FORT HILLS ENERGY CORPORATION
FORT HILLS OIL SANDS PROJECT

Directive 085

MEASUREMENT SYSTEM PLAN

SUBMITTED TO:

ALBERTA ENERGY REGULATOR

October 10, 2024

Operated by

Executive Summary

The purpose of this Measurement System Plan (Plan) is to meet the requirements of Section 5 of Directive 085 (AER 2017a) and the *Measurement System Plan Requirements* letter dated October 25, 2017 (AER 2017b) for Fort Hills operations. The Plan will be updated as needed to reflect changes to tailings management operations and revisions to date are outlined in the table below.

Version	Date	Comment
3	October 10 2024	Updates to reflect changes to tailings scheme approved by Integrated Plan Amendment (application number 1935845) as well as updated tailings water balance.
2	December15, 2022	Updated to reflect: requirement of AER letter dated February 23, 2022 requiring water quality characterization and reporting.
1	August 28, 2019	Original

According to Suncor's Mission, Vision and Values (www.suncor.com), Suncor values safety above all else. With this in mind, the Measurement System Plan (Plan) proposed herein will and may be modified as required to ensure that all field activities are carried out in a safe manner.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Suncor Energy Operating Inc. (SEOI), on behalf of Fort Hills Energy Corporation (FHEC), and in its capacity as operator of the Fort Hills Oil Sands Project (FHOSP) submits updated Measurement System Plan. All references to SEOI are to be interpreted as SEOI acting as the agent of FHEC, unless otherwise noted.

Fort Hills has prepared this *Measurement System Plan* in accordance with Section 5 of *Directive 085* (AER 2017) and the *Measurement System Plan Requirements* letter (AER 2019) dated February 25, 2019. Additional requirements are summarized in Section 1.3 and Appendix 10.3.

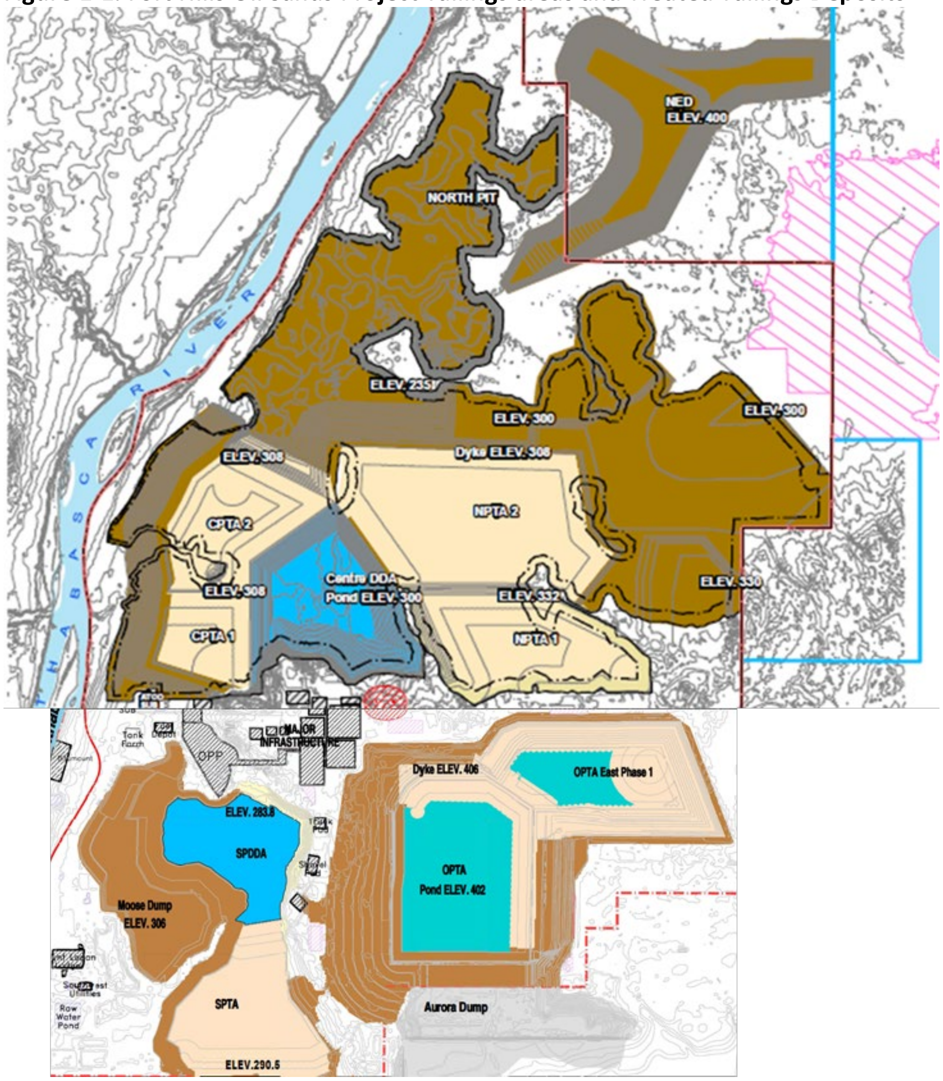
This *Measurement System Plan* will support the requirements of the *Annual Fluid Tailings Management Report* for the processing plant and associated mines which are collectively referred to as the Fort Hills Oil Sands Project, and include:

- Ore Processing Plant (OPP) and Plant site;
- Current and future mine pits including:
  - South Pit;
  - Centre Pit: and,
  - North Pit;
- Current and planned Tailings Areas including:
  - Out-of-pit Tailings Area (OPTA);
  - OPTA East;
  - South dedicated disposal area (DDA);
  - Centre DDA
  - South Pit Tailings Ares (SPTA)
  - Centre Pit Tailings Area 1 (CPTA 1)
  - Centre Pit Tailings Area 2 (CPTA 2)
  - North Pit Tailings Area 1 (NPTA 1) and
  - North Pit Tailings Area 2 (NPTA 2)

The current and future Tailings Areas are shown in Figure 1-1.

As the operator of the Fort Hills Oil Sands Project, SEOI is guided by Suncor's Mission, Vision and Values (www.suncor.com). Suncor values *safety above all else*. With this in mind, the *Measurement System Plan* proposed herein will and may be modified if field conditions are considered unsafe. Potential changes or modifications may include variations in field procedures and methods, delay of field testing and/or sample collection for the affected area or time period.

Figure 1-1: Fort Hills Oil Sands Project Tailings areas and Treated Tailings Deposits



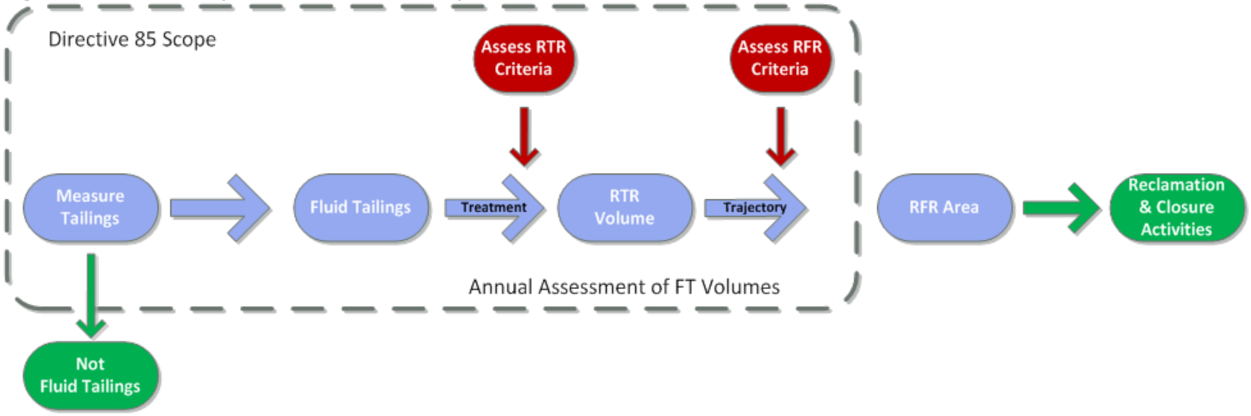
1.1 BACKGROUND

As part of the Fort Hills TMP (FHEC 2017b), Fort Hills provided the AER with a summary of how key components of tailings management and reclamation activities are related. The relationship of tailings management and reclamation activities and how the terminology described is used by Fort Hills is provided in (originally included as Figure 2.6 of Fort Hills [FHEC 2017b]). Figure 1-2 summarizes the scope of Directive 85 measurement. The following points summarize these relationships:

- Oil sands mine tailings volumes will be assessed annually, as per *Directive 085* (AER 2017) requirements.
- The majority of the tailings material produced will not be fluid tailings (FT) and will continue to be monitored through other regulatory mechanisms (i.e. *EPEA* and *OSCA* Approvals).
- The FT that have been treated through an approved technology and placed in their final landscape position (except for specified exceptions) are assessed to determine if ready to reclaim (RTR) performance criteria has been met.
- RTR performance criteria are measures that is assessed annually to determine whether a volume of material has been treated and are progressing to support future planned reclamation activities.
- Tailings areas that have finished receiving treated FT are further assessed to determine if these areas have met ready for reclamation (RFR) criteria and are capable of supporting planned reclamation activities.
- The RFR criteria is a final measure (post meeting the RTR criteria) that determines if the deposit is ready for reclamation activities and the trajectory is monitored through other regulatory mechanisms (i.e. EPEA and OSCA Approvals).

This *Measurement System Plan* has been updated to align with the regulatory approvals received for the Fort Hills Integrated Plan Amendment (FHEC 2022).

Figure 1-2: Summary of Directive 085 Scope



1.2 Measurement System Plan Annual Cycle

The *Measurement System Plan* cycle is an annual cycle with 5 key activities, including:

- Field program development,
- Field assessment activities,
- Modelling and analysis,
- Quality assurance and quality control (QA/QC), and
- *Annual Fluid Tailings Management Report* submission.

Field assessments are completed during the summer months when access to the deposits is safest. In order to ensure that the requirements of Section 5 of *Directive 085* (AER 2017) are met, data collection in the field must be completed with sufficient time to allow for modelling, analysis and QA/QC to occur prior to report submission.

To ensure the accuracy of reported FT volumes and to meet the requirement that all reported volumes are to be measured volumes, Fort Hills has selected August 1st as the target '*year-end*' (i.e. annual cycle from August 1st to July 31st. To achieve this, specific assets that have the largest influence on the overall FT inventory (i.e. assets that either contain the most FT or assets that are subject to higher annual FT volumes fluctuations) will be scheduled to have field assessments completed as close to this date as practicable (i.e. targeting within 30 days). This minimizes the variation in the reported FT inventory due to time gaps between assessments.

