Fluid Tailings Management Plan* (SCE, 2016b) in Figure E-3, this material will be removed from the RTR inventory for the purposes of annual reporting. Monitoring requirements going forward will be developed based on the requirements for dam decommissioning as per AEP Dam and Canal Directive (December 2018) along with stewarding to the mine reclamation plans (MRP) that align with the Life of Mine Plan.

It should be noted, that some stand-alone TT was deposited at the southern end of the ETF NPD from Q4 2015 to Q1 2017 (as indicated in 2016 FTMP), resulting in approximately 12 m of deposit formed from primarily TT slurry. This material has been included with the mixed deposit for the purposes of performance monitoring. This was done because based on trafficability and monitoring of the materials solids content, the geotechnical performance is in line with the remainder of the mixed deposit and this material has already achieved the RTR final criteria required for NPD. 2018 sampling from this area indicated the deposit formed from primarily TT deposition has achieved an average solids content of 77.8%, with an average fines content of 21.9% (based on 25 samples).

5.2.2 IPC3 Mixed Deposit Operation and Ready-to-Reclaim Performance

The IPC3 mixed deposit lies in the southeast corner of the IPC3 facility. Deposition has been ongoing since the end of 2016. The facility contains both a mixed deposit and CST beaches along the south and west perimeter. Volumes reported for IPC3 reflect only the portion of beach that is considered mixed deposit. The approximate area of the mixed deposit is highlighted in Figure 6. The mixed deposit portion of the beach is subject to RTR monitoring and performance reporting and these values are presented in Table 3.

Treatment System	Deposition Date	Material Age (years)	Nominal Elevation (masl)	Estimated Deposit Volume (MCM)	Average Solids Content* (%)	Average SFR	RTR Status
Mixed Deposit	2016 - Jun. 23, 2017	1-2	231-246	2.1	69.5	2.08	On Approved Trajectory over 5 years
Mixed Deposit	Jun. 23, 2017- Jun. 19, 2018	0-1	246-261	8.9	60.5	1.16	On Approved Trajectory over 5 years
Total				**11.0**	**-**	**1.29****	**-**

*Geotechnical solids content including bitumen.
**Average calculated based on weighted average of fines content.

Table 3: IPC3 Mixed Deposit Performance

5.3 Thickened Tailings Deposits

Thickened Tailings at MRM are used for the formation of both mixed deposits and TT deposits. The only TT deposit formed without the opportunity to mix with TSRU (and form a mixed deposit) during the reporting period at MRM is located in IPC2. Data related to TT deposits are presented in the following sections. Thickened Tailings was previously deposited in the southern portion of the NPD in a location that was far enough from CST and TSRU tailings deposition that the deposit was considered primarily TT. Information on this material is reported in section 5.2.1.

5.3.1 IPC2 TT Operation and Ready-to-Reclaim Performance

The IPC2 TT beach is formed from occasional emergency TT deposition from the southwest corner of the area of IPC2 that was formerly IPC2B (see Figure 18). CST is also deposited onto this beach; however, deposit formed from TT deposition has a distinct composition allowing it to be identified based on fines content.

Thickened tailings is not planned for IPC2 based on the 2016 FTMP (SCE. 2016B); however the performance of the TT in the facility does not currently impact the end land use as stated in the 2016 Closure Plan based on the observed geotechnical performance.

Information regarding the TT deposit formed in IPC2 during the reporting period is included in Table 4. Further investigation of this deposit is planned for 2019. The TT deposit did not account for the entire beach where deposition occurred and location of TT beach is approximate. Reported TT beach volumes were calculated based on characterization of the material and production volumes. This was because the deposit was too small to be accurately modelled based on CPT depths and available survey.

Additional data, including observed undrained shear strengths, pore pressures, and effective stress for a representative section of the TT beach are presented in the section provided in Figure 33. The observed higher sand to fines ratio (compared to TT in the ETF) may be an indication of the influence of CST on the TT deposit.

Treatment System	Deposition Date	Material Age (years)	Nominal Elevation (masl)	Estimated Deposit Volume (MCM)	Average Solids Content** (%)	Average SFR	RTR Status
TT	May 20, 2017- Jun. 19, 2018	0-1	259-264	0.8	75.3	3.57	Achieved RTR Final Criteria*
Total				**0.8**	**75.3**	**3.57**	**-**

*Based on 2016 FTMP (SCE. 2016B), as no RTR criteria for TT was provided in Approval No 8512J. Performance is also in line with "mixed deposit in (JPM) ETF" RTR as stated in Approval No. 9756H Table 1 Appendix C. The "mixed deposit in (JPM) ETF" is compositionally similar to MRM TT, as placed in IPC2.
** Geotechnical solids content including bitumen.

Table 4: IPC2 TT Deposit Performance

5.4 Atmospheric Fines Drying Deposits

Atmospheric Fines Drying (AFD) is a thin lift FT treatment technology. Deposits can be formed in the treatment location or the treated solid tailings can be hauled into dumps.

To date, under the AER's previous guidance (Directive 074) and Canadian Natural's previously submitted plans, AFD treated tailings have been stored in the non-trafficable waste zones (NTWZ) of Dump 2X (upstream toe-berm of In-Pit Dyke 3S), Dump 2C, Southwest Dump (SWD), and the upstream toe berm of In-Pit Dyke 6 (IPD6). Future disposal locations will additionally include the dump portion of In-Pit Dyke 5 and Dump 7 which have also been assessed for treated tailings placement. As stated in *Muskeg River Mine Fluid Tailings Management Plan* (SCE, 2016b) the monitoring of these mixed deposits of AFD will continue as part of the closure landform monitoring under EPEA.

No fluid tailings at MRM were treated using the AFD technology in the reporting period.

5.5 Settlement and Consolidation

Settlement and consolidation are not directly tracked in active deposits. Settlement gauges are installed as deposits reach their ultimate height and direct monitoring of settlements are used for closure design. During active deposition, settlement and consolidation are monitored by tracking the annual change in solids content (presented in the tables above) and by monitoring the dissipation of excess pore pressure.

6 POND STATUS AND MASS OF FINES IN FLUID TAILINGS

6.1 Fluid Tailings and Water Volumes from 2018 Investigation

The volumes of FT and water in each tailings pond are estimated based on the results of the annual investigation program and block modelling results. Table 5 presents a summary of the total volumes of FT and water in each of the MRM tailings ponds as of the 2018 investigation. The FT volumes reported in Table 5 include FT that has been identified as being trapped under the TSRU tailings beach in IPC1 and under the TSRU tailings mats in the ETF.

Pond	FT (MCM)	Water (MCM)
ETF*	52.7	0.0
SEA	1.4	0.0
IPC1	31.4	7.3
IPC2**	24.7	13.4
IPC3	9.7	1.3
MRM Site	**119.9**	**22.0**

* Volume includes Transition Zone material for NPD BBW deposit.
**IPC2 volumes reflect the combined volumes from surveying IPC2A and IPC2B. The volumes have been adjusted to match the survey date of IPC2A.

Table 5: FT and Water Volumes from 2018 Investigation

6.2 Fluid Tailings Properties

The composition of each FT body is measured during the annual investigation using sampling and block modeling as described in previous sections. The resultant average values are presented in Table 6.

<table>
<tr><th colspan="2">Pond</th><th>Average Solids (%)</th><th>Average Bitumen (%)</th><th>Average Water (%)</th><th>Average 44um Fines (%)</th></tr>
<tr><td colspan="2">ETF</td><td>54.4</td><td>4.2</td><td>41.4</td><td>62.9</td></tr>
<tr><td colspan="2">SEA</td><td>49.2</td><td>1.4</td><td>49.4</td><td>68.0</td></tr>
<tr><td colspan="2">IPC1</td><td>45.9</td><td>2.9</td><td>51.2</td><td>68.4</td></tr>
<tr><td rowspan="2">IPC2</td><td>IPC2A</td><td>44.7</td><td>2.1</td><td>53.2</td><td>64.6</td></tr>
<tr><td>IPC2B</td><td>39.9</td><td>1.6</td><td>58.5</td><td>77.1</td></tr>
<tr><td colspan="2">IPC3</td><td>36.1</td><td>4.4</td><td>59.6</td><td>76.7</td></tr>
</table>

Table 6: 2018 Site FT Properties

6.3 Projected Fluid Tailings and Water Volumes for December 31, 2018

The volumes of FFT and water in each tailings pond are projected from the measured values collected during the investigation based on planning models and production data. Table 7 presents a summary of the total volumes of FFT and water predicted in each of the MRM tailings ponds as of December 31, 2018.

Pond	FT (MCM)	Water (MCM)
ETF*	51.7	0.0
SEA	0.2	0.2
IPC1	31.4	9.6
IPC2	26.5	8.4
IPC3	11.9	2.4
MRM Site	**121.7**	**20.6**

* Volume includes Transition Zone material for NPD BBW deposit.

Table 7: FT and Water Volumes for December 31, 2018

6.4 Pond Capacity Projections

Projections showing the estimated available storage for fluid (water and FT) until 2023 are provided in Table 8. These projections are based on planned mine progress and dyke construction. Table 9 provides the complementary data, indicating current estimates for how much fluid will require storage.

Pond	Available Storage (MCM)					
	2018	2019	2020	2021	2022	2023
ETF	44.5	44.5	44.5	44.5	44.5	44.5
IPC1	48.1	48.1	48.1	48.1	48.1	48.1
IPC2	74.1	98.7	98.7	98.7	98.7	98.7
IPC3	24.3	49.0	75.4	89.8	104.7	120.0
IPC4	NA	NA	NA	25.3	65.1	125.5
MRM Site	**191.0**	**240.3**	**266.7**	**306.3**	**361.1**	**436.8**

Table 8: Available Pond Storage Projections

Pond	Total Volume Requirement (MCM)					
	2018	2019	2020	2021	2022	2023
ETF	NA	43.5	43.7	44.2	44.2	44.2
IPC1	NA	38.0	40.7	42.4	43.9	45.4
IPC2	NA	55.4	72.8	90.6	94.2	94.2
IPC3	NA	44.0	70.1	86.9	91.3	95.4
IPC4	NA	NA	NA	10.2	42.6	80.7
MRM Site	**NA**	**180.9**	**227.3**	**274.3**	**316.2**	**360.0**

Table 9: Required Capacity Projections

6.5 Mass of Fines Processed

Table 10 shows the mass of fines (<44 μm) that was processed in the ore mined during the reporting period. Fines delivered to MRM tailings ponds exclude fines of rejected ore and includes TSRU tailings produced at JPM. A characterization of the ore-to-crusher feed is provided in Table 11.

Period	Fines in Ore to Crusher (Mt)	Fines in Rejects (Mt)	Fines in JPM TSRU Tailings (Mt)	Fines Delivered to MRM Tailings Ponds (Mt)
Jan. 1, 2018 to Dec. 31, 2018	12.0	0.32	1.18	12.8

Table 10: Mass of Fines in Ore

Period	Average Solids (%)	Average Bitumen (%)	Average Water (%)	Average 44um Fines (%)
Jan. 1, 2018 to Dec. 31, 2018	83.9	11.1	5.1	15.7

Table 11: Characterization of Ore Feed

6.6 Mass of Fines in Fluid Tailings

This section presents the estimated mass of fines contained in the FT during the investigation. Section 4.2 outlines the method used for the estimation. Table 12 outlines the specific mass of fines contained in each pond at the time of the 2018 investigation. These values were calculated based on both the corrected fines content that relates to the 2017 laboratory methodology and based on the improved fully dispersed laboratory methodology implemented in 2018. The artificial increase in mass of fines resulting from this change in methodology is also reported.

Pond	**2018 Annual Investigation (Mt)** (Comparable to 2017 Methodology)	**2018 Annual Investigation (Mt)** (Improved Laboratory Method - Fully Dispersed)	Stepwise Impact of Improved Laboratory Methodology (Mt)
ETF	29.1	32.2	3.1
SEA	0.7	0.8	0.1
IPC1	14.4	15.9	1.5
IPC2	9.2	10.3	1.1
IPC3	3.8	4.4	0.6
MRM Site	**57.2**	**63.6**	**6.4**

Table 12: Mass of Fines Present in Fluid Tailings

6.7 Settlement and Consolidation

Settlement and consolidation are not directly tracked in active ponds due to the complexity and inaccuracy inherent in measuring and calculating these values. Estimations of the impact of settlement and consolidation are produced on a planning level, based on laboratory testing (Large Strain Consolidation testing). These estimates are implemented in planning models to support accurate estimation of CWZ volumes. Effects such as wave action, active dredging, dilution during transport, and the entrainment of coarse material all combine to make any laboratory derived estimate of consolidation an overestimate. Due to these factors Canadian Natural has excluded the impact of settlement and consolidation for the purpose of annual reporting, to ensure conservatism in the MRM FTMP, and to provide more reliable long-term estimates of required storage in primary FT storage areas.

Settlement and consolidation of FT will be measured and tracked as accurately as possible in any pond that is no longer active (end of deposition).

7 TAILINGS WATER

The following section provides information regarding management of water at MRM. This includes a water balance, current inventories, and an environmental characterization of pond water. The pond water contains hydrologic water (precipitation and surface runoff), recycled process water, and water released from both FT and treated tailings deposits during consolidation.

7.1 MRM Water Balance

Water from the Athabasca River is pumped from the river water pump house to the Raw Water Pond and to the RCW. In 2018, 23.99 MCM of water from the Athabasca River was used at the Albian site with 10.07 MCM sent to the Raw Water Pond and 13.92 MCM diverted to the RCW. The Athabasca River water intake is allocated to MRM and JPM usage. In 2018, 15.83 MCM was allocated to MRM and 8.16 MCM to JPM.

Of the 15.83 MCM of river water allocated to MRM usage, 8.78 MCM was pumped to the Raw Water Pond and the remainder, 7.04 MCM, was diverted to the RCW. The raw water system provides water to the following systems.

- Gland water system for MRM and JPM.
- Boiler feed water makeup for JPM.
- Chlorinated boiler feed water makeup for MRM.
- Chlorinated water for ATCO’s cogeneration unit.
- Fire water.

The recycle water system is designed to maximize the reuse of on-site process affected water to minimize the use and import of fresh water from the Athabasca River. Utilities provide hot and cold recycled water for a variety of uses. 84.79 MCM of recycled water was allocated to MRM In 2018.

Reclaimed water from MRM and JPM tailings ponds are the main water sources for the RCW. 75.53 MCM of water was reclaimed from the MRM tailings ponds in 2018.

In addition to river import, MRM accounted for the following external sources of water in 2018.

- 2.24 MCM of water from precipitation and surface runoff.
- 0.92 MCM of water from aquifer depressurization.
- 4.81 MCM of connate water (i.e., water in ore) which reported to MRM Ore Prep plant.
- 4.43 MCM of water transferred from JPM to MRM from the JPM froth sent to the Froth Treatment plants on the MRM site. This water reports to the TSRU tailings streams for deposition into IPC3.

MRM accounted for the following losses of water in 2018.

- 1.47 MCM of water evaporated from the MRM tailings based on temperature differentials from CST slurry deposition.
- 0.20 MCM, 0.76 MCM, and 0.003 MCM were lost to Utilities, cooling, and product sent for further processing at the Scotford Upgrader, respectively.

MRM tailings facilities received 27.69 MCM of water, which includes clear water inventory and water trapped in tailings pore spaces in both the fluid and deposit.

A schematic detailing the 2018 water balance for MRM is provided in Appendix B.

7.1.1 Clear Water Inventory

The actual total water volume at MRM at the end of 2018 was 20.6 MCM, as shown in Table 13. This was higher than the planned volume of 12.0 MCM in the FTMP submission due to operational challenges.

Pond	Plan/Actual	2016 (MCM)	2017 (MCM)	2018 (MCM)
ETF	Plan [1]	1.9	1.5	1.0
	Actual [2]	0.8	1.1	0.2
IPC1	Plan [1]	8.1	8.5	8.0
	Actual [2]	8.4	7.9	9.6
IPC2	Plan [1]	1.0	1.0	2.0
	Actual [2]	2.3	5.2	8.4
IPC3	Plan [1]	2.0	1.0	1.0
	Actual [2]	1.6	2.1	2.4
MRM Site	**Plan [1]**	**13.0**	**12.0**	**12.0**
	Actual [2]	**13.2**	**16.3**	**20.6**

[1] Plan from FTMP Table C-1: Tailings Plan Volumetrics.

[2] MRM year-end volume calculation.

Table 13: MRM Clear Water Volumes Comparison

The actual volume of 0.2 MCM of water was less than the planned value of 1.0 MCM in the MRM ETF. This is attributed to the transferring of diluted FT from the ETF to IPC2 to support infilling operations. It was originally assumed that the transferred FT would be approximately 30% solids, but in reality it was 18%, which resulted in an increase in water transferred out of the ETF. A second FFT transfer line from the ETF to IPC2 was installed and became operational in September 2018.

The actual volume in IPC2 of 8.4 MCM was greater than the planned volume of 2.0 MCM. This increase is due to the diluted FFT transferred from the ETF and increased deposition into the cell. As less deposition occurred than planned in the ETF, due to issues of transferring out FFT, there was increased deposition in IPC2 and IPC3. There was also higher production overall at MRM in 2018 than planned. The IPC2 reclaim water system capacity was increased in September 2018 to support site water management and increase the volume of reclaim water sent to IPC1.

The actual volume in IPC3 of 2.4 MCM was greater than the planned volume of 1.0 MCM. Tailings from the HT TSRU began depositing in IPC3 in late 2016 while LT TSRU and TT began depositing in IPC3 in 2017. The water inventory increase in IPC3 is the result of poor reclaim water quality, lower than planned solids content in the TT stream, and increased deposition into the cell. The poor water quality in IPC3 resulted in less water transferred out to IPC1. As a result, the CWZ target for IPC3 was increased to improve water quality which increased the overall inventory in the cell. The TT solids content was 19%, compared to the planned solids content of 30%, and this dilution lead to increased water deposited in the cell.

The primary process water reclaim system is maintained in IPC1. The water inventory in IPC1 was 9.6 MCM at the end of the year, compared to the planned volume of 8.0 MCM. Operational challenges with poor reclaim water quality from the ETF and IPC3, as well as inadequate reclaim capacity from IPC2, led to increased river intake and higher overall site water inventory.

7.2 Water Quality Results

Water quality samples are periodically taken from the tailings ponds for laboratory testing and annual reporting to the AER. Table 14 presents the average values of key water quality variables and their standard deviation for MRM water throughout the reporting period.

	Units	IPC1-2018		IPC2(A)-2018		IPC2(B)-2018		IPC3-2018		ETF-2018	
		Avg.	St. Dev	Avg.	St. Dev	Avg.	St. Dev	Avg.	St. Dev	Avg.	St. Dev
pH	-	8.41	0.06	8.61	0.06	8.50	0.13	8.36	0.09	8.51	0.11
Calcium (Ca)	mg/L	35.05	20.58	23.10	3.96	18.80	0.71	8.36	0.09	47.95	4.60
Magnesium (Mg)	mg/L	15.25	5.02	14.55	1.06	11.40	0.71	7.06	2.35	22.75	1.48
Sodium (Na)	mg/L	297	53.03	361	19.80	328	4.95	301	10.61	324	9.90
Potassium (K)	mg/L	16.55	2.19	18.85	0.07	16.60	0.42	15.70	0.14	18.20	0.57
Carbonate (CO_3)	mg/L	6.55	1.91	18.65	3.61	11.30	4.38	5.20	0.14	453.50	23.33
Bicarbonate (HCO_3)	mg/L	417	48.79	541	30.41	497	36.06	386	14.85	386	14.85
Chloride (Cl)	mg/L	81	110.55	3	0.59	3	0.21	132	7.07	3	0.51
Sulphate (SO_4)	mg/L	176	67.18	189	7.07	172	14.14	223	18.38	142	1.41
TDS (1/2EC)	mg/L	963	47.38	1070	0.00	1007	18.38	888	31.11	1120	14.14
TSS	mg/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iron (Fe)	mg/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkalinity as $CaCO_3$	mg/L	352	36.77	475	30.41	426	21.92	320	18.38	393	12.02
Electrical Conductivity	µS/cm	1575	134.35	1735	77.78	1685	176.78	1450	127.28	1730	84.85

Table 14: Pond Tailings Water Environmental Characterization

8 EXISTING TAILINGS TECHNOLOGY SUMMARY

Fluid Fine Tailings treatment options are currently being assessed for Canadian Natural's operations. Details pertaining to treatment options are outlined in the document previously submitted by Shell Canada Limited to the AER titled *Muskeg River Mine Fluid Tailings Management Plan* (SCE, 2016b). The two primary strategies for FT management during the reporting period were TT and mixed deposition. The following sections describe the annual performance of these strategies.

8.1 Thickened Tailings

The TT operation at MRM consists of two thickeners that treat hydro-cyclone overflow from the extraction process. Both IPC2 and IPC3 receive TT; however, IPC3 is using TT to form a mixed deposit with TSRU tailings. This section refers only to the TT beach in IPC2.

8.1.1 Thickened Tailings Production

Table 15 shows TT slurry volumes for the reporting period.

Treatment System	Destination	Production Volume for 2018 (MCM)
TT	IPC2	11.4

Table 15: Thickened Tailings Treatment Volumes

8.1.2 Thickened Tailings Monitoring

Monitoring of the TT process throughout the reporting period primarily consisted of monitoring of slurry solids content, fines content, and destination. This data is presented in Table 16.

Date	Destination	TT Slurry	
		Average Solids Content (%)	Average Fines Content (%)
Q1 2018	IPC2	20.1	69.4
Q2 2018	IPC2	18.1	69.4
Q3 2018	IPC2	17.2	72.0
Q4 2018	IPC2	18.9	61.8
Average		**18.6**	**68.2**

Table 16: Thickened Tailings Process Monitoring

8.2 Mixed Deposition

Mixed deposit tailings are the result of a combination of TT, TSRU tailings, and CST deposition on the same beach. The mixing of these streams forms a deposit that maintains some of the strength and geotechnical characteristics of the CST component while entraining fines from the TT and TSRU tailings streams. This treatment strategy was previously used to form the NPD. A mixed deposit is currently being formed in IPC3. Refer to the *Muskeg River Mine Fluid Tailings Management Plan* (SCE, 2016b) for more detail on mixed deposition (referred to as North Pool Deposit Type).

8.2.1 Mixed Deposition Production

Table 17 shows slurry volumes used for mixed deposition during the reporting period.

Treatment System	Destination	Production Volume for 2018 (MCM)
CST	IPC3	11.6
TT	IPC3	11.5
TSRU	IPC3	22.0
Total		**45.1**

Table 17: Mixed Deposition Tailings Slurry Volumes

8.2.2 Mixed Deposition Monitoring

Monitoring of the mixed deposition process throughout the reporting period primarily consisted of monitoring slurry solids content, fines content, destination, and deposition ratios. Deposition ratios are reported as the volumetric ratio of deposit formed by each stream. It is calculated based on the solids recorded in each slurry stream and assumed deposit densities derived from locations where those streams are deposited in isolation. This data is presented in Tables 18 and 19.

Date	Destination	TT Slurry		CST Slurry		TSRU Tailings Slurry	
		Solids Content (%)	Fines Content (%)	Solids Content (%)	Fines Content (%)	Solids Content (%)	Fines Content (%)
Q1 2018	IPC3	20.1	69.4	52.4	6.4	18.2	57.9
Q2 2018	IPC3	18.1	69.4	51.8	6.7	17.8	55.2
Q3 2018	IPC3	17.2	72.0	50.8	7.9	15.5	59.0
Q4 2018	IPC3	18.9	61.8	49.7	6.7	17.8	56.9
Average		**18.6**	**68.2**	**51.2**	**6.9**	**17.3**	**57.3**

Table 18: Mixed Deposition Tailings Process Monitoring

Date	Dest.	Estimated TT Deposit Fraction		Estimated CST Deposit Fraction		Estimated TSRU Tailings Deposit Fraction		Total Volume (MCM)
		Volume (MCM)	Volume Ratio (%)	Volume (MCM)	Volume Ratio (%)	Volume (MCM)	Volume Ratio (%)	
Q1 2018	IPC3	-	0	1.3	51	1.3	49	2.7
Q2 2018	IPC3	0.4	12	1.9	57	1.0	31	3.3
Q3 2018	IPC3	0.4	14	1.2	42	1.2	44	2.7
Q4 2018	IPC3	0.5	15	1.4	45	1.3	40	3.2
Total/Average		**1.3**	**10**	**5.8**	**49**	**4.8**	**41**	**11.9**

Table 19: Mixed Deposition Tailings Deposit Ratios

8.2.3 Mixed Deposition Operational Controls

Based on historical deposit performance, development of a NPD-type deposit has shown to be effective for fines capture and have sufficient strength to be capped with CST to support the final landscape. In MRM IPC3, both LTFT and HTFT TSRU streams have been strategically deposited alongside TT and CST/WT, resulting in different TSRU and TT ratios than the MRM ETF NPD.

Results from the 2018 LSC and advanced geotechnical testing of TSRU and mixed-deposit containing TSRU show material with higher TSRU contents continue to have low compressibility and have relatively high strengths compared to their solids contents. From this, it was determined that the mixed deposit in IPC3 is on a trajectory to meet RTR criteria, and will have sufficient strength to be capped with CST; therefore, the increased fraction of TSRU poses minimal risk to end land use requirements in IPC3.

The decision was made to take an observational approach in which the deposit performance and fines treatment efficiency are monitored. Operational controls include tracking TT and CST/WT deposition volumes to support the NPD-type deposition formation. Continued monitoring of the IPC3 mixed deposit and further analysis of each TSRU mixed deposit will increase the understanding of mixing ratios on fines treatment and geotechnical deposit performance. These learnings will be used to optimize mixing ratios in the future.

9 TAILINGS TECHNOLOGY RESEARCH AND SUMMARY OF IMPROVEMENTS

A summary of Canadian Natural's tailings research has been prepared and is included in Appendix D. The research projects undertaken by Canadian Natural's Technology Development group have been designed to provide information to allow the selection of tailings technologies for commercial implementation. Tailings research is also used in the development of Canadian Natural's Tailings Plans, including Canadian Natural's FTMPs, which enables Canadian Natural to explore continuous improvement.

Canadian Natural continues to refine its tailings technologies and depositional strategies. The following efforts were made to improve the state of Canadian Natural's tailings at MRM.

- FFT Consolidation: Casing Project.
- Chemical Amendment of FFT.
- Soft Deposit Capping: AFD Test Cell Capping.
- End of Pipe Tailings Treatment.
- Geotube Pilot.
- FFT Pressure Filtration Pilot.

Appendix D includes tailings technology research performed in support of tailings operations at MRM and JPM, and excludes any research performed by Canadian Natural for Horizon Mine.

10 ENVIRONMENTAL MONITORING (SUB OBJECTIVE 2)

According to the 2016 FTMP Approval, for sub objective 2 RTR criteria, groundwater is monitored as required by the *Environmental Protection and Enhancement Act* (EPEA) Approval No. 20809-02-00. Environmental monitoring with respect to MRM tailings facilities includes groundwater and surface water monitoring. The objectives of the groundwater monitoring program at MRM are to establish groundwater baseline conditions, evaluate for potential changes in groundwater quantity (groundwater elevations) and groundwater quality (chemistry), and assess the potential impact of MRM on groundwater quantity and quality. Monitoring activities include field measurements of physical and chemical parameters (e.g. temperature, pH and conductivity) and sampling for laboratory testing (of a comprehensive analyte suite, including routine parameters, dissolved metals, naphthenic acids, and hydrocarbon constituents). Laboratory results are analyzed statistically to assess for any changes or deviations from the baseline. The potential risk of environmental effects are continually evaluated, using comparisons of baseline environmental conditions versus ongoing monitoring conditions of tailings source, pathway, and receptors, within the framework of the regulatory guidelines for environmental contaminants. If changes are identified, they are investigated in accordance with the site's groundwater response plan, including increasing the monitoring frequency wells when changes are identified. The monitoring well locations for the MRM ETF seepage system are shown in Figure 35.

Based on the 2018 groundwater monitoring results, indicator parameters tested in monitoring wells fall within the historical background chemistry ranges, with further field monitoring, laboratory testing, analysis and investigation scheduled for 2019.

11 STAKEHOLDER ENGAGEMENT

A summary of stakeholder engagement activities performed over the reporting period is included in Appendix C and includes engagements performed in support of tailings operations at MRM and JPM.

12 CONCLUSION

This report was compiled by various authors in the various disciplines to meet the requirements of Directive 085. Data collected to inform this report adheres to the procedures and methods described in the *Muskeg River Mine and Jackpine Mine Measurement Plan* (CNRL, 2018) and guidelines provided in the *Guideline for Determining Oilsands Fluid Tailings Volumes* (COSIA, 2015).

Based on the currently available data, and current projections, Muskeg River Mine continues to be operated based on the plan laid out in the *Muskeg River Mine Fluid Tailings Management Plan* (SCE, 2016b).

Ongoing efforts continue to be focused on evaluating the mechanisms responsible for the variability in fines capture observed throughout the site, improving and optimizing the currently operational tailings treatments, and developing novel treatments. Current progress in these areas indicates MRM will meet the requirements laid out in Approval No. 8512J.

Prepared by:

APRIL 30, 2019
WATER BALANCE

Tailings Modelling

Karsten Rudolf
Engineer, Tailings

Vera-Marie Whitehead
Engineer, Tailings Planning

Technical Review by:

Monica Ansah-Sam, MESc, P.Eng
Delegated Responsible Discipline Member

Approval by:

Scott Martens
Manager, Mine Geotechnical/Geology

APEGA permit to practice No. P06872

13 REFERENCES

CNRL 2018. "Muskeg River Mine and Jackpine Mine Measurement Plan." Canadian Natural Resources Limited, 30 November 2018.

CNRL 2019. "2018 Annual Environment Report." Canadian Natural Resources Limited, 2019.

COSIA 2015. "Guideline For Determining Oil Sands Fluid Tailings Volumes." Canada Oil Sands Innovation Alliance, June 2015. https://www.cosia.ca/resources/project-research#tailings.

SCE 2016a. "Muskeg River Mine External Tailings Facility Overburden Capping Design Report." Shell Canada Energy, 26 September 2016.

SCE 2016b. "Muskeg River Mine Fluid Tailings Managment Plan." Shell Canada Energy, 7 October 2016.

14 ACRONYMS

ACPR	Annual Construction Performance Report
AFD	Atmospheric Fines Drying
AL	Atterberg Limits
ASTM	American Society for Testing and Materials
BAW	Beach Above Water
BBW	Beach Below Water
CPT	Cone Penetration Testing
CST	Coarse Sand Tailings
CWZ	Clear Water Zone
D085	Directive 85
DS	Dean Stark
ETF	External Tailings Facility
FFT	Fluid Fine Tailings
FT	Fluid Tailings
FTMP	Fluid Tailings Management Plan
HTFT	High Temperature Froth Tailings
HT TSRU	High Temperature Tailings Solvent Recovery Unit
IPC1	In-Pit Cell 1
IPC2	In-Pit Cell 2
IPC2A	In-Pit Cell 2A
IPC2B	In-Pit Cell 2B
IPC3	In-Pit Cell 3
JPM	Jackpine Mine
LD	Laser Diffraction
LTFT	Low Temperature Froth Tailings
LT TSRU	Low Temperature Tailings Solvent Recovery Unit
MBI	Methylene Blue Index
MC	Moisture Content
MRM	Muskeg River Mine
NPD	North Pool Deposit
RCW	Recycle Water Pond
RTR	Ready-to-Reclaim
SEA	South Expansion Area
TSRU	Tailings Solvent Recovery Unit
TSS	Total Suspended Solids
TT	Thickened Tailings
TZ	Transition Zone
WT	Whole Tailings

15 GLOSSARY OF TERMS

Fluid Tailings

Fluid tailings (treated or non-treated tailings) are the discard from bitumen extraction facilities containing more than 5% (mass) suspended mineral solid and having an undrained shear strength less than 5 kPa. The ConeTec CT09 tool is used to determine the approximate hard bottom surface during the annual tailings investigations.

The 5% solids content mark is defined as the mudline and is determined by using a Geoforte density plate calibrated to a specific gravity of 1.05. Fluid below the mudline is classified as fluid tailings.

As accounted in this report, the fluid tailings inventory includes some treated material that has not yet exceeded the undrained shear strength requirement.

Clear Water Zone

The Clear Water Zone is the supernatant fluid above the mudline. Water above the mudline is recycled to the extraction plant.

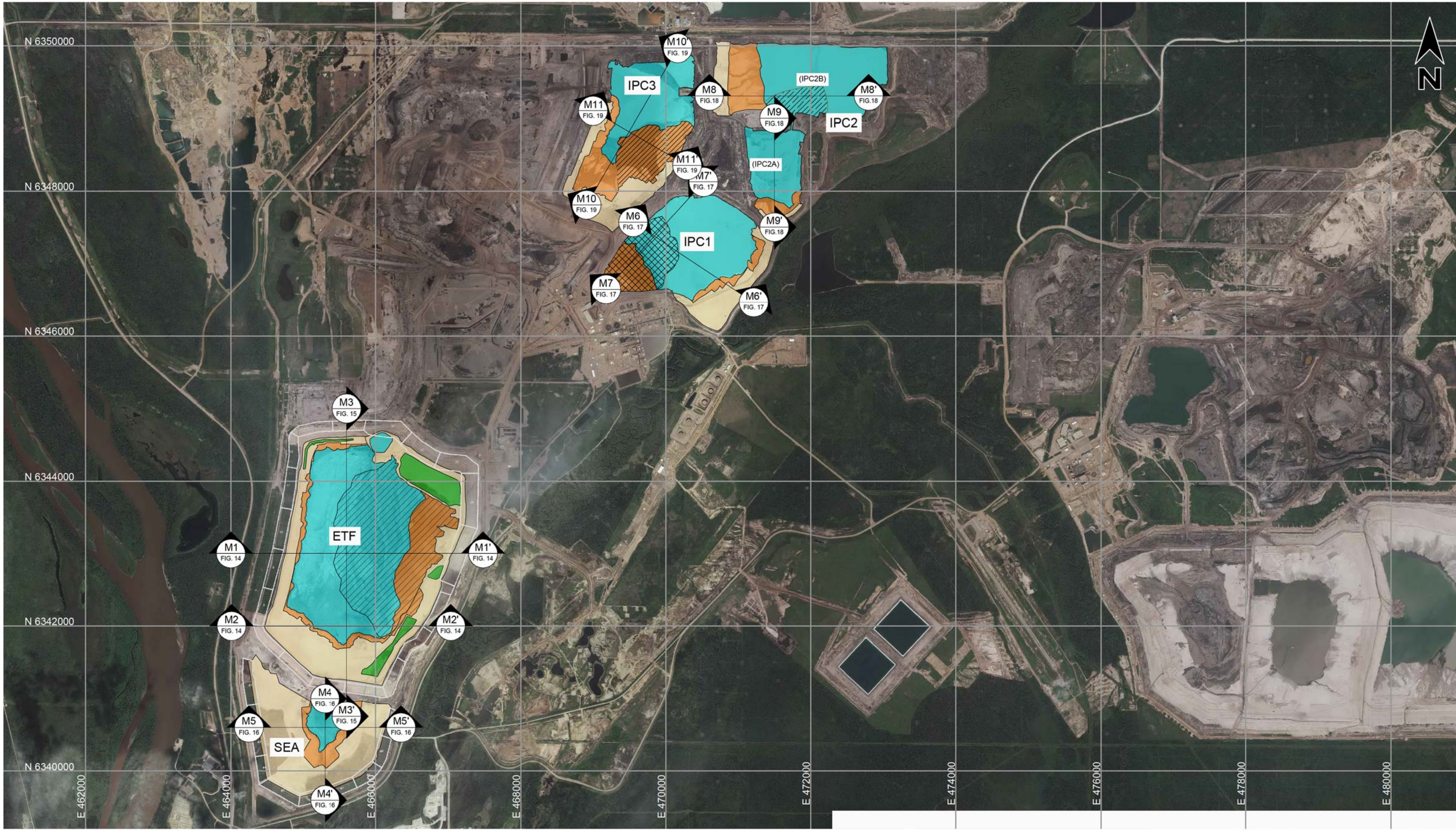
Solid Tailings

Solid tailings are fine tailings deposits having an undrained shear strength greater than 5 kPa. Solid tailings at Muskeg River Mine include Beach Below Water and Beach Above Water deposits formed from the discharge of Coarse Sand Tailings, Thickened Tailings, Tailings Solvent Recovery Unit and Whole Tailings streams.

Available Storage

Available storage is the volume available between the projected pond and beach-above-water surface and the planned freeboard elevation for a given period.

APPENDIX A:
MRM Fluid Tailings Management Report Figures



NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.
3. AERIAL PHOTO DATED 2018-07-27.