The proposed reporting cycle is consistent with the definition of "*Fluid Tailings Inventory*" that states "*total volume of fluid tailings measured in treated tailings deposits or fluid tailings ponds, excluding any volume that meets specific RTR criteria at time of measurement*" (Appendix 3 of *Directive 085* [AER 2017]). However, this is different from the requirement of Section 6.2, Condition 21 of *Directive 085* (AER 2017) which states that "*operators must submit Annual Fluid Tailings Management Reports to the AER by April 30 for the previous year's performance (January to December)*". By taking this approach Fort Hills will not have to project the FT inventory from August 1st to end of December using modelled values. By removing the need to report on measured and modelled values, Fort Hills expects that the requirements of accuracy and precision will be met (Section 5 of *Directive 085* [AER 2017]).

The annual cycle incorporates an ongoing continuous improvement process, and includes:

- Analysis and modelling of data from the previous year's program,
- Assessment of improvements to program to ensure quality information is provided as per Section 5 of *Directive 085* (AER 2017), and
- Definition of upcoming assessment scope based on learnings.

This may result in increases or decreases to planned scope, including:

- Field measurements,
- Samples collection and laboratory testing,
- Modelling, and
- Analysis procedures.

Fort Hills will also continue to improve and revise reporting to help ensure transparency in how Fort Hills is meeting the outcomes specified in *Directive 085* (AER 2017). This may result in changes to the reporting methodologies as described within this plan.

1.3 Concordance and Reporting Requirements

The purpose of this *Measurement System Plan* is to provide the planned measurement methodologies in accordance with the following requirements:

- *Directive 085* (AER 2017)
  - Section 5 (Conditions 17 to 20)
- "Measurement System Plan Requirements" letter (AER 2019)
- Industry Wide Water Quality Submission Requirements (AER 2022)

To identify the sections within this *Measurement System Plan* that satisfy specific requirements as outlined above, concordance tables are provided in Appendix 10.3.

This *Measurement System Plan* also provides the measurement methodologies required to support the *Annual Fluid Tailings Management Report*. A concordance for the requirements of the annual report is provided in Appendix 10.3, including:

- *Directive 085* (AER 2017) (Section 6.2);
  - Fluid Tailings Volume Reporting Requirements, and
  - Monitoring Reporting Data Requirements.
- *OSCA* Approval No. 9241K, Condition 42.

2 JUSTIFICATION OF MEASUREMENT, SAMPLING AND SPACING INTERVALS

Leveraging the Base Plant historical pond assessment techniques, Fort Hills has proposed an initial target spacing of 30 – 40 ha[1] for determining sample locations. This data shall be utilized to develop a representative 3-dimensional geologic block model of the tailings deposit for evaluation of tailings performance. Fluid tailings facilities tend to be laterally continuous due to material properties that are influenced through vertical settlement. To evaluate the sample spacing and subsequent number of test locations, a block model is created with all the available data and mass total estimates of the FT compositions. A sample location would then be removed at random from the data set, the model is rerun, and a comparison of the model outputs is assessed. This exercise would continue until the estimated totals deviate significantly from the full data set compilations.

This *Measurement System Plan* embeds continuous improvement initiatives to ensure ongoing quality analyses. Prior to producing the block model, data from the test sites are analysed geostatistically to determine how they relate to each other. Physical considerations such as structural controls, pond bottom slopes, deposition and withdrawal conditions and are included, with the sample relationships determining how the various sample datasets will be combined in the block model. This geostatistical analysis also provides clear estimates of likely error and provides the number of sites and spacing requirements for the asset. This methodology is an important component of the measurement plan, to confirm if the tailings assets conform to vertical settlement as the dominant control on material properties.

3 DETERMINATION OF FLUID TAILINGS

Fort Hills performs annual assessments of tailings deposits to measure the total site inventory of FT. This assessment measures the volume of FT in accordance to *Directive 085* (AER 2017), which defines FT as "*any fluid discard from bitumen extraction facilities containing more than 5 mass percent suspended solids and having less than an undrained shear strength of 5 kilopascals*".

3.1 RTR STATUS

Following RTR criteria has been approved for fluid tailings treated with Passive Aquatic Storage Structure (PASS) and deposited within the Dedicated Disposal Areas (DDAs) by OSCA Approval 9241K.

Subobjective 1	Clay to water ratio (CWR) threshold >0.3 based on deposit sampling.
	Expressed water from DDA annual average total suspended solids <500 mg/L

[1] This value may be increased dependent on tailings facility specific safe access conditions

Subobjective 2	Surface water and seepage: The closed-circuit water management system operating as designed. Ground water adjacent to, or in communication with, fluid tailings deposits to be effectively monitored, reported, managed, and mitigated as required by EPEA Approval No. 151469-01-00 as amended or renewed.

4 KEY MEASUREMENT METHODS & PARAMETERS

4.1 Deposit Measurements

Consistent with, or in addition to the methodology outlined in the *Guidelines for Determining Oil Sands Fluid Tailings Volumes* (COSIA 2015b) and included as Appendix 4 of *Directive 085* (AER 2017), the volume of FT within a tailings asset is determined (illustrated in Figure 4-1) following the standards referenced in Table 4-1.

Figure 4-1: Tailings Asset Volumetrics

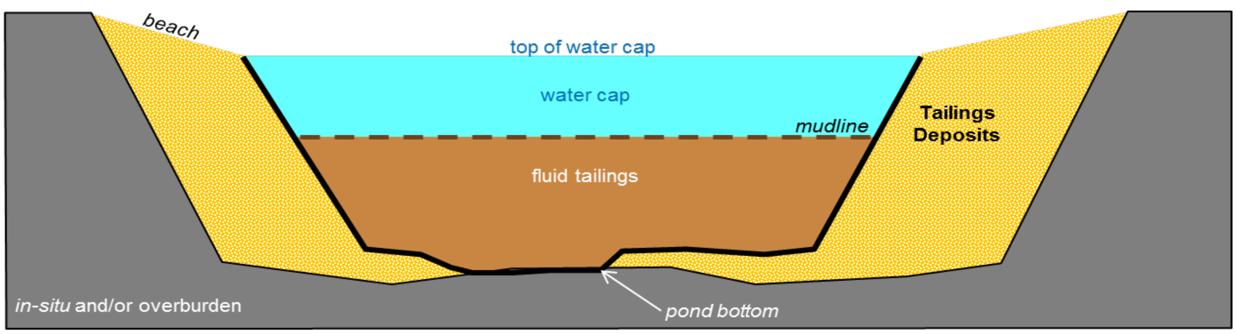


Table 4-1: Tailings Testing References

Test Name	Reference
Clay to water ratio	*Laboratory Test – Methylene Blue Procedure dried solids* OR *Laboratory Test – Methylene Blue Procedure sludges and slurries*
	Appendix 10.5- Methylene Blue Testing Procedures
Bitumen/Mineral/ Water content (Dean and Stark)	*Unified Fines Method for minus 44 micron material and for Particle Size Distribution*
	refer to COSIA (2016); Dean and Stark methodology is described in Appendix A of this document
Particle Size Distribution	*Unified Fines Method for minus 44 micron material and for Particle Size Distribution*
	refer to COSIA (2016)
Top of water cap	*Guideline for Tailings Deposit Sampling and Measuring Tools*
	refer to COSIA (2015a)
Top of FT	*Guideline for Tailings Deposit Sampling and Measuring Tools*
	refer to COSIA (2015a)
Pond Bottom	*Guideline for Tailings Deposit Sampling and Measuring Tools*
	refer to COSIA (2015a)

Test Name	Reference
NORMs concentration	Gamma CPT Indicator Mineral Identification
	Appendix 10.6- Gamma-CPT Identification of NORM Potential in Tailings Deposits
Deposit Strength	*Measuring Undrained Shear Strength of Oil Sands Tailings Deposits*
	refer to COSIA (2015b)
CPT Testing	*Guideline for Tailings Deposit Sampling and Measuring Tools*
	refer to COSIA (2015a)
Tailings Behaviour Type	*Guideline for Tailings Deposit Sampling and Measuring Tools*
	refer to COSIA (2015a)
Water Chemistry	Water Quality Testing Guide
	Appendix 10.7- Water Quality Testing Guide

4.1.1 Fort Hills Testing Methodology

4.1.1.1 Fort Hills Specific

Fort Hills plans to use two methylene blue laboratory testing methodologies. The testing procedures, summarized in Appendix 10.5, are utilized for determination of clay content and deposit CWR. These tests have been developed over several decades and have been used consistently and reliably to describe the behaviour of the Fort Hills tailings materials. Test methodologies have either been developed by research facilities or by independent organizations who have improved on standard test methodologies.

4.1.2 Field Testing

4.1.2.1 Volumetric Surveys

The volume of FT is defined as the materials above the pond bottom and below the mudline, as illustrated in Figure 4-1. The total volume of water cap is defined as all materials located above the mudline and below the air-water interface. The methodology used to survey the pond bottom (or hard bottom), mudline and water cap are summarised in the following sections.

Measuring the Pond Bottom

The pond bottom surface (Figure 4-1) is measured through the use of drop weights (or drop soundings) in water capped tailings ponds using the CT09™ sounding tool (or similar), and Cone Penetration Test (CPT) strength testing in areas where drop weights are not practical. Reference details are provided in Table 4-1.

Measuring the Mudline

The top of fluid tailings, referred to as the mudline (Figure 4-1), is most often measured using a sonar survey on deposits with a water cap, or by an aerial survey such as LiDAR or air photo or satellite image interpretation where there is no water cap. Reference details are provided in Table 4-1.

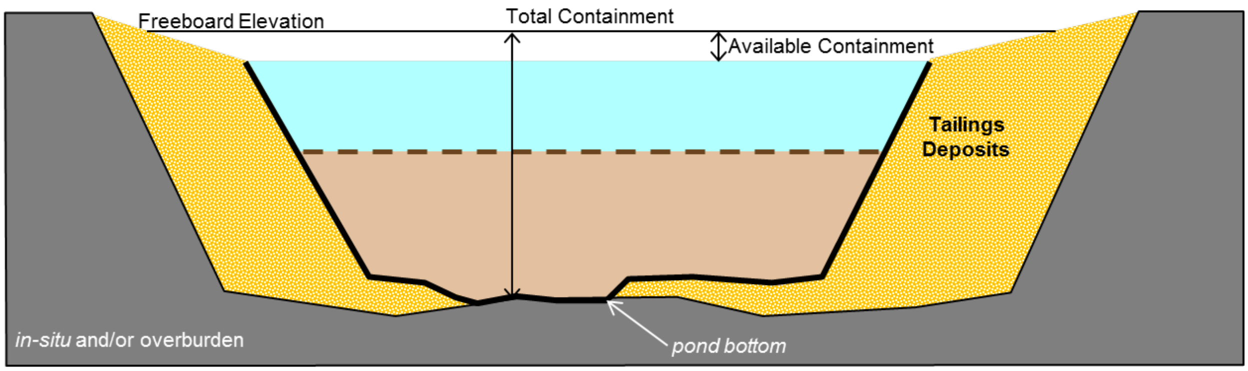
Measuring the Water Cap

In areas where water volume needs to be measured, the water surface elevation is measured using surface survey techniques or can be determined from LiDAR or air photos. Reference details are provided in Table 4-1.

Total Containment

Total containment is defined as the total available containment of fluids (e.g. FT and water) in a tailings asset maintained below the allowable freeboard elevation (i.e. maximum allowable fluid elevation within a tailings asset) and above the pond bottom. The freeboard elevation is dictated by the geotechnical design and performance of the containment structure and meeting dam safety regulations, as illustrated in Figure **4-2**.

Figure 4-2: Tailings Asset Containment



Available Containment

Available containment is defined as the unused portion of the total containment that is available for fluid containment by the operations. This volume is calculated as the volume beneath the freeboard elevation and above the used containment (i.e. typically top of water cap or top of FT if no water cap is present).

4.1.2.2 Material Properties

In order to understand material properties of the various deposits contained within a tailings asset, samples are collected for laboratory analysis, as well several downhole tools are used to obtain material properties of in-situ materials.

4.1.2.3 Fluid Sampler

The Fluid Sampler tool is capable of obtaining samples of both water and FT material at depth, which are then analyzed in the lab. Reference details are provided in Table 4-1.

4.1.2.4 Sonic Sampler

This system uses a sonic piston sampler and a drill rig that has been fitted with a sonic drill head. It is designed to collect a 50 mm diameter sample in one or two meter lengths. This system is best used to sample competent tailings materials with higher yield strengths than fluid tailings. Once samples are collected, they are then sent to the lab for analysis. Reference details are provided in Table 4-1.

4.1.2.5 Gamma and Gamma Ball CPT

In recent years, work on downhole tools, such as the CPT; have enabled field measurement of tailings properties which had previously only been available from laboratory analysis of collected samples. The use of these tools allows for a larger dataset which can be assessed for the deposit and which allow for a more representative sampling program.

The G-CPT and GB-CPT uses a receiver to determine the amount of gamma rays being emitted by the surrounding material. In conjunction with additional measures taken by the tool, including tip and sleeve resistance and pore pressure measurements, a series of correlations can be made to material properties.

Once this data is collected, the various readings can be correlated to the specific material types and physical characteristics in the deposit. Through examining readings such as tip resistance, sleeve friction, pore water pressure and gamma counts per second (cps), a correlation algorithm known as the Tailings Behaviour Type (TBT) analysis is capable of producing reliable assessments of tailings deposits which includes % solids by weight, fines content, in-situ strength, and clay-to-water ratios. In addition, the tool provides an almost continuous trace within the deposit, increasing the number of analysis points when compared with interval point samples. Statistical validity of the continuous traces is compared to laboratory sample profiles to validate the TBT analysis, and is also used to refine and improve TBT results. As data is collected and correlations improved, reliance on laboratory sampling may be reduced in future.

Due to the presence of naturally occurring radioactive materials (NORMs) within any tailings deposits, gamma ray detectors can determine the presence of higher concentrations of NORMs within a deposit. The conventional gamma probe used in conjunction with penetration testing is the standard industry practice.

Reference details for both the G-CPT and TBT aspects of this method were provided in Table 4-1.

4.1.2.6 Vane Shear Testing

This test is conducted to understand the in-situ undrained shear strength of a deposit. The test involves the use of a calibrated vane, inserted into the tailings deposit to be tested, and turned at a specific rate of rotation. Measurements are taken as to how much force is required to start and maintain this rotation, and those values are recorded as strengths of the deposit. In general use, this test is done on a few of the sites as a validation of strength measurements taken with the G-CPT and GB-CPT tests only.

Reference details for this test are provided in were provided in Table 4-1.

4.2 Laboratory Tests

Testing of oil sands tailings materials have been conducted for several decades through the collection of samples in the field, followed by analysis in the laboratory. Several tests have become standard, and are used by Fort Hills to predict the behaviour of the material both in the field and during processing.

4.2.1 Bitumen, Mineral and Water

The Dean and Stark test, also known as a Bitumen Mineral Water (BMW) test, is the standard in measuring weight percent values of bitumen, mineral, and water in a sample. In addition to the standard method, Fort Hills also uses a modified Dean and Stark which can identify the presence of light hydrocarbon. Both Dean and Stark procedures are provided in in Appendix A of COSIA (2016).

4.2.2 Particle Size Distribution

A common determination of material behaviour is the size of the mineral particles in the sample (i.e. particle size distribution [PSD]). The use of the wet sieve test is common, with the oil sands industry selecting a particle size of 44 microns as the differentiator between sand and fines (see Table 4-2).

Table 4-2: Particle Size Distribution Classifications

Material	Parameter	Measurement Method
Sand	> 0.044 mm particle site	weight percent retained by 325 mesh sieve
Fines	< 0.044 mm particle site	weight percent passing 325 mesh sieve

Sands and fines contents are to be reported as the wt/wt percent of the total dry mineral or as ratios. Sand to Fines Ratio (SFR) is often used as a performance parameter, and is reported as a ratio of the weight percentages of each material in the analysed sample.

4.2.3 Methylene Blue Test and Clay to Water Ratio

In order to determine clay content, and the CWR, industry standard BMW tests are combined with those designed to quantify the clay activity in a sample. The standard for measuring clay characteristics is x-ray diffraction (XRD). This provides both mineralogy and available surface area (based on the specific surface area contribution by each clay mineral). While detailed XRD can be considered the standard, it is an expensive and time consuming test.

Work done by the Advanced Separation Technology group at CANMET in Devon, Alberta, has compared several measurement methods with XRD, and determined that the methylene blue test provides the most consistent results that correlate well with detailed XRD results.

Fort Hill's basis for the use of the methylene blue test as the standard laboratory test to obtain CWR for all tailings streams and deposits is documented in the *ERP* (FHEC 2017a). Testing procedures for methylene blue test are located in Appendix 10.5.

CWR can then be used to correlate with deposit dewatering behaviour, strength of the deposit and hydraulic conductivity.

4.2.4 Water Chemistry Testing

Routine water chemistry analysis is conducted on samples from various locations throughout the year. Details on the sampling program, including test methodologies are located in Appendix 10.7.
The water quality characterization and reporting has been updated per AER letter dated February 23, 2022 (AER2022). Suncor notes in Appendix 10.7 that the measurement method for Naphthenic acids commercially performed is similar to method stated in AER Letter (AER2022) which specifies a three step extraction similar to the method developed by Syncrude Research. Three step extraction method is not commercially available at this time. Fort Hill's current vendor offers two testing methods which both use FTIR measurement but vary the extraction method used prior to the FTIR measurement. One is based on the USEPA 3510 Standard or a second modified version of the Syncrude Method that also uses a single extraction step. Suncor's historical measurements of Naphthenic acids has been to USEPA 3510 extraction method and the Measurement System Plan reflects this to maintain historical data integrity. Asset specific testing requirements are provided in the asset description sheets in Appendix 8.

4.3 Key Measurement Parameter Summary

Overall, performance of tailings is assessed using the parameters summarized in Table 4-3 and described in the previous sections.

Table 4-3: Measurement Method Summary

Key Parameter	Analysis Supported	Measurement Methods Employed
CWR	primarily dewatering	G-CPT, laboratory sample analysis (BMW, methylene blue and PSD)
% solids by weight	dewatering indicator	G-CPT, laboratory sample analysis (BMW)
fines content (% fines)	SFR and fines in FT	G-CPT, laboratory sample PSD
in-situ strength	FT inventory determination	G-CPT, vane shear
% bitumen	composition requirement	laboratory sample analysis (BMW)
water volume	total contained water	water surface survey, sonar
mudline (for water capped pond)	FT volume determination	sonar
pond bottom	FT volume determination	CT09™ / CPT
NORMs concentration	indicator of other COPCs	G-CPT
water quality	water chemistry changes with time	laboratory sample methods (See Appendix 10.7)

4.4 PROCESS MEASUREMENTS

4.4.1 Site wide water balance

In response to Fort Hills 2023 Directive 85 Fluid Tailings Management Report SIR 1 and subsequent discussions with AER on October 3, 2024, Fort Hills has revised the template for site wide water balance reporting. The measurement reporting period will be same as pond assessment period i.e. August 1 to July 31.

Figure 4-3: Site Wide Water Balance Report Template

Figure 4-3 Site Wide Water Balance

To be reported with annual Pond Assessment Cycle

Previous Year's water inventory =

+

Water Inputs		
		Volume Mm3
a*	**Net River import**	
b**	**Net surface runoff to close circuit**	
c**	**Ground water to close circuit loop**	
d**	**Connate water to close circuit**	
e**	**Water recovered from treated tailings**	
Total		

-

Water Sinks/ out of of closed loop		
		Volume Mm3
f**	**Cogen steam evaporation**	
g**	**Pore water in new tailings beach**	
h**	**Pore water in new Fluid Tailings**	
**	**Water export to other operations if applicable**	
Total		

This year inventory=
Variance=

* measured
** Modeled with actual inputs: production, precipitation etc.

4.4.2 Thickeners

Primary tailings treatment technologies that are part of the approved Fort Hills Oil Sands Project, namely the use of a thickener, are not FT treatment technologies as defined by *Directive 085*. The thickeners are a key aspect of the extraction plant which allows water recycle and reduce heat loss.

4.4.3 Permanent Aquatic Storage Structure Treatment Process

Volumes of FT transferred and treated by the Permanent Aquatic Storage Structure (PASS) process (described further in Section 6.3), and deposited in DDAs will be measured and reported. The outputs of this activity will generate an average deposit CWR, solids content and resultant DDA volume which shall inform the volume of water released from the treatment activities. A tailings material block model will be generated to assess the deposit performance against the RTR criteria.

5 ASSESSMENT AND MODELING

Fort Hills conducts several phases of analysis of field and laboratory data in order to understand and report on FT performance. These activities meet the requirements of Section 5 of *Directive 085* (AER 2017). This effort can be divided into several steps including the statistical analysis of field data, geospatial analysis of field data and pond material changes and validation, as described in the following sections. Most of the discussion provided in this section is focussed on depositional data, not water chemistry.