0 500 1000 1500 2000 m

1 : 50,000

LEGEND:
- POND
- TAILINGS BEACH
- CELL SAND
- MIXED TAILINGS BEACH
- TSRU
- AFD/FFT DRYING CELLS

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	1:50,000

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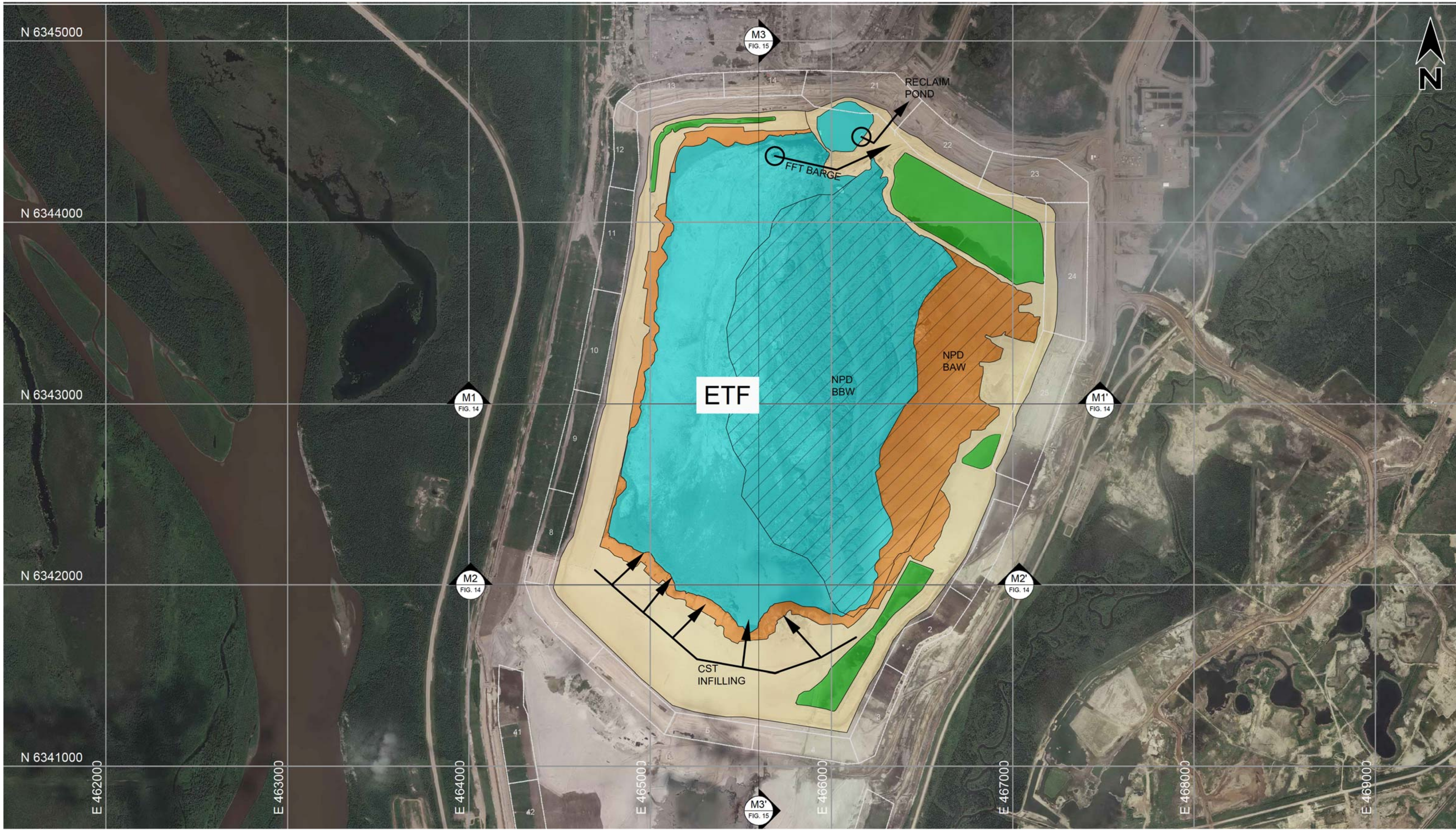
Canadian Natural Albian Sands
Mine Geotechnical and Geology

MUSKEG RIVER MINE
SITE PLAN

DATE: 2019-03-07

FIGURE: 1

UPDATE: April 25, 2019 - 5:05pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - SITE PLAN.dwg



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2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.
3. AERIAL PHOTO DATED 2018-07-27.

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1 : 20,000

LEGEND:
- POND
- TAILINGS BEACH
- CELL SAND
- MIXED TAILINGS BEACH
- AFD/FFT DRYING CELLS

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MUSKEG RIVER MINE
EXTERNAL TAILINGS FACILITY
PLAN VIEW

DATE: 2019-03-07

FIGURE: 2

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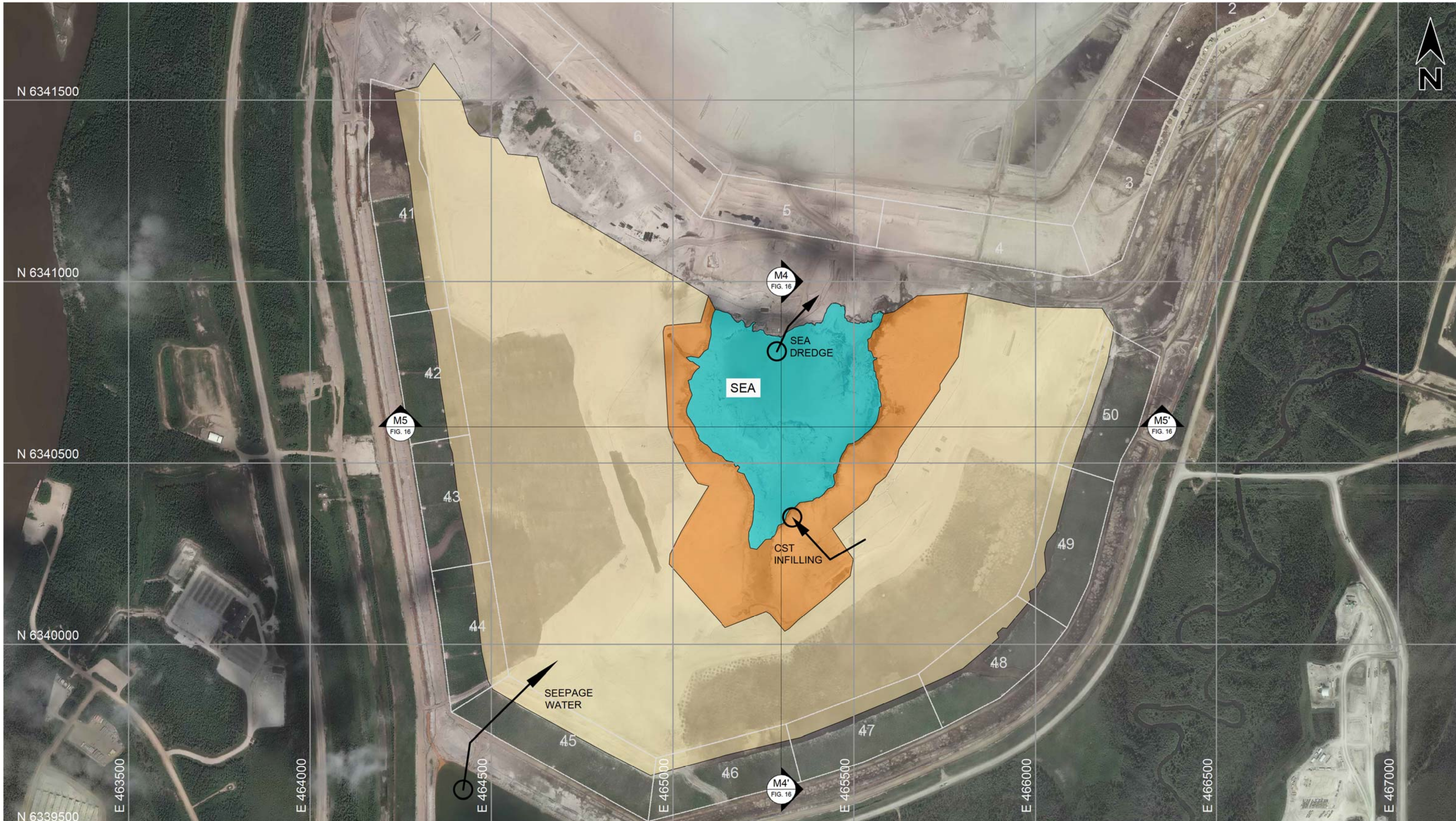

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.
3. AERIAL PHOTO DATED 2018-07-27.

0 100 200 300 400 m

1 : 10,000

LEGEND:
- POND
- TAILINGS BEACH
- CELL SAND

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MUSKEG RIVER MINE
SOUTH EXPANSION AREA
PLAN VIEW

DATE: 2019-03-07
FIGURE: 3

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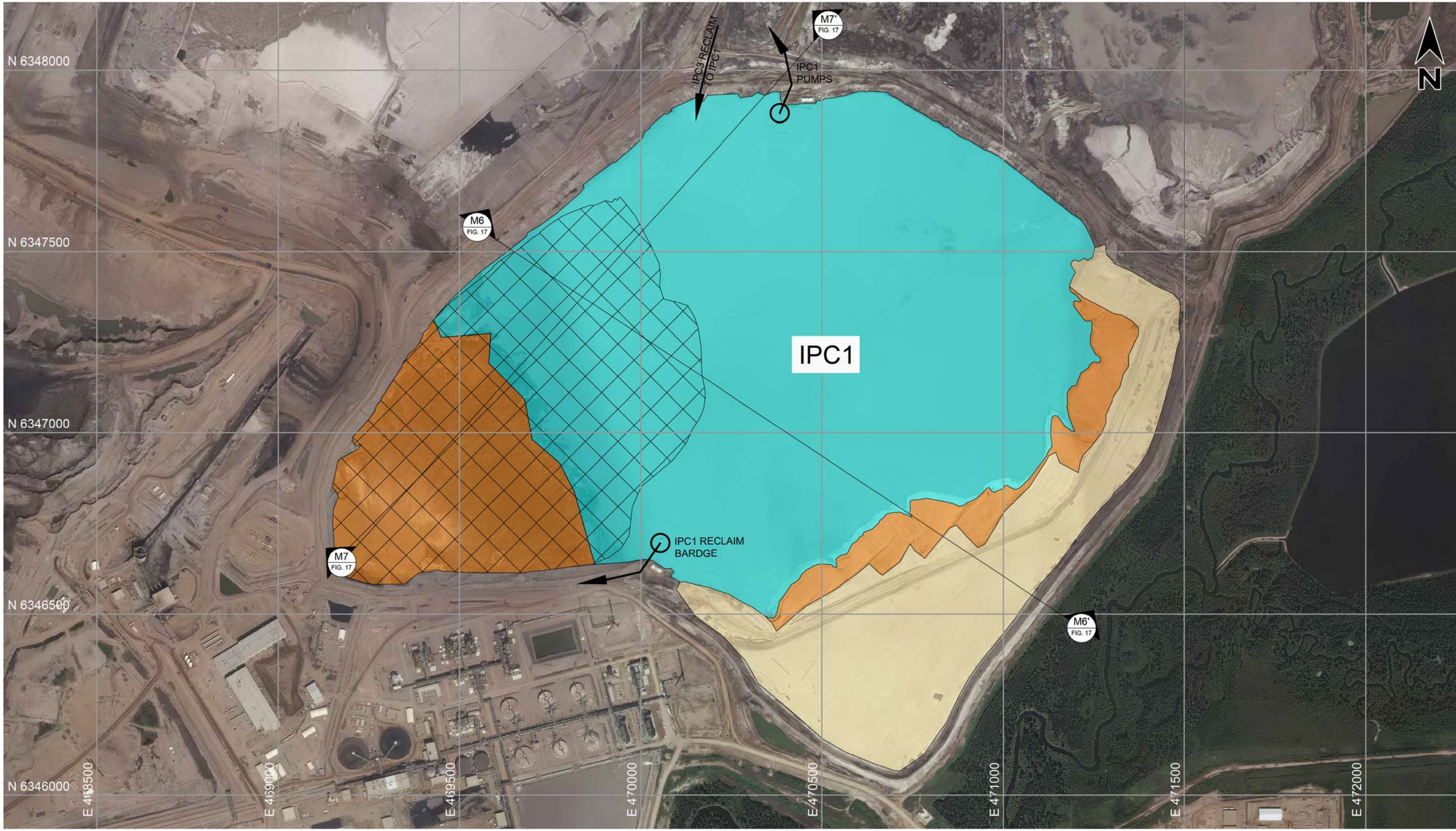

NOTES:
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2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.
3. AERIAL PHOTO DATED 2018-07-27.

0 100 200 300 400 m

1 : 10,000

LEGEND:
- POND
- TAILINGS BEACH
- CELL SAND
- TSRU

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MUSKEG RIVER MINE
IN-PIT CELL 1
PLAN VIEW

DATE: 2019-03-07

FIGURE: 4

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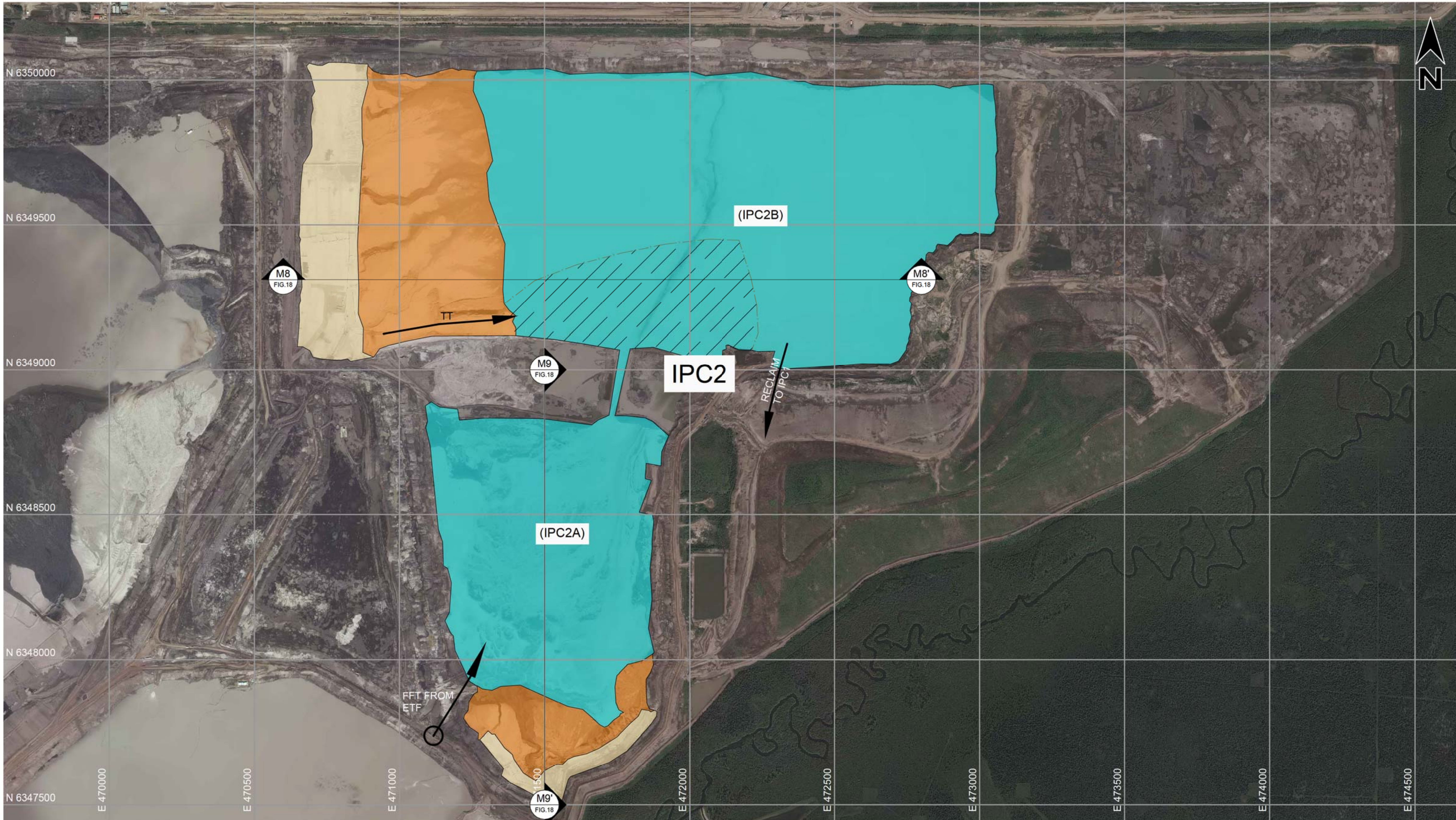

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0 100 200 300 400 500 m

1 : 12,500

LEGEND:
- POND
- TAILINGS BEACH
- CELL SAND
- IPC2 TT

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SCALE:	1:12,500

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MUSKEG RIVER MINE
IN-PIT CELL 2 (2A/2B)
PLAN VIEW

DATE: 2019-03-07

FIGURE: 5

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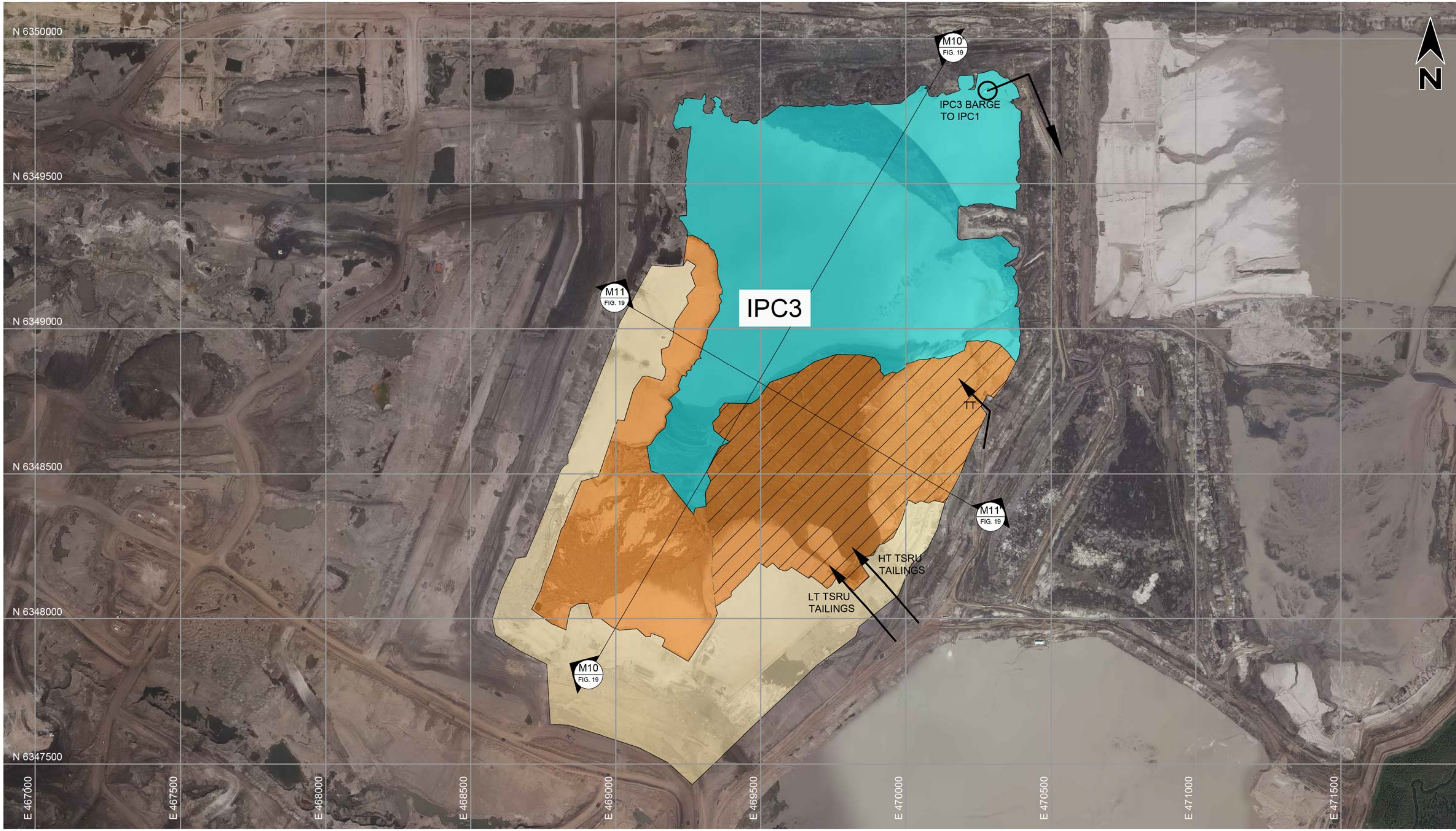

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3. AERIAL PHOTO DATED 2018-07-27.

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1 : 12,500

LEGEND:
- POND
- TAILINGS BEACH
- CELL SAND
- MIXED TAILINGS BEACH

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APPROVED BY:	MAS
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MUSKEG RIVER MINE
IN-PIT CELL 3
PLAN VIEW

DATE: 2019-03-07
FIGURE: 6

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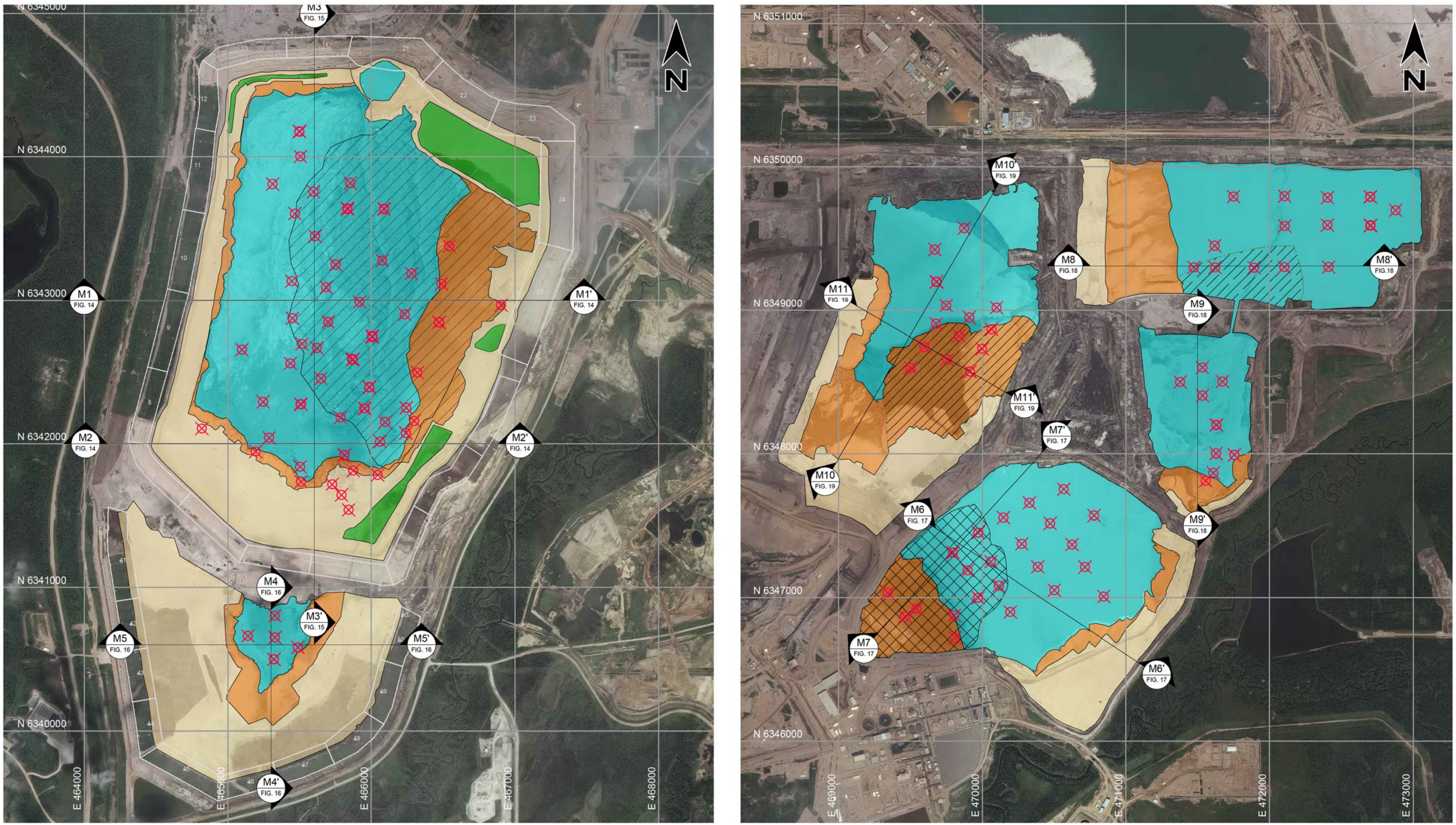

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NOTES:
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0 200 400 600 800 1000 m

1 : 25,000

LEGEND:
SAMPLING LOCATIONS

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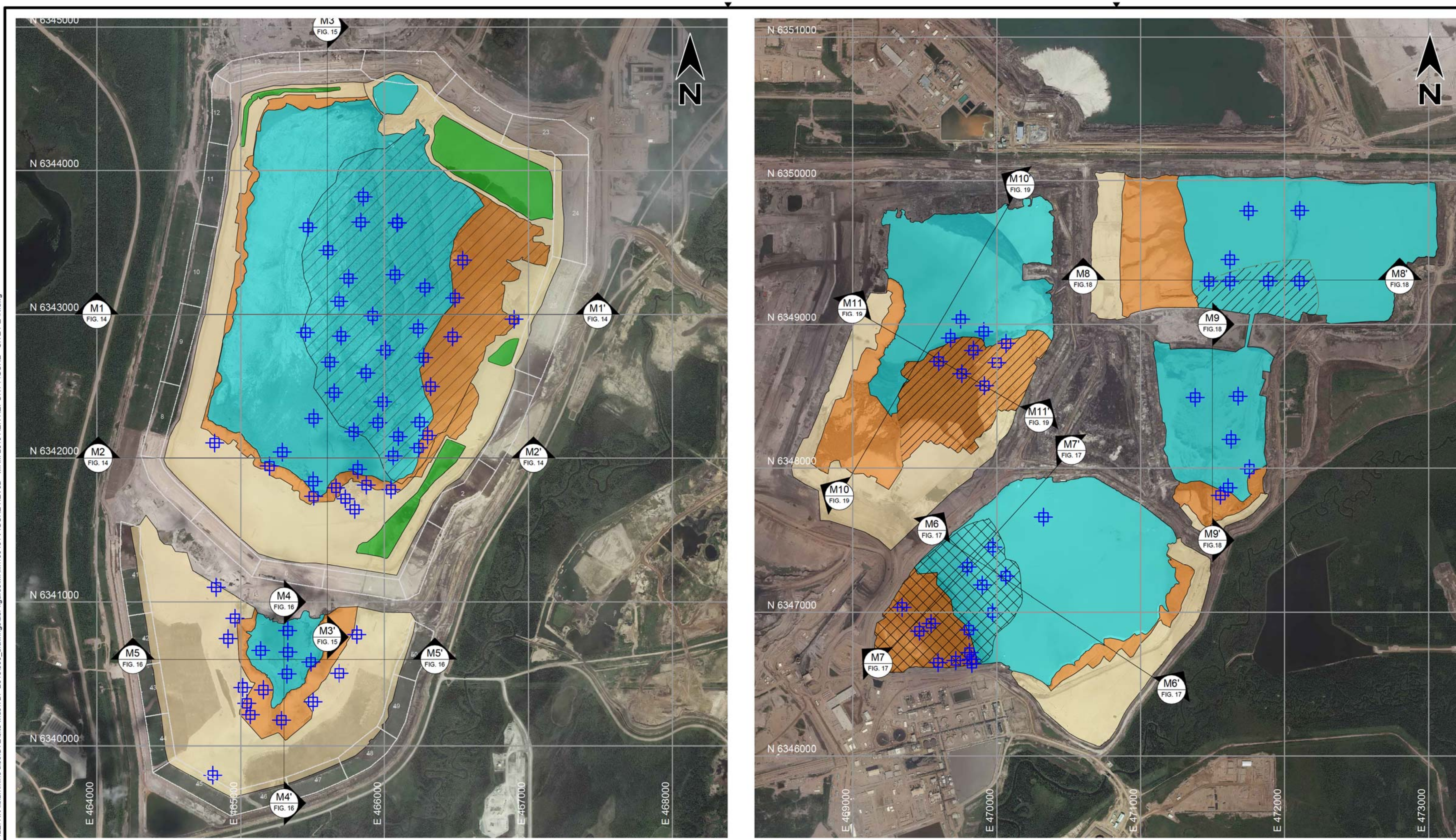
SITE PLAN
2018 SAMPLING LOCATIONS

DATE: 2019-03-07

FIGURE: 7



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LEGEND:
CPT LOCATIONS

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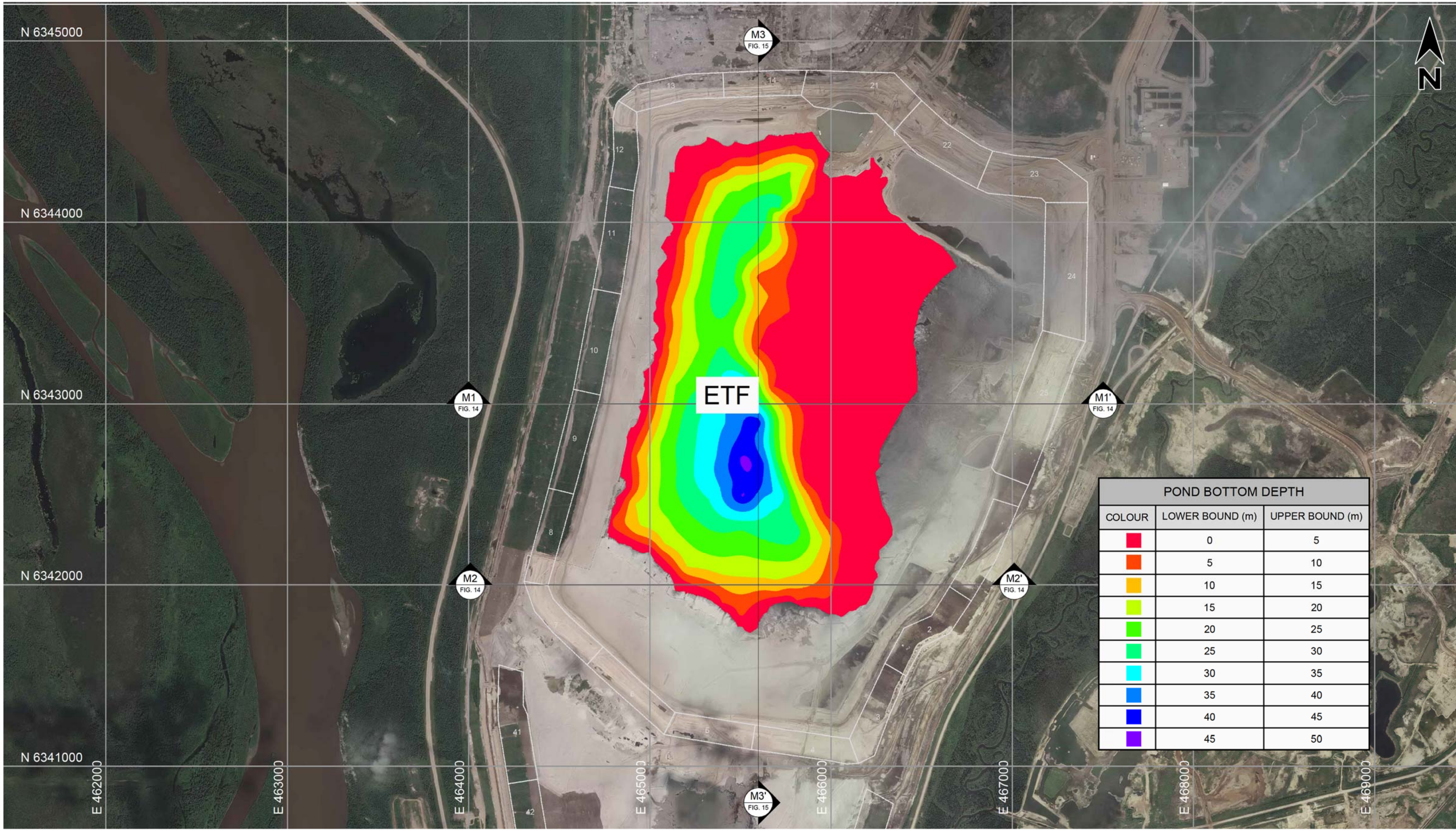
SITE PLAN
2018 CPT LOCATIONS

DATE: 2019-03-07

FIGURE: 8



POND BOTTOM DEPTH		
COLOUR	LOWER BOUND (m)	UPPER BOUND (m)
	0	5
	5	10
	10	15
	15	20
	20	25
	25	30
	30	35
	35	40
	40	45
	45	50

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.
3. AERIAL PHOTO DATED 2018-07-27.

0 200 400 600 800 m

1 : 20,000

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POND DEPTH CONTOURS

DATE: 2019-03-19
FIGURE: 9

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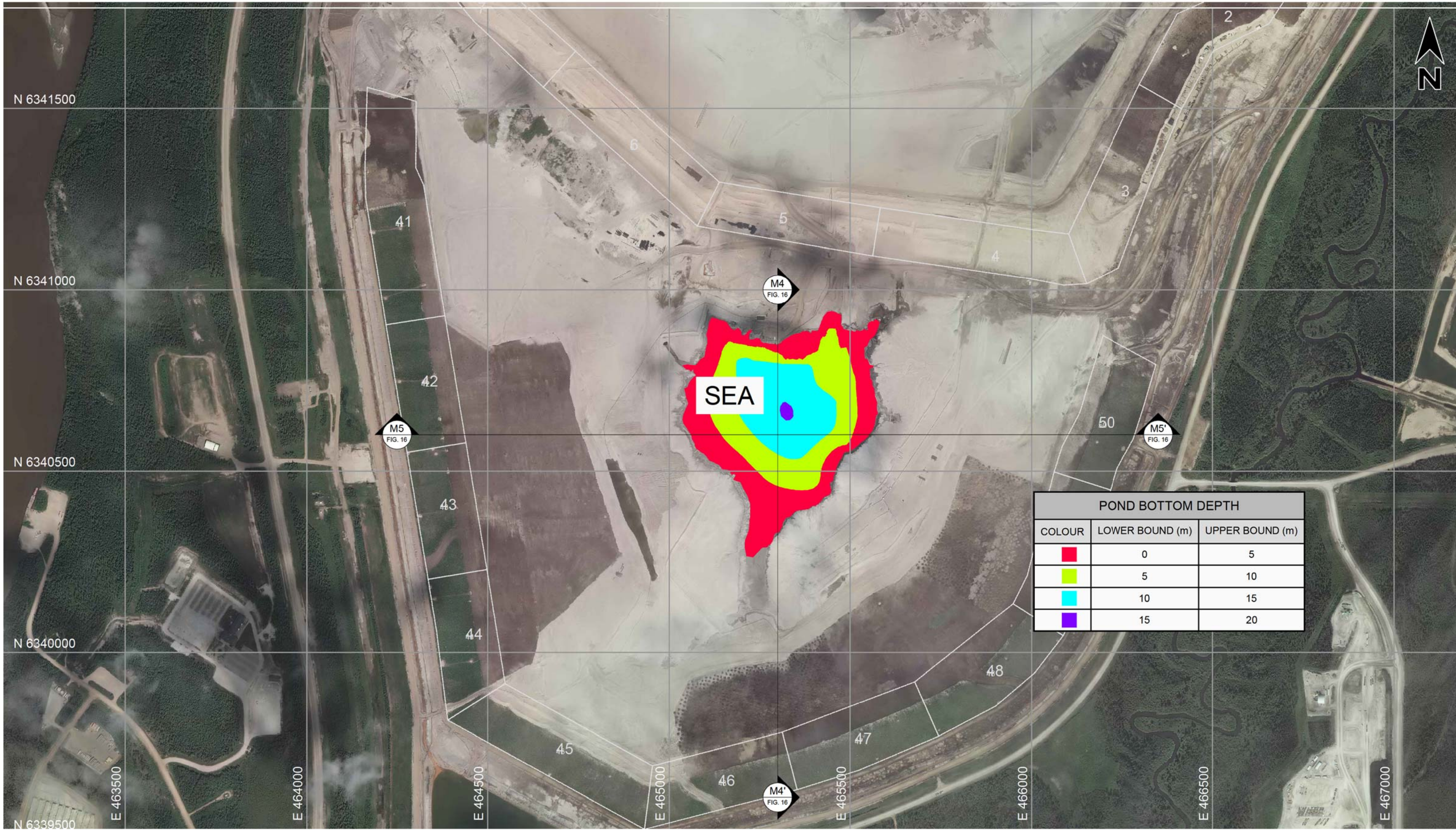

POND BOTTOM DEPTH		
COLOUR	LOWER BOUND (m)	UPPER BOUND (m)
(red)	0	5
(yellow-green)	5	10
(cyan)	10	15
(purple)	15	20

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.
3. AERIAL PHOTO DATED 2018-07-27.

0 100 200 300 400 m
1 : 10,000

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MUSKEG RIVER MINE
SOUTH EXPANSION AREA
POND DEPTH CONTOURS

DATE: 2019-03-22
FIGURE: 10

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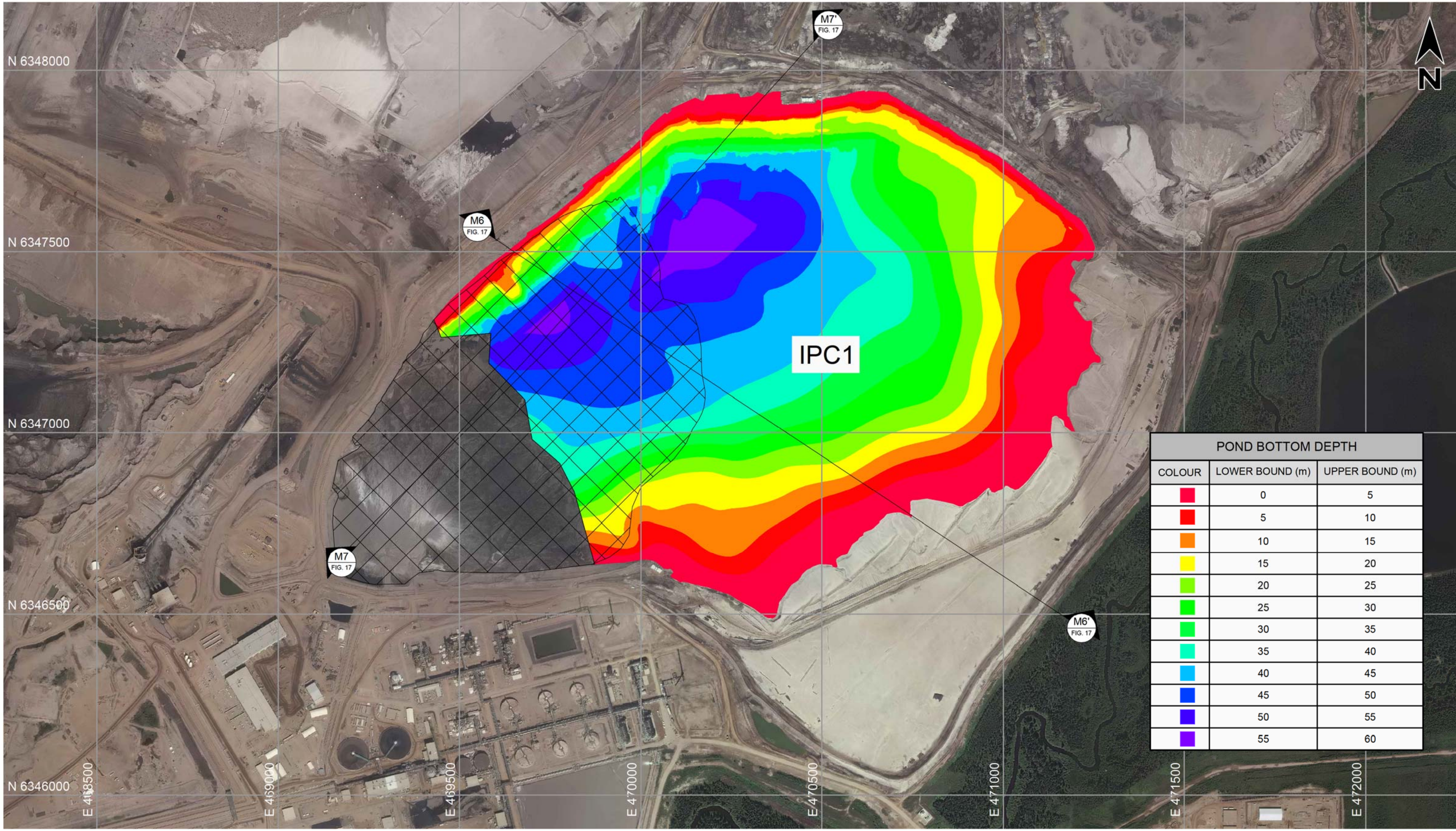

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NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.
3. AERIAL PHOTO DATED 2018-07-27.