5.1 Statistical Analysis of Field Data

Once datasets have been collected, statistical analysis is conducted from a number of perspectives. Each dataset is analysed with the following:

1. All Asset data – summary statistics
   a) Univariate and covariate statistics for each of the following, including comparisons with depth:
      i. % solids by weight
      ii. % clay
      iii. % fines
      iv. % bitumen
2. Specific Asset Data – summary statistics
   b) Univariate and covariate statistics for each of the following, including comparisons with depth:
      i. % solids by weight
      ii. % clay
      iii. % fines
      iv. % bitumen
3. Outlier investigation
   a) Examine each dataset for outliers
   b) Determine whether each outlier is justified or requires investigation or reruns
   c) Flag any uncertain or incorrect data points as "*Not for Use*"
4. Comparison of current summary statistics to previous year's data
   a) Can the changes observed be explained by evolution of the asset (i.e. FT densification with time, dredge withdrawal impacts, sand placement, etc.)?
   b) Determine if changes in summary statistics are appropriate (If not, investigate data sets and results and correct where needed.
5. Examine distributions within individual material classifications

5.2 Geospatial Analysis of Field Data

Once the base datasets have been statistically validated, the next step is to conduct preliminary spatial analysis. This includes:

- Plot location maps of average values per hole
- Create maps of above values to look for spatial trends in X-Y plane
- Examine data for trends with depth
- Examine data for potential spatial sampling biases i.e. conduct declustering analysis.
- Estimate and model variograms in horizontal and vertical directions. Look for anisotropy in horizontal directions
- Krige models and perform cross-validation analysis
  - Check for unbiased errors and conditional unbiasedness. This helps to identify potential mistakes and to set problem datum
- Conduct multi-variate and multi-variate spatial analyses:
- Calculate correlations between variables of interest
- Assuming multi-variate correlations exist, perform stochastic modeling:
  - Perform Project Pursuit Multivariate Transform (PPMT), to transform to a de-correlated multi-Gaussian space
  - Use sequential Gaussian simulation to model each property of interest in Gaussian units.
  - Perform PPMT back transform to get back to original unit space
- Perform simulated model validation:
  - Check for accuracy and precision in the simulated results using accuracy plots
  - Check for histogram, variogram and multi-variate correlation reproduction
- Calculate post-modeling products:
  - Average of all realizations (E-Type model)
  - Field-wide average parameters with uncertainty distribution

Once this analysis is complete, the univariate and multi-variate spatial analysis will be used for:

- Determining tailings area average values (such as CWR) with confidence intervals
- Determining material totals for each asset
  - Mass of fines/sand/water/bitumen
  - Volumes of contained material
- To identify strong and weak portions of the tailings area
- To identify areas of varying water quality and how it changes over time
- Characterizing how much (proportion) of a tailings area meets criteria (e.g. RTR) and mapping the volumetric locations of each.

5.3 Tailings Area Material Changes and Validation

In alignment with Section 5 of *Directive 085* (AER 2017), requirements for verification and validation, Fort Hills conducts several checks to historical information to help verify and validate volume estimates. Once all spatial models are complete, Fort Hills compares the new results with the previous year's block models, when available. This comparison includes determination of the changes in the pond deposit's volume and tonnage, where applicable.

The intent of this check is to determine how the various deposits within the tailings asset have changed since the last assessment was completed. With current and prior year modelled values, differences can be compared to the process records, mass balance, operational events and impacts data for the same time period. This allows for a degree of validation as the datasets are independent. Where differences occur, further investigation will be conducted to determine the causes. If required, pending further investigation, the data provided through this validation may be used to adjust the assessment.

It is not intended that this information will be reported. It may be shared if it helps to identify any issues with the current year's assessment and is required to help explain what has occurred and why the assessment has been adjusted.

6 ASSET DESCRIPTIONS AND TAILINGS DEPOSITS

The Fort Hills tailings management plan forecasts a variety of deposit types within the current and future tailings assets. These deposits will be classified according to their behaviour within these assets; with the behaviours correlated to specific laboratory and field testing techniques utilized and refined over 50 years of oil sands operations. The deposits are broadly described as coarse tailings beach, fluid tailings, froth treatment tailings and treated tailings. Additional details specific to how each are measured is provided in the subsequent sections.

6.1 Coarse and Fine Tailings Deposition

These deposits are the result of deposition of Extraction tailings that result primarily in the construction of a coarse tailings beach, often used in dyke construction activities, and a fluid run-off that forms both a fluid tailings and recycle water inventory. Coarse tailings deposition areas will be assessed for fluid storage capacity and fluid tailings as per Section 4.1.2 and 3. The Fort Hills tailings management plan currently forecasts 7 deposition assets for Extraction tailings which are OPTA, OPTA East, SPTA, CPTA1, CPTA2, NPTA1 and NPTA2.

6.1.1 Measurement of Coarse and Fine Tailings Deposits

Once the data analysis is complete for the tailings deposition area, reporting tables and maps will be produced for the annual report. This report will include:

- Map showing the location of all test sites
- Representative cross sections of block model values
- Fluid tailings inventory volume and material properties

6.2 Froth Treatment Tailings (FTT)

The FTT at Fort Hills is called Tailings Solvent Recovery Unit (TSRU) tailings. The Fort Hills tailings management plan places TSRU tailings within OPTA for the life of mine. While the volume of TSRU tailings produced is small in comparison to Extraction tailings, and primarily forms water for recycling and a non-fluid deposit, there are aspects of these tailings that are specific to the froth treatment process. These differences arise from the utilization of a solvent to generate a saleable product and the flotation process in extraction which can result in an increase in the concentration of hydrophobic (or oleophilic) minerals in the bitumen froth. Additional measurements associated with the deposition of TSRU tailings are discussed in Section 6.2.1 and 6.2.2.

6.2.1 Measurement of TSRU Tailings Placement

To meet *OSCA* Approval 9241K, Condition 6c, Fort Hills will only place TSRU tailings in OPTA and will measure this by providing pipeline location data each year, showing discharge locations of specific tailings lines, pipeline diagrams showing routes of these lines, and notated air photos identifying line relocations with time.

6.2.2 Measurement of Residual Solvent

Prior to transport and deposition within the tailings area, the FTT are processed in a TSRU to recover and recycle solvent for reuse in the operation. The presence of light hydrocarbons, associated with the solvent, may impact tailings deposit performance. To assess this potential impact the measurement plan proposes the modified Dean and Stark test (Appendix A of COSIA [2016]) to OPTA where TSRU tailings are deposited. The detailed scope of the investigation will be determined based on the conditions in the field, and will be reported as part of the *Annual Fluid Tailings Management Report*.

6.2.3 Measurement of Potential COPCs

Due to the presence of Naturally Occurring Radioactive Minerals (NORMs) within tailings deposits, gamma ray detectors can determine the presence of higher concentrations of NORMs with confidence. The conventional gamma probe used in conjunction with penetration testing is the standard industry practice. When the presence of elevated NORMs are detected in fluid tailings, typically characterised by gamma readings in excess of 60 cps (see Appendix 10.6), the area will be identified for follow-up. NORMs are used as an indicator of other COPCs, and if the area has not been previously identified, the follow-up investigation will be conducted with the objectives to confirm the presence of COPCs; to determine the location, concentration and form of the COPCs; and to identify the make-up of the deposit including mineralogy, hydrocarbon content and density as necessary. The detailed scope of the investigation will be determined based on the conditions in the field, and will be reported as part of the *Annual Fluid Tailings Management Report*.

6.3 Treated Tailings

Fluid tailings are forecast for treatment and deposition within the South DDA and Center DDA. These tailings will be measured using the same standards and procedures as the coarse tailings deposition areas. Test sites will be selected based on a starting basis of 30 - 40 ha per site (as described in Section 2), with each test profile covering the entire deposit depth from the measured mudline to the pond bottom. Once this data is collected, total volume calculations, standard geospatial analysis and block modelling will be completed to determine the deposit performance. To attempt to minimize errors in assessing performance due to multiple seasons of operation, Fort Hills will perform checks and validations as outlined in Section 5.3.

6.3.1 Treated Tailings Measurement and Reporting

The treated FT deposits within the DDAs will be measured and reported as follow;

6.3.2 Clay to Water Ratio

The treated FT in DDAs will be measured for determination of CWR using the same standards and procedures as other assets that contain FT. Test sites will be selected based on a starting basis of 35 hectares per site (as described in Section 2), with each test profile covering the entire deposit depth from the measured mudline to the pond bottom. Once this data is collected, total volume calculations, standard geospatial analysis and block modelling will be completed, to determine the deposit CWR.

The full depth of treated FT in DDAs will be sampled, and this will represent more than one year's deposition.

6.3.3 Total Suspended Solids

Total suspended solids will be managed from samples taken from DDA's recycle water barge. Annual average will be calculated based on this sampling.

Reporting

Once all the data analysis is complete, reporting tables and maps will be produced for the annual report.

This report will contain:

- Map showing the location of all test sites
- Representative cross sections of block model showing CWR
- Histogram of CWR data
- Comparison of CWR based on deposit sampling to RTR criteria
- Comparison of annual average TSS to RTR criteria

Suncor will report both the CWR and TSS as described above. If the situation arises where the CWR in some areas of the deposit are less than 0.3, but the TSS RTR criteria is achieved, Suncor will not report the treated material with CWR of less than 0.3 as RTR.

If during a given year the average TSS is greater than the RTR criteria, Suncor will report that year's treatment as not RTR until the appropriate mitigations can be applied. Previous year's RTR FT inventory status will not be changed.

6.3.4 Closed-Circuit Water Management Systems

All treated tailings deposits (South DDA and Center DDA) have a subobjective 2 RTR criteria for "Surface water and seepage" that must demonstrate that:

"the closed circuit water management system is operating as designed".

This will be demonstrated in the Annual Fluid Tailings Management Report by reporting the frequency of system inspections, summary of loss of containment incidents with mitigations, and notated annual air photo inspection documents.

7 DATA QUALITY ASSURANCE

7.1 Validation of Laboratory Data

As part of the scope of work, the service provider will provide to Fort Hills on an annual basis written documentation of the results of internal QA/QC activities as they apply to the program. This documentation is to include, as a minimum, an outline of the provider's QA/QC philosophy (i.e. the methodology used to confirm the validity of the measurements, e.g. in terms of repeatability, accuracy, potential for measurement bias, conformance to analytical procedures), as well as a summary report of quality control statistics for the analytical program (e.g. by showing variability in blind duplicates for a representative number of samples within the total program). To further ensure best QC practices are being followed, sample blanks and/or duplicates will be sent to an additional service provider. A comparison of these data will be assessed prior to data being used in the *Annual Fluid Tailings Management Report*.

7.2 Validation of Field Data

Volumetric testing focuses on pond bottom measurements with the CT09™ tool, mudline soundings with sonic equipment, and strength testing with vane shears or G-CPT.

In general, QA/QC efforts focus on equipment maintenance and calibration (using ASTM standards where available), collection and evaluation of repeat soundings, cross validation with different tools or field samples, and monitoring and control of equipment positions during testing as described in Appendix 10.4. Ensuring proper training and adherence to procedures is important, and the contractor provides verification records on these efforts.

7.3 Validation of Gamma and Gamma-Ball CPT

Similar to validation work of volumetric data, geo-physical QA/QC focuses on equipment maintenance and calibration (using ASTM standards), as well as the collection and evaluation of repeat site profiles. In addition, equipment components, like the gamma detection module, are calibrated against known source materials to ensure proper responses.

Further details on this validation are provided in Appendix 10.4.

7.4 Validation of Spatial Model Data

Once the spatial models have been completed, a series of statistical analysis are produced to determine confidence intervals in the values, correlations between variables, accuracy in the simulated results using accuracy plots, and a check that the histogram, variogram, and multi-variate correlations are comparable to the original sample values.

8 DATA MANAGEMENT SYSTEM

As per Section 5, Condition 18 of *Directive 085* (AER 2017), Fort Hills utilises existing database systems and processes, including (but not limited to) Fort Hills' geological data. This system meets the requirements of this condition in the following manner:

- Verification: the process to ensure that data are evaluated for accuracy, errors and inconsistencies after data migration is done.
- Fort Hills uses a database to store geoscience data. Upon import, data is validated against strict import rules, native to the software. Fort Hills also utilises custom data verification on import, ensuring issues with data are captured early in the process. These processes are flexible, allowing Fort Hills to improve data validation over time, and thus reducing errors and inconsistencies prior to importing.
- Validation: follows verification; a process to compare data to documented acceptance criteria.
- Following import to the database, new data can be analysed and compared to existing data. Statistics and graphs can then be run from the database system itself, or exported for analysis via other platforms, to assess trends and identify outliers. Several tools are available for storing and analysing QA/QC sampling data, such as duplicate samples, inter-laboratory samples, blind samples, standards, blanks etc.
- Integrity: maintaining and assuring the accuracy and consistency of data over its entire life cycle.
- Fort Hills utilises database record tracking as a live audit trail of data updates over time. Record tracking captures all changes to data. Data can also be locked down, to prevent any updates.

Fort Hills has stringent database backup processes in place for disaster recovery.

9 SUMMARY

Fort Hills *Measurement System Plan* as submitted, achieves the measurement outcomes as outlined in Section 5 of *Directive 085* (AER 2017), by utilizing the following:

- An annual assessment cycle structured to provide accurate and representative data,
- A robust system based on standardized industry testing,
- A sampling program based on continuous improvement that provides a representative and complete data set,
- A system with checks and balances which ensures comparability of data,
- A suite of assessment techniques focused on providing the ability to discriminate differences in performance, and
- A data management system which verifies, validates and ensures the long-term integrity of data.

Fort Hills is continuously looking to improve its methods for FT measurement and treatment performance. Fort Hills will be undertaking an annual review of its *Measurement System Plan* to ensure that it continues to meet the measurement outcomes as defined in Section 5 of *Directive 085* (AER 2017).

10 APPENDICES

Appendix 10.1 - Acronyms and Definitions

Appendix 10.2 – References

Appendix 10.3 – Concordance Tables

- *Concordance to Directive 085*
- *Concordance to Measurement System Plan Requirements Letter*
- *Concordance to OSCA Approval No. 9241K*

Appendix 10.4 – Pond Assessment Field Techniques (QA/QC Processes)

Appendix 10.5 – Methylene Blue Testing Procedures

Appendix 10.6 – Gamma CPT Identification of NORM Potential in Tailings Deposits

Appendix 10.7 – Water Quality Testing Guide

Appendix 10.8 – Tailings Asset Description Sheets

10.1 Acronyms

Acronym	Definition
AER	Alberta Energy Regulator
ASTM	America Society for Testing and Materials
BMW	Bitumen Mineral Water
cm	centimetre
COPC	Constituents of Potential Concern
COSIA	Canadian Oil Sand Innovation Alliance
cps	counts per second
CPT	Cone Penetration Test
CPTA	Centre Pit Tailings Area
CT	Consolidated Tailings
CT09™	Conetec 2009
CWR	Clay to Water Ratio
DDA	Dedicated Disposal Area
EPA	Environmental Priority Area
EPEA	*Environmental Protection and Enhancement Act*
ERP	Enhanced Review Process
FTIR	Fourier Transform Infrared Spectroscopy
FT	Fluid Tailings
FTT	Froth Treatment Tailings
G-CPT	Gamma - Cone Penetration Test
GB-CPT	Gamma Ball - Cone Penetration Test
m	meter
MBI	Methylene Blue Index
mm	millimeter
MFT	Mature Fine Tailings
NORM	Naturally Occurring Radioactive Minerals
NPTA	North Pit Tailings Area
OSCA	*Oil Sands Conservation Act*
OPTA	Out of Pit Tailings Area
ppm	parts per million
PPMT	Project Pursuit Multivariate Transform
PSD	Particle Size Distribution
QA/QC	Quality Assurance/Quality Control
RFR	Ready for Reclamation
RTK GNSS	Real Time Kinematic – Global Navigation Satellite System
RTR	Ready to Reclaim
SFR	Sand to Fines Ratio
TBT	Tailings Behaviour Type
TD	Tailings Directive (referring to *Directive 085*)
TSS	Total Suspended Solids
wt/wt	weight to weight ratio
XRD	X-Ray Diffraction

10.2 References

Alberta Energy Regulatory (AER). 2017. Directive 085. Fluid Tailings Management for Oil Sands Mining Projects. October 12, 2017.

AER. 2019. “Measurement System Plan Requirements” Letter to FHEC dated February 25, 2019.

Canadian Oil Sand Innovation Alliance (COSIA). 2015a. Guideline for Tailings Deposit Sampling and Measuring Tools. Prepared by COSIA Geostatistical and Deposit Sampling Working Group. April 27, 2015. http://cosia.ca/uploads/documents/id21/Guidelines%20for%20Tailings%20Deposit.pdf

COSIA. 2015b. Guidelines for Determining Oil Sands Fluid Tailings Volumes. June 2015 https://www.cosia.ca/uploads/documents/id19/FT%20Volume%20Measurement%20%20June%202015%20b.pdf

CanmetEnergy. 2008a. Methylene Blue Procedure : Dean-Stark Solids. Natural Resources Canada, CanmetENERGY-Devon Extraction and Tailings, January 6, 2008.

CanmetEnergy. 2008b. Methylene Blue Procedure : Sludges and Slurries. Natural Resources Canada, CanmetENERGY-Devon Extraction and Tailings, January 6, 2008.

FHEC. 2022. Fort Hills Integrated Plan Amendment Application (Application number 1935845), Submitted to the AER: February 9, 2022.

AER. 2022. “Notice of Reporting Requirement Clarification Directive 085 - Fluid Tailings Management Reporting Requirements Water Quality Characterization and Reporting” letter to industry dated February 23, 2022 and “Directive 085 Reporting Requirement Clarification – Water Quality Characterization” letter dated June 28, 2022.

10.3 Concordance Tables

10.3.1 Concordance to *Directive 085*

		Requirement	"Project Title" Section
Section 5: Measurement Outcomes			
17)		Operators must provide quality information and ensure that the measurement system used for fluid tailings management achieves the following outcomes to the satisfaction of the AER:	Section 1
	a)	Accuracy: the degree to which the measurement matches the correct value.	*all sections*
	b)	Precision: the measure of agreement among repeated measurements of an indicator.	*all sections*
	c)	Sensitivity: the degree of ability to discriminate differences in performance of indicators	*all sections*
	d)	Representativeness: the degree that the data is a suitable measure of the condition being examined.	*all sections*
	e)	Comparability: a qualitative expression of the confidence that the quality of data is sufficient to contribute to analysis, even when measurement methods differ.	*all sections*
	f)	Completeness: the measure of the amount of valid data not omitted.	*all sections*
	g)	Bias: the measure of systematic distortion of measurements.	*all sections*
18)		Operators must maintain a data management system that supports the following outcomes to the satisfaction of the AER:	Section 1
	a)	Verification: the process to ensure that data are evaluated for accuracy, errors, and inconsistencies after data migration is done.	Section 1
	b)	Validation: follows verification; a process to compare data to documented acceptance criteria.	Section 1
	c)	Integrity: maintaining and assuring the accuracy and consistency of data over its entire life cycle.	Section 1
19)		Operators must submit their measurement system plan to the AER within six months following approval of the tailings management plan.	*This document*
20)		Operators must address deficiencies in their measurement system plan identified by the AER.	-
Section 6: Fluid Tailings Management Reporting **Section 6.2: Fluid Tailings Management Report Requirements**			
Fluid Tailings Volume Reporting Requirements			
Include a project site summary of all annual fluid tailings volumes, as per the accounting table in appendix 3.			Annual FT Management Report Section 2
		• Previous year inventory of new and legacy FT • FT inventory • Change in new and legacy FT inventory • New and legacy FT inventory • Approved profile new and legacy FT inventory • rolling profile deviation for new and legacy FT	
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).			Annual FT Management Report

Requirement		"Project Title" Section
Describe if and how activities have deviated from the fluid tailings management plan and any modifications made to improve performance		*not a measurement*
Identify the management level (as described in the TMF) that the operation's performance falls within.		*not a measurement*
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.		*not a measurement*
Provide a site-wide water balance or provide the reference to another AER report and location where this information can be obtained.		Section 4.4.1
Provide a water volume (in tabular form) or provide the reference to another AER report and location where this information can be obtained. The table must include, for each treated tailings deposit and fluid tailings pond		Sections 4, 1 and 6
	• total volume of water at the beginning of the reporting period, • total volume of water at the end of the reporting period, • characterization of the quality of water, and • the volume and quality of water recovered from fluid tailings and runoff from RTR tailings.	Section 4.1, 4.2, 4.4, 1, 6
Provide information about fines that were not captured, which form fluid tailings, including:		*not a measurement*
	• quantity of fines in the ore processed during the reporting period, and • quantity of fines in fluid tailings.	
Estimate the change in fluid tailings volume inventory as a result of settling and consolidation and provide an explanation if inconsistent with the predictions.		Section 1
Provide a status map of the current locations and sizes of all fluid tailings ponds and treated deposits for the project.		*not a measurement*
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).		Sections 3, 4, 1 and 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.		*not a measurement*
For each fluid tailings treatment technology,		Section 4 and 6
	• provide volume of fluid tailings treated and where they were placed; • provide chemical and physical properties of the treated fluid tailings and the water recovered from treatment; and • if the technology is not performing as predicted, provide mitigation measures to rectify performance (address any impacts on the deposit performance).	
Monitoring Reporting Data Requirements		
For each monitoring dataset required in the annual fluid tailings management report,		Section 1 and 7
	• identify any uncertainties and • explain the dataset adequacy.	
For each treated tailings deposit and fluid tailings ponds and their surrounding environment provide monitoring results, including the following:		Sections 4, 1 and 6; Appendix 10.8
	• a map and tabular data showing the survey locations of tailings deposits; • 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;	

Monitoring Reporting Data Requirements		
	• 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; and • verification that the tailings deposit is meeting the milestones in the fluid tailings management plan.	