0 100 200 300 400 m

1 : 10,000

LEGEND:
TSRU TAILINGS

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DRAWN BY: LH
REVIEWED BY: MG
APPROVED BY: MAS
SCALE: 1:10,000

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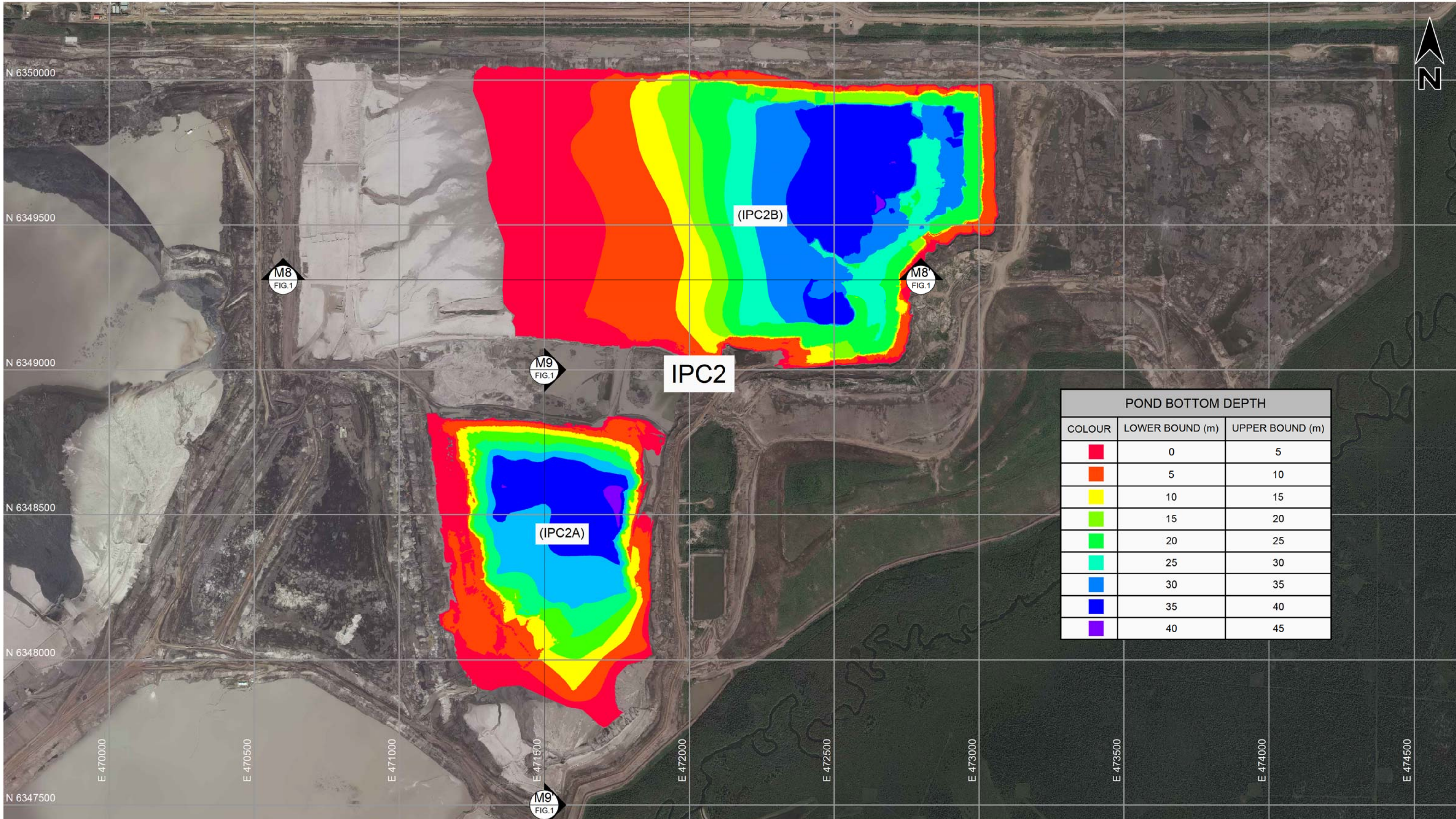
MUSKEG RIVER MINE
IN-PIT CELL 1
POND DEPTH CONTOURS

DATE: 2019-03-21
FIGURE: 11



POND BOTTOM DEPTH		
COLOUR	LOWER BOUND (m)	UPPER BOUND (m)
Red	0	5
Orange	5	10
Yellow	10	15
Light green	15	20
Green	20	25
Cyan	25	30
Light blue	30	35
Blue	35	40
Purple	40	45

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.
3. AERIAL PHOTO DATED 2018-07-27.

0 100 200 300 400 500 m

1 : 12,500

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APPROVED BY: MAS
SCALE: 1:12,500

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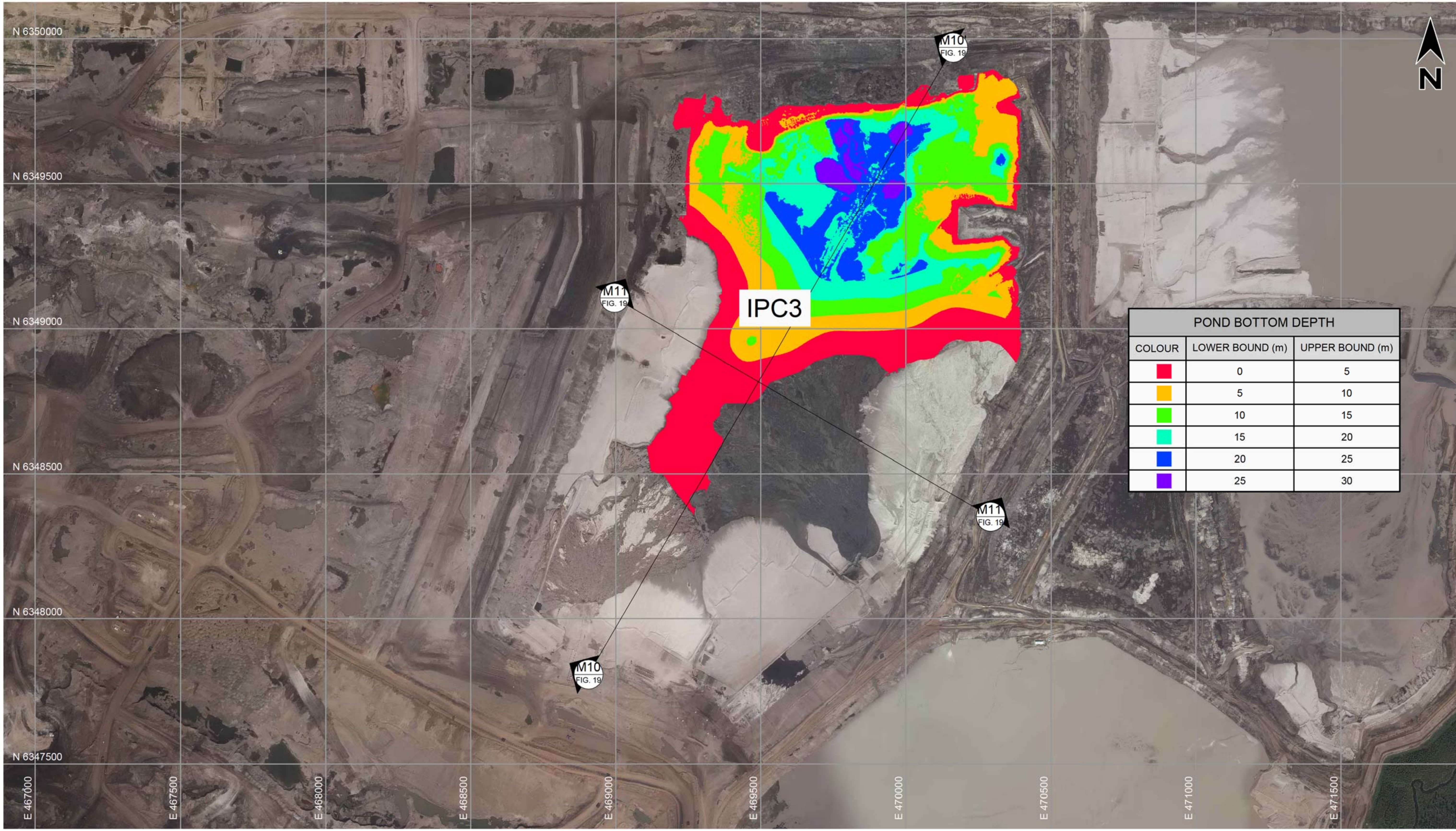
MUSKEG RIVER MINE
IN-PIT CELL 2 (2A/2B)
POND DEPTH CONTOURS

DATE: 2019-03-27
FIGURE: 12

UPDATE: April 25, 2019 - 5:17pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - IPC2.dwg



POND BOTTOM DEPTH		
COLOUR	LOWER BOUND (m)	UPPER BOUND (m)
(red)	0	5
(orange)	5	10
(green)	10	15
(cyan)	15	20
(blue)	20	25
(purple)	25	30

UPDATE: April 25, 2019 - 4:50pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - IPC3.dwg

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.
3. AERIAL PHOTO DATED 2018-07-27.

0 100 200 300 400 500 m
1 : 12,500

DESIGNED BY: KR
DRAWN BY: LH
REVIEWED BY: MG
APPROVED BY: MAS
SCALE: 1:12,500

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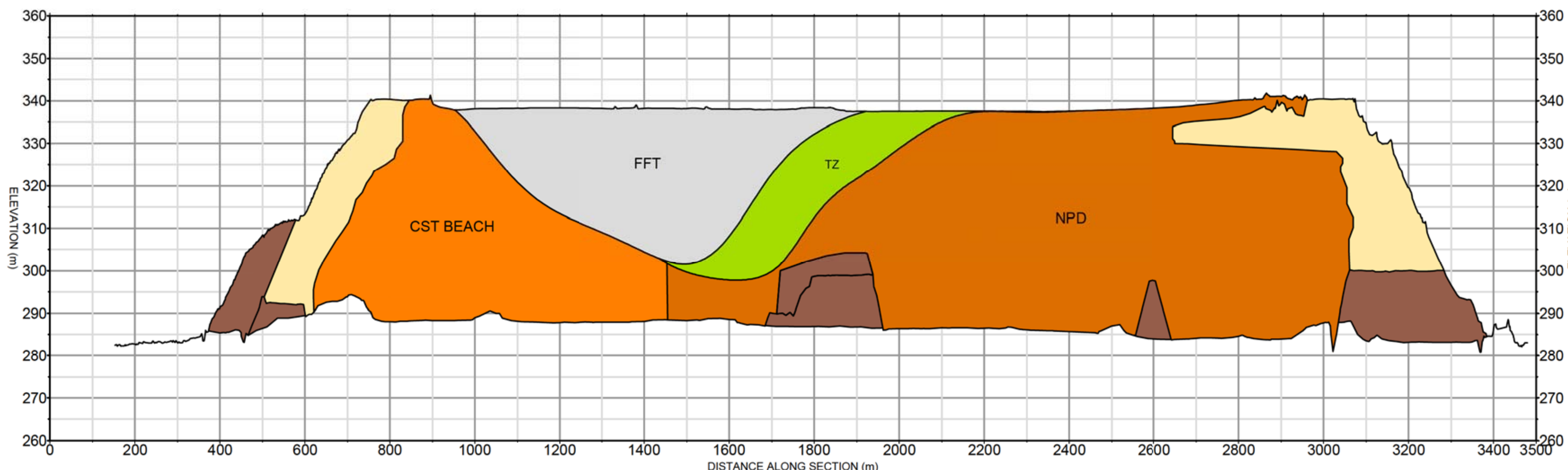
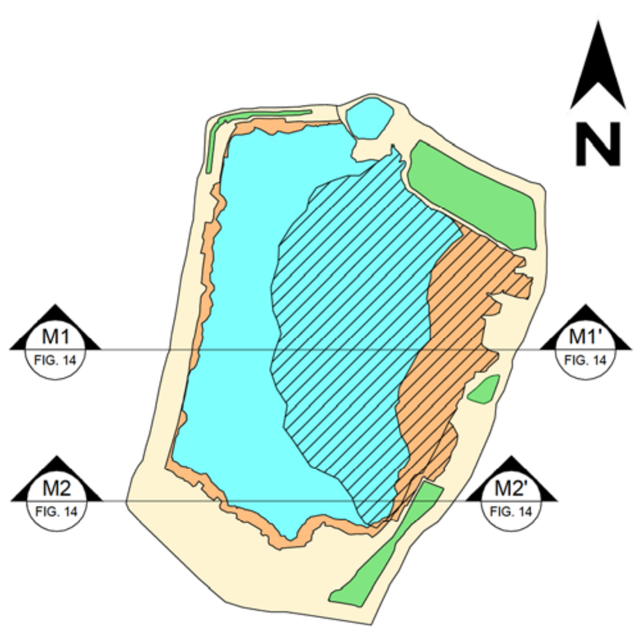
MUSKEG RIVER MINE
IN-PIT CELL 3
POND DEPTH CONTOURS

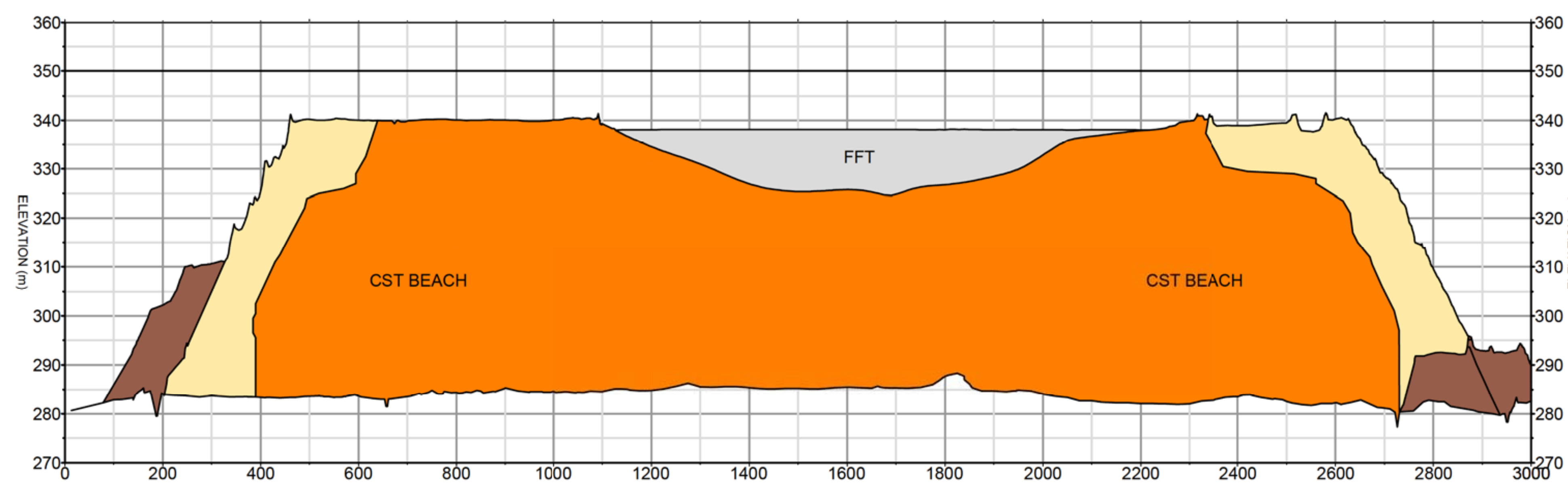
DATE: 2019-03-27
FIGURE: 13



M1-M1' FIG. 1 PROFILE THROUGH MRM ETF
10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:50,000



M2-M2' FIG. 1 PROFILE THROUGH MRM ETF
10X VERTICAL EXAGGERATION

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 500 m
1 : 12,500

LEGEND:
- CELL SAND
- CST
- CWZ
- FFT
- LEAN OIL SANDS
- NORTH POOL DEPOSIT (NPD)
- TRANSITION ZONE FT

DESIGNED BY: KR
DRAWN BY: LH
REVIEWED BY: MG
APPROVED BY: MAS
SCALE: AS SHOWN

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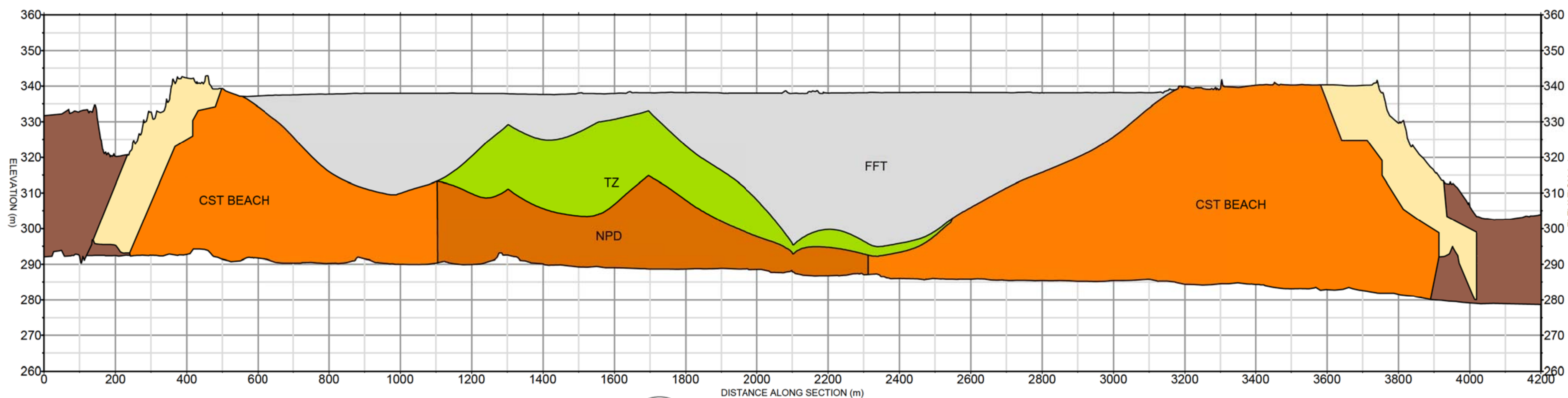
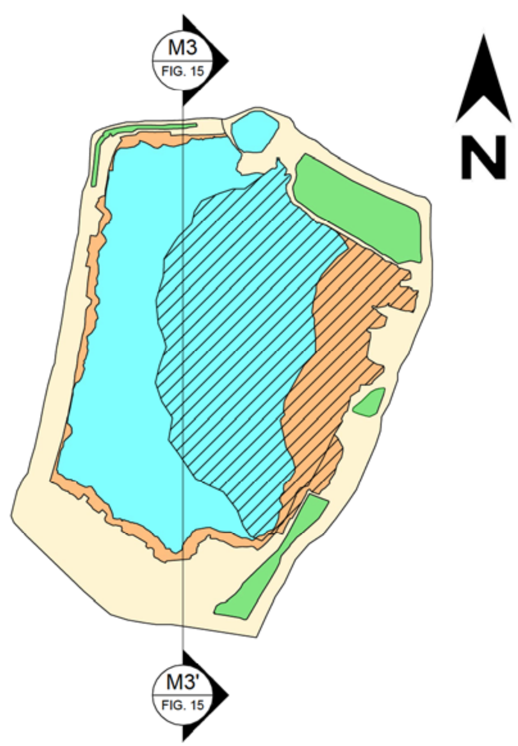
MUSKEG RIVER MINE
EXTERNAL TAILINGS FACILITY
SECTIONS M1-M1' & M2-M2' PROFILES

DATE: 2019-03-19
FIGURE: 14

UPDATE: April 25, 2019 - 5:08pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - ETF.dwg



M3-M3' FIG. 1 — PROFILE THROUGH MRM ETF
10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:50,000

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 500 m
1 : 12,500

LEGEND:
- CELL SAND
- CST
- CWZ
- FFT
- LEAN OIL SANDS
- NORTH POOL DEPOSIT (NPD)
- TRANSITION ZONE FT

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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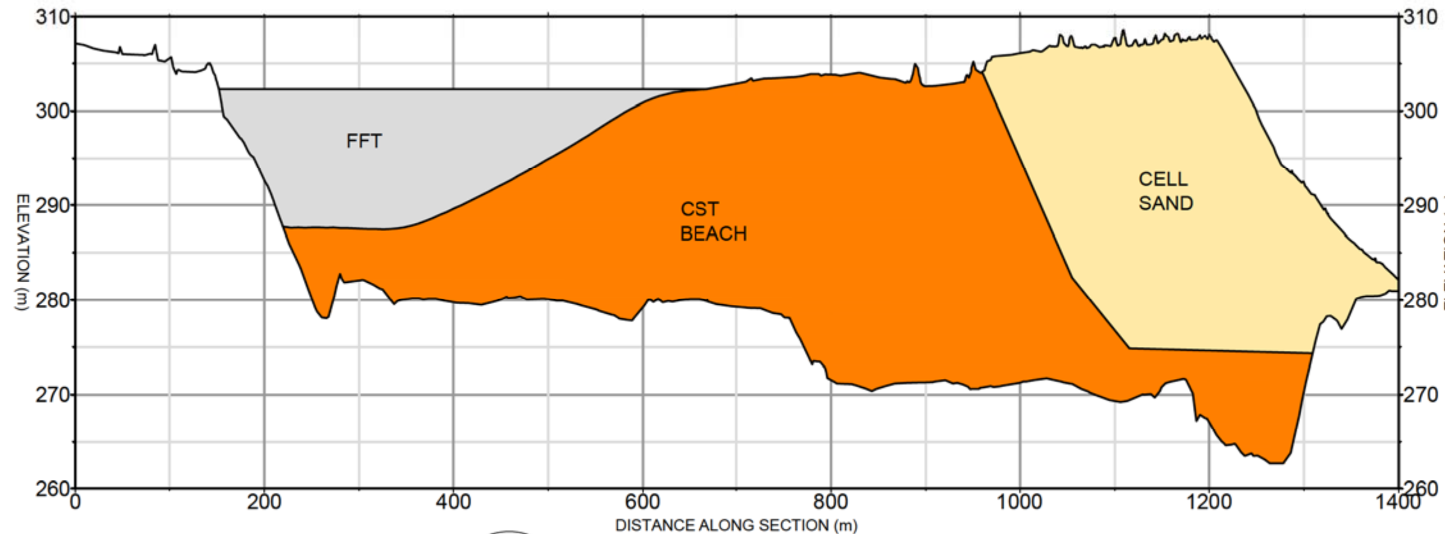
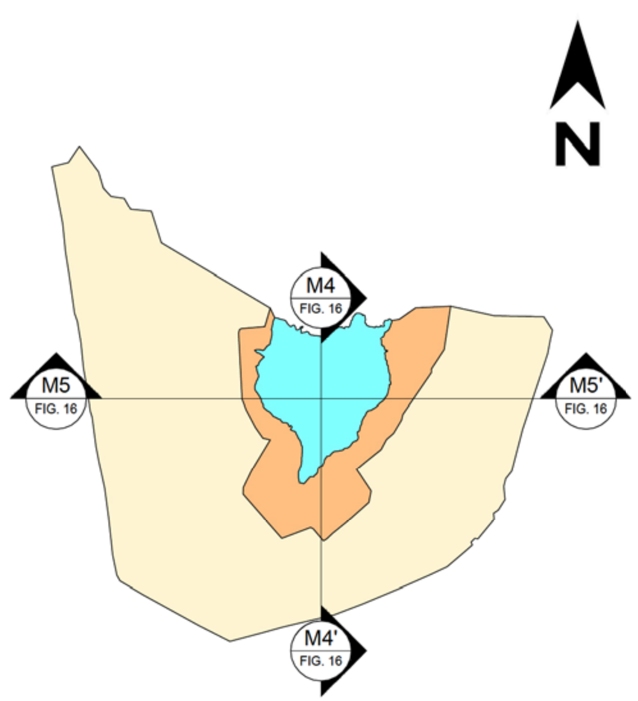
MUSKEG RIVER MINE
EXTERNAL TAILINGS FACILITY
SECTION M3-M3' PROFILE

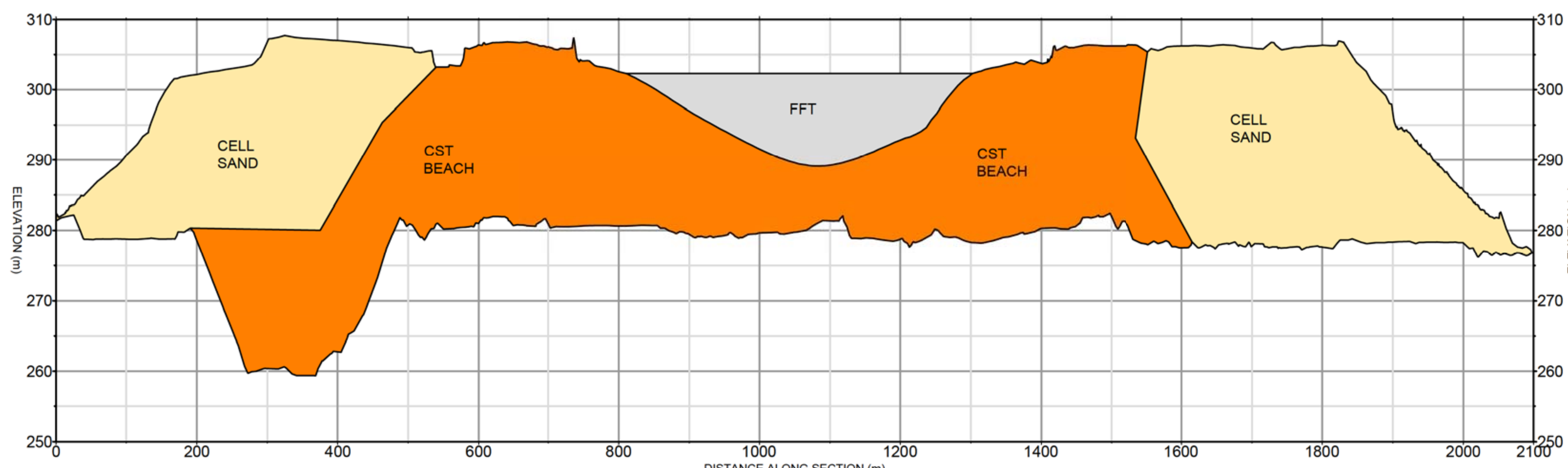
DATE: 2019-03-19
FIGURE: 15



M4-M4' / FIG. 1 PROFILE THROUGH MRM SEA
10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:50,000



M5-M5' / FIG. 1 PROFILE THROUGH MRM SEA
10X VERTICAL EXAGGERATION

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 m

1 : 8000

LEGEND:
- CELL SAND
- CST
- FFT

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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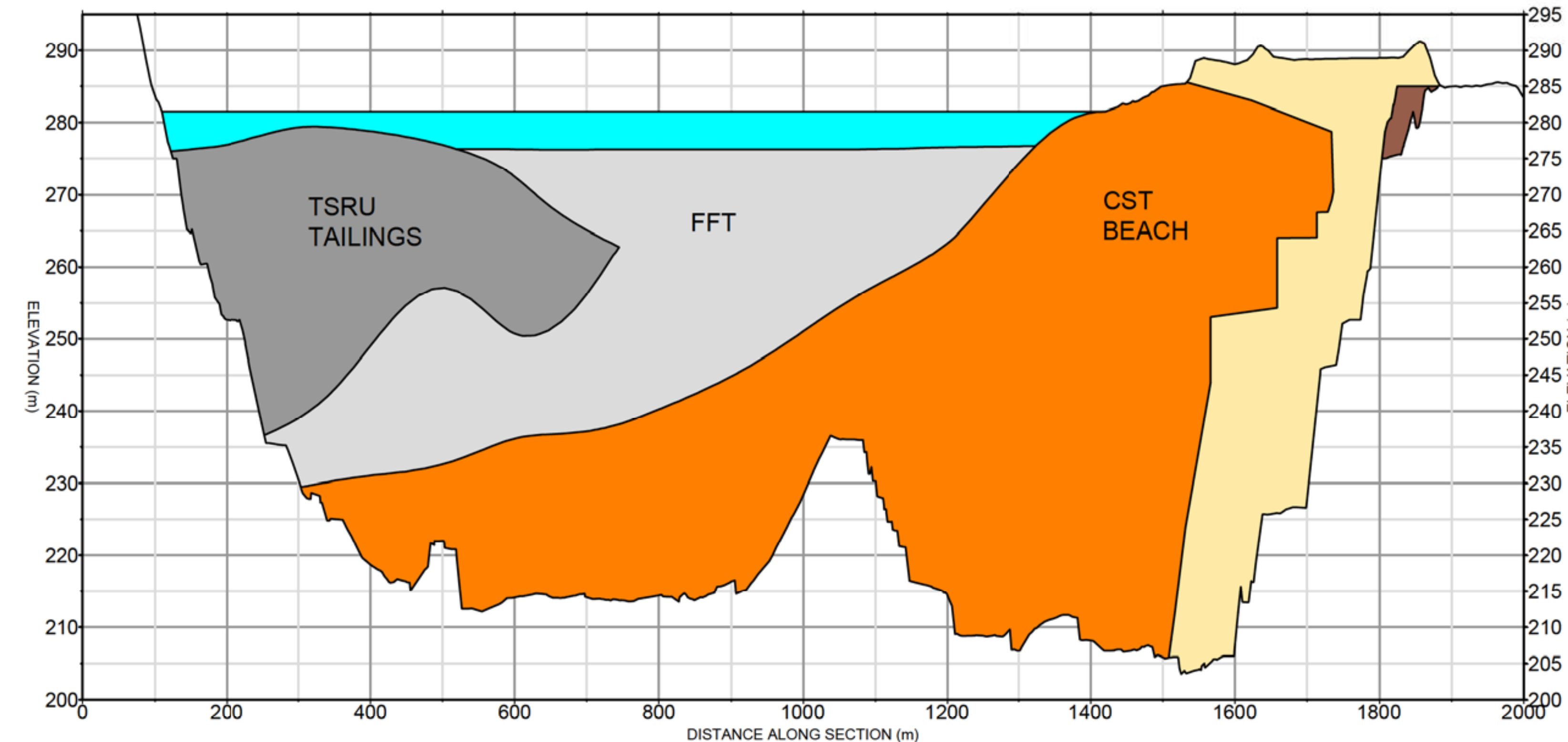
MUSKEG RIVER MINE
SOUTH EXPANSION AREA
SECTIONS M4-M4' & M5-M5' PROFILES

DATE: 2019-03-22

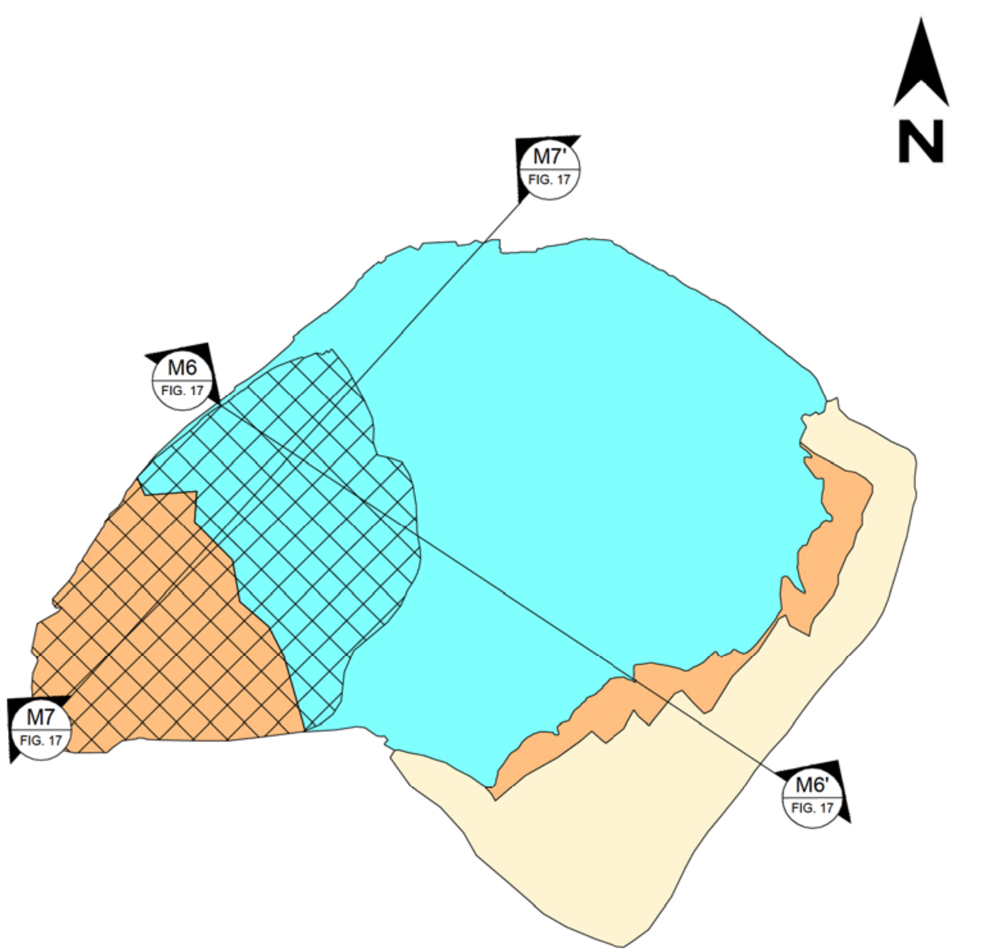
FIGURE: 16

UPDATE: April 25, 2019 - 5:25pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - SEA.dwg

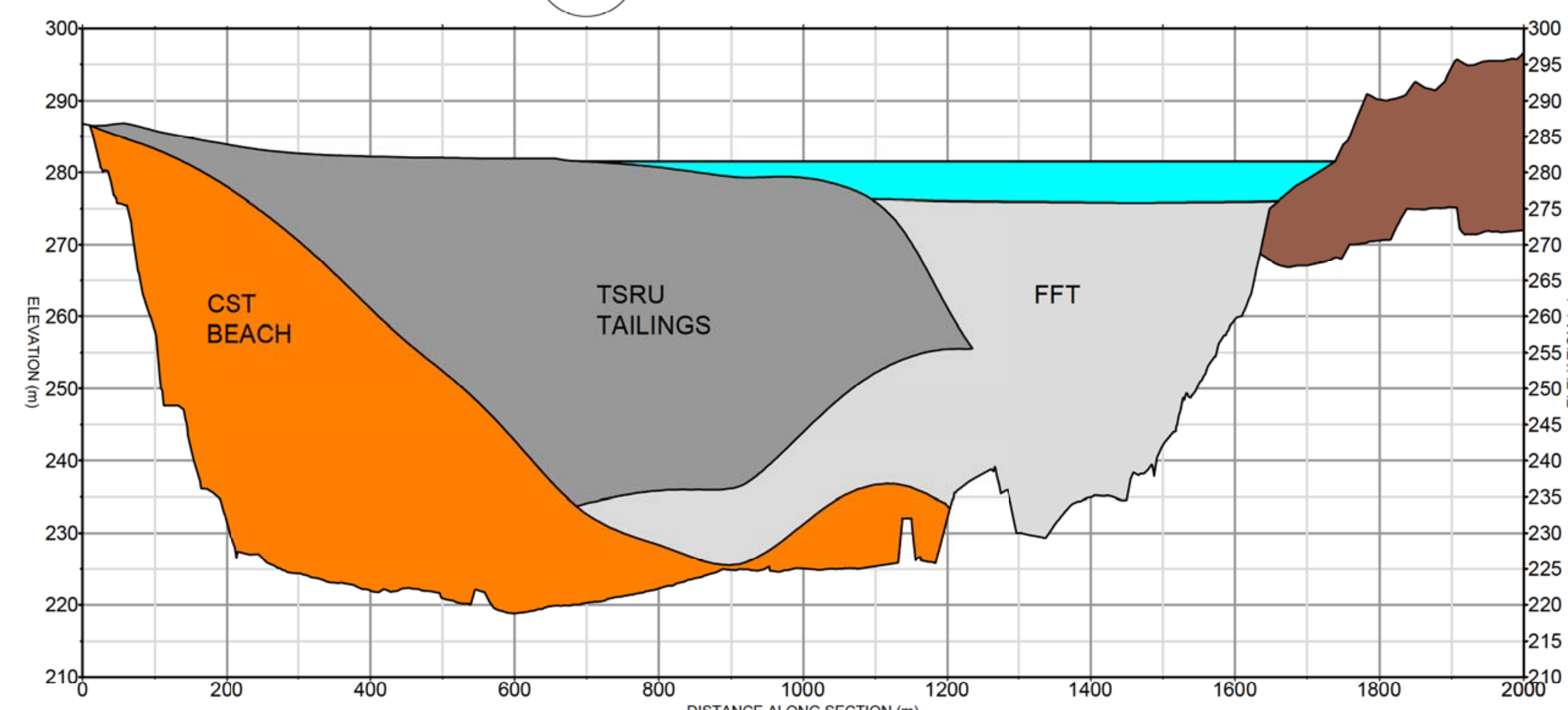


M6-M6'
FIG. 1

PROFILE THROUGH MRM IPC1
10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:20,000