10.3.2 Concordance to "Measurement System Plan Requirements" Letter dated February 25, 2019

Requirement		"Project Title" Section
The measurement system plan must also include identification of substances of concern from TSRU tailings, and measurement locations and measurement methodology for the substances of concern.		6.2.2 and 6.2.3
The measurement plan must include the following:		-
	Key definition of parameters for fluid tailings.	Section 3 and 4
	Reference of standards and procedures used to measure fluid tailings and treated tailings.	Section 4; Table 4-1
	An explanation of and justification for measurement procedures that are unique to Fort Hills and this plan.	Section 4.1
	Evidence that the plan will address the measurement outcomes as per section 5 of Directive 085, as amended.	Section 2, 3, 4, 1, 6 and 9
	An explanation of how each deposit will be measured, calculated and reported.	Section 4, 5 and 6; Appendix 10.8
	A description of the fluid and TSRU tailings deposit sampling, measurement, and survey program.	Section 4 and Appendix 10.4
	Justification of how measurement, sampling, and spacing intervals will identify any characteristic markers that specifically indicate the presence of TSRU tailings.	Section 2, 1 and 6.2.3
	Justification of how measurement, sampling, and spacing intervals will show the variation of the fluid and TSRU tailings deposit properties	Section 2, and 6.2.3
	Justification of how measurement, sampling, and spacing intervals will identify if any material in the tailings deposit is not performing to expectations.	Section 2 and1

10.3.3 Concordance to *OSCA* Approval No. 9241K

Requirement			"Project Title" Section
42	The Operator shall, in addition to any reporting requirements under Directive 085, provide in the annual fluid tailings management report:		-
	(a)	Repealed (April 11, 2024; Oil Sands Conservation Act Scheme Approval No. 9241K)	*not a measurement*
	(b)	the available storage capacity of each tailings deposit or pond or tailings area that contains water or tailings at the end of the reporting period;	Section 4.1.2.1 and 6; Appendix 10.8
	(c)	annual storage capacity and volume requirements for the five years following the end of the reporting period	*not a measurement*
	(d)	surface water quality parameters characterized and reported at environmentally relevant detection limits;	
	(e)	a description of the activities undertaken in the reporting period for each froth tailings deposit including material placement, handling, or removal;	
	(f)	an updated risk assessment for acid rock drainage potential, including froth tailings research / learnings as it applies to operational activities (ex. depositional strategy) unless otherwise authorized in writing by the AER; and,	
	(g)	any other information the AER may require.	

10.4 Pond Assessment Field Techniques (QA/QC Processes)

1. Introduction

Fort Hills relies on 3rd party expertise to conduct pond assessments, field sample collection and laboratory analysis. Where available, 3rd parties follow ASTM or industry standards for the work completed. For activities not included in industry standard documentation, these 3rd parties are required by Fort Hills to develop and execute QA/QC programs for the work planned, which results in reasonable assurances that the data provided is of sufficient quality to base technical and business decisions.

2. General Field Testing QA/QC

*Quality Control (QC) p*rocedures are put in place to ensure the performed services adhere to a defined set of quality criteria.

- Quality criteria:
- data must be correct and complete
- Control procedures:
- ensure equipment is working properly through instrument calibration, field checks (including instrument baseline verification and monitoring, depth verification, data quality checks)
- data analysis team performs checks and verification on data collected using specialized software and standardized processes
- senior review of data and data reports
- post processing checklists for data review process
- quality memos generated and communicated to all personnel

Quality Assurance (QA) procedures are put in place to ensure that the maintenance of a desired level of quality is maintained.

- Training conducted with all personnel on procedures and protocols, in
- annual company training
- new hire training
- on the job training
- On site field visits by project managers for verification of field procedures and quality checks
- Manuals and protocol documents generated, maintained and available to all personnel for reference and review

Fort Hills uses Conetec Investigations Ltd. (Conetec) as the primary contractor for assessing tailings assets. The equipment and quality checks provided here are those used by Conetec. Alternative contractors executing this works will be required to meet or exceed the QA/QC standards described here.

Fort Hills uses industry standard tools and techniques for assessing tailings deposits. Table 1 provides an index of the techniques used for each of the primary tailings material classes.

Table 1: Tailings Asset Field Assessment Techniques

Tailings Material	Technique	Primary Measures
Fluid Tailings	Gamma Ball CPT (GB-CPT)	Strength, TBT, temperature
	CT09™ Pond Bottom Sounding	Pond bottom
	Fluid Sampling	FT Laboratory Material Properties
	Vane Shear	Strength validation
Mudline	Sonar Mudline	Mudline
	Fixed Interval Sampling	Mudline validation by sampling
Non-Fluid Tailings	Gamma CPT (GCPT)	Strength, TBT, temperature
	Sonic Sampling	Laboratory Material Properties
	Vane Shear	Strength validation

2.1 CT09™ – Pond Bottom Soundings

The primary tool used by Conetec to determine pond bottom is known as the CT09™.

The objective of a CT09™ survey is to define the bottom bounding surface (termed "pond bottom" or "hard bottom") for modelling fluid constituents and volume.

QA/QC activities

- Provide individual cone penetrometer calibration records used on the project
- provides the appropriate data to show that the penetrometer has been properly calibrated within a timely manner in general accordance with ASTM standard D5778
- On a per-sounding basis, highlight hard bottom selection criteria, manual or automated, hard bottom achieved or not
- Conduct multiple CT09™s in a cluster to assess repeatability in each pond in multiple areas (shallow, deep, hard refusal areas, frictional refusal areas). Recommended 8 per cluster (with small offsets), multiple clusters in pond centered on a G-CPT or GB-CPT profile, ideally paired with sample data. ConeTec to assess the repeatability of CT09™ hard bottom measurement

versus G-CPT or GB-CPT and sample results and to provide a statistical analysis on a per-pond basis that evaluates the accuracy and precision of CT09™ measurements in the facility.

- In ponds where hard bottom is not achieved with the CT09™ due to a frictional refusal, suggest using G-CPT or GB-CPT as a more representative test.
- When the boat is not in a fixed location (dynamic positioning), collect high quality coordinates throughout the test sounding. *Guidelines for Tailings Deposit Sampling and Measuring Tools* (COSIA 2015) recommends that horizontal deviation does not exceed 5% of sounding depth. Currently this is not always possible due to weather conditions and the depth to mudline (i.e. in ponds where the mudline is deeper than 8 m, efficient anchoring is not possible with the current equipment). Opportunities for equipment improvement include:

- longer (telescopic) anchoring spuds
- RTK GNSS system (Real Time Kinematic – Global Navigation Satellite System) on workboat (centimeter accuracy) for positioning and coordinate measurement pre/post/during sounding

Quality Activities

- Cone calibration date is within 1 year of testing date
- Collect pre and post sounding coordinates, report horizontal deviation, it should never exceed 5% of sounding depth.
- Up/down difference does not exceed 0.4 m for soundings where depth is greater than 10 m
- Up/down difference does not exceed 0.2 m for soundings where depth is less than 10 m
- Cone penetrometer cleaned at the end of each day
- Cone penetrometer saturated prior to each sounding

2.1.1 Mudline Measurements – Acoustic Techniques

In water capped tailings deposits, determining the top of the FT material is required to obtain inventory volumes. Fort Hills relies on acoustic measurements, as the FT mudlines tend to occur as sharp increases in % solids by weight and form a clear surface off of which acoustic signals readily reflect.

The objective of testing is to delineate the upper boundary surface (mudline) for fluid tailings (FT) volume and constituent modelling.

2.1.1.1 Single Beam Sonar

QA/QC Activities

- Provide measurement uncertainty value for each reported elevation
- Provide a table in the report that outlines equipment precision, equipment uncertainty and offset measurements

Quality Activities:

- Measure and document the transducer depth below water and verify keel offset settings in software
- Verify sonar depth measurement versus an area with physically verified depth each day to verify setup
- Sonar transducer mounted to a outrigger barge for dynamic surveying, verifies that transducer elevation does not change as boat pitch and draft change due to travel velocity and turning
- Static sonar readings at sampling locations should agree within 10 cm of collected mudline from sampling

2.1.1.2 Swath Bathymetry

QA/QC Activities

- Provide measurement uncertainty value for each reported elevation
- Provide a table in the report that outlines equipment precision, uncertainty and equipment offset measurements (transducer depth, offset from GNSS antenna)
- Provide any equipment calibration reports (Sound Velocity Probe)

Quality Activities

- Compare sonar mudline measurements with Fixed Interval Sampler mudline measurements to ensure they agree within the measurement uncertainties
- Perform 'Patch Test' calibration for equipment each time the equipment is deployed on a vessel.
- Ensure 3DSS Sound Velocity Probe is calibrated yearly

2.1.2 Field Sampling – Fluid, Sonic and Fixed Interval Sampling

Samples of FT are typically taken within a FT deposit as vertical profiles from the mudline surface to pond bottom. The distance between samples varies depending on the variability within the deposit, the total thickness of the deposit, and the degree of confidence provided by previous assessments and geostatistical modelling. Samples have provided the basis for historical assessments of the Fort Hills assets, and will continue to form a key component in the evaluation of the facilities as technology advances allows for migration to in-situ based material assessments.

Objective of tailings sampling: Collect profiles of physical samples for laboratory analysis, providing solids content, fines content, bitumen content, and clay reactivity testing.

QA/QC Activities

- Collect duplicate samples for every 50th sample.
  - analyze duplicate pairs for repeatability and provide summary statistics per deposit.
  - duplicate sampling density may need to be increased in smaller tailings facilities in order to get a statistically meaningful set of data pairs for the deposit
  - this error analysis will contain components of field collection error, spatial variability error and laboratory analysis error
- Laboratory subcontractor to select certain samples to duplicate for their own QA/QC
  - laboratory duplicate samples can be combined with Suncor's duplicate samples for statistical analysis
- Instruct the laboratory to split occasional samples and report the laboratory split data
  - analyze laboratory duplicate pairs for repeatability and provide summary statistics per deposit
  - duplicate laboratory sampling density will need to provide a statistically meaningful set of data pairs
  - the error analysis will contain components of sub-sampling error and laboratory process error
- Compare laboratory splits to field duplicates to get an approximation of field error versus laboratory error

Quality Activities:

- Record gas pressure during deployment of gas actuated piston samplers (verify that gas pressure exceeds deposit pressure).
- Collect photographs of all samples.
- Mudline from sonar reading is within 10 cm of the mudline from FIS samples
- Locations with paired sampling/G-CPT/CT09™:
  - mudlines should be within 10 cm
  - fluid sampler refusal is within 1 m of CT09™ refusal
- YSI (environmental multi-meter to measure pH, ORP, Conductivity, temperature) calibrations performed daily in non-expired solutions
  - calibration readings are recorded after each sample profile

- if the calibration readings are not within acceptable limits then the probe is recalibrated (currently deciding what the quantitative value of these limits is)
- it should be noted that this tool provides a qualitative assessment of pH, ORP, and conductivity. It is designed and intended for water samples.

2.2 Gamma (Ball) CPT - In-Situ Material Testing

2.2.1 Fluid Tailings

The primary tool used by Conetec to assess in-situ material properties for FT material is known as the GB-CPT. The strength of FT is presented as the primary defining characteristic of FT by the AER. As such, Fort Hills has selected GB-CPT as the primary measure of undrained shear strength.

The objective of GB-CPT testing is to assess the undrained shear strength of tailings that flow around the penetrometer. GB-CPT testing collects direct measurements of ball tip resistance, pore pressure and passive gamma. The calculated undrained shear strength and passive gamma data is used to provide tailings constituents (i.e. TBT).