M7-M7'
FIG. 1

PROFILE THROUGH MRM IPC1
10X VERTICAL EXAGGERATION

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 m
1 : 10,000

LEGEND:
- CELL SAND
- CST
- CWZ
- FFT
- LEAN OIL SANDS
- TSRU TAILINGS

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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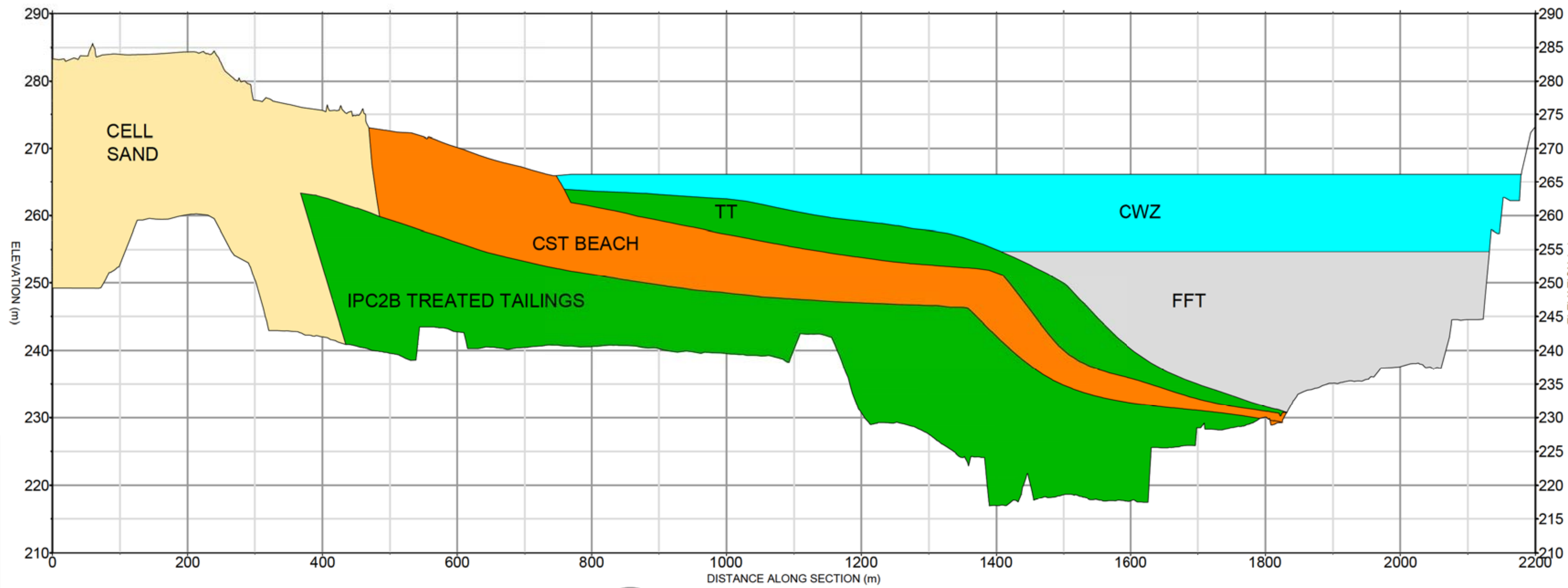
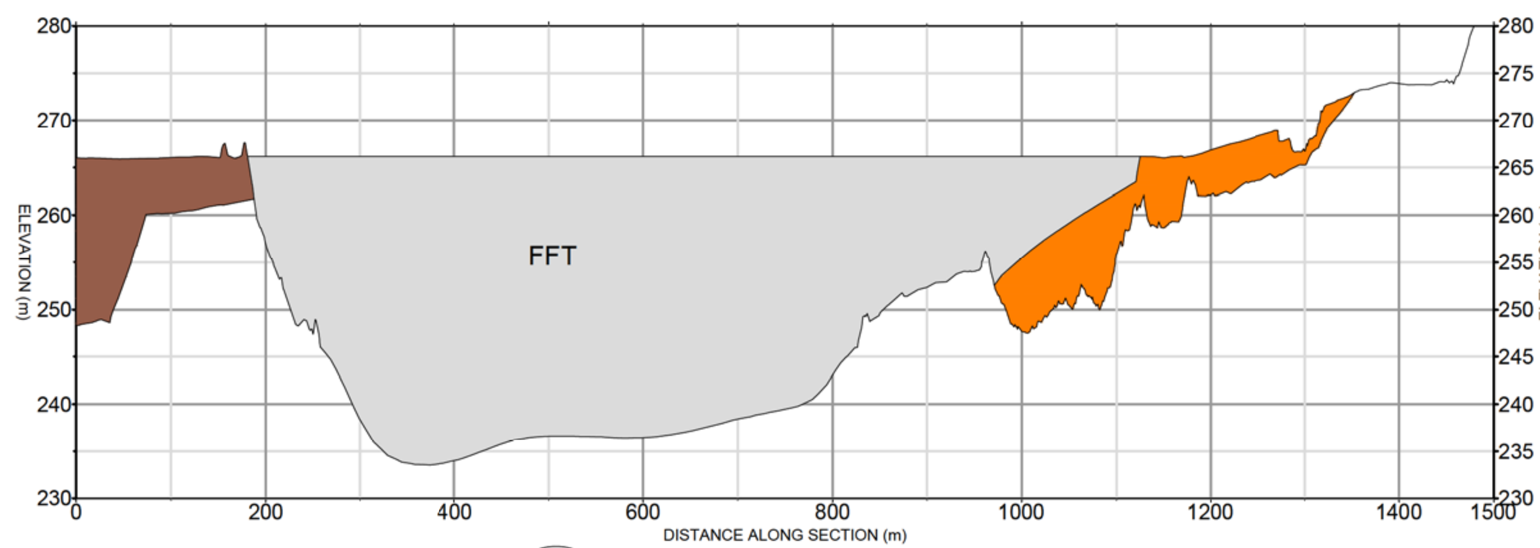
MUSKEG RIVER MINE
IN-PIT CELL 1
SECTIONS M6-M6' & M7-M7' PROFILES

DATE: 2019-03-27
FIGURE: 17

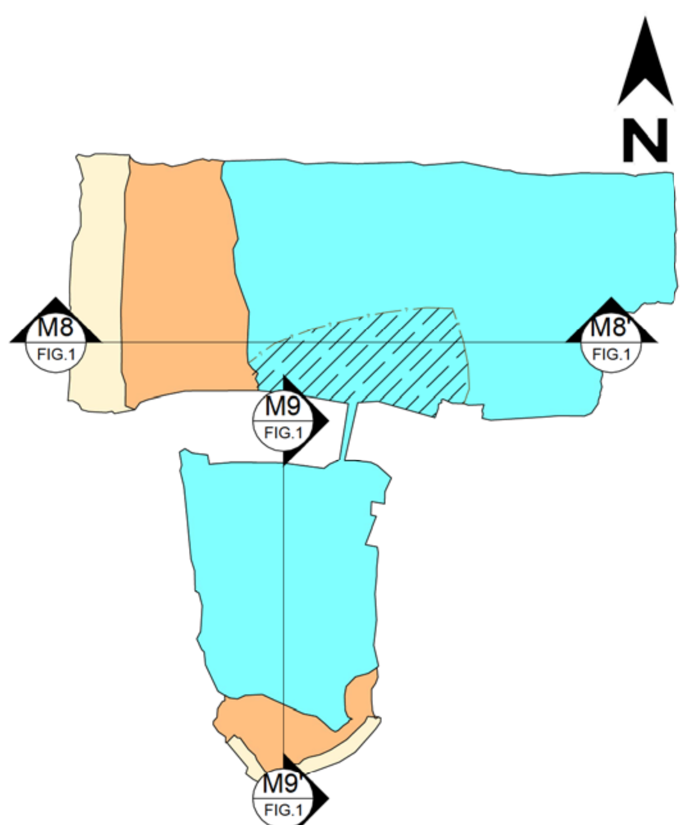
UPDATE: April 25, 2019 - 5:26pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM\190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - IPC1.dwg



M8-M8' PROFILE THROUGH MRM IPC2
FIG. 1 10X VERTICAL EXAGGERATION



M9-M9' PROFILE THROUGH MRM IPC2
FIG. 1 10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:30,000

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 m
1 : 8000

LEGEND:
- CELL SAND
- CST
- CWZ
- FFT
- LEAN OIL SANDS
- IPC2B TREATED TAILINGS/TT

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REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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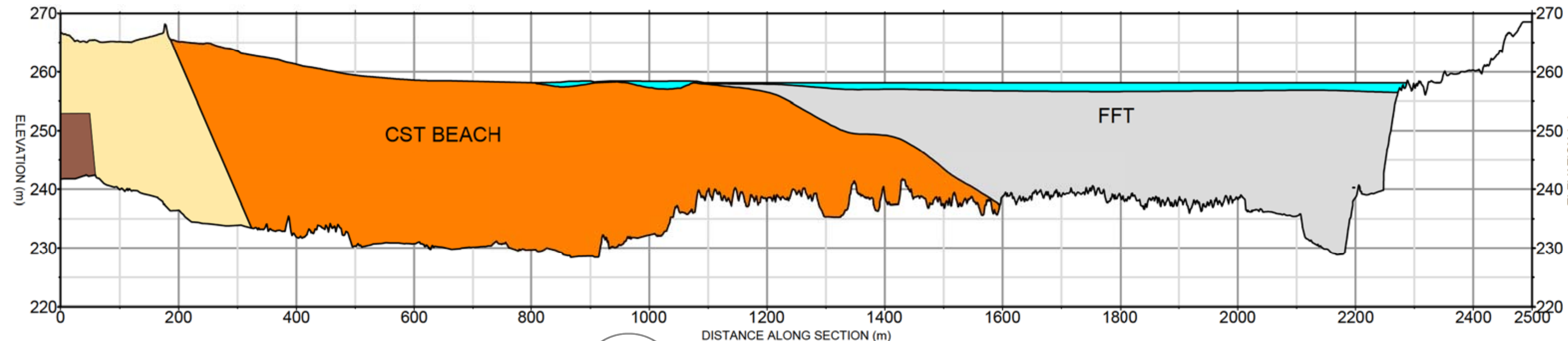
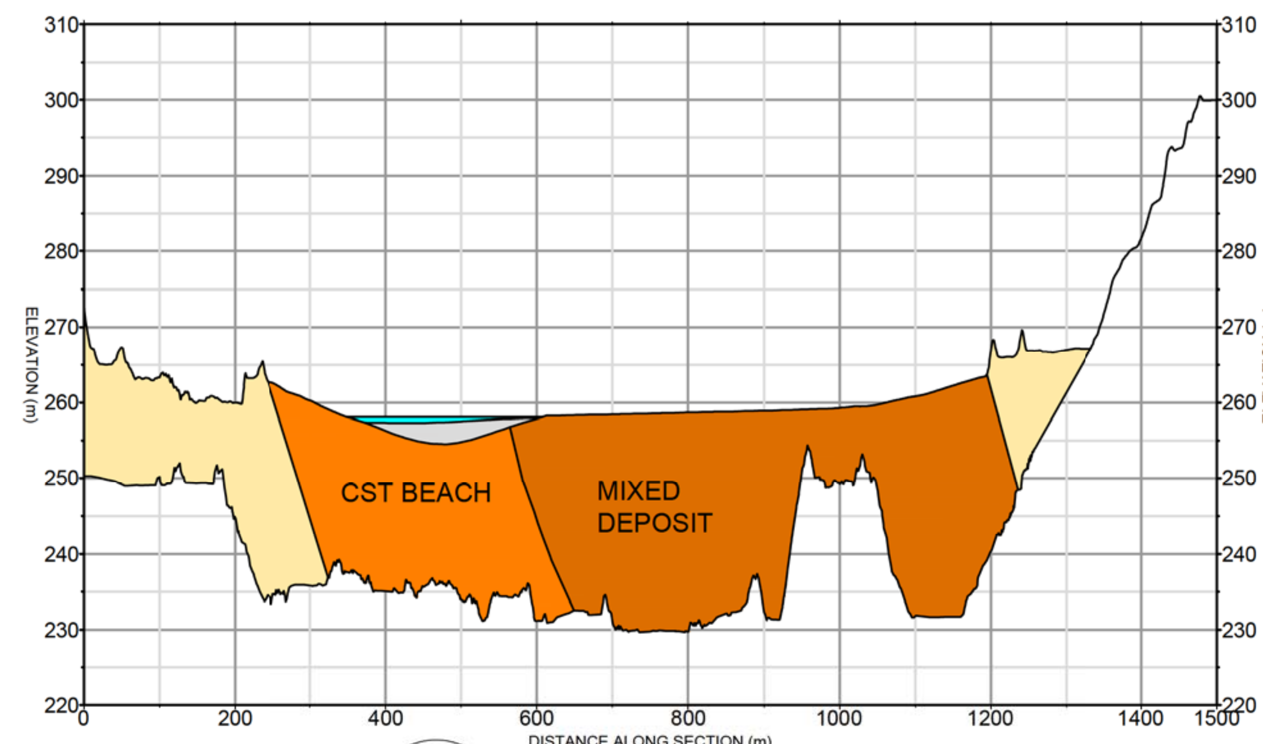
MUSKEG RIVER MINE
IN-PIT CELL 2 (2A/2B)
SECTIONS M8-M8' & M9-M9' PROFILES

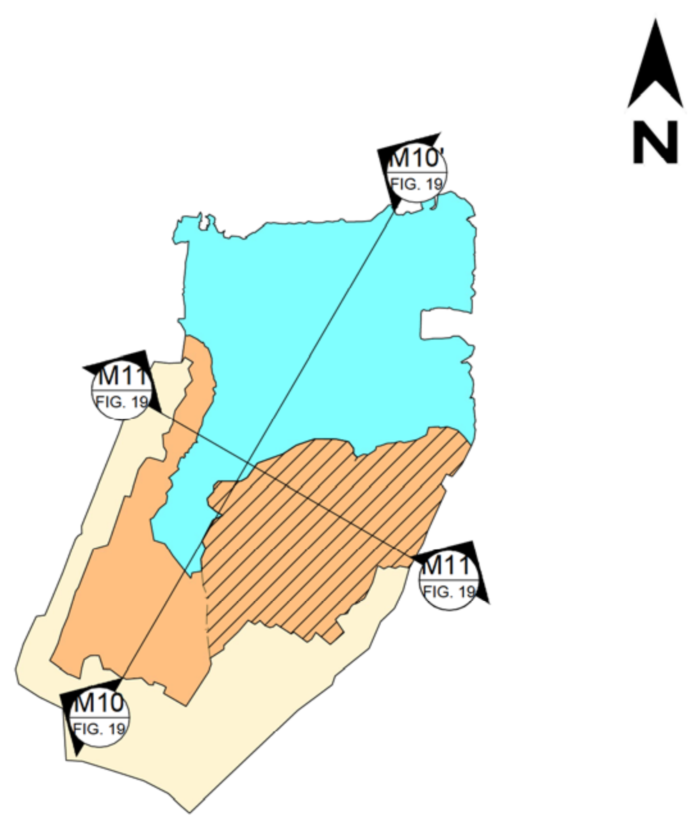
DATE: 2019-03-26
FIGURE: 18



M10-M10' FIG. 1 — PROFILE THROUGH MRM IPC3
10X VERTICAL EXAGGERATION



M11-M11' FIG. 1 — PROFILE THROUGH MRM IPC3
10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:30,000

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 m
1 : 10,000

LEGEND:
- POND
- FFT
- TAILINGS BEACH
- CELL SAND
- LEAN OIL SANDS
- MIXED DEPOSIT

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APPROVED BY:	MAS
SCALE:	AS SHOWN

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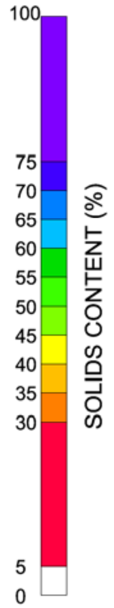
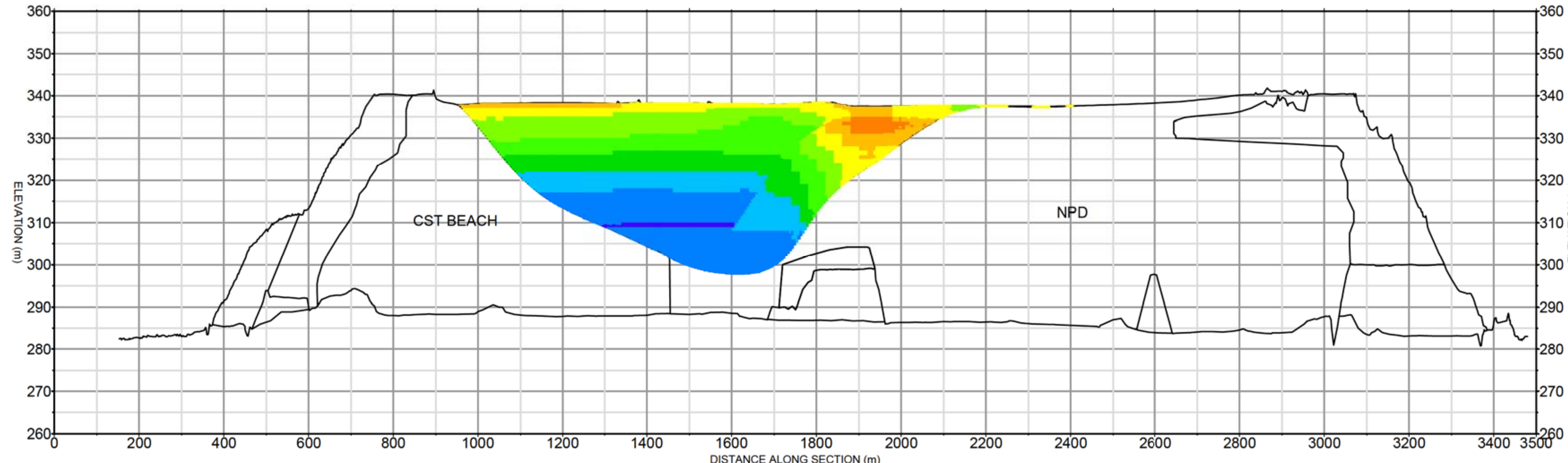
MUSKEG RIVER MINE
IN-PIT CELL 3
SECTIONS M10-M10' AND M11-M11' PROFILES

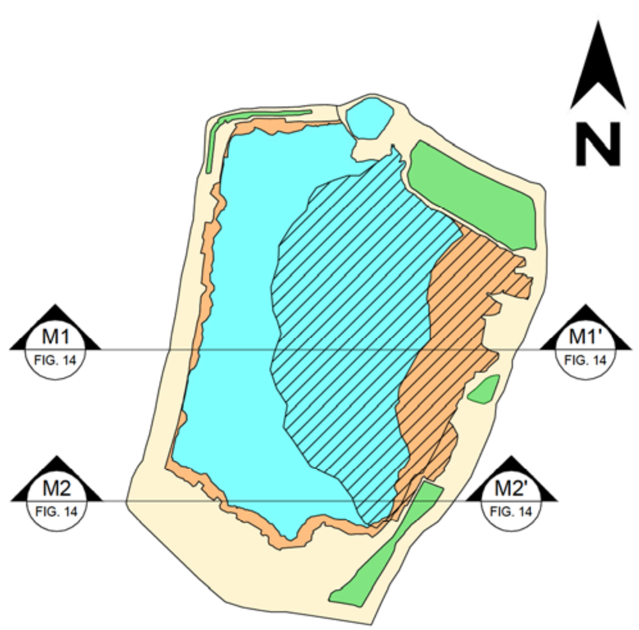
DATE: 2019-03-25
FIGURE: 19

UPDATE: April 25, 2019 - 4:55pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - IPC3.dwg

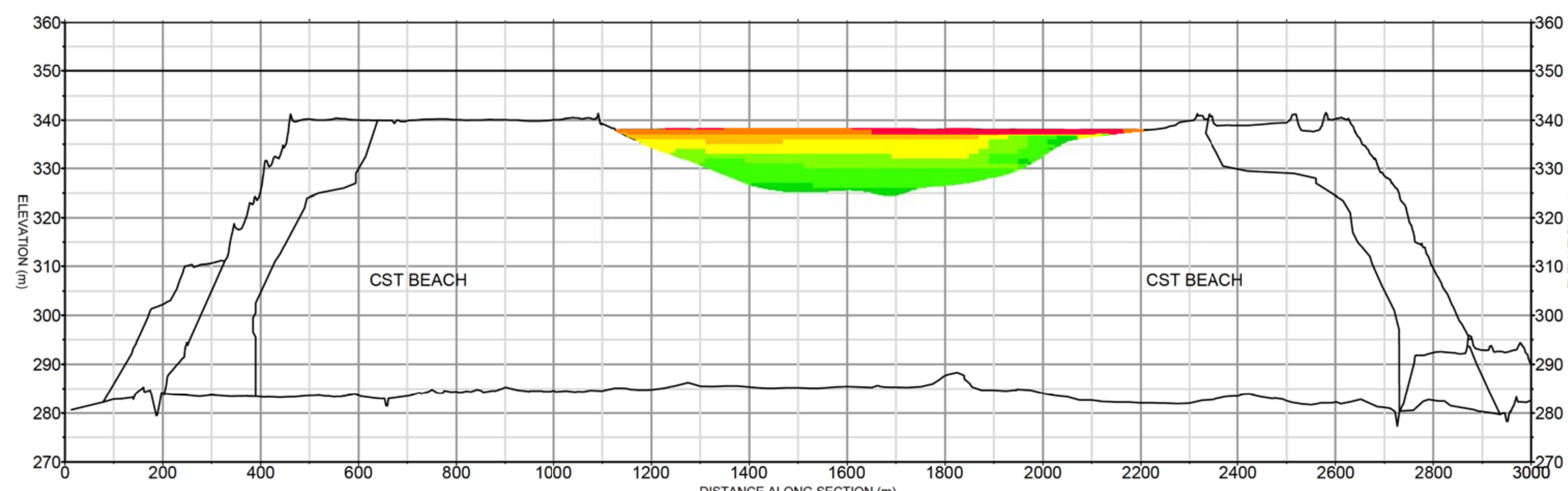




M1-M1' FIG. 1 PROFILE THROUGH MRM ETF
10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:50,000



M2-M2' FIG. 1 PROFILE THROUGH MRM ETF
10X VERTICAL EXAGGERATION

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 500 m
1 : 12,500

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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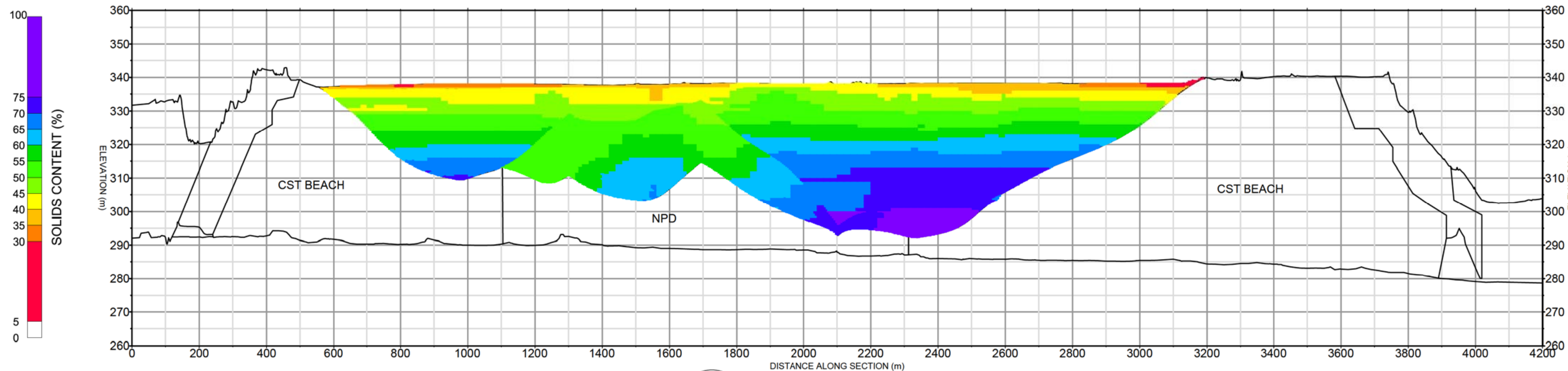
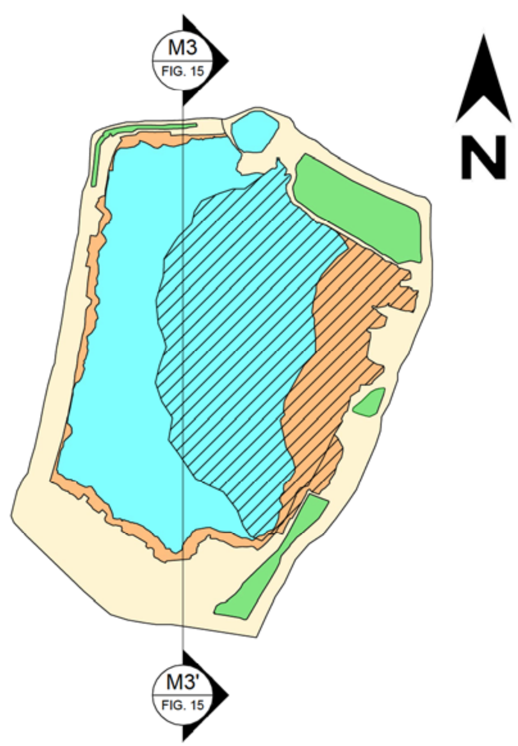
MUSKEG RIVER MINE
EXTERNAL TAILINGS FACILITY
SECTIONS M1-M1' & M2-M2' SOLIDS PROFILES

DATE: 2019-03-19
FIGURE: 20

UPDATE: April 25, 2019 - 5:09pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - ETF.dwg



M3-M3' PROFILE THROUGH MRM ETF
FIG. 1 10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:50,000

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 500 m
1 : 12,500

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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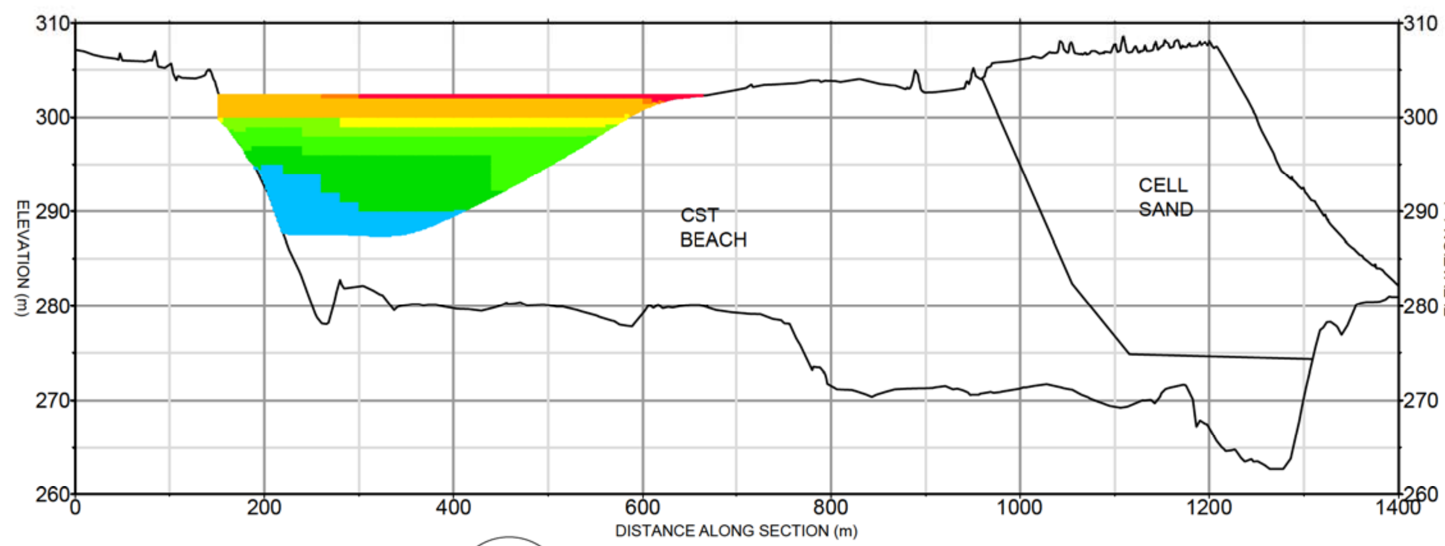
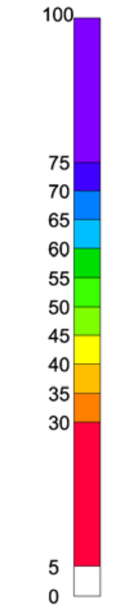
EXTERNAL TAILINGS FACILITY
SECTION M3-M3' SOLIDS PROFILE

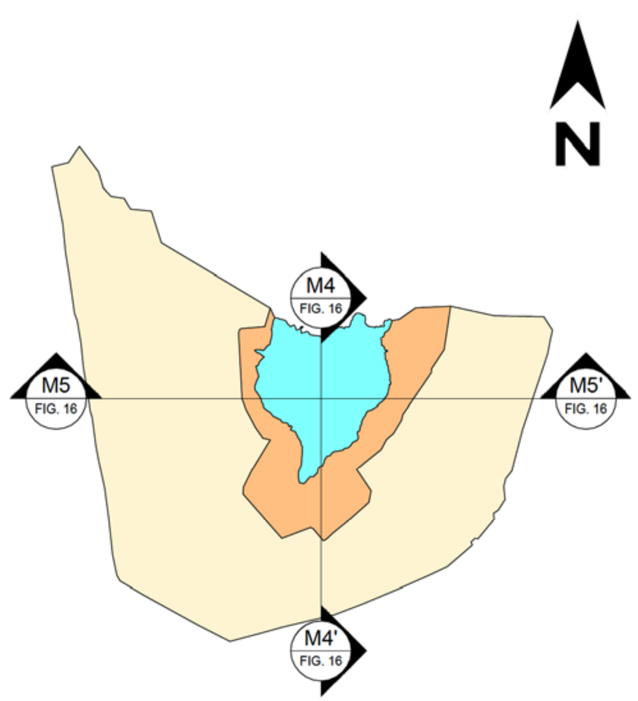
DATE: 2019-03-19
FIGURE: 21

UPDATE: April 25, 2019 - 5:09pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM\190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - ETF.dwg

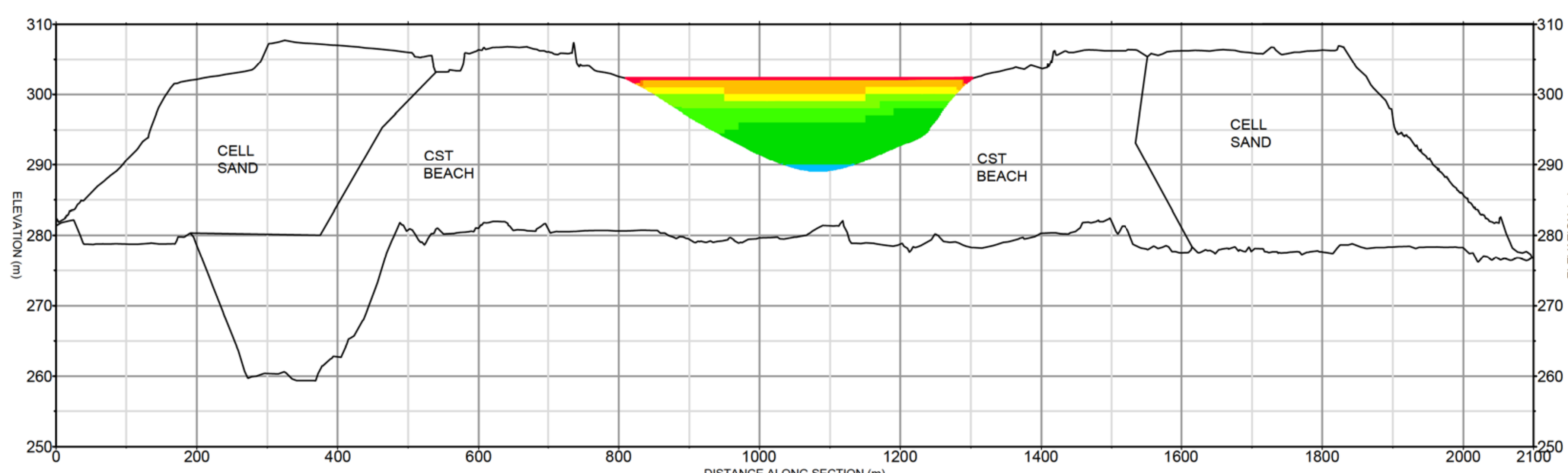


M4-M4' FIG. 1 PROFILE THROUGH MRM SEA
10X VERTICAL EXAGGERATION





KEY PLAN
SCALE 1:50,000



M5-M5' FIG. 1 PROFILE THROUGH MRM SEA
10X VERTICAL EXAGGERATION

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 m
1 : 8000

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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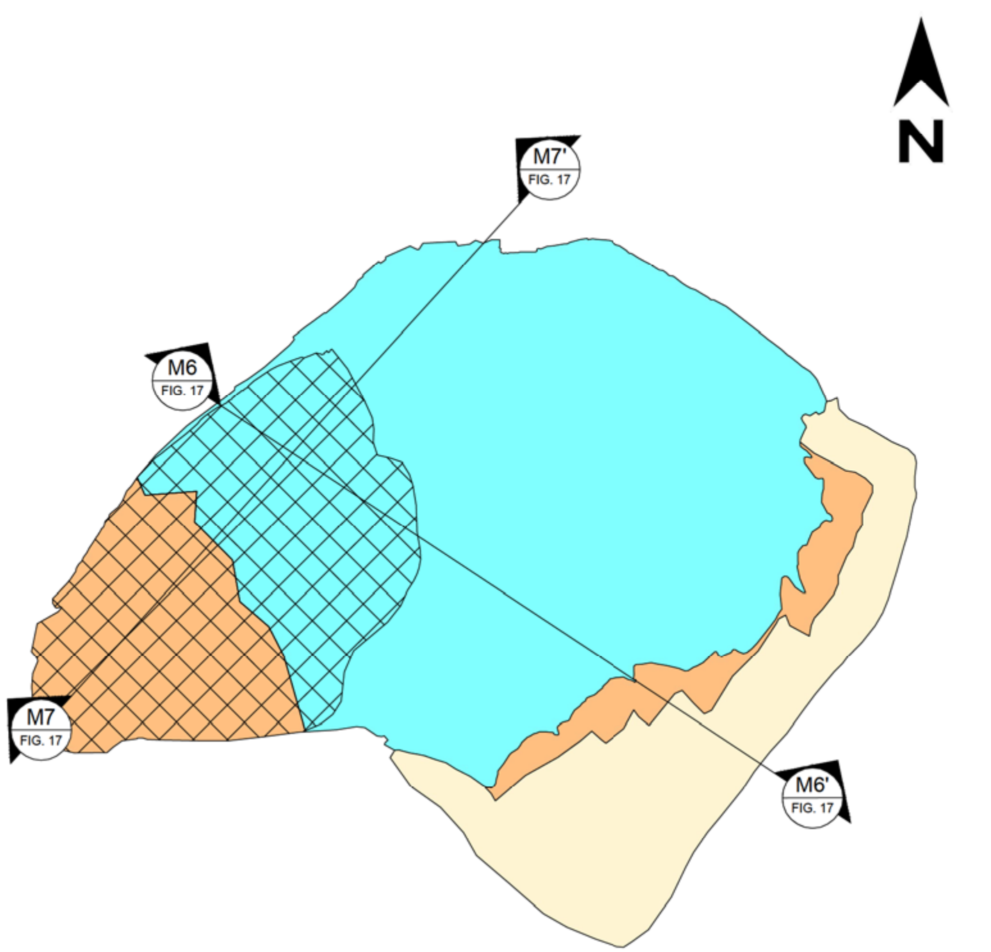
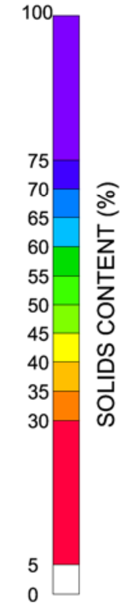
MUSKEG RIVER MINE
SOUTH EXPANSION AREA
SECTIONS M4-M4' & M5-M5' SOLIDS PROFILES

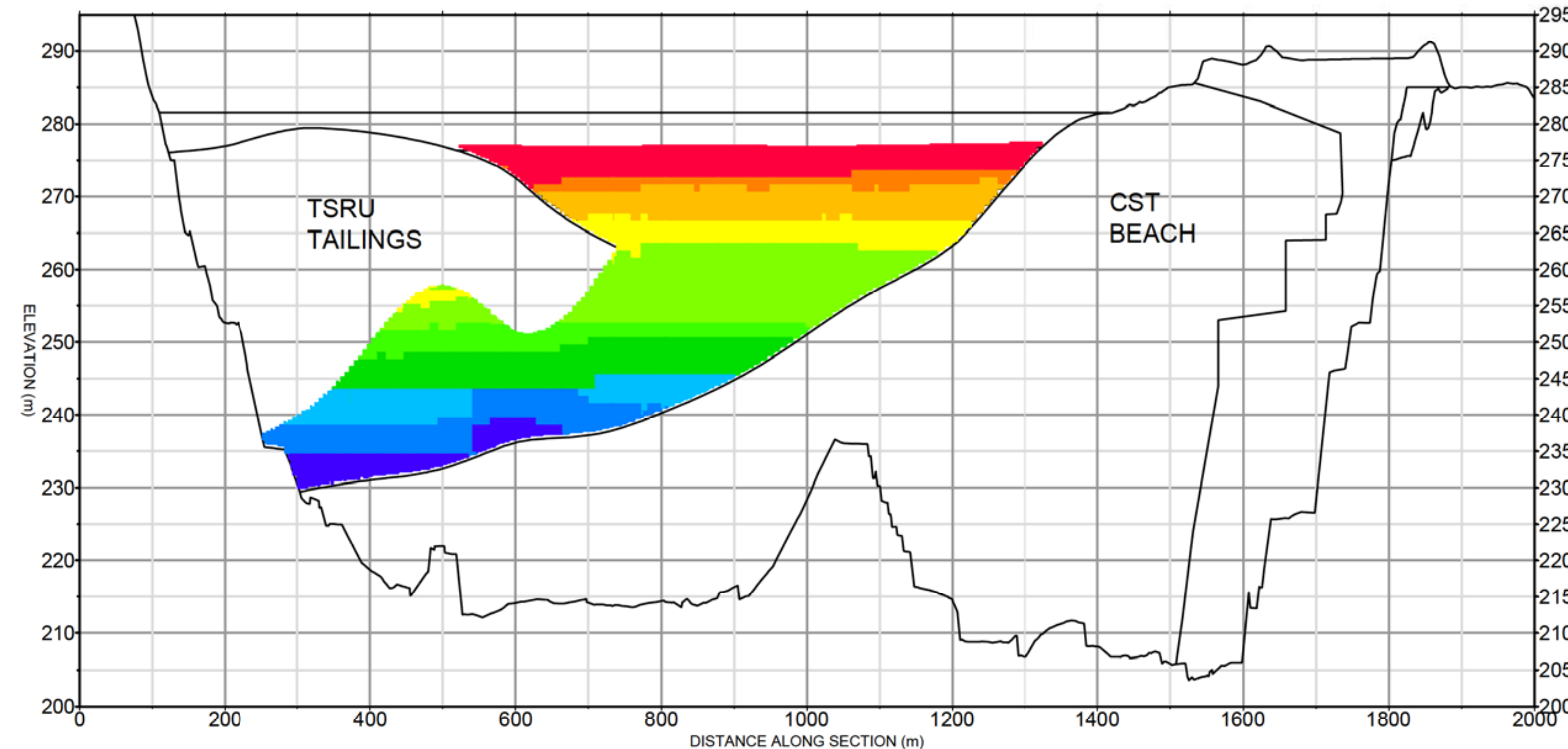
DATE: 2019-03-27
FIGURE: 22

UPDATE: April 25, 2019 - 5:25pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - SEA.dwg

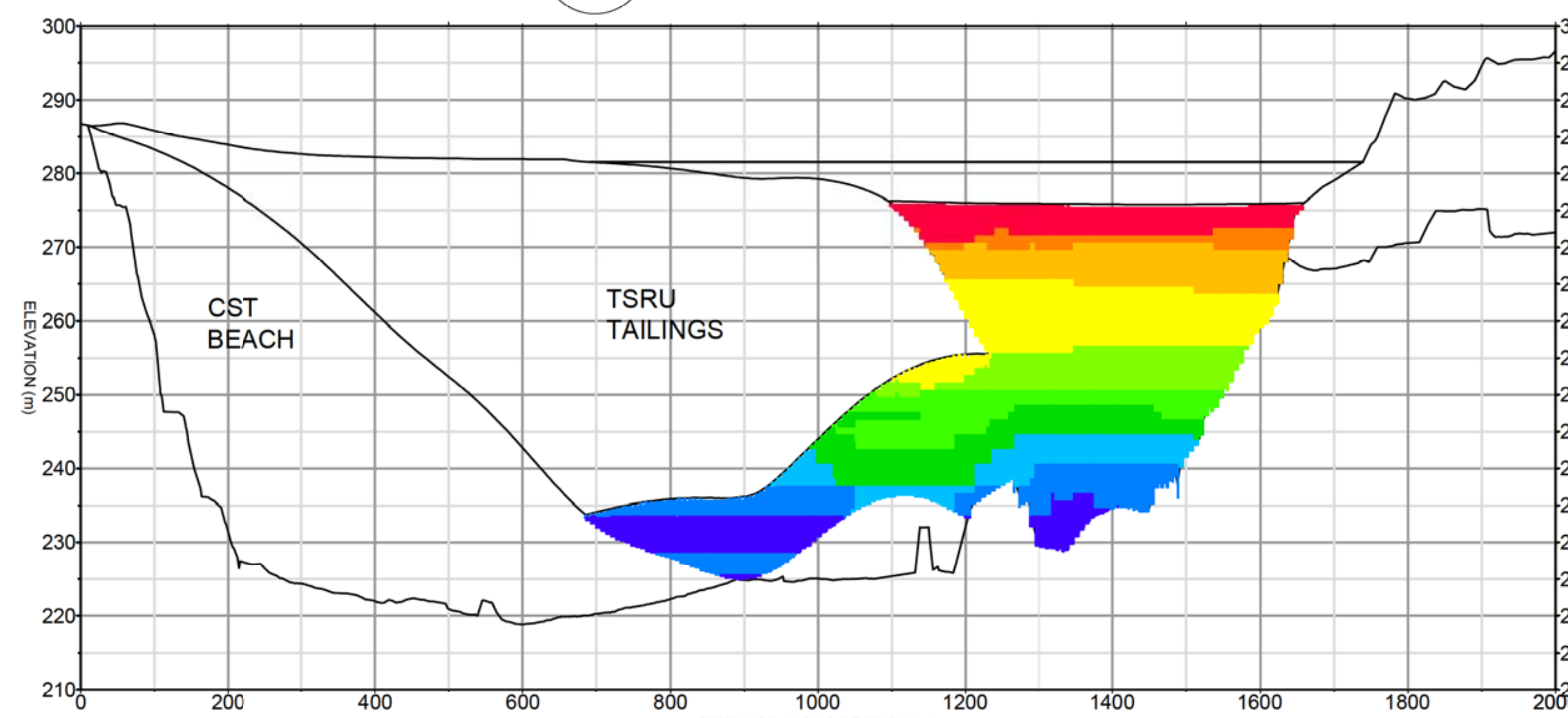


KEY PLAN
SCALE 1:20,000





M6-M6' FIG. 1 PROFILE THROUGH MRM IPC1
10X VERTICAL EXAGGERATION



M7-M7' FIG. 1 PROFILE THROUGH MRM IPC1
10X VERTICAL EXAGGERATION

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 m
1 : 10,000

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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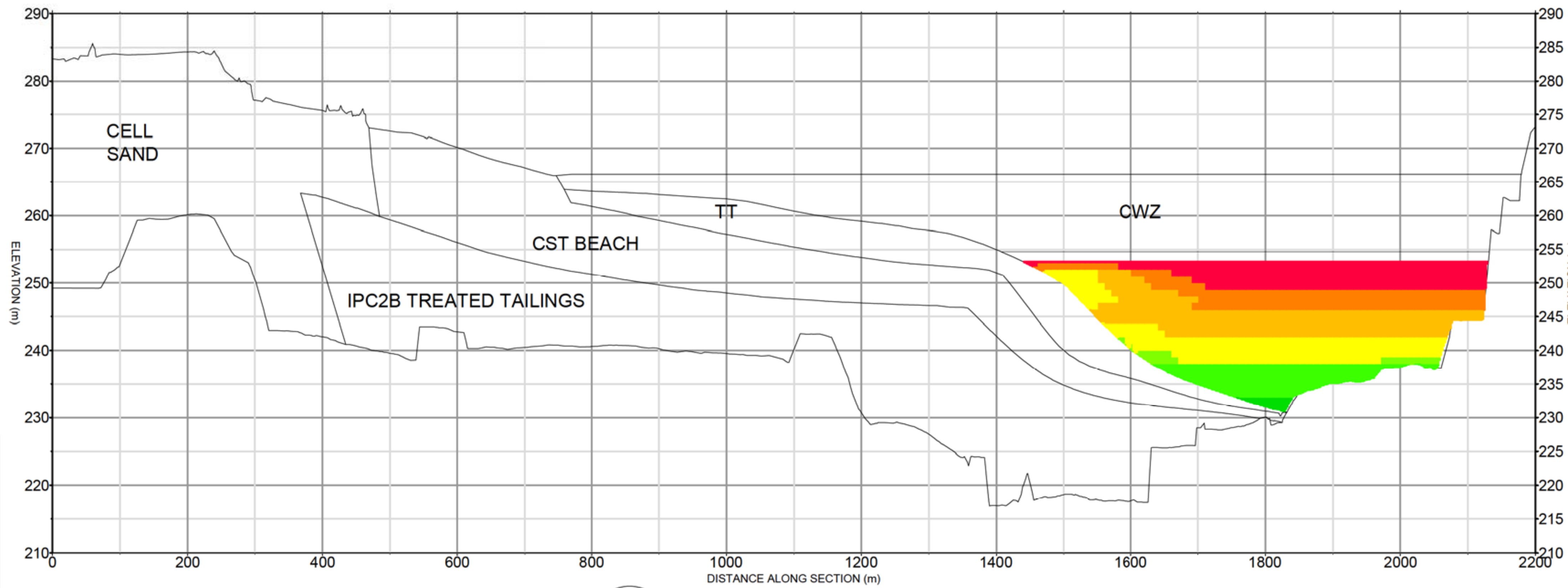
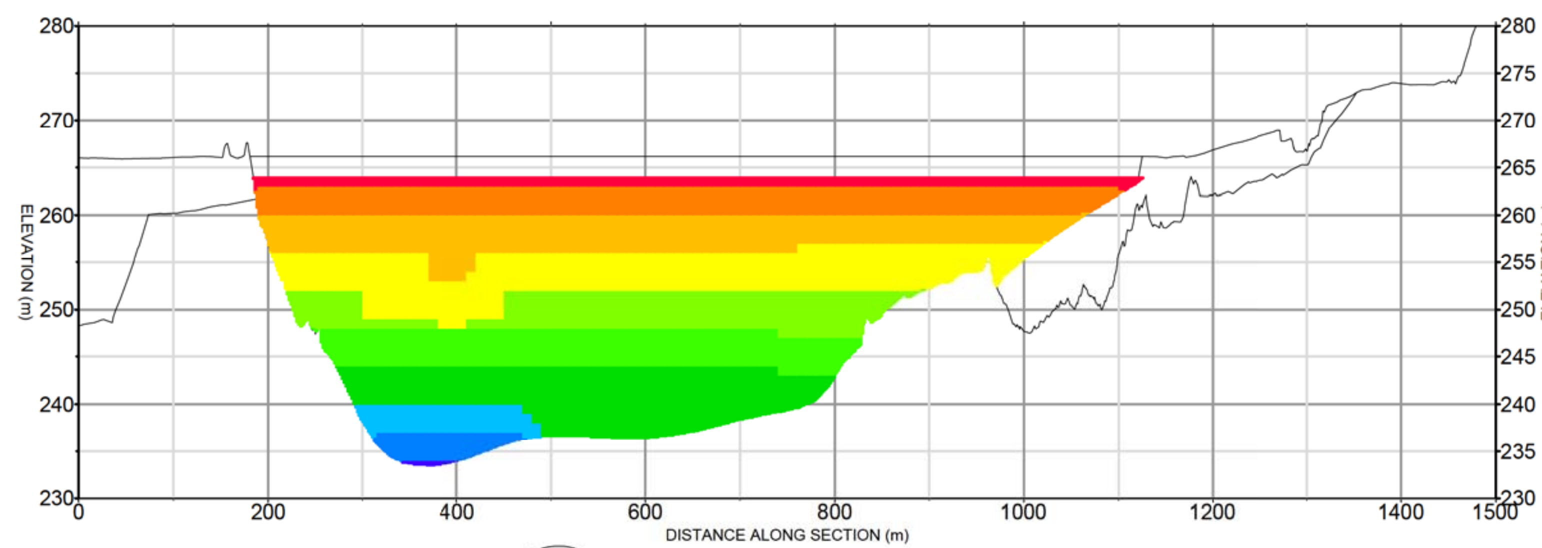
MUSKEG RIVER MINE
IN-PIT CELL 1
SECTIONS M6-M6' & M7-M7' SOLIDS PROFILES

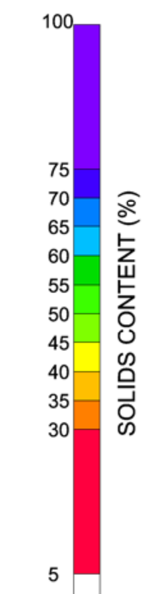
DATE: 2019-03-27
FIGURE: 23

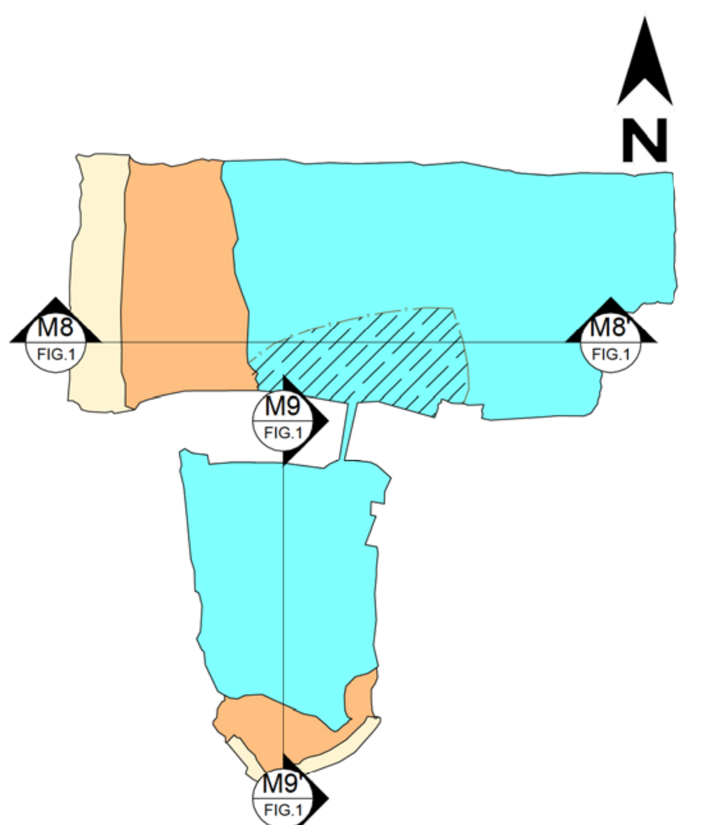


M8-M8' FIG. 1 PROFILE THROUGH MRM IPC2
10X VERTICAL EXAGGERATION



M9-M9' FIG. 1 PROFILE THROUGH MRM IPC2
10X VERTICAL EXAGGERATION





KEY PLAN
SCALE 1:30,000

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12

0 100 200 300 400 m
1 : 8000

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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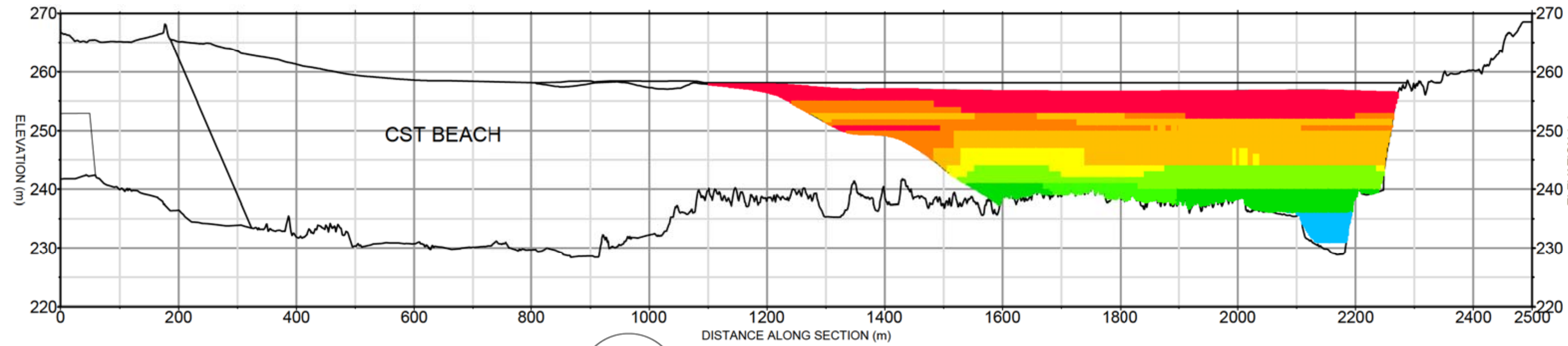
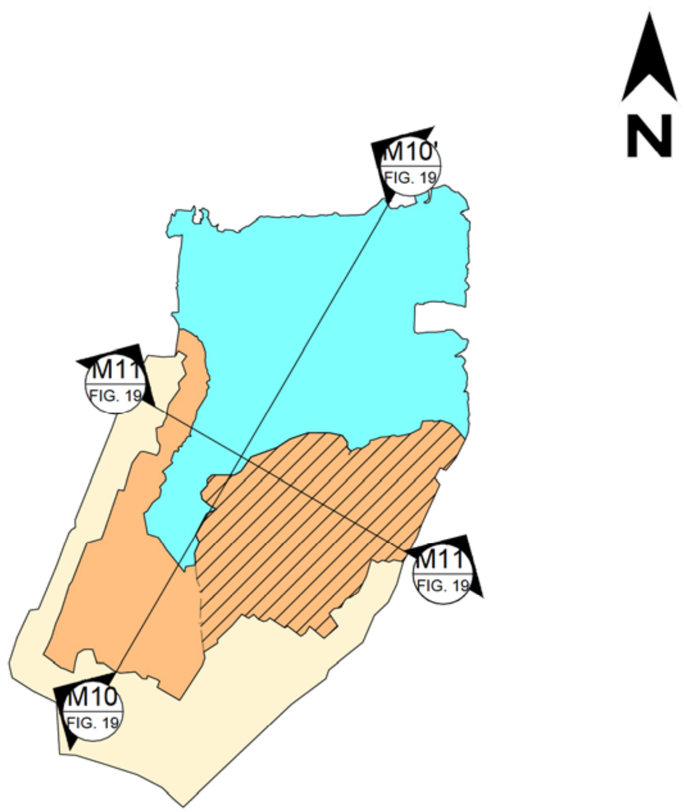
MUSKEG RIVER MINE
IN-PIT CELL 2 (2A/2B)
SECTIONS M8-M8' & M9-M9' SOLIDS PROFILES

DATE: 2019-03-26
FIGURE: 24

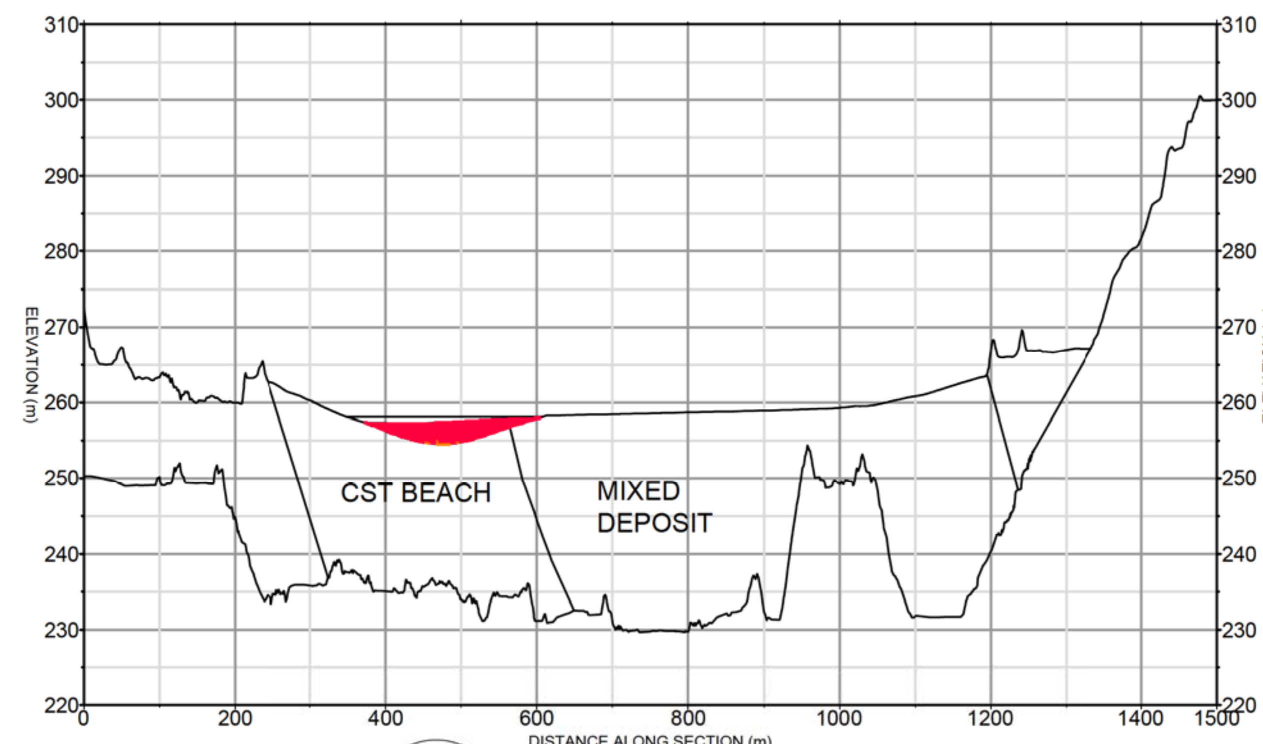
UPDATE: April 25, 2019 - 5:18pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM\190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - IPC2.dwg



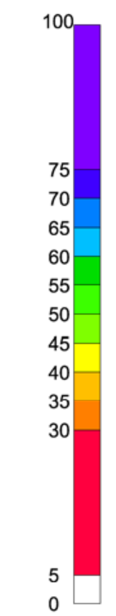
M10-M10' FIG. 1 PROFILE THROUGH MRM IPC3
10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:30,000



M11-M11' FIG. 1 PROFILE THROUGH MRM IPC3
10X VERTICAL EXAGGERATION



NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 m
1 : 10,000

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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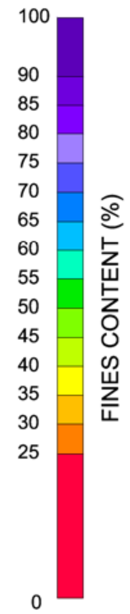
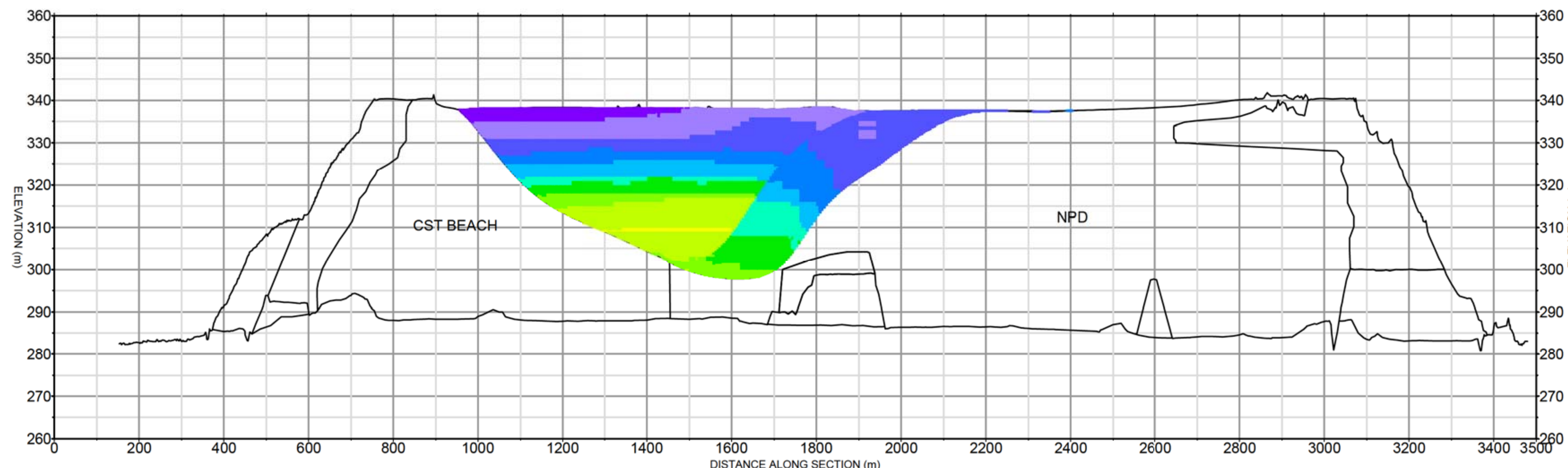
MUSKEG RIVER MINE IN-PIT CELL 3
SECTIONS M10-M10' & M11-M11'
SOLIDS PROFILES

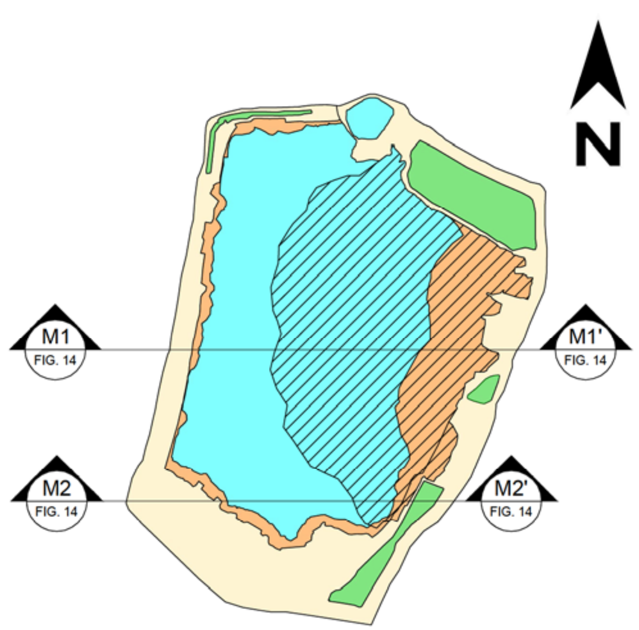
DATE: 2019-03-27
FIGURE: 25

UPDATE: April 25, 2019 - 4:56pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - IPC3.dwg

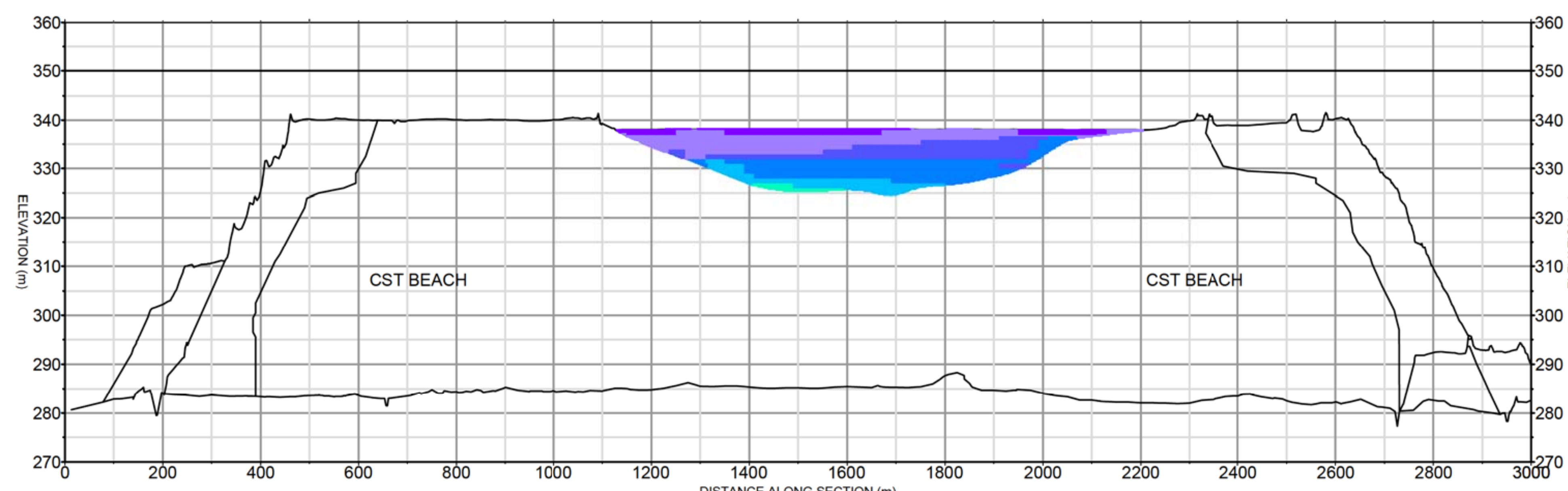




M1-M1' PROFILE THROUGH MRM ETF
FIG. 1 10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:50,000



M2-M2' PROFILE THROUGH MRM ETF
FIG. 1 10X VERTICAL EXAGGERATION

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 500 m

1 : 12,500

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DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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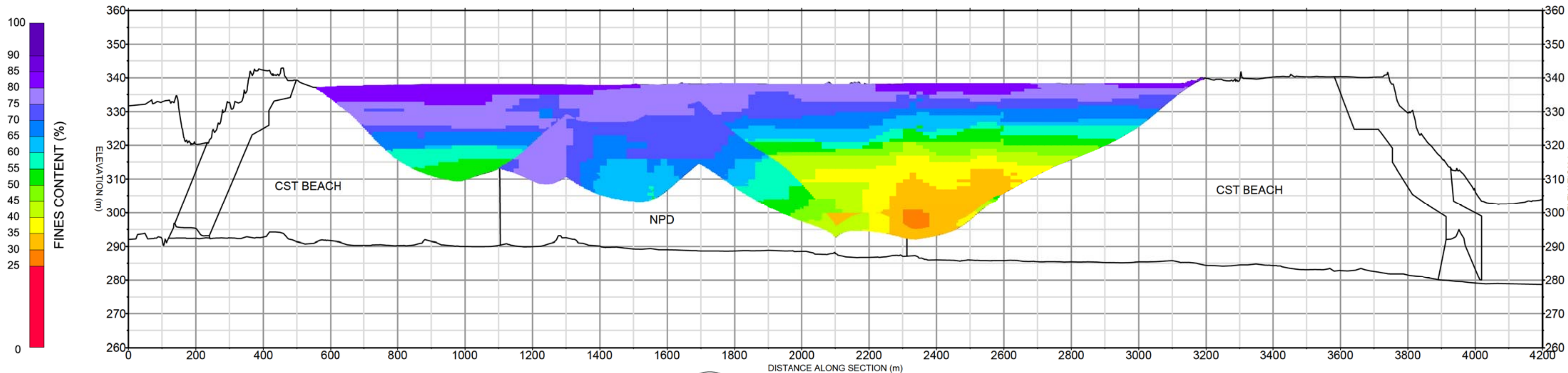
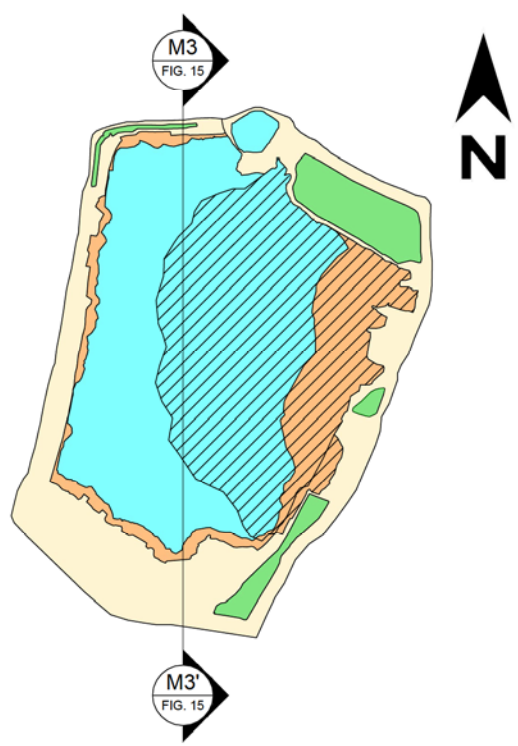
MUSKEG RIVER MINE
EXTERNAL TAILINGS FACILITY
SECTIONS M1-M1' & M2-M2' FINES PROFILES

DATE: 2019-03-19
FIGURE: 26

UPDATE: April 25, 2019 - 5:09pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM\190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - ETF.dwg



M3-M3' PROFILE THROUGH MRM ETF
FIG. 1 10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:50,000

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 500 m
1 : 12,500

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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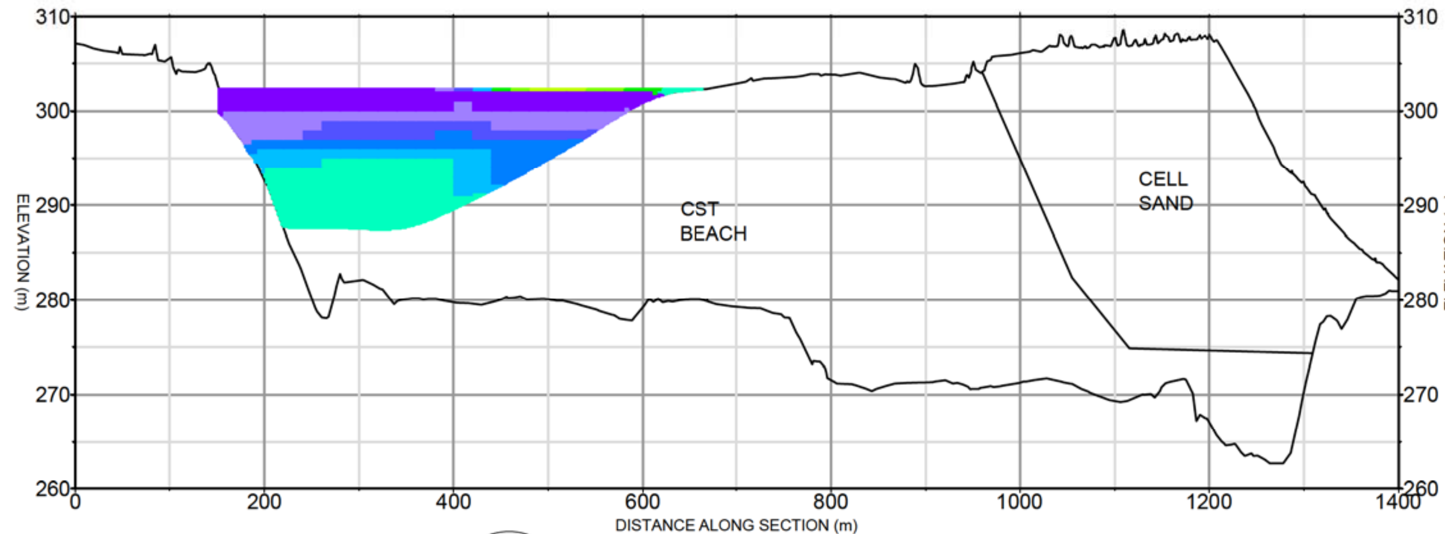
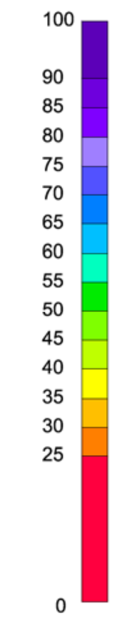
MUSKEG RIVER MINE
EXTERNAL TAILINGS FACILITY
SECTION M3-M3' FINES PROFILE

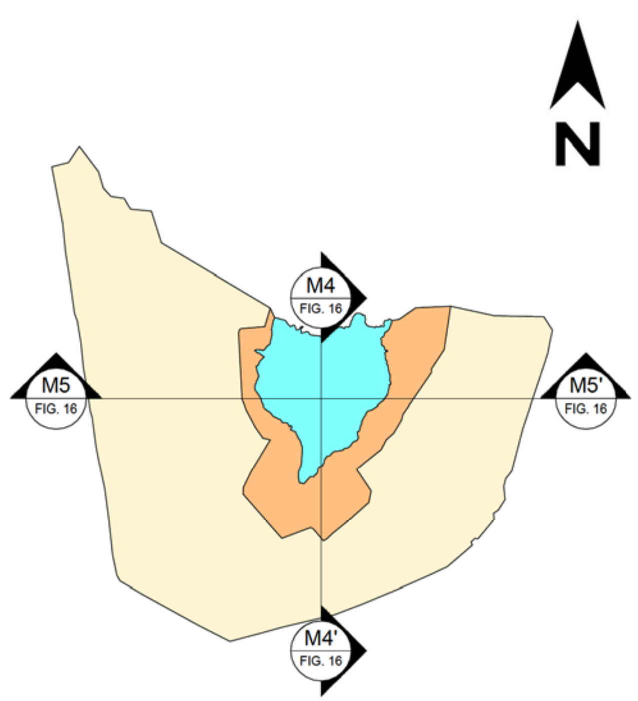
DATE: 2019-03-19
FIGURE: 27

UPDATE: April 25, 2019 - 5:09pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM\190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - ETF.dwg

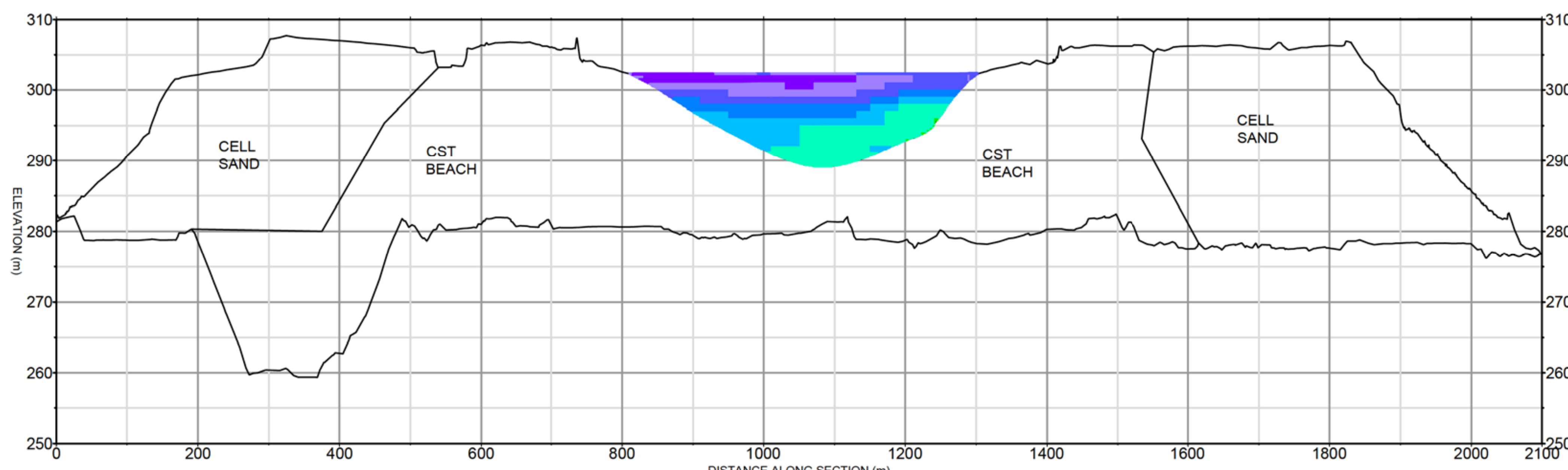


M4-M4' FIG. 1 — PROFILE THROUGH MRM SEA, 10X VERTICAL EXAGGERATION





KEY PLAN
SCALE 1:50,000



M5-M5' FIG. 1 — PROFILE THROUGH MRM SEA, 10X VERTICAL EXAGGERATION

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 m
1 : 8000

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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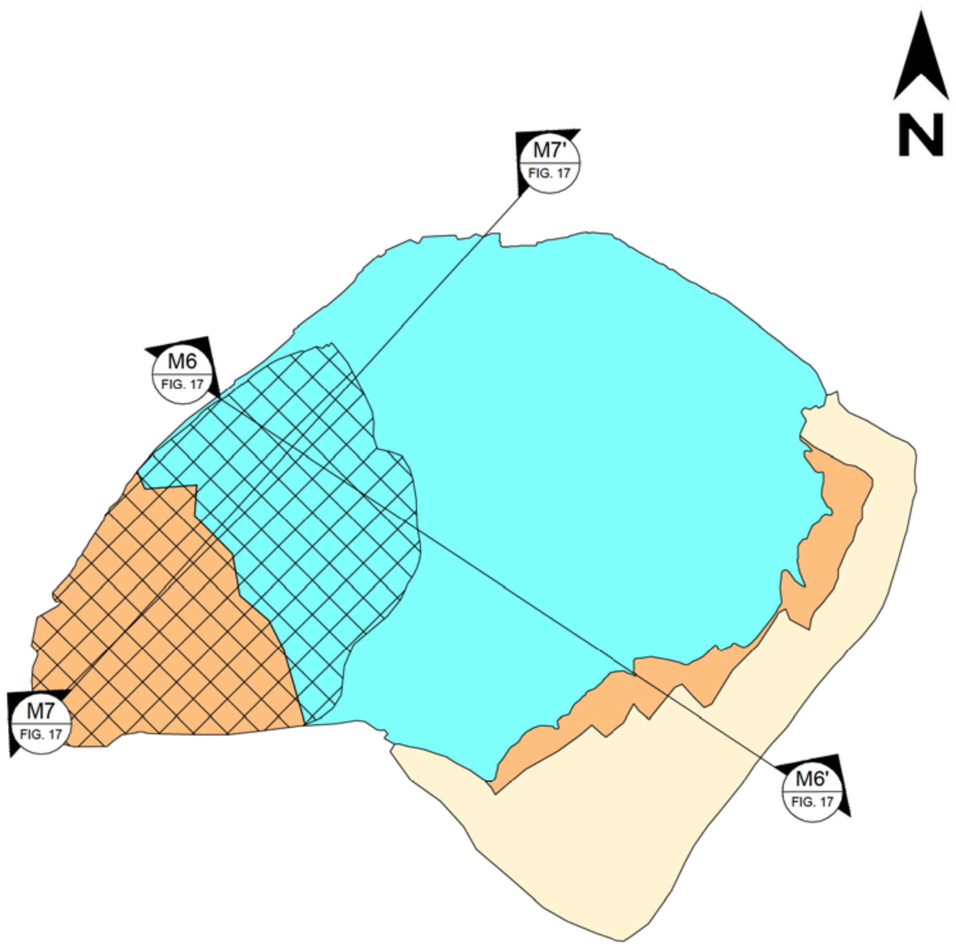
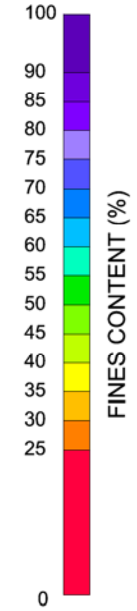
MUSKEG RIVER MINE
SOUTH EXPANSION AREA
SECTIONS M4-M4' & M5-M5' FINES PROFILES