QA/QC activities

- Provide individual cone penetrometer calibration records used on the project.
- provides the appropriate data to show that the penetrometer has been properly calibrated within a timely manner in general accordance with ASTM standard D5778
- Provide dimension verifications for GB-CPT wear parts. This procedure is common in natural soils and compacted soils, however will provide limited value in FT besides operational transparency.
- Provide zero load readings for each sounding.
- Baselines between soundings should be similar for the same cone
- Provide the cone calibration check record for cones that have undergone a load-cell shift.
- Provide a table highlighting the point reading resolution for each capacity of penetrometer used on the project.
- TBT interpretations to be compared with sample results collected adjacent to the sounding. A statistical analysis of TBT variance from laboratory data will be presented with each report.
- Twinning a minimum of one sounding or approximately 1/10 of G-CPT holes with electric downhole vane shear testing to confirm assumptions in undrained shear strength interpretations in each tailings facility. Provided basis for Nball factor used in calculating the data.

Quality Activities

- Cone calibration date is within 1 year of testing date

- Testing procedures generally meet or exceeds ASTM D5778.
- Each filter is saturated in silicone oil or glycerine under vacuum pressure prior to use
- Recorded cone penetrometer baselines are checked with an independent multi-meter (applicable to analog systems only)
- Baseline readings are compared to previous readings
- Soundings are terminated at the client's target depth or at a depth where an obstruction is encountered, excessive rod flex occurs, excessive inclination occurs, equipment damage is likely to take place, or a dangerous working environment arises
- Differences between initial and final baselines are calculated to ensure zero load offsets have not occurred and to ensure compliance with ASTM standards
- Cone penetrometer is cleaned between soundings
- Before and after each sounding, gamma modules are verified against reference values from materials having consistent output. These values are recorded for inspection during data processing. Data scaling may be conducted using pre and post calibration values.

2.2.2 G-CPT for Non-Fluid Tailings

The primary tool used by Conetec to assess in-situ material properties for non-FT material is known as the Gamma Cone Penetrometer, or G-CPT test.

The objective of G-CPT testing is to provide detailed stratigraphic log of tailings deposit with direct measurements of tip resistance, sleeve friction, pore pressure and passive gamma. This measured data is used to calculate geotechnical parameters such as shear strength and tailings constituents (TBT).

QA/QC activities

- Provide individual cone penetrometer calibration records used on the project.
- Provides the appropriate data to show that the penetrometer has been properly calibrated within a timely manner in general accordance with ASTM standard D5778
- Provide dimension verifications for CPT wear parts. This procedure is common in natural soils and compacted soils, however will provide limited value in FT besides operational transparency.
- Provide zero load readings for each sounding.
- Baselines between soundings should be similar for the same cone
- Provide the cone calibration check record for cones that have undergone a load-cell shift.
- Provide a table highlighting the point reading resolution for each capacity of penetrometer used on the project.
- TBT interpretations to be compared with sample results collected adjacent to the sounding. A statistical analysis of TBT variance from laboratory data will be presented with each report.

- Recommend twinning a minimum of one sounding or approximately 1/10 of G-CPT holes with electric downhole vane shear testing to confirm assumptions in undrained shear strength interpretations in each tailings facility. Provided basis for Nkt factor used in calculating the data.
- Report on methodology unit weight assumptions and method of determination. Unit weights are determined from either from PPD tests (in fluid slurries) and SBT zones (in materials generating effective stress), or from the laboratory data with the following assumptions; SG_{fines}=2.62, SG_{sand}=2.57, SG_{oil}/water=1 and unit Unit $Weight_{water}$=9.8 1 kN/m^3 or TBT.

$$G_{S\ total\ Sample} = \left[\frac{\frac{Total\ Sample\ Percent}{100\%}}{\left(\frac{(sand\ wt\%)}{G_{s\ sand}\ x\ 100\%} + \frac{(fines\ wt\%)}{G_{s\ fines}\ x\ 100\%} + \frac{(Oil\ wt\% + water\ wt\%)}{G_{s\ oil+water}\ x\ 100\%} \right)} \right]$$

$$\gamma_{material} = \gamma_{water}\ x\ G_{S\ total\ sample}$$

Quality Activities

- Testing procedures generally meet or exceeds ASTM D5778.
- Cone calibration date is within 1 year of testing date
- Each filter is saturated in silicone oil or glycerine under vacuum pressure prior to use
- Recorded cone penetrometer baselines are checked with an independent multi-meter (applicable to analog systems only)
- Baseline readings are compared to previous readings
- Soundings are terminated at the client's target depth or at a depth where an obstruction is encountered, excessive rod flex occurs, excessive inclination occurs, equipment damage is likely to take place, or a dangerous working environment arises
- Differences between initial and final baselines are calculated to ensure zero load offsets have not occurred and to ensure compliance with ASTM standards
- Cone penetrometer is cleaned between soundings
- Before and after each sounding, gamma modules are verified against reference values from materials having consistent output. These values are recorded for inspection during data processing. Data scaling may be conducted using pre and post calibration values.
- There are certain geotechnical properties or physical laws that cannot be violated and as such are used for detailed quality control checks. The review procedure identifies any such violations and recommends small adjustments to the data or a re-collection of field data.
- fs >= 0, qt >= 0
- Sleeve friction cannot be negative (because of the design, a ConeTec cone sleeve load cell cannot go into tension) nor should the tip resistance.
- qt >= ud

- Because the tip is a total stress sensing device the tip resistance (qt) cannot be less than the total overburden stress. In typical geotechnical testing the unit weight of the material must be estimated to determine the total overburden stress, however, in FT the total stress is a result of the fluid pressure which is directly measured by the dynamic pore pressure (ud) channel.
- $\sigma_v' >= 0.0$
- Effective vertical stress must not be negative. Due to the fact that in ConeTec software the total stress and the fluid pressure are independently calculated, slightly negative values may be computed.

2.2.3 Tailings Strength Validation - Vane Shear Testing

The strength of FT is presented as the primary defining characteristic of FT by the AER. As such, Suncor has selected multiple measurement methods to employ in the field to build comparative datasets. The vane shear test is conducted in the field, but is subject to differing error conditions than the primary GB-CPT method.

Objective of vane shear testing: Provide a direct measurement of undrained shear strength in-situ.

QA/QC Activities

- Provide calibration records for each vane load cell used on project. Calibrations comply with ASTM D2573/D2573M.
- Provide zero load readings for each sounding (baseline counts)
- Provide a table of point reading resolution for each capacity of downhole load cell used on the project.
- Provide proof or record of elapsed time from insertion to rotation. From remolding to remold testing.
- In sand/fine mixtures (CT, high SFR FT) evaluate drained versus undrained behaviour to assure VST is representative of an undrained shear strength

- This is achieved by performing an adjacent CPT pore pressure dissipation test to obtain the coefficient of consolidation (cvh)
- A non-dimensional vane test time factor is then calculated based on the time elapsed between vane insertion and failure (tf) and the vane diameter (D) such that T = cvh*tf/D2
- If T is less than 1.3 then can assume undrained conditions
- A recent paper by Reid (2016) evaluated T from VST in silty Australian mine tailings and showed the need to perform faster VST to avoid partially drained vane strength measurements.

Quality Activities

- Testing procedures generally meet or exceeds ASTM D2573. Variances from standard:
  - Extra-large vane for profiling FT (150x300mm)
  - Depths referenced to the middle of the vane blade, not to the vane tip
  - Rate of remolding is not recorded
  - Instead of plotting torque vs rotation, plot shear stress and rotation
- Appropriate vane selected for testing based on adjacent G-CPT or GB-CPT calculated undrained shear strength assuming an Nkt factor of 15 or Nball factor of 11.
- Vane load cell calibration date is within 1 year of testing date
- Zero load readings between soundings are similar (within 1% of the measured Su value)
- Peak test starts within 5 minutes of reaching the required test depth
- Remold test starts within 1 minute after remolding process
- Vane is inspected for damage before use. Vane blade thickness and stem diameter are measured and recorded.

10.5 Methylene Blue Testing Procedures

This Appendix includes copies of the following:

- Methylene Blue Procedure : Dean-Stark Solids (CanmetENERGY 2008a)
- Methylene Blue Procedure : Sludges and Slurries (CanmetENERGY 2008b)

10.6 Gamma CPT Identification of NORM Potential in Tailings Deposits

The G-CPT (Gamma Cone Penetration Test) and GB-CPT (Gamma Ball Penetration Test) are performed by advancing instrumented probes into the tailings at 2 cm/sec. The probe sensors are sampled and recorded every 2.5 cm of penetration. Both probes are attached in front of a passive-gamma module. The module housing contains a scintillating crystal that glows when it is struck by gamma rays. The observed gamma-ray incidents are counted and used to calculate the gamma counts-per-second (cps), which is reported in the G-CPT and GB-CPT soundings every 10 cm of penetration.

There are three main naturally occurring radioisotopes: Potassium 40, Thorium 232, and Uranium 238. These radioisotopes exist naturally because their very long half-life times are a similar magnitude to the age of the earth. A small fraction of all of the potassium in the world is this natural radioisotope Potassium 40. Some clay minerals in the oil sand tailings, such as illite and mica, contain potassium atoms. When the passive-gamma module is in the presence of clay-minerals it will start to glow and will be recorded as an increased rate of gamma rays, as it does in the presence of other NORMs. In the tailings deposit, gamma rays will interact with the tailings material and lose energy as it travels from the source mineral, until it is completely absorbed. For the typical densities of tailings, gamma rays may travel 20 to 30 cm, which means that the passive gamma measurements respond to the local material adjacent to the probe.

When the passive-gamma module is above the mudline there are almost no gamma rays observed. A value of 6 cps can be used as a threshold to profile the depth to the mudline using the passive-gamma readings. Typical passive-gamma rates of 20 to 50 cps are found when in fluid FT, where the rate of gamma rays depend on the quantity of suspended fines. In contrast, when the gamma module is in sand beach tailings, passive-gamma rates of 10 to 20 cps are measured.

Fluid tailings typically do not produce passive gamma rates in excess of 60 cps. When this cps point is exceeded, it is indicative of potential presence of froth treatment tailings.

10.7 Water Quality Testing Guide

Testing of water quality within the recirculating process water systems includes a standard set of analyses, shown in Table 1. Samples will be collected from return water barge or catwalks leading to the barge at OPTA in April and August to accommodate seasonal variation. Samples are taken from specific sample locations, analysed, and entered into Fort Hill's process database.