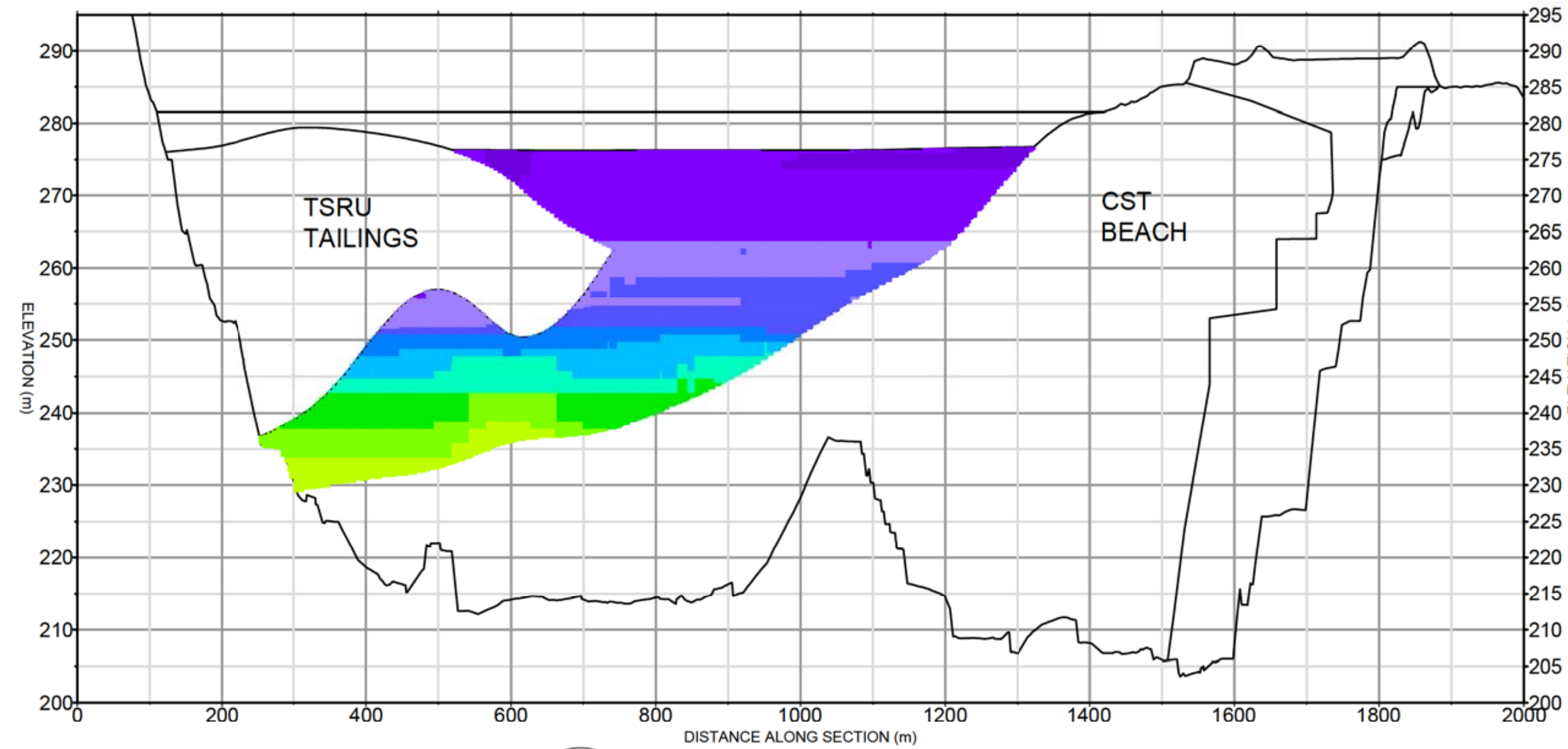
DATE: 2019-03-27
FIGURE: 28

UPDATE: April 25, 2019 - 5:25pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - SEA.dwg

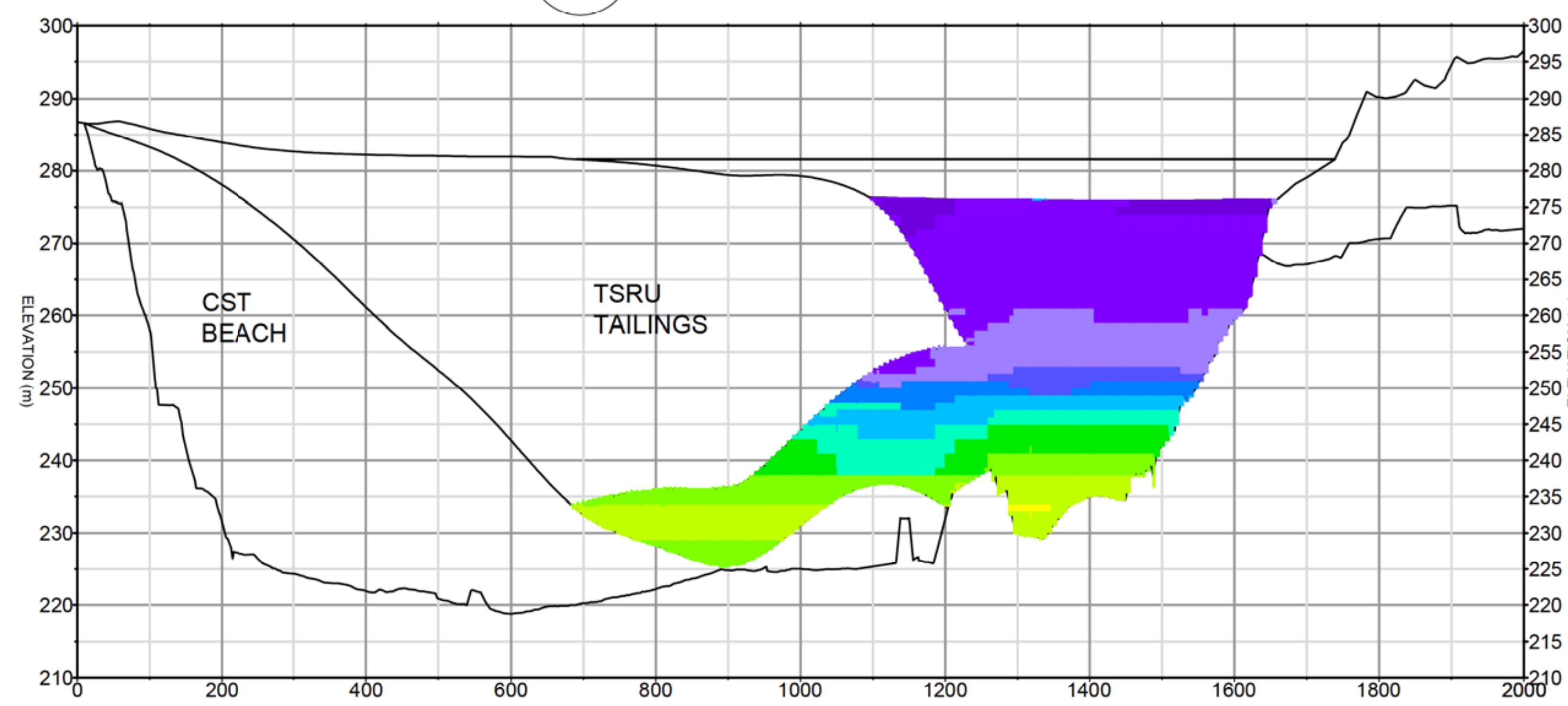


KEY PLAN
SCALE 1:20,000





M6-M6' FIG. 1 PROFILE THROUGH MRM IPC1
10X VERTICAL EXAGGERATION



M7-M7' FIG. 1 PROFILE THROUGH MRM IPC1
10X VERTICAL EXAGGERATION

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 m
1 : 10,000

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REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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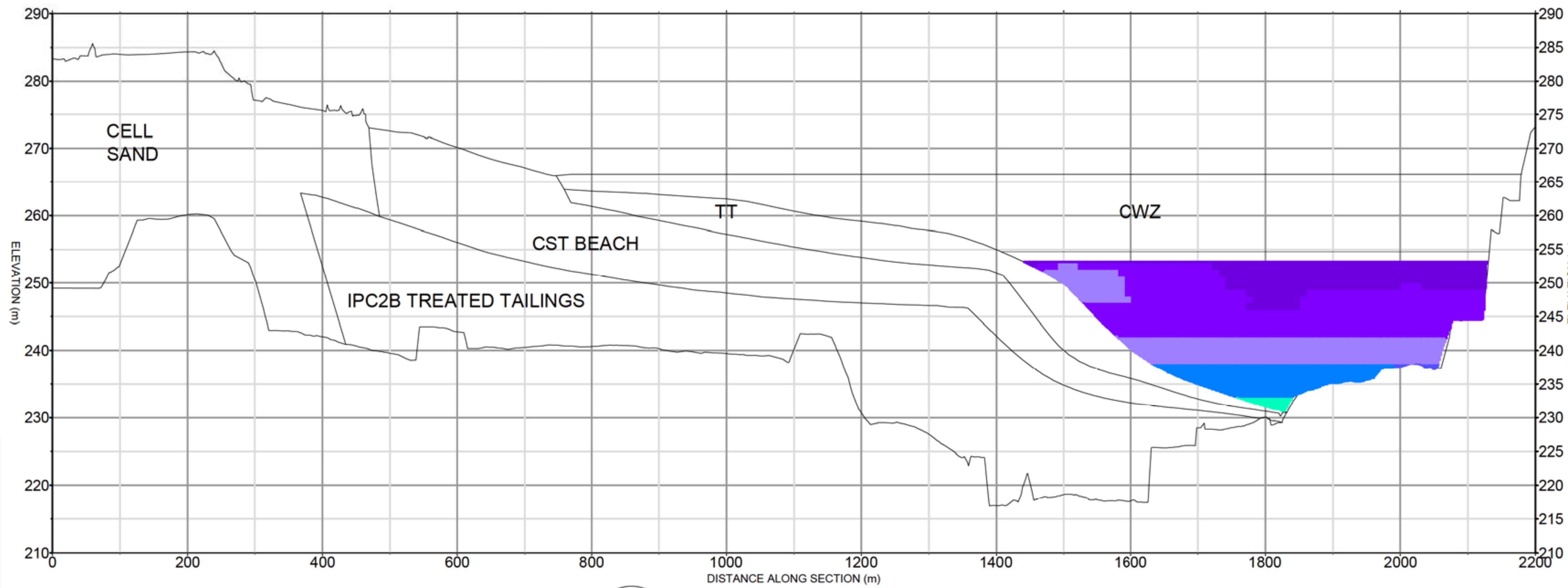
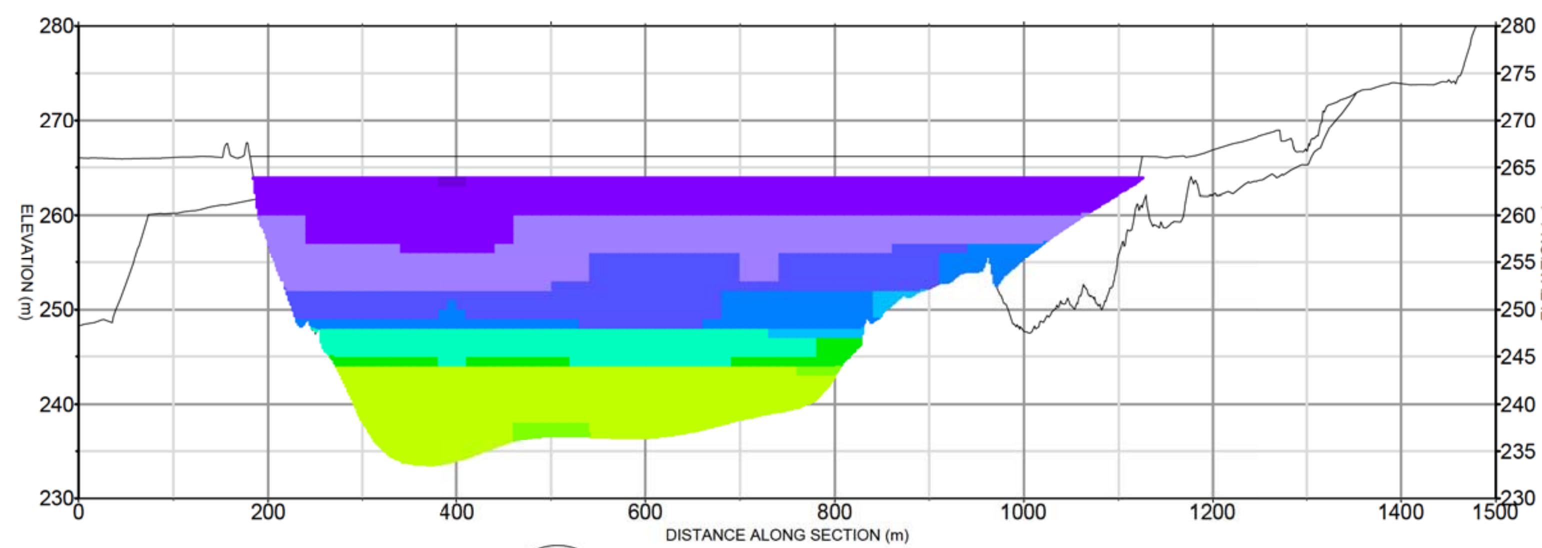
MUSKEG RIVER MINE
IN-PIT CELL 1
SECTIONS M6-M6' & M7-M7' FINES PROFILES

DATE: 2019-03-27
FIGURE: 29

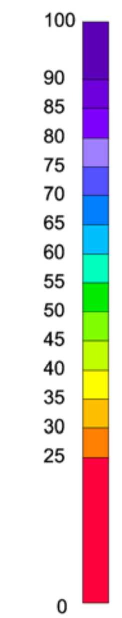
UPDATE: April 25, 2019 - 5:26pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM\190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - IPC1.dwg

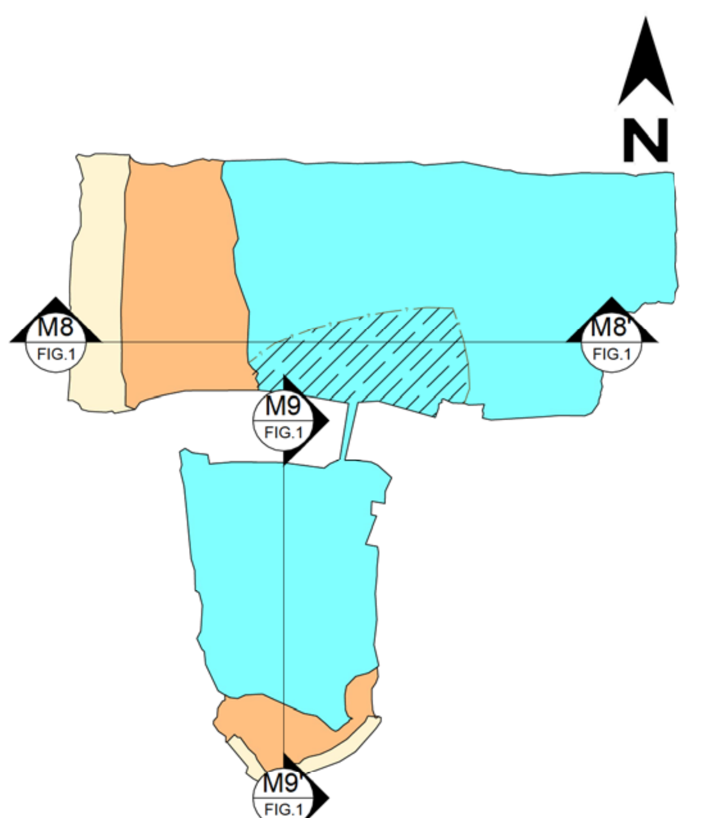


M8-M8' FIG. 1 PROFILE THROUGH MRM IPC2
10X VERTICAL EXAGGERATION



M9-M9' FIG. 1 PROFILE THROUGH MRM IPC2
10X VERTICAL EXAGGERATION





KEY PLAN
SCALE 1:30,000

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 m
1 : 8000

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DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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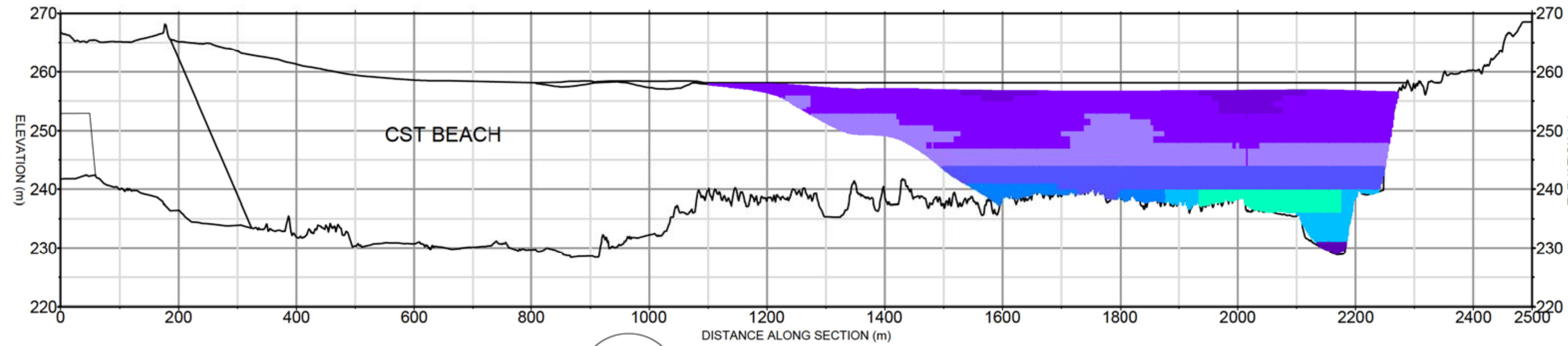
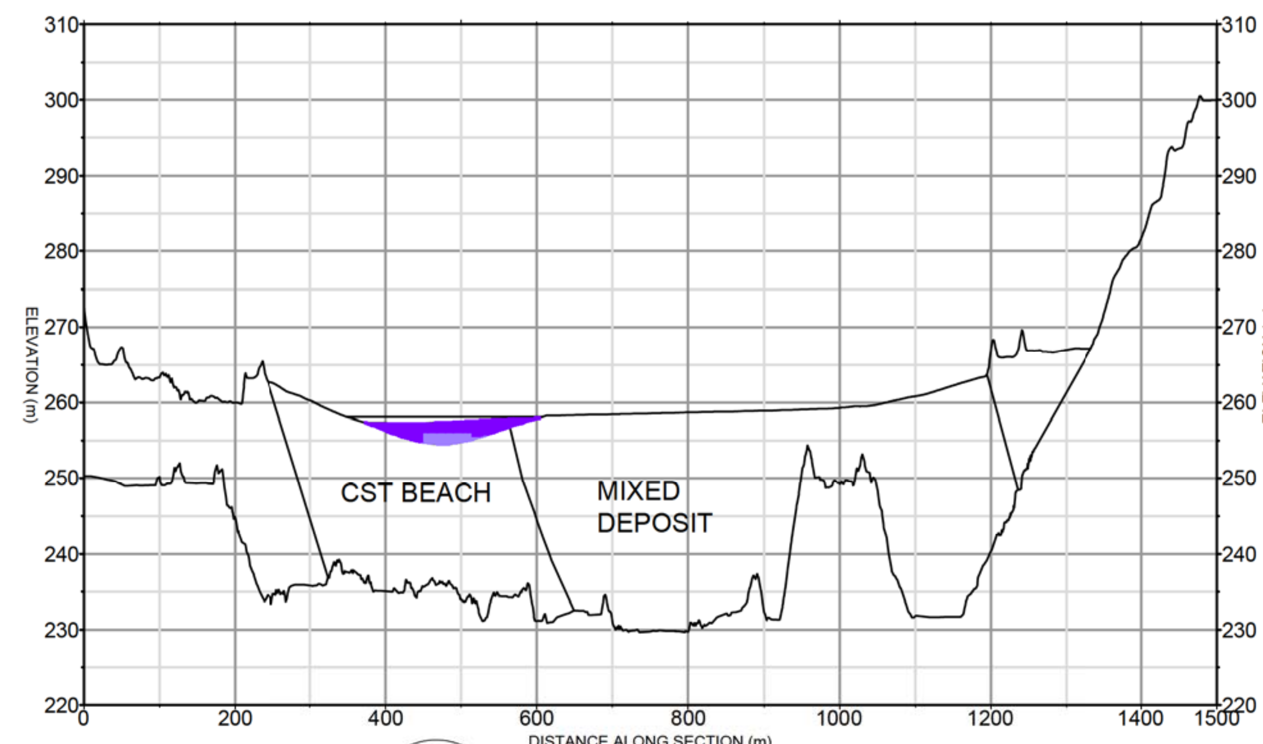
MUSKEG RIVER MINE
IN-PIT CELL 2 (2A/2B)
SECTIONS M8-M8' & M9-M9' FINES PROFILES

DATE: 2019-03-26
FIGURE: 30

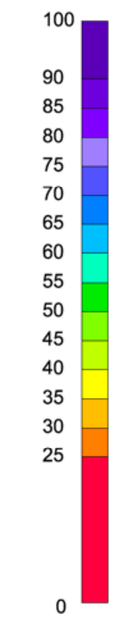
UPDATE: April 25, 2019 - 5:18pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM\190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - IPC2.dwg

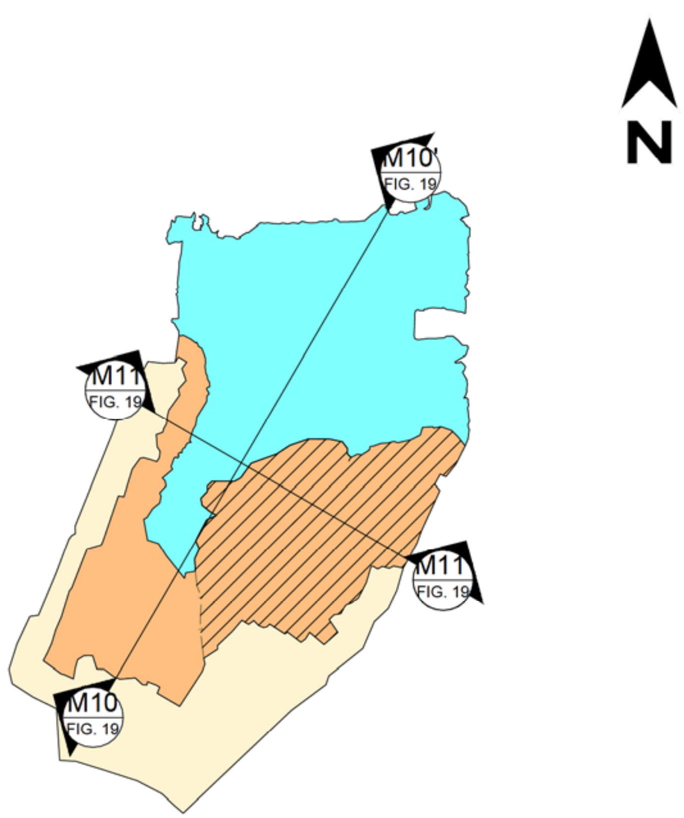


M10-M10' / FIG. 1 PROFILE THROUGH MRM IPC3
10X VERTICAL EXAGGERATION



M11-M11' / FIG. 1 PROFILE THROUGH MRM IPC3
10X VERTICAL EXAGGERATION





KEY PLAN
SCALE 1:30,000

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 100 200 300 400 m
1 : 10,000

UPDATE: April 25, 2019 - 4:57pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - IPC3.dwg

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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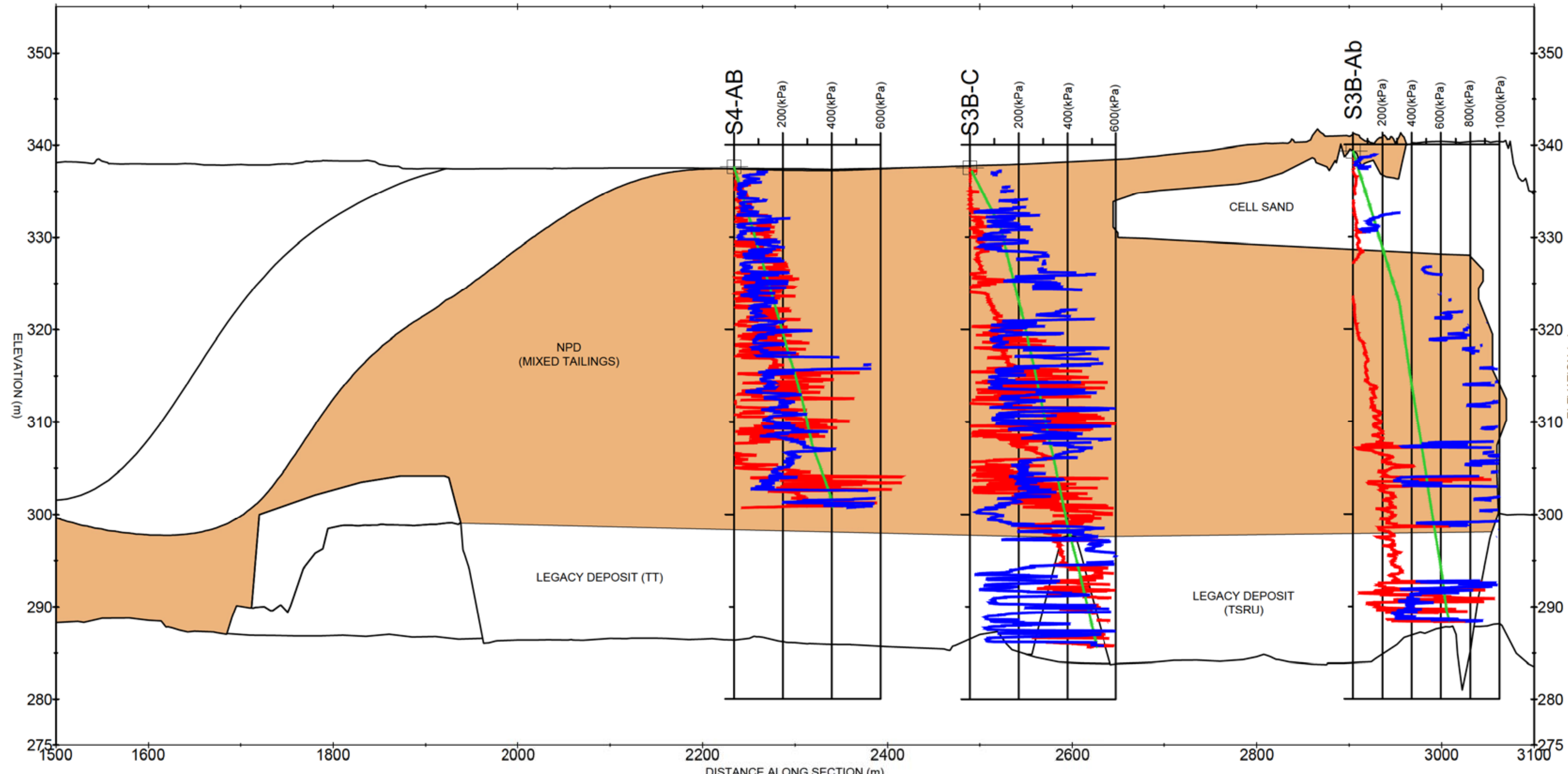
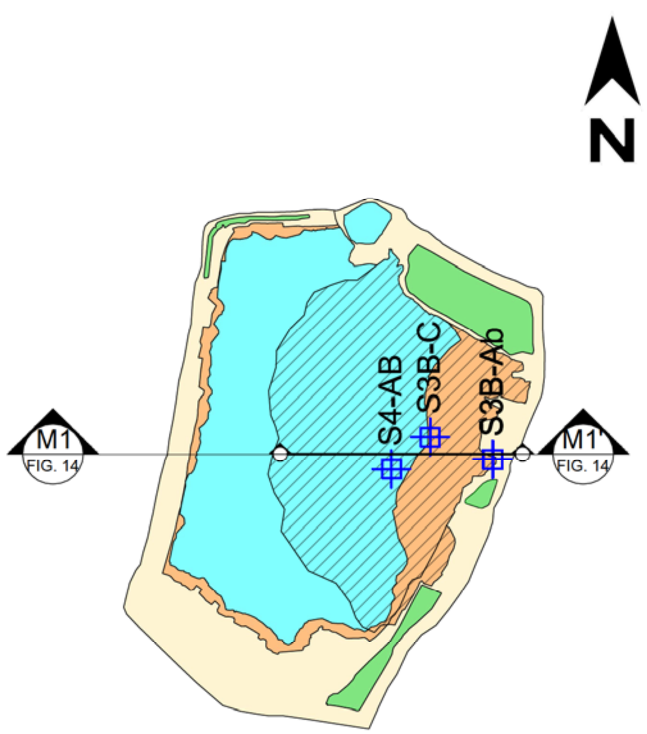
MUSKEG RIVER MINE IN-PIT CELL 3
SECTIONS M10-M10' & M11-M11'
FINES PROFILES

DATE: 2019-03-27
FIGURE: 31



M1-M1' PROFILE THROUGH MRM ETF
FIG. 1 10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:50,000

UPDATE: April 25, 2019 - 5:00pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - CPT.dwg

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 60 120 180 240 m
1 : 6000

LEGEND:
- UNDRAINED SHEAR STRENGTH, Su (Nkt=15.0) (Su NOT CALCULATED FOR MATERIALS BEHAVING AS DRAINED MATERIALS)
- AVERAGED DYNAMIC PORE PRESSURE, u
- EFFECTIVE STRESS, $\sigma' = \sigma_t - u_{eq}$

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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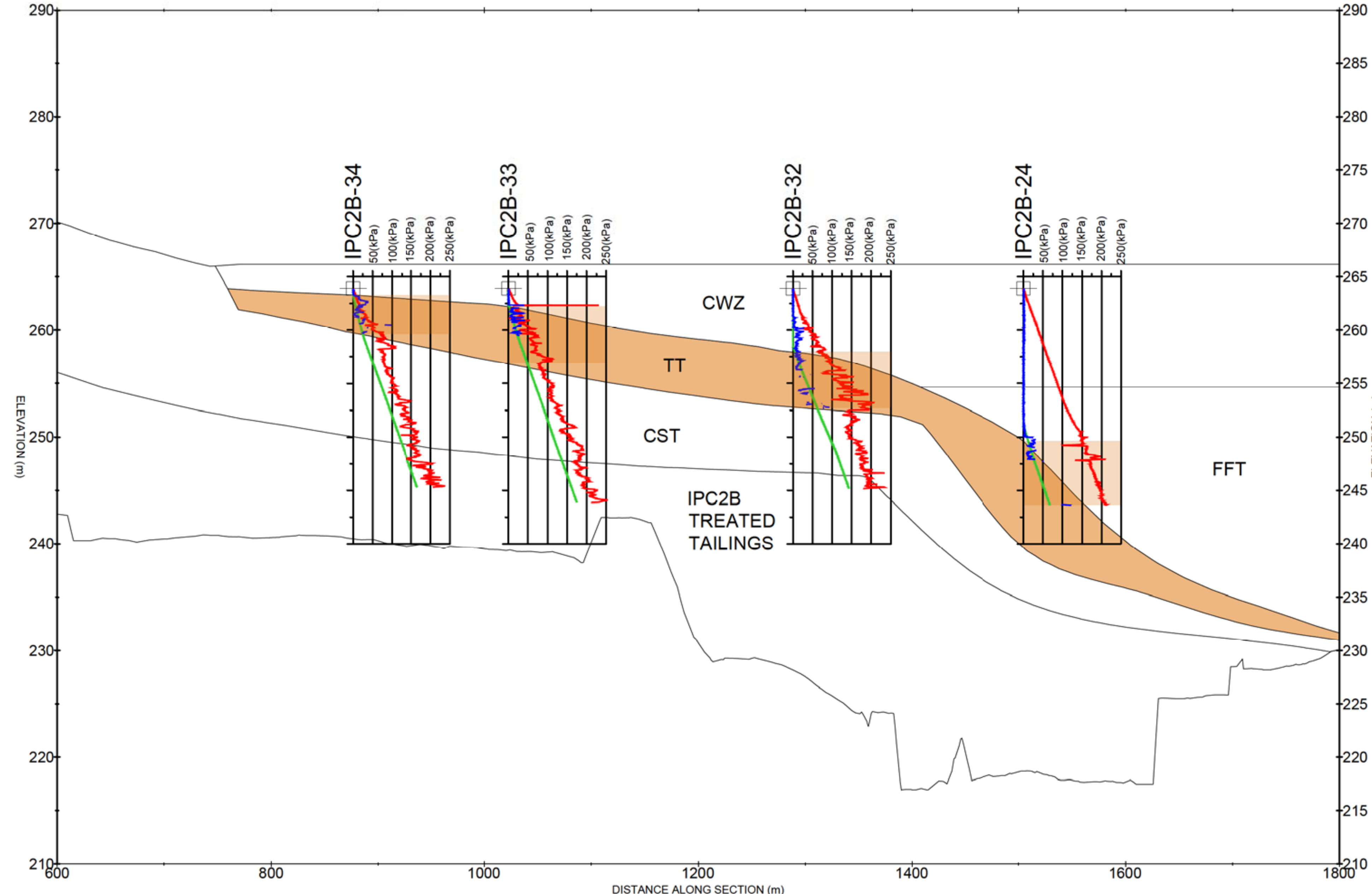
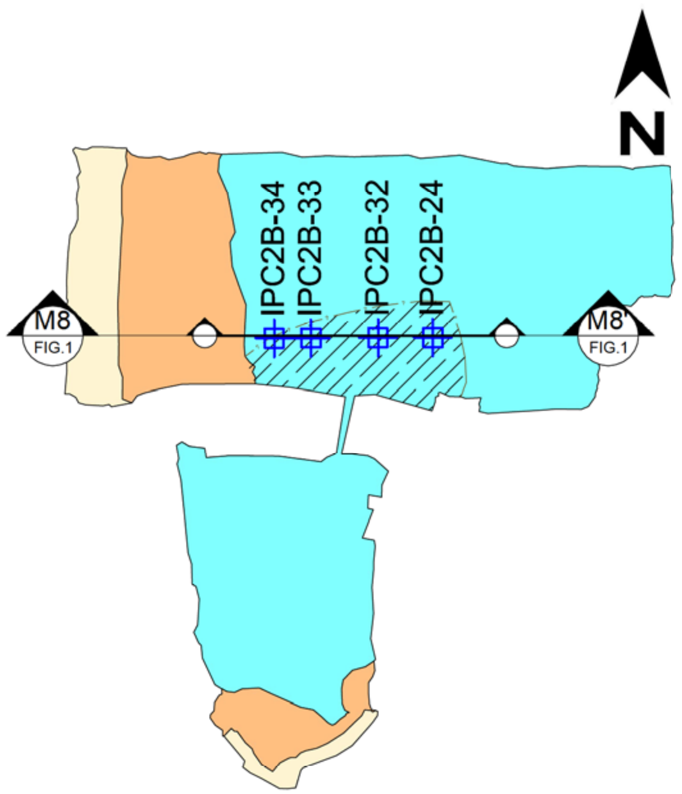
MUSKEG RIVER MINE
EXTERNAL TAILINGS FACILITY
SECTION M1-M1' STRENGTH PROFILE

DATE: 2019-03-27
FIGURE: 32



M8-M8' FIG. 1 PROFILE THROUGH MRM IPC2
10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:30,000

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 50 100 150 200 m
1 : 5000

LEGEND:
- UNDRAINED SHEAR STRENGTH, Su (Nkt=15.0) (Su NOT CALCULATED FOR MATERIALS BEHAVING AS DRAINED MATERIALS)
- AVERAGED DYNAMIC PORE PRESSURE, u
- EFFECTIVE STRESS, $\sigma' = \sigma_t - u_{eq}$

DESIGNED BY:	KR
DRAWN BY:	LH
REVIEWED BY:	MG
APPROVED BY:	MAS
SCALE:	AS SHOWN

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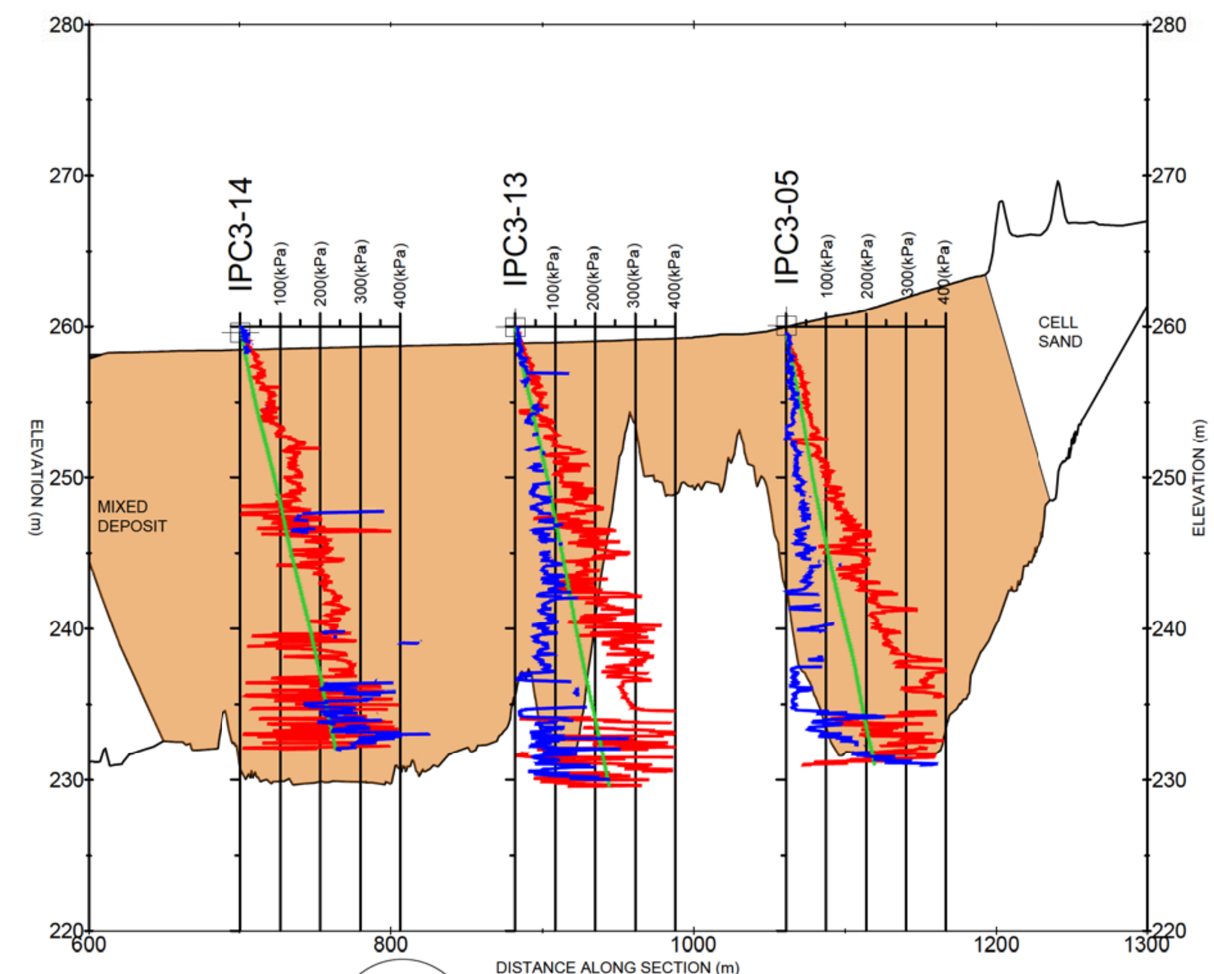
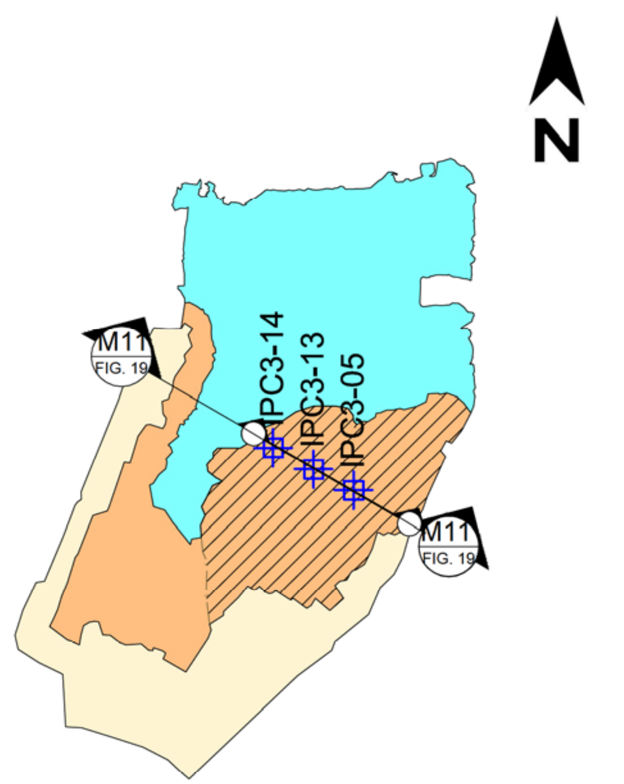
MUSKEG RIVER MINE
IN-PIT CELL 2 (2B)
SECTION M8-M8' STRENGTH PROFILE

DATE: 2019-03-27
FIGURE: 33

UPDATE: April 25, 2019 - 5:03pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM\190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - CPT.dwg



M11-M11' PROFILE THROUGH MRM IPC3
FIG. 1 10X VERTICAL EXAGGERATION



KEY PLAN
SCALE 1:30,000

NOTES:
1. ALL DIMENSIONS AND ELEVATIONS IN METRES.
2. THE COORDINATE SYSTEM IS IN UTM NAD 83 ZONE 12.

0 50 100 150 200 m
1 : 5000

LEGEND:
UNDRAINED SHEAR STRENGTH, Su (Nkt=15.0) (Su NOT CALCULATED FOR MATERIALS BEHAVING AS DRAINED MATERIALS)
AVERAGED DYNAMIC PORE PRESSURE, u
EFFECTIVE STRESS, $\sigma' = \sigma_t - u_{eq}$

DESIGNED BY: KR
DRAWN BY: LH
REVIEWED BY: MG
APPROVED BY: MAS
SCALE: AS SHOWN

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MUSKEG RIVER MINE
IN-PIT CELL 3
SECTION M11-M11' STRENGTH PROFILE

DATE: 2019-03-27
FIGURE: 34

UPDATE: April 25, 2019 - 5:05pm, FILE: R:\Albian\mine disc\GTE\site wide\TDP 2018\300_drawings\aer figures\MRM\190401 FIGURE REV0B - MRM 2019 AER REPORT FIGURE - CPT.dwg

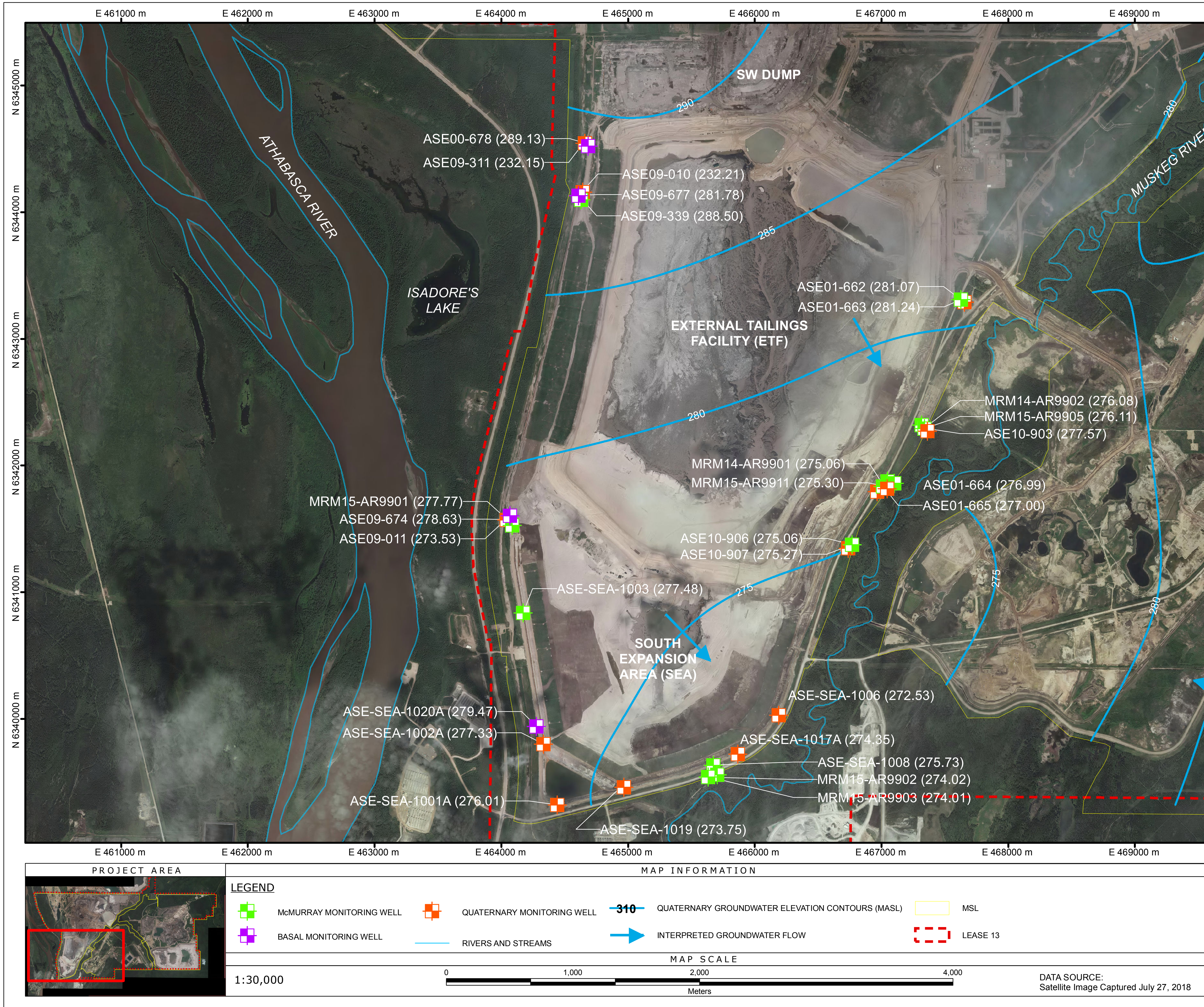

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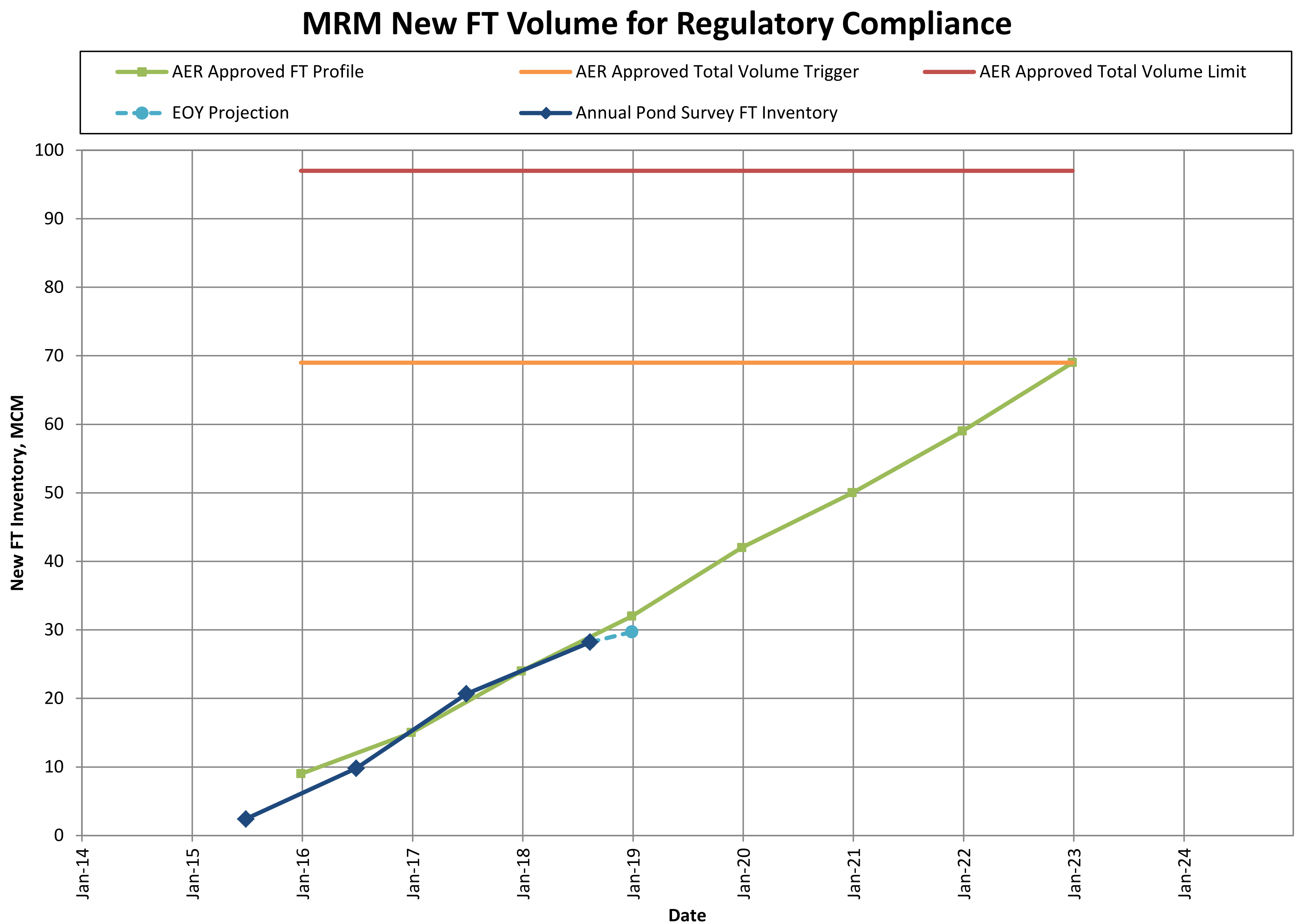
FIGURE 35: MONITORING WELL LOCATIONS - TAILINGS POND SEEPAGE

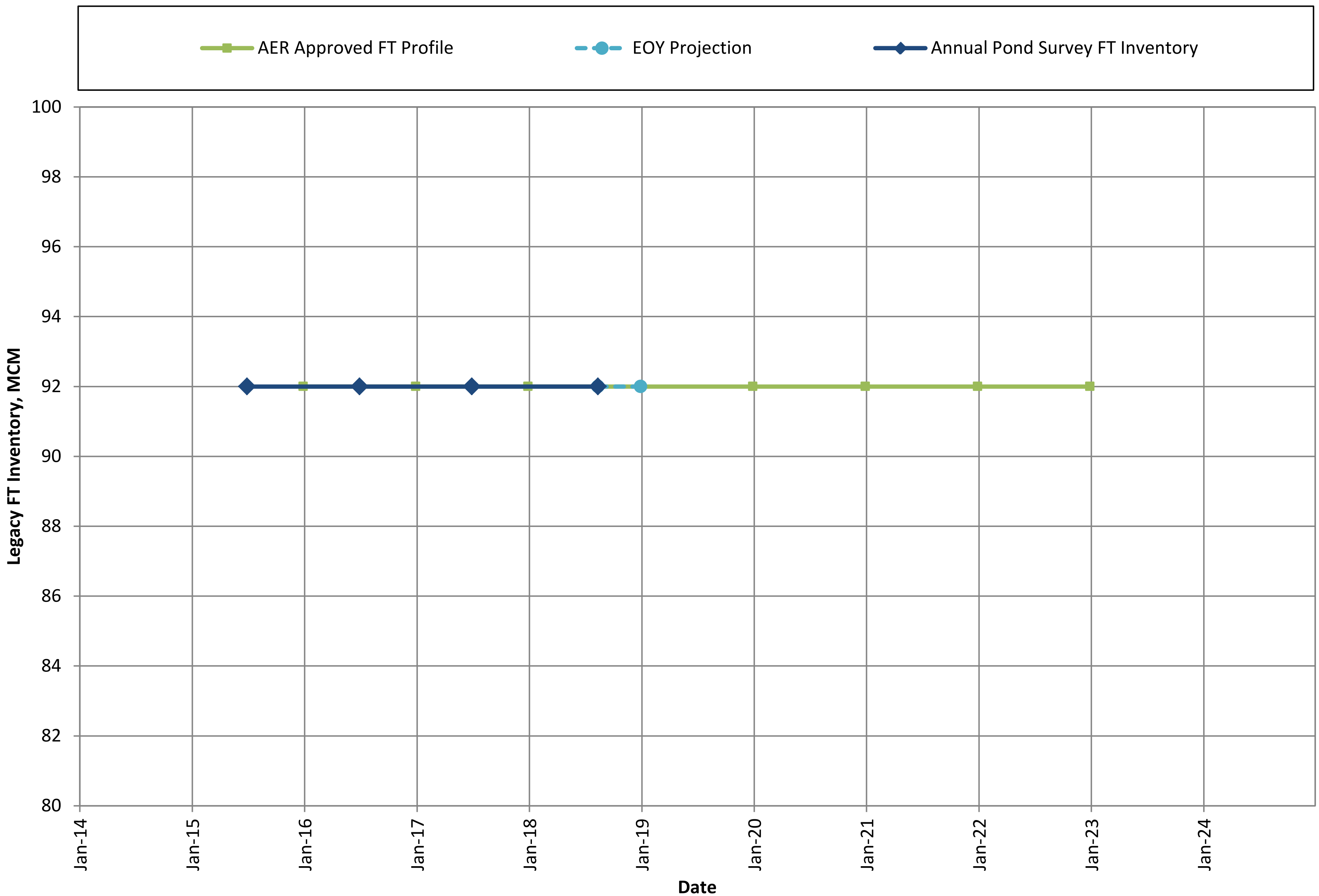
Drawn By: S.V.
Date: 25-March-2019
Reviewed By: B.D.
NAD83 UTM Zone 12N

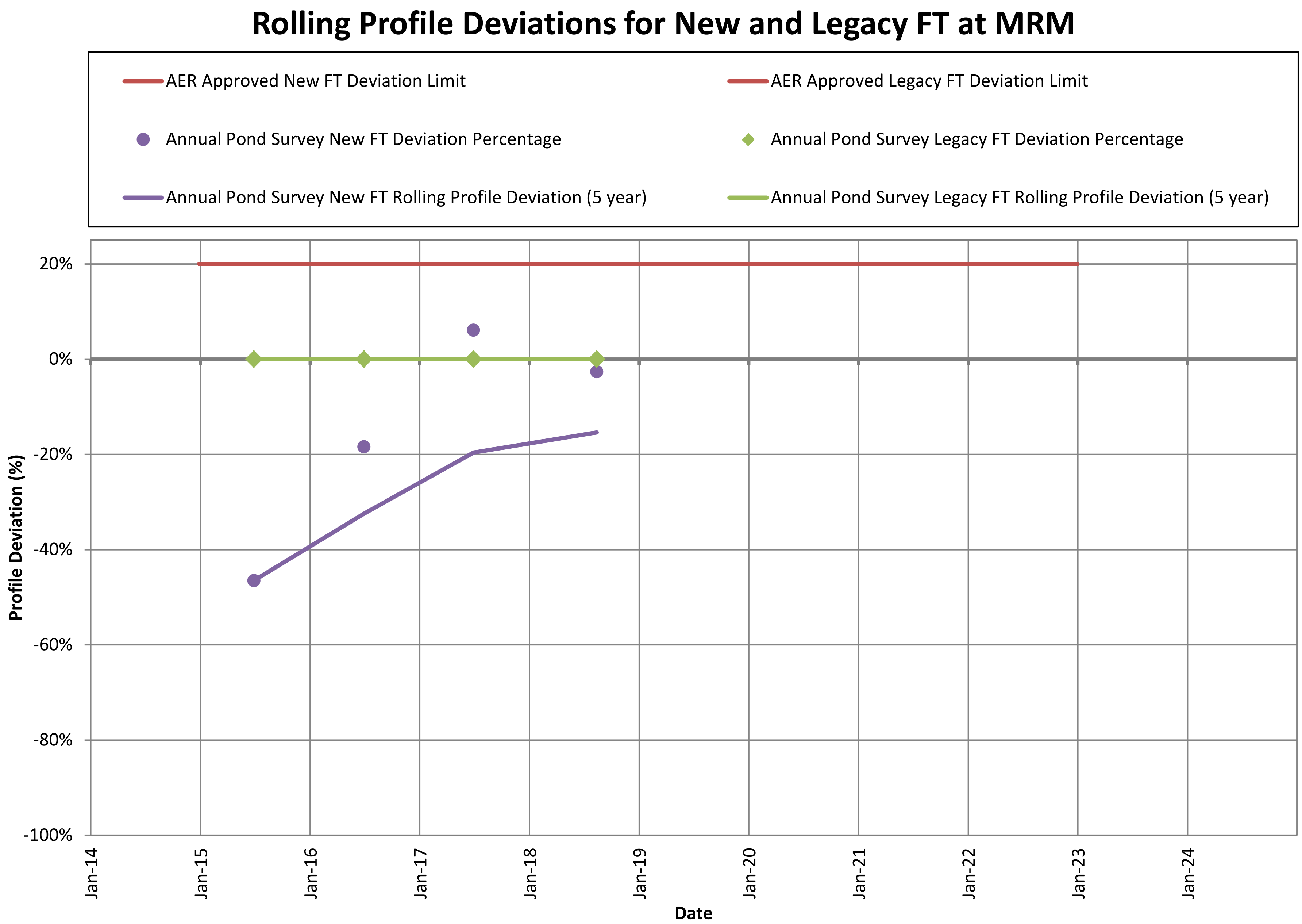
APPENDIX B:

AER Accounting Table,Graphs and Water Balance


MRM New FT Volume for Regulatory Compliance
AER Approved FT Profile
AER Approved Total Volume Trigger
AER Approved Total Volume Limit
EOY Projection
Annual Pond Survey FT Inventory
New FT Inventory, MCM
0
10
20
30
40
50
60
70
80
90
100
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Jan-20
Jan-21
Jan-22
Jan-23
Jan-24
Date

MRM Legacy FT Volume for Regulatory Compliance



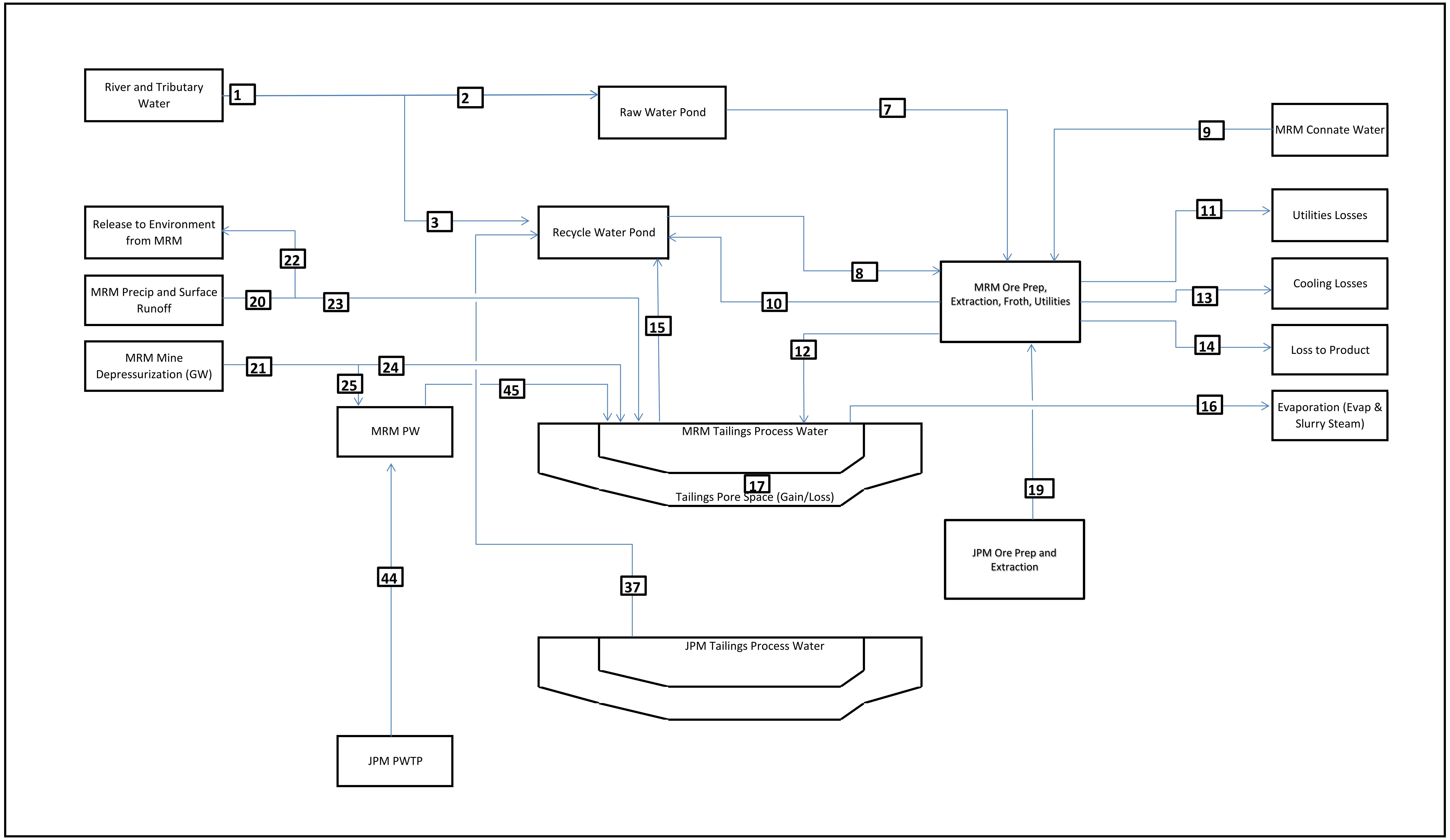

Rolling Profile Deviations for New and Legacy FT at MRM
AER Approved New FT Deviation Limit
AER Approved Legacy FT Deviation Limit
Annual Pond Survey New FT Deviation Percentage
Annual Pond Survey Legacy FT Deviation Percentage
Annual Pond Survey New FT Rolling Profile Deviation (5 year)
Annual Pond Survey Legacy FT Rolling Profile Deviation (5 year)
20%
0%
-20%
-40%
-60%
-80%
-100%
Profile Deviation (%)
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Jan-20
Jan-21
Jan-22
Jan-23
Jan-24
Date

YEAR	Previous Year New FT Inventory	Previous Year Legacy FT Inventory	Fluid Tailings Inventory	Change in New FT Inventory	Change in Legacy FT Inventory	New FT Inventory	Legacy FT Inventory	Approved Profile New FT Inventory	Approved Profile Legacy FT Inventory	New FT Rolling Profile Deviation	Legacy FT Rolling Profile Deviation
2015	0	92	98.1	6.1	0	6.1	92	9	92	-32%	0%
2016	6.1	92	107.2	9.1	0	15.2	92	15	92	-15%	0%
2017	15.2	92	116.0	8.8	0	24.0	92	24	92	-10%	0%
2018*	24.0	92	121.7	5.7	0	29.7	92	32	92	-9%	0%
2019								42	92		
2020								50	92		
2021								59	92		
2022								69	92		

* 2018 EOY value is based on projected volumes using mid-year survey, production and planning data for the remainer of the year. All other EOY values are linearly interpolated from actual survey volumes.

** Formulas and definitions as stated in Directive 085, Appendix 3 (released October 12, 2017).

2018 MRM Water Balance



Inlet Streams (Mm3/year)

1	15.83	Athabasca River Diversion - allocated to MRM
9	4.81	MRM - Connate Wate to MRM Ore Prep
20	4.16	MRM - Precipitation and Natural Surface Runoff
21	0.93	MRM - Mine Depressurization

25.73 Mm3/yr (Inlet) - River, Precip, Depressurization

19	4.43	JPM - Water in JPM froth to Froth Treatment

30.17 Mm3/yr (Inlet) - external and internal

Internal Streams (Mm3/year)

2	8.78	River to Raw Water Pond
3	7.04	River to Recycle Pond
7	8.78	Raw Water to MRM and Utilities
8	84.79	Recycled Water to MRM and Utilities
10	1.78	Utilites sumps to Recycle Water Pond
12	101.50	MRM - Ore Prep, Extraction, and Froth to Tailings
15	75.53	MRM - Reclaimed Water to Recycle Water Pond
17	27.69	MRM - Tailings Pore Space, FFT, Water inventory
23	2.24	MRM - Precip & Runoff to Tailings
24	0.92	MRM - Mine Depressurization to Tailings
25	0.01	MRM - Potable Water Diversion
44	0.02	MRM - Potable Water from JPM

Outlet Streams (Mm3/year)

11	0.20	Utilities Losses
13	0.76	Cooling Losses
14	0.00	Loss to Product
16	1.47	MRM - Tailings Evaporation (Steam)
22	1.91	MRM - Precip and Natural Surface Runoff released to Environment

4.35 Mm3/yr (Outlet)

APPENDIX C:
Stakeholder Engagement

As per approval 8512J and 9756H, Canadian Natural held a tailings forum with indigenous stakeholder communities between November 2018 and February 2019. During each session, Canadian Natural presented a Muskeg River Mine (MRM) and Jackpine Mine (JPM) tailings information package and gathered input and feedback on Canadian Natural's current tailings management. Each stakeholder was identified as a result of having either Sustainability agreements or Community Building agreements with MRM and JPM. During each in person engagement session, Canadian Natural provided an update on the following:

1. Current Tailings Management Activities
    - Overview of current tailings facilities and storage at both MRM and JPM including the External Tailings Facilities and in-pit storage facilities.
    - Current tailings management technologies including Thickened Tailings at MRM and Thickened Tailings and centrifuging at JPM.
    - The use of Atmospheric Fines Drying.

2. Pond Status and Fluid Profiles
    - Total fluid tailings volumes compared to approved fluid tailings profile.
    - Site wide water balance.

3. Tailings Technology Research
    - Update on current tailings projects at MRM and JPM.

4. Progressive Reclamation and MRM ETF Closure Design
    - Reclamation activities by applying adaptive management.
    - Examples of progressive reclamation on the MRM ETF and SEA.
    - Planning Level Closure Design Surface for the MRM ETF.

Further information on each engagement session is contained within Table C1 below.

Table C1: Summary of Stakeholder Engagements

Stakeholder Group	Meeting Date(s)	Notes reviewed and approved by Stakeholder	Stakeholder Tailings Concerns/Requests	Canadian Natural Response
Fort McKay First Nation (FMFN) and Fort McKay Metis (FMMCA)	27-Jun-2018 Site tour	N/A	MRM ETF is visible from Fort McKay. Fort McKay wants to better understand Tailings and Tailing Pond Reclamation. They are concerned about tailings as it creates dust, there are potential water quality impacts and the reclamation areas will look very different from the original landscape.	Canadian Natural presented an Introduction to Tailings including a discussion on the different types of tailings, the monitoring that occurs and the process of tailings reclamation. A field visit occurred to the MRM ETF highlighting permanent reclamation and noting the aesthetic slope changes that have been incorporated based on Fort McKay's feedback.
			Impact of recycled tailings water going into the Athabasca and Muskeg Rivers and into the watershed.	Process affected water (PAW) is currently not released into the environment. Release criteria for PAW needs to be developed by the Federal/Provincial government. PAW (including water from some end pit lakes) will only be released once it satisfies the release criteria.
	18-Sep-2018 In person meeting (CAG meeting)	N/A	Identification of alternatives to end pit lakes.	Canadian Natural provided an end pit lake 101 presentation to address concerns and educate community members on end pit lakes. Different types of end pit lakes (water capped tailings and end pit lakes with no tailings) were discussed. Reasons why oil sands mines require end pit lakes and research on end pit lake design, modeling, and activities to reduce tailings generation was discussed. Canadian Natural will continue to share and provide updates on EPLs with stakeholders. Canadian Natural has identified thin lifting drying as an alternative to end pit lakes in the

				FTMP applications for MRM and JPM. This will be further discussed during subsequent engagements.
	13-Nov-2018 (tailings forum) In person meeting, 2.0 hours including presentation and Q & A.	Yes	Requested to be informed of any changes to extraction technology.	Canadian Natural is involved in extraction technology research. Learnings from a pilot project at Horizon will be shared with Albian. If new technology is used at MRM or JPM, Fort McKay will be informed.
			Differences in ratios between pre-disturbance (more wetlands) ecosystems than post disturbance ecosystems	Canadian Natural's reclamation program returns a "self-sustaining locally common boreal forest" ecosystem with equal capability but one that will not be exactly the same as pre-disturbance. Upland forests, wetland areas, lakes, and riparian zones will be present however in different proportions than what was originally here. Native seeds are collected and when required for reclamation, seedlings are grown in the nursery and planted in reclamation areas ensuring plants with the same genetics as the pre-disturbance areas are represented in reclamation.
			Dust control and noise from MRM ETF.	Progressive reclamation is occurring on the MRM ETF to address Fort McKay's concern. The timeline of MRM ETF reclamation has been accelerated. Noise from the bird deterrent system is reduced by using a marine radar based detection system so the bird deterrents are only activated when birds are present.
			Informed Canadian Natural that members are not in favor of end pit lakes.	Canadian Natural confirmed that both pit lakes and water capped tailings end pit lakes are in the closure plan. The 2016 MRM Closure Plan showed approximately 5% of the surface area as

				these types of Lakes. Canadian Natural will continue to provide information and educate stakeholders on the benefits of EPLs in the Closure landscape. Canadian Natural has identified thin lifting drying as an alternative to water capped tailings pit lakes in the FTMP applications for MRM and JPM. This will be further discussed during subsequent engagements.
McMurray Metis (ML 1935)	14-Nov-2018 (tailings forum) In person meeting, 1.5 hours including presentation and Q & A.	Yes	Reclamation success with current tailings technology.	Canadian Natural will continue hosting ML 1935 members to demonstrate reclamation occurring at the MRM and JPM sites so members can see progress over time.
			Water quality and water usage.	Canadian Natural reports annual water quality and water use data in the annual Albian Environment Report submitted to the AER. A copy is provided to ML 1935.
			Reclamation research involving plant growth in tailings material. Community members want confidence in plant health and growth.	Canadian Natural participates in numerous reclamation research projects. There are a number of projects focusing on plant growth currently underway. When the project with NAIT is complete the report will be provided to ML 1935.
			Impacts to wildlife and human health due to consumption.	ML 1935 concerns were noted. Canadian Natural has a number of wildlife monitoring programs. Human health & consumption of wildlife are not in the scope of these studies.
Fort Chipewyan Metis (ML	28-Nov-2018 (tailings forum) In person	Yes	Vegetation growing directly in tailings material may conflict with cultural protocols and some specific	Canadian Natural is aware that spiritual values and practices should be considered in reclamation planning and execution.

125)	meeting, 1.5 hours including presentation and Q & A.		spiritual/ceremonial plant use.	
			Cultural preservation over time. The land, and maintaining cultural and spiritual relationship with it, is needed to be able to support the transfer of knowledge.	Canadian Natural noted ML 125 concerns. Once reclamation certificates are granted the land will be returned to the Crown. One of the goals of the annual tour is to bring community members to the same piece of land to begin to form a relationship with the reclaimed area.
Mikisew Cree First Nation (MCFN)	17-Dec-2018 (tailings forum) In person meeting, 1.5 hours including presentation and Q & A.	Yes	Mikisew Cree and Canadian Natural Albian Sands have outlined an internal process to resolve the concerns of the community with respect to Tailings Management Plans.	Canadian Natural has agreed to the process proposed by MCFN.
Athabasca Chipewyan First Nations (ACFN)	19-Feb-2019 (tailings forum) In person meeting, 1.5 hours including presentation and Q & A.	Draft of meeting notes provided to ACFN (at time of submission no response has been received)	Capacity Funding is not included for community participation in the Tailings Forum but it should be. In addition there should be additional technical funding to permit the generation of a plain language document to help community members understand the tailings plans.	Canadian Natural advised ACFN to clearly identify the costs associated with this in any future technical review proposals and it will be considered on a case by case basis
			Wildlife safety and monitoring.	Canadian Natural plans to present the 2018 wildlife monitoring data at the next regulatory meeting once the 2018 Environment Report, submitted to the AER, has been finalized.
			Requested an overview of MRM/JPM ground water monitoring program.	Canadian Natural plans to present the 2018 ground water monitoring data at the next

				regulatory meeting once the 2018 Environment Report, submitted to the AER, has been finalized.
			Request that community members have access information about tailings reclamation and the potential contaminants in material being used to reclaim the land. Specific concerns with Arsenic, Mercury, and hydrocarbon leaching.	Canadian Natural plans to present the 2018 ground water monitoring data at the next regulatory meeting once the 2018 Environment Report, submitted to the AER, has been finalized.
			Request to include Advisory Committee (AC) members in future tailings discussions.	Canadian Natural will review the format of the Tailings Forum engagements and determine through discussion with ACFN whether AC members should attend the Forum or have a separate discussion at a regular AC committee meeting.
			Water withdrawal rates from the Athabasca River.	Canadian Natural provided MRM/JPM current water withdrawal data including the total volume approved through MRM and JPM's water license during the February 19 meeting.

APPENDIX D:

2018 Technology Update

Canadian Natural Albian Sands
TAILINGS RESEARCH AND DEVELOPMENT
Summary of 2018 Tailings Projects

Date: April 30, 2019
Submitted to:

Alberta Energy Regulator

Executive Summary

The purpose of this report is to provide a summary of the tailings research projects executed by Canadian Natural's Technology Development in 2018. The scope of this report is limited to project objectives, project design, and executed activities; detailed results and/or performance data are not described in this report. Where appropriate, formal reports issued by Canadian Natural's consultants or Canadian Natural have been referenced for additional information.

Nine projects are summarized in this report:

1. FFT Consolidation: Casing Project
2. Chemical Amendment of FFT
3. Modified Atmospheric Fines Drying
4. Deep Cohesive Deposits
5. Soft Deposit Capping: AFD Test Cell Capping
6. Soft Deposit Capping: Centrifuge Cake Test Cell Capping
7. End of Pipe Tailings Treatment
8. Geotube Pilot program
9. FFT Pressure Filtration Pilot

The various projects include tests conducted at different sizes (e.g., lab, pilot, and commercial scale) and different time scales (e.g., months and years) in order to validate the numerical modelling used in the analysis and design of tailings deposition and reclamation strategies.

Research projects undertaken by Canadian Natural's Technology Development group are designed to provide information to allow the selection of tailings technologies for commercial implementation. Tailings research is also used in the development of Canadian Natural's Tailings Plans, including Fluid Management Plans.

Table of Contents

List of Figures

List of Tables

1. FTT Consolidation: Casing Project

1.1. Overview

Canadian Natural has been conducting an integrated program of testing, the Tailings Consolidation Casing Experimental Pilot Project (TCCEPP), to measure the consolidation properties that govern storage and settlement of tailings. The initial program included a series of tests to account for the possibility that the size of the test specimen could influence the measured consolidation behaviour. The tests spanned a range of effective stresses and overall sample volumes. The representative properties have been used for scale up modelling to compare the performance of tailings treatment options for field scale deposits. The field scale predictions are used to investigate the impact that treatment technologies may have on reclamation objectives (e.g., parameters such as tailings and water volumes, time for consolidation, and the expected amount of settlement).

The current update on the 2018 TCCEPP activities continues the multi-year performance monitoring of the casings. Performance monitoring includes extensive instrumentation and multiple sampling campaigns including geophysical logging, core sampling and in-situ testing (vane shear testing and ball penetration testing), and water quality sampling. Detailed performance data, including consolidation, is not described in this report, but results will be disclosed in upcoming releases documenting the performance.

Table 1-1 Summary of Casing Contents and Pour Durations

Casing	FFT Source	Amendment / Treatment	Pour duration
1	Albian Sands MRM-ETF[1]	FFT	30 Aug. 2015
2	Albian Sands MRM-ETF	HPAM (SNF) / Inline Flocculated	3–15 Sep. 2015
3	Albian Sands MRM-ETF	XUR / Inline Flocculated	9–17 Sep. 2015
4	Albian Sands MRM-ETF	XUR-4A / Inline Flocculated	4–16 Sep. 2015
5	Suncor FFT Pond[2]	HPAM (BASF) / Inline Flocculated	24 Sep.–2 Oct 2015
6	Suncor FFT Pond	HPAM (SNF) / Inline Flocculated	25 Sep.–1 Oct. 2015
7	Albian Sands – JPM-SC1[3]	FFT	22-23 Nov. 2016

Casing	FFT Source	Amendment / Treatment	Pour duration
8	Albian Sands JPM-centrifuge plant[4]	HPAM (SNF)/ Centrifugation	24–26 Sep. 2015

TABLE NOTES:

1. Muskeg River Mine, External Tailings Facility.
2. Suncor provided ~150 m^3 of FFT via four 20-m^3 vacuum trucks.
3. JPM, Sand Cell 1.
4. Albian JPM centrifuge plant uses FFT feed from the JPM Sand Cell 1.

A COSIA partner supported two of the casings (Casings 5 and 6) and performance data for these two casings is provided to that partner on a regular basis.

1.2. Objective

The objective of the TCCEPP is to refine existing assumptions regarding the self-weight consolidation behaviour of various tailings treatments; supported by numerical modelling, the results from this project will enable improved technology selection.

The project will meet this objective by monitoring the performance of the casings through:

- Increasing deposit thickness beyond those associated with laboratory-scale initiatives, enabling evaluation of consolidation at self-weight stress states approaching those experienced in the field
- Evaluating scale-up of tailings mixing systems beyond lab scale
- Providing opportunities to evaluate multiple drainage and/or loading scenarios
- Consolidation modelling sensitivity analysis using various boundary conditions

1.3. Monitoring & Sampling Campaigns

Monitoring of each casing continued through 2018 to provide the data needed to evaluate consolidation. Key measurements include fluid level, mudline, pore pressure, total stress and geophysical properties. Table 1-2 summarizes the installed instrumentation.

Table 1-2 Summary of the instrumentation system

Instrument	Measurement
Temperature probe	Air temperature
Barometric pressure sensor	Barometric pressure
Temperature profiler (Thermistor string)	Temperature of water/tailings in casing
Vibrating wire piezometers (VWPs)	Pore pressure in tailings
Total pressure cells (TPCs)	Total pressure at the base of tailings
Pressure transducer on mudplate (PLS)	Tailings settlement (thickness of the water cap above mudline)
Sonic ranger	Water level
Ultrasonic sensor	Tailings settlement (location of mudline)
Wireline casing	Conduit for geophysical downhole wireline tools

Instrumentation data is used in conjunction with manual mudline measurements and data from sampling campaigns to analyze consolidation performance. Figure 1.1 and Figure 1.2 provide mudline and solids content data for all eight casings as an example of data presented in ongoing performance updates.

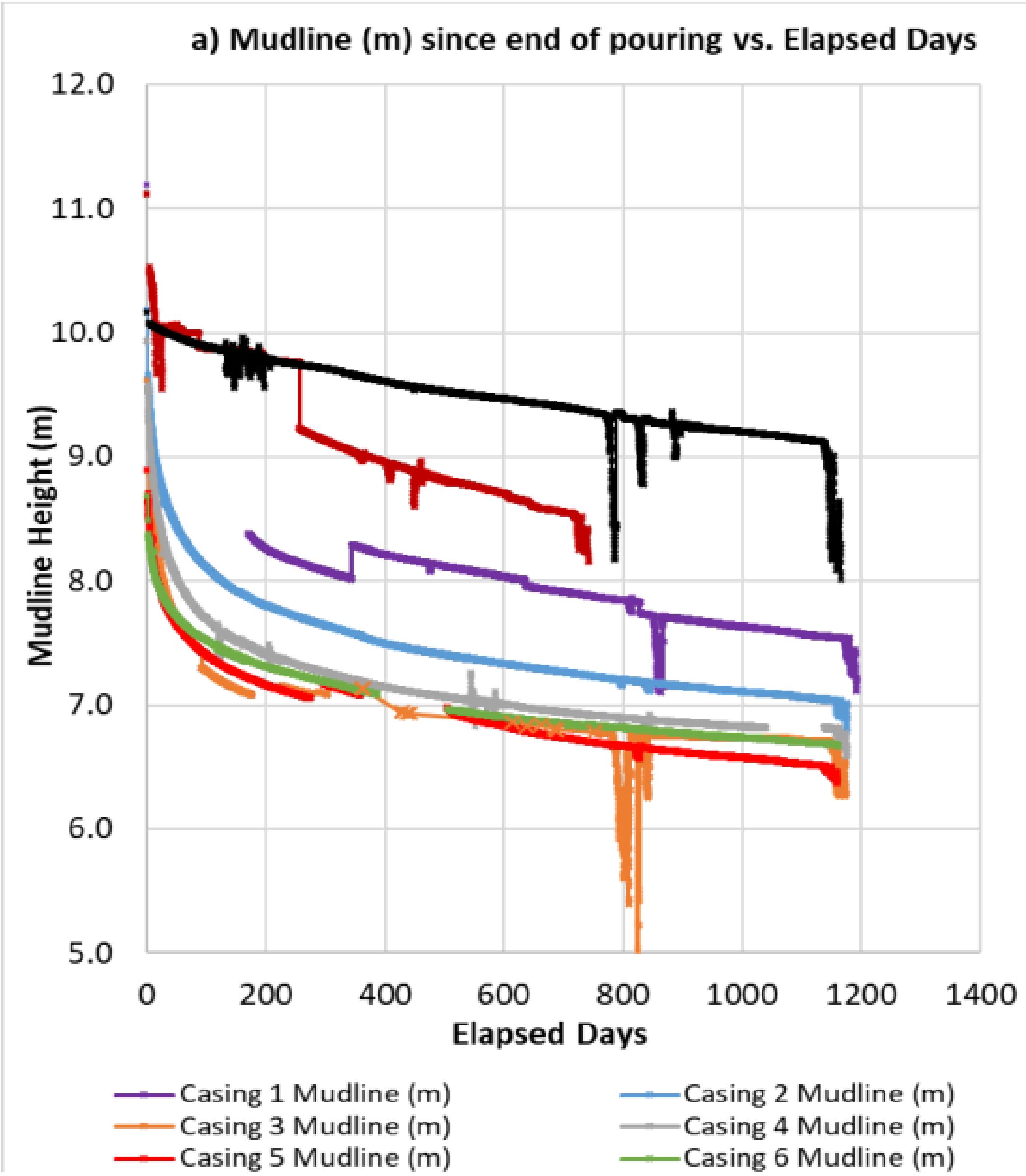


Figure 1-1 Mudline data for all casings for consolidation analysis

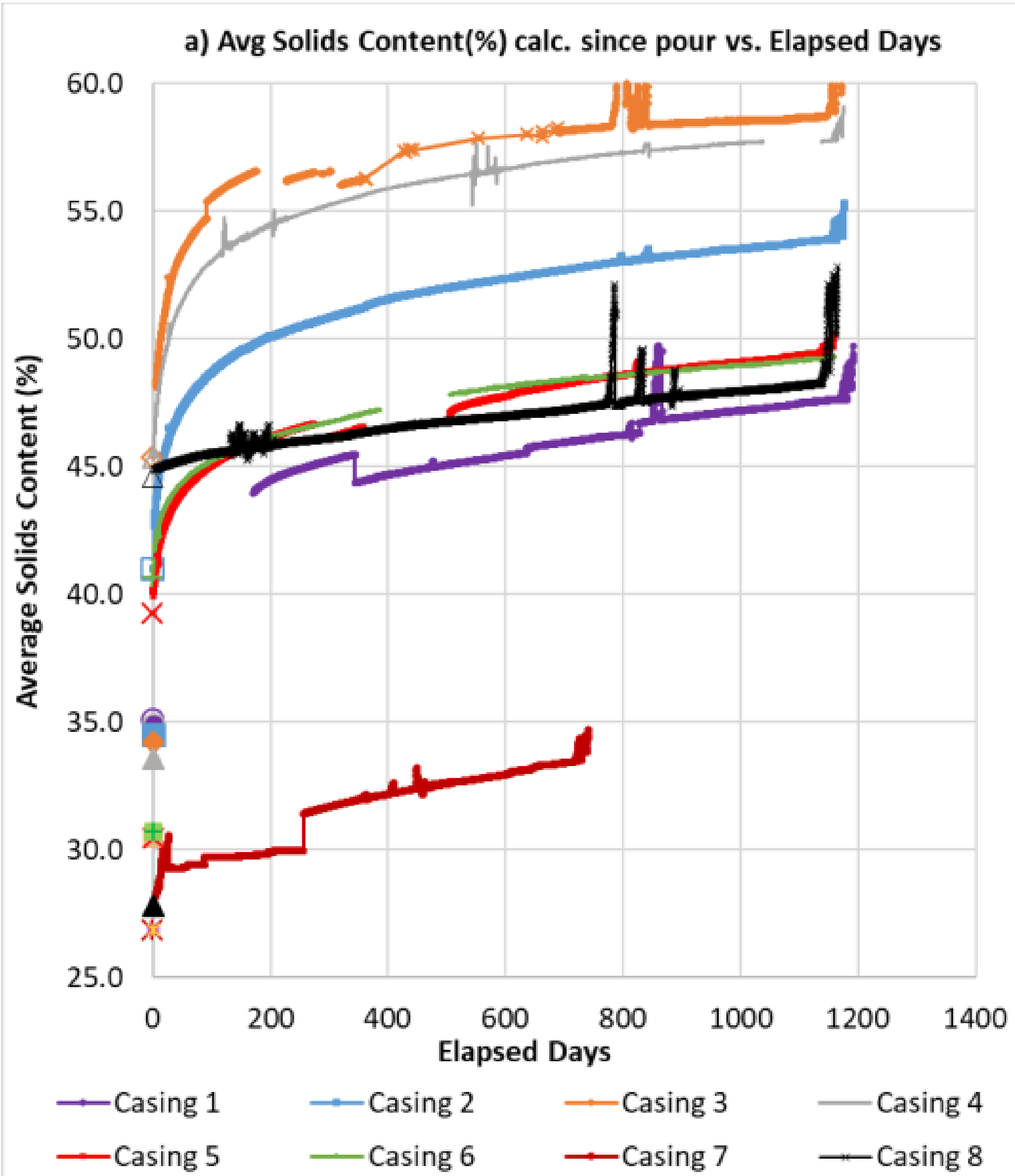


Figure 1-2 Solids Content data for all casings for consolidation analysis

1.4. Planned 2019 Activities

Performance monitoring of the TCCEPP is planned to continue through 2019 as part of the multi-year monitoring campaign. The resulting data will be used as it becomes available to refine current assumptions about consolidation behaviour and to aid in numerical modelling for various tailings treatments. Furthermore, the TCCEPP's multi-year evaluation provides an opportunity for modifying select casings to evaluate de-watering with under-drains, wicks or other methods, and for the application of surcharges. At this time, none of the de-watering opportunities mentioned are planned for 2019 but may be considered at a future date.

Numerical modelling back analysis has been conducted for seven of the eight casings. The consolidation properties have been evaluated and used in the selection of representative compressibility and hydraulic conductivity parameters for the different tailings treatment scenarios. To date, the model calibration has been extended using monitoring data up to June 1, 2017.

Preparation of the 2018 TCCEPP Monitoring and Performance report is already in progress with assistance of consultants and is expected to be complete in Q2 2019.

1.5. References

2017 Shell Canada TAILINGS RESEARCH AND DEVELOPMENT; Summary of 2016 Tailings Projects. Submission to AER.

Barr Engineering (2017, October) Tailings Consolidation Casing Experimental Pilot Project (TCCEPP) 2016-2017 Water Quality Report – Data Summary.

ConeTec (2017, October) Presentation of Site Investigation Results. Tailings Consolidation Casing Experimental Pilot Project (TCCEPP).

Golder Associates (2018). 2017 MONITORING AND PERFORMANCE REPORT Tailings Consolidation Casing Evaluation Pilot Project (TCCEPP)

Golder Associates (2019). 2018 MONITORING AND PERFORMANCE REPORT Tailings Consolidation Casing Evaluation Pilot Project (TCCEPP) (in progress)

2. Chemical Amendment of FFT

2.1. Overview

Canadian Natural continues to pursue chemical amendment of tailings as the potential treatment method for the large volume of Fluid Fine Tailings (FFT) stored at the External Tailings Facilities (ETF) at the MRM and JPM sites. The research and technology development initiatives encompass laboratory-based research projects and pilot programs focused on In-Line Flocculation (ILF) and corresponding Instrumentation and Control (I&C) system for automation of the process. The technology comprises of contacting tailings with polymer flocculants by in-line dynamic mixing with instrumentation to control the flocculated material quality. In 2018, the following laboratory development activities were undertaken:

1) Feed-forward mapping for control program for alternative chemistries
2) Preliminary evaluation of alternative classifier/s to predict flocculation performance
3) Testing of improved instrument spool and accessories prototypes to address operational issues
4) Rapid laboratory technique for polymer concentration measurement

2.2. Feed-forward mapping for control program for alternative chemistries

Up to 2017 the control system software for ILF was based on the widely used polyacrylamide (PAM) chemistry only. However, addition of coagulants can potentially enhance the performance of settling and which was not factored into developing the software for control. In addition, Canadian Natural has found that polymers based on other chemistries such as polyethylene oxides (PEO) can provide better consolidation and dewatering over time for which the parametric correlations between feed properties and control did not exist.

As part of the 2018 laboratory programs on ILF I&C, a laboratory project was undertaken to develop the feed-forward control mapping with Dow XUR flocculant. Models were developed describing the influence of tailings density and clay content along with polymer dosage and mixer speed on flocculated material properties. A limited amount of data on mapping was also generated for some less widely used chemistries (Kemira 4993, BASF 1047, BASF 1176, NRG 1320) to support execution of field pilot projects at Canadian Natural.

Laboratory investigation was undertaken to assess the impact of coagulant (alum) addition on the control system response. Also, the impact of alum on feed properties measurement was assessed at a bench-scale to improve inline monitoring tools such as the Near Infrared (NIR).

2.3. Preliminary evaluation of alternative classifier to predict flocculation performance

In the ILF control system the quality of flocculation is assessed largely by imaging with a Particle Vision Measurement (PVM) instrument and then analyzing the images by Fourier

Transformation and Eigen-function analysis for determining the class (quality) of the material. However, this mathematical approach is site- and scale-specific, and requires extensive machine learning across a wide range of parameters for both on- and off-spec materials at each installation.

Several candidate algorithms were tested on field data generated from past pilot projects and compared with the performance of the maximum likelihood algorithm currently used.

An existing neural-net based tool (GoogleNet) was also used to evaluate images directly with no pre-processing. This technique and its variant will be further tested in 2019 as potential alternatives to the existing algorithm.

2.4. Testing of improved instrument spool and accessories prototypes to address operational issues

Many of the online instruments used in the ILF control system are optical/light-based and require visibility of the feed or flocculated product. However, due to the presence of bitumen the optical windows/lenses can often get fouled which reduces the performance. For the PVM and Focused Beam Reflectance Measurement (FBRM) instruments devices were designed that could isolate the probes from the flow for retraction and cleaning. However, this still required manual operator intervention. For the NIR instrument, there was essentially no way to isolate the instrument for cleaning without stopping the process. In late 2017, a project was undertaken to develop an inline cleaning device that was completed in 2018. The device uses high pressure jet-streams of water and is constructed as part of the probe assemblies or spool pieces used for these instruments. Laboratory testing was conducted on spool pieces with varying extent of fouling on the windows/lenses and with different nozzle arrangement and jet pressure. The cleaning performance was found satisfactory with the exception of cleaning extra-stubborn bitumen which still required manual cleaning. The devices are set to be field tested in 2019.

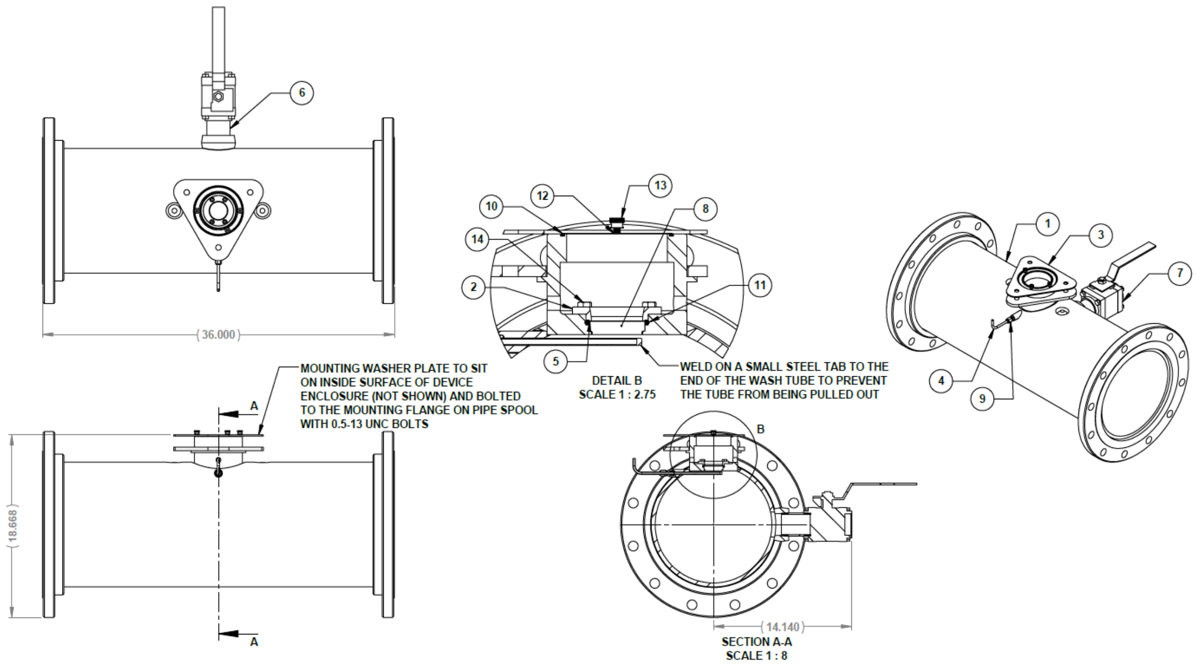


Figure 2-1 NIR spool designed in the lab with high pressure jet-based self-cleaning features.

2.5. Rapid laboratory technique for polymer concentration measurement

A technique was developed for instantaneous field measurement of polymer concentrations using the Kjeldahl method. This rapid measurement technique will assist in conducting quick onsite calibration of the viscometer used to control the polymer dosage for flocculation which would be a step change over the existing overnight oven drying method. Laboratory tests had been conducted on samples with variable concentrations to verify the methodology.

3. Modified Atmospheric Fines Drying

3.1. Overview

Atmospheric Fines Drying (AFD) has been used at Canadian Natural for several years and is currently one of the FFT treatment technologies in commercial operation at JPM. The option of placing flocculated FFT or FFT centrifuge product onto tailings beaches and after drying and a full freeze/thaw cycle has been completed placing another lift on top of the previous deposit. In this manner the high cost of rehandling the dried AFD material to a dump location is minimized as material is left in place and ultimately becomes part of the dry tailings structure, a process referred to as Modified Atmospheric Fines Drying (MAFD).

In 2018 the performance of different polymers was tested for this method of deposition. The field trial was conducted in specially constructed cells on the west beach of JPM DDA-1.

The depositional behaviour, initial dewatering and atmospheric drying was monitored. In 2019 a sampling program will be conducted to determine the effect of the freeze thaw cycle. Data compilation and reporting will be completed by Q2 2019.

An example of a test cell and the depositional behaviour of flocculated FFT is shown in Figure 3.1.

Figure 3-1 Flocculated FFT depositional behaviour

4. Deep Cohesive Deposit Tests

4.1. Overview

Deep fines dominated cohesive deposits are considered to be a potential treatment method for water recovery and land reclamation from chemically-treated tailings. This technology relies on settlement and consolidation of the tailings in cells of generally >3 meter depth. The objective would be to release/recover water rapidly, ultimately leading to a consolidated solids-rich deposit with adequate material strength required for reclamation.

Previous lab-scale testing at Canadian Natural found that a certain polyethylene oxide-based chemistry, manufactured by Dow and commonly referred to as the Dow XUR, is promising for producing flocculated tailings suitable for deep deposition. The polymer was able to achieve much higher solids concentration (>55 wt.%) in settling tests with bench-scale and geo-column setups in a reasonably short period of time (3-6 months) compared to conventional polymers. The chemistry also was claimed to produce treated tailings insensitive to the impacts of shear which makes it easier to transport for deposition. The performance of this treatment had not been evaluated at a large-pilot/field-scale.

The 2018 activities on deep cohesive deposit are as follows:

- Construction of two fully instrumented test cells for deposition of the following materials:
    - Dow XUR-treated FFT
    - Kemira 4993-treated and centrifuged FFT cake
- Evaluation of deposit performance by periodic sampling, monitoring, survey and *in situ* data collection
- Laboratory settling and consolidation tests and analyses for short- and long-term behavior prediction

Two trapezoid-shaped cells of 4m depth, namely Cell 1 and Cell 5 were excavated for the deposit tests at the Jackpine Mine (JPM) MAFD area These cells were both equipped with instruments mounted on two posts. The instrument posts have three arms at 1, 2 and 3 m height from the foundation. Each instrument post is mounted with Total Pressure Cells, Vibrating Wire Piezometer, Thermistor Strings, and Mudplate with Transducer, all of which are connected to a Data Acquisition System.

Following construction, in August 2018 the cells were filled with Kemira 4993-treated (dosage: ~900-1000 g/ton of solids) centrifuged FFT cake (Cell 1) and Dow XUR-treated (dosage ~400-440 g/ton of solids) FFT (Cell 5) transported by a 10” pipeline. Floating docks were installed on the surface (4 m into the cell, 1 per post) to allow sampling and observation.

Figure 4-1 Deep deposit cell construction at the JPM MAFD area: excavated cell area (left); instrument poll with x-arms (middle); and data logger (right).

Figure 4-2 Pouring of flocculated MFT at Cell 5 (left); surface of Cell 1 six weeks after pouring (middle); and surface of Cell 5 five weeks after pouring (right).

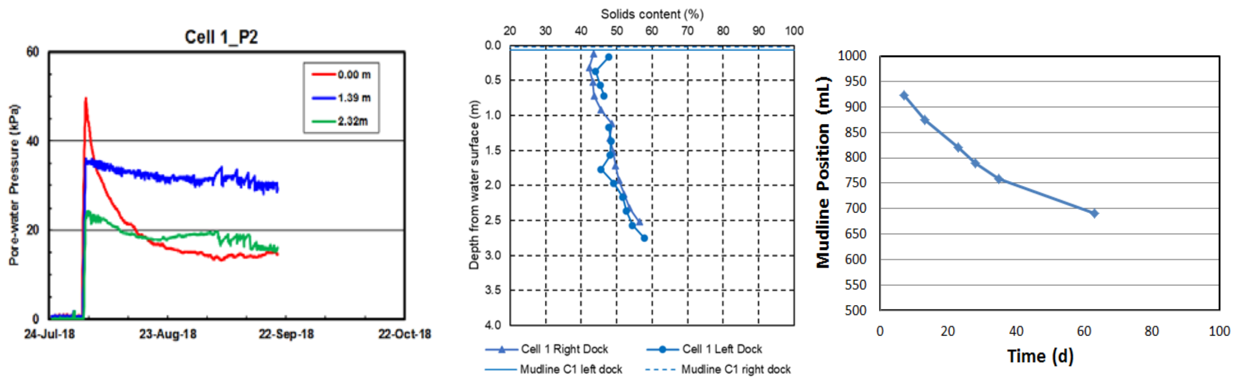


Figure 4-3 Monitoring and laboratory data from the test cells: pore water pressure measured by sensors at various depths in Cell 1 (left); solids content along the depth in Cell 5 as measured by survey (middle); and laboratory settling data on Cell 5 as-poured samples (right).

The cells are continuously being monitored, surveyed and sampled from to evaluate performance of the deposits. Samples were also taken during the pouring of Cell 5 to study settling and consolidation behaviour based on laboratory analysis in parallel to field measurements.

Regular survey, monitoring, sampling and analyses will continue in 2019. The instrumentation in the cells will be used to generate information on water, excess pore pressure, temperature and mudline changes over time which are important parameters to evaluate the settling and consolidation behavior of the deposits.

Further sampling and capping of these deposits will proceed in Spring 2019.

5. Soft Deposit Capping: Atmospheric Fines Drying Test Cell

5.1. Overview

As mentioned in the 2017 report to AER, the Deep Stack AFD test cell, located at MRM Lower AFD area, was capped with 2m of sand and 1m of inter-burden waste in August and October of 2016. Surveying and monitoring of the capped deposit continued during 2017 and the first 6 months of 2018 to evaluate the performance of the deposit under the cap surcharge load.

Monitoring of instruments and regular surveys has been in progress to compare the consolidation in the wick drain areas with the rest of the deposit under the surcharge load of the cap.

In June 2018, a site investigation program was completed to take tailings samples and to assess the in-situ shear strength of the deposit. The samples were characterized at the Canadian Natural labs and the results were compared with the instrumentation data. The cell is no longer available as the area was decommissioned and subsequently mined through shortly after the 2018 sampling campaign.

Figure 5-1 Mechanical placement of sand in 2016, The test cell deposit thickness was 4.5m initially and ~3m at the time of capping

5.2. References

Golder Associates (2017). AFD Deep Stack Wick Drain Installation (Daily Report); Aug. 27, 2017.

Golder Associates (2019). AFD Deep Stack Consolidation and Capping Test (Final Report); in preparation

6. Soft Deposit Capping: Centrifuge Cake Test Cell

6.1. Overview

The JPM centrifuge test cell was constructed in the fall of 2015 and filled with centrifuge cake in January 2016. A site investigation was completed in August of 2016, and since the centrifuge cake deposit was not deemed strong enough to support a cap, no additional work was performed in 2016 aside from ongoing dewatering of ponded water within the cell. The 2017 and 2018 activities focused on exploring potential strength and consolidation improvement options.

The centrifuge cake deposit surface was divided into a number of segments, including one control area (blank zone) and other areas that were used for evaluation of different vegetation species and wick drain installation. The deposit was continuously monitored using the installed instrumentation and regular surveying of settlement plates. Two site investigation campaigns were completed in April and September 2018.

The 2018 field work included the following activities:

- A vegetation survey, leaf biomass sampling, and root sampling (performed by NAIT)
- Shallow and deep centrifuge cake sampling and laboratory testing (performed by BGC)
- Hand vane shear testing and field tensiometer measurements of shallow cake deposit (performed by BGC)
- In-situ ball penetration testing (BCPT), electronic vane shear testing (eVST) and cone penetration testing (CPT) (performed by ConeTec)

The field activities planned for 2019 include:

- June 2019: Another vegetation survival assessment; vane shear tests and sample collection from the deposit crust to determine further strength gain. Full seed application to the entire cell in preparation for a deltaic capping program in 2020.
- August September 2019: CPT and sampling program, plate bearing tests, vegetation survey and analysis

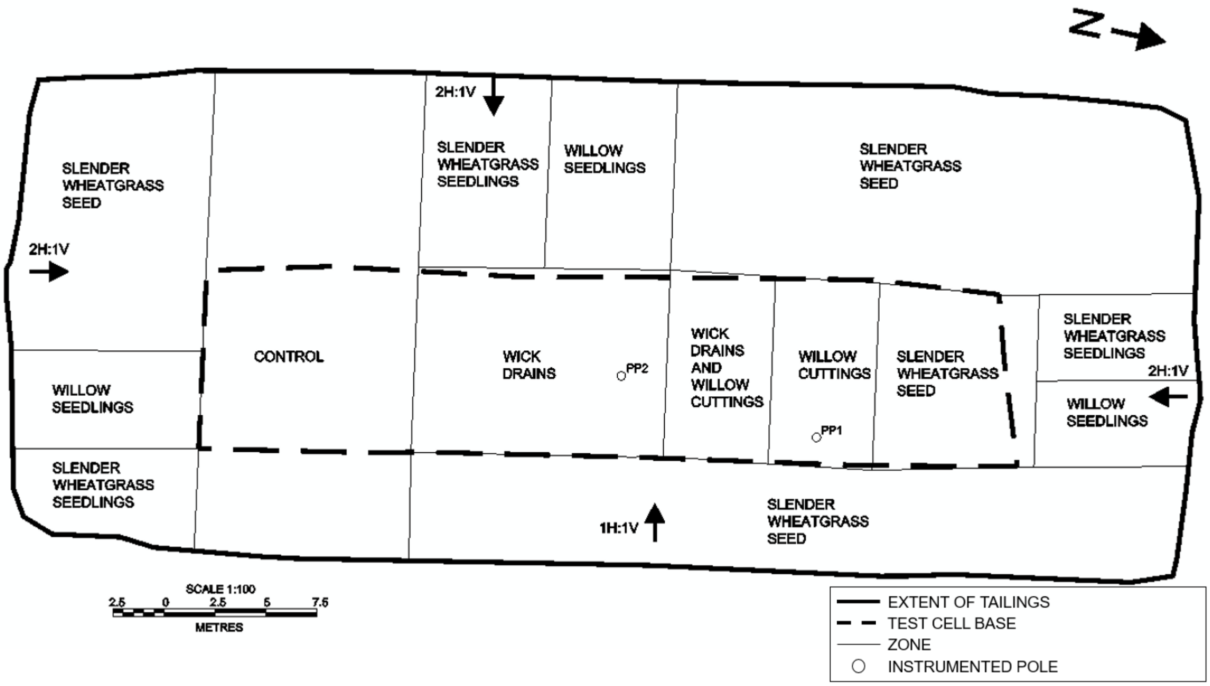


Figure 6-1 The test cell layout, illustrating the variety of treatments being studied

6.2. References

BGC Engineering Inc. Jan. 31, 2018. Canadian Natural Albian Sands JPM Centrifuge Test Cell Sep./Oct. 2017 Field Program (Draft).

William Smith[1], Erin Olauson[1], et. al. IOSTC 2018, Evaluation of Strength Improvement and Dewatering Technologies for a Soft Oil Sands Tailings Deposit.

7. End of Pipe Tailings Treatment

7.1. Overview

The End of Pipe Tailings Treatment (EPTT) process refers to an end of pipe flocculation of a mixed CST, FFT, and TT stream. The proposed option is to extend pipelines in the existing CT infrastructure at MRM site in order to mix CST, TT and FFT streams, inject flocculant, at the end of the pipe and discharge the treated slurry using a plunge pool deposition. This concept relies upon establishment of a fluid phase (the chemically treated clays and silts) which can support the sand grains until the mixture settles to the point where sand grain to grain contact is achieved and a high strength deposit is created. The basis of the EPTT approach at MRM is to use thickener underflow combined with a coarse sand stream and a small stream of FFT to maintain sand to fine ratio of approximately 4:1 ideally treating a sand dominated slurry that is pumpable, but will rapidly settle or consolidate to a relatively high density, trafficable deposit.

Field testing of EPTT options was completed in 2018 at MRM. The EPTT test was executed at the MRM Cell 2B as shown in Figure 7.1. Treated material was deposited in Cell 2B and the deposit was sampled for determination of deposit performance and fines capture.

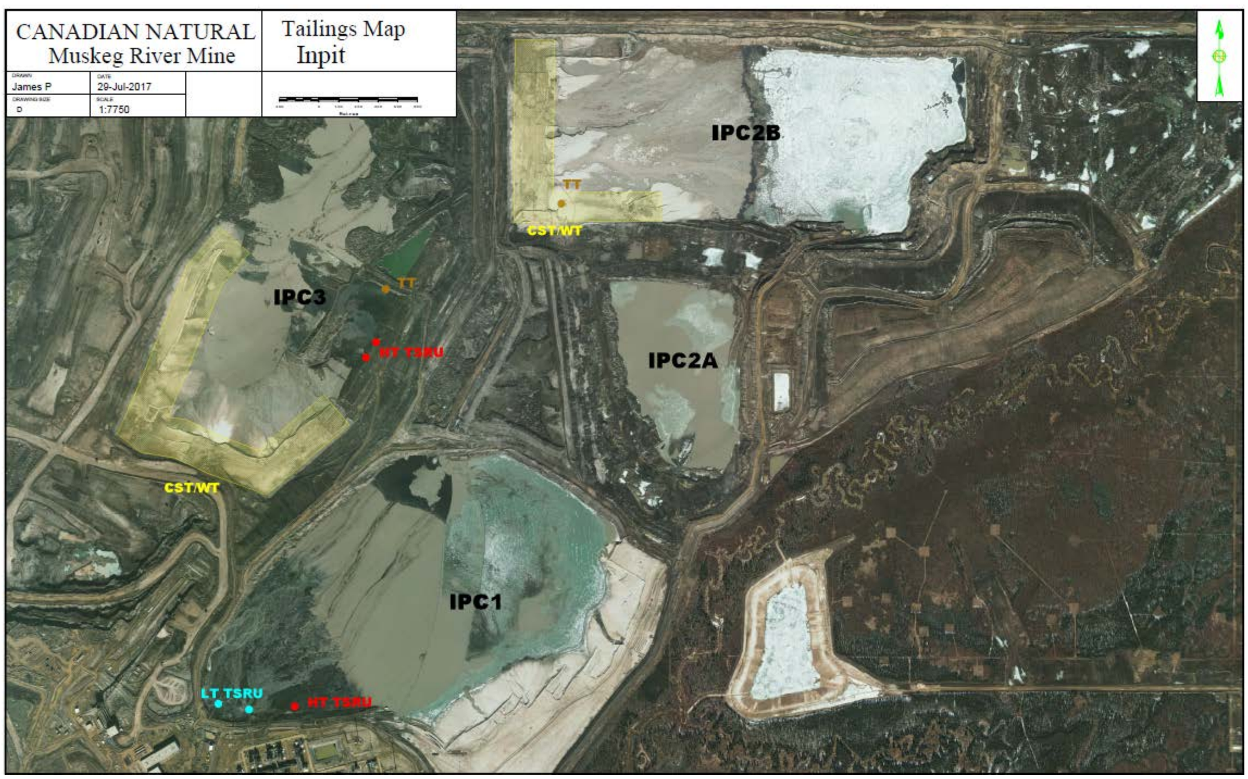


Figure 7-1 Location of EPTT field trial at MRM (outlined in red)

Evaluation of fines capture in the deposit is the major objective of this test program and it is a key performance indicator. Fines capture analysis will be done based on mass balance of the fines deposited compare to fines estimated from core sampling.

Three deposition events were conducted, the most successful one in terms of producing a deposit which could be sampled was from flocculation of a whole tailings stream composed of recombined CST (coarse sand tailings) and TT (thickened tailings). The data analysis and reporting of this test run will be completed by Q2 2019, however early indications are that the flow was fully segregated and beach fines capture was poor.

8. Geotube Pilot Program

8.1. Overview

Canadian Natural is assessing the feasibility of geotubes (or geobags) in the context of creating terrestrial, out-of-pit, reclamation features with treated fluid fine tailings (FFT). Several small scale field trials have been undertaken in the past, culminating with a large-scale demonstration that was completed in the fall of 2018. The objective of the program was to assess and demonstrate the commerciality, including economic feasibility, of geobags in FFT service. Specifically, the following key components were evaluated.

- Scaling Factors
  - Assess the effect of geobag size on dewatering performance.
- Stackability
  - Assess the safety, required conditions and labour associated with stacking geobags.
- Chemical Treatments
  - Assess the effect of various chemical treatments and mixing arrangements on dewatering performance, geotechnical performance, and release water quality.

The program which was conducted at MRM, involved the design, construction, filling, and initial performance monitoring of 11 geobags filled with oil sands fluid fine tailings (FFT) treated with various chemicals ("recipes"). In total, six different recipes were used to treat the FFT. The recipes varied by the coagulant dosage, polymer type and dosage, FFT/chemical mixing arrangement (spool, static or dynamic mixing), and the initial target FFT solids content that was fed to the geobags.

All of the FFT used in the program was sourced from the MRM External Tailings Facility (ETF).

In addition to evaluating different recipes, four different geobag sizes, ranging from pilot small to commercial long, were used in the program. The different sizes were used to evaluate scaling factors related to geobag size. Stackability of the geobags was evaluated by stacking one of the geobags on top of two other geobags.

During pilot operation (i.e. periods of geobag filling), the process was monitored through in-line instrumentation and daily sampling of key process streams. The geobags were also monitored during filling and afterwards through daily geobag height surveying, geotechnical investigations (core sampling and VST), and instrumentation (TPCs, VWPs, and thermistors).

Throughout the course of the pilot, a total, 6,962 dry tonnes of FFT was treated and poured into the geobags, A factual report focusing on the design, planning, field execution, and results of the program to the end of October 2018 has been prepared. Detailed performance data, including dewatering performance and consolidation within the geobags, and interpretation/analysis of results are not described in this report. These items will be the focus of future performance assessments and reports.

Figure 8-1 View of the MRM Geotube Pilot

8.2. References

2018 Geobag Pilot Program: *Factual Report (prepared by Barr Engineering)* February 11, 2019

9. FTT Pressure Filtration Pilot

9.1. Overview

The filter press is a well-known technology that improves water recovery from treated FFT by mechanically pressing water out of fine clay materials to form a dense clay-like cake suitable for transport to a reclamation area. Eventual clogging of filter materials by fines (solid particles less than 44 microns) and residual bitumen has, however, prevented adoption of the technology for treating fluid fine tailings (FFT). The added step of chemically treating the FFT before mechanical filtration resulted in promising results at a laboratory scale. This project is a commercial scale demonstration study that builds on the success of the previous laboratory scale results. The goal is to deliver in excess of 70% solids by weight in the pressed product (cake). The purpose of the current project is to deliver all of the information required to design a commercial plant and to evaluate the technology with alternative treatment technologies.

The commercial scale demonstration plant will be deployed in the field, with live feed coming from a FFT harvesting operation. This demonstration plant will consist of a feed conditioning system and two filter presses of different design. Engineering for the commercial scale demonstration plant was completed in 2018. Construction commenced in 2018 and will continue through the spring of 2019. The demonstration plant will operate through the summer of 2019 with results available late in 2019.

It is expected that the commercial scale demonstration plant will deliver the following information for a future commercial operations design:

- required operating pressure;
- cycle time / throughput;
- verification of chemical amendments and pre-filtration processing
- filter press product and discharge management system
- operations and maintenance requirements

Based on the studies conducted to date, filter presses appear to be a competitive technology for producing a sufficiently dense product from FFT that is suitable for rapid terrestrial reclamation (and creating a dry landform).