Table 1: Water Quality Testing Analyses

Conventional Parameters			
Analyte	Unit	Laboratory Method	Analytical Method
Conductivity	uS/cm	AB SOP-00005	Alkalinity Acidity Conductivity Fluoride and pH by PC-Titrate (Modified SM 2510 B, SM 4500 H+B, SM 2320 B, SM 4500-F C, SM 2310 B) - Soil & Waters PC Titrate Conductivity (25 °C) Alkalinity Fluoride pH Acidity
pH	pH		
Anion Sum	meq/L	Auto Calculated	Auto Calculated
Cation Sum	meq/L		
Ion Balance (% Difference)	%		
Hardness (CaCO3)	mg/L		
Alkalinity (PP as CaCO3)	mg/L	AB SOP-00005	Alkalinity Acidity Conductivity Fluoride and pH by PC-Titrate (Modified SM 2510 B, SM 4500 H+B, SM 2320 B, SM 4500-F C, SM 2310 B) - Soil & Waters PC Titrate Conductivity (25 °C) Alkalinity Fluoride pH Acidity
Alkalinity (Total as CaCO3)	mg/L		
Total Dissolved Solids (Calculated)	mg/L	Auto Calculated	Auto Calculated

Total Suspended Solids	mg/L	AB SOP-00061	Total Suspended Solids, Total Fixed Solids, Total Volatile Solids (Modified SM 2540 D, E) Gravimetric Total Suspended Solids Total Suspended Solids Fixed Total Suspended Solids Volatile

Major Ions			
Analyte	Unit	Laboratory Method	Analytical Method
Bicarbonate (HCO3)	mg/L	AB SOP - 00005	Alkalinity Acidity Conductivity Fluoride and pH by PC-Titrate (Modified SM 2510 B, SM 4500 H+B, SM 2320 B, SM 4500-F C, SM 2310 B) - Soil & Waters PC Titrate Conductivity (25 °C) Alkalinity Fluoride pH Acidity
Carbonate (CO3)	mg/L		
Hydroxide (OH)	mg/L		
Chloride (Cl)	mg/L	AB SOP-00020	Chloride and Sulfate Analysis by Discrete Autoanalyzer (Modified SM 4500 Cl E & SM 4500 SO4 E) – Soils and Waters Chloride *Sulfate
Sulphate (SO4)	mg/L		

Total and Dissolved Metals			
Analyte	**Units**	**Laboratory Method**	**Analytical Method**
Aluminum (Al)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Antimony (Sb)	mg/L		
Arsenic (As)	mg/L		
Barium (Ba)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified EPA 6010 D) - Soils and Waters ICP/OES
Beryllium (Be)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Boron (B)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified EPA 6010 D) - Soils and Waters ICP/OES
Cadmium (Cd)	ug/L		

Calcium (Ca)	mg/L		
Chromium (Cr)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Cobalt (Co)	mg/L		
Copper (Cu)	mg/L		
Iron (Fe)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified EPA 6010 D) - Soils and Waters ICP/OES
Lead (Pb)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Lithium (Li)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified EPA 6010 D) - Soils and Waters ICP/OES
Magnesium (Mg)	mg/L		
Manganese (Mn)	mg/L		
Mercury (Hg)	ug/L	AB SOP-00084	Mercury in Waters, Leachates and Liquids by Bromination and Cold Vapour [Modified BC MOE LABORATORY MANUAL SECTION C and EPA 245.7] Mercury
Molybdenum (Mo)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Nickel (Ni)	mg/L		
Phosphorus (P)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified EPA 6010 D) - Soils and Waters ICP/OES
Potassium (K)	mg/L		
Selenium (Se)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Silicon (Si)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified EPA 6010 D) - Soils and Waters ICP/OES
Silver (Ag)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Sodium (Na)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified

Strontium (Sr)	mg/L		EPA 6010 D) - Soils and Waters ICP/OES
Sulphur (S)	mg/L		
Thallium (Tl)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Total Tin (Sn)	mg/L		
Titanium (Ti)	mg/L		
Uranium (U)	mg/L		
Vanadium (V)	mg/L		
Zinc (Zn)	mg/L		
Nutrients			
Analyte	**Units**	**Laboratory Method**	**Analytical Method**
Nitrate (N)	mg/L	AB SOP-00091	NO2 and TON by Gallery Plus (Modified SM 4500-NO3-H and 4500-NO2)
Nitrate plus Nitrite (N)	mg/L		
Total Nitrogen (N)	mg/L	AB SOP-00093	Total Nitrogen by Konelab (Modified SM 4500-N C) – Soil and Water Colorimetric
Total Total Kjeldahl Nitrogen (Calc)	mg/L	BBY WI-00033	Auto Calculated
Ammonium	mg/L		
Hydrocarbons - BTEX			
Analyte	**Units**	**Laboratory Method**	**Analytical Method**
F1 (C6-C10) - BTEX	ug/L	AB SOP-00039	Extraction and Analysis of BTEX/F1 and select Volatiles by HS/GC/MS/FID Water, Soil and Oil (BTEX: Modified EPA 8260D, GC/MS – HEADSPACE) (F1/PHC: Modified CCME Petroleum Hydrocarbons - Tier 1 Method and EPA5021A) – Soils and Waters (BTEX TCLP: EPA 1311) GC/MS - HEADSPACE
F1 (C6-C10)	ug/L		
F2 (C10-C16 Hydrocarbons)	mg/L	AB SOP-00040	Analysis of Extractable Hydrocarbons in Water and Soils by GC/FID (Modified Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil – Tier 1 Method) Modified EPA 1617)- Sheen
F3 (C16-C34 Hydrocarbons)	mg/L		
F4 (C34-C50 Hydrocarbons)	mg/L		
Benzene	ug/L	AB SOP-00039	Extraction and Analysis of BTEX/F1 and select Volatiles by HS/GC/MS/FID Water, Soil and Oil

Toluene	ug/L		(BTEX: Modified EPA 8260D, GC/MS – HEADSPACE) (F1/PHC: Modified CCME Petroleum Hydrocarbons - Tier 1 Method and EPA5021A) – Soils and Waters (BTEX TCLP: EPA 1311) GC/MS - HEADSPACE
Ethylbenzene	ug/L		
m & p-Xylene	ug/L		
o-Xylene	ug/L		
Xylenes (Total)	ug/L		
Volatile Organic Compounds			
Analyte	**Units**	**Laboratory Method**	**Analytical Method**
Total Trihalomethanes	ug/L	AB SOP-00056	Preparation and Analysis VOC -Water and Soil by HS/GC/MS (Modified from EPA8260D and EPA5021A) (VOC TCLP: EPA 1311) - Soils and Waters
Bromodichloromethane	ug/L		
Bromoform	ug/L		
Bromomethane	ug/L		
Carbon tetrachloride	ug/L		
Chlorobenzene	ug/L		
Dibromochloromethane	ug/L		
Chloroethane	ug/L		
Chloroform	ug/L		
Chloromethane	ug/L		
1,2-dibromoethane	ug/L		
1,2-dichlorobenzene	ug/L		
1,3-dichlorobenzene	ug/L		
1,4-dichlorobenzene	ug/L		
1,1-dichloroethane	ug/L		
1,2-dichloroethane	ug/L		
1,1-dichloroethene	ug/L		

cis-1,2-dichloroethene	ug/L		
trans-1,2-dichloroethene	ug/L		
Dichloromethane	ug/L		
1,2-dichloropropane	ug/L		
cis-1,3-dichloropropene	ug/L		
trans-1,3-dichloropropene	ug/L		
Methyl methacrylate	ug/L		
Methyl-tert-butylether (MTBE)	ug/L		
Styrene	ug/L		
1,1,1,2-tetrachloroethane	ug/L		
1,1,2,2-tetrachloroethane	ug/L		
Tetrachloroethene	ug/L		
1,2,3-trichlorobenzene	ug/L		
1,2,4-trichlorobenzene	ug/L		
1,3,5-trichlorobenzene	ug/L		
1,1,1-trichloroethane	ug/L		
1,1,2-trichloroethane	ug/L		
Trichloroethene	ug/L		
Trichlorofluoromethane	ug/L		
1,2,4-trimethylbenzene	ug/L		
1,3,5-trimethylbenzene	ug/L		
Vinyl chloride	ug/L		
Phenols			
Analyte	**Units**	**Laboratory Method**	**Analytical Method**

Phenols	mg/L	AB SOP-00088	Phenol Phenolics-Automated 4--Aminoantipyrine Colorimetry (Modified SSMA Chapter 40 & EPA 9066) - Water Colorimetric – Distillation Extraction
Naphthenic Acids			
Analyte	**Units**	**Laboratory Method**	**Analytical Method**
Naphthenic Acids	mg/L	AB SOP-00060	Naphthenic Acids in water by FTIR (Modified EPA 3510C R3/FTIR) IR
Naphthenic Acids	mg/L	AB SOP-00070	Extraction and Analysis of Naphthenic Acids in Water (DCM Extraction) [Modified from Syncrude 1995 m] IR DCM Extraction Naphthenic Acids

PAH’s and Alkylated PAH’s			
Analyte	**Units**	**Laboratory Method**	**Analytical Method**
B[a]P TPE Total Potency Equivalents	ug/L	AB SOP-00037 CAL SOP-00250	Preparation and analysis of Alkylated PAH in soils and water (Modified SM 8270 E and ESTD-OR-20) – Soils and Waters GC/MS – Extraction
Acenaphthene	ug/L		
Acenaphthylene	ug/L		
Acridine	ug/L		
Anthracene	ug/L		
Benzo(a)anthracene	ug/L		
Benzo(b&j)fluoranthene	ug/L		
Benzo(k)fluoranthene	ug/L		
Benzo(g,h,i)perylene	ug/L		
Benzo(c)phenanthrene	ug/L		
Benzo(a)pyrene	ug/L		
Benzo(e)pyrene	ug/L		
Chrysene	ug/L		
Dibenz(a,h)anthracene	ug/L		
Fluoranthene	ug/L		

Fluorene	ug/L		
Indeno(1,2,3-cd)pyrene	ug/L		
Indeno(1,2,3-cd)fluoranthene	ug/L		
2-Methylnaphthalene	ug/L		
Naphthalene	ug/L		
Phenanthrene	ug/L		
Perylene	ug/L		
Pyrene	ug/L		
Quinoline	ug/L		
Retene	ug/L		
C1-Naphthalene	ug/L		
C3-Naphthalene	ug/L		
C4-Naphthalene	ug/L		
C2-Naphthalene	ug/L		
Biphenyl	ug/L		
C1-biphenyl	ug/L		
C2-biphenyl	ug/L		
C1-fluorene	ug/L		
C2-fluorene	ug/L		
C3-fluorene	ug/L		
Dibenzothiophene	ug/L		
C1-dibenzothiophene	ug/L		
C2-dibenzothiophene	ug/L		
C3-dibenzothiophene	ug/L		

C4-dibenzothiophene	ug/L		
C1 phenanthrene/anthracene	ug/L		
C2 phenanthrene/anthracene	ug/L		
C3 phenanthrene/anthracene	ug/L		
C4 phenanthrene/anthracene	ug/L		
C1 fluoranthene/pyrene	ug/L		
C2 fluoranthene/pyrene	ug/L		
C3 fluoranthene/pyrene	ug/L		
C4 fluoranthene/pyrene	ug/L		
C1 benzo(a)anthracene/chrysene	ug/L		
C2 benzo(a)anthracene/chrysene	ug/L		
C3 benzo(a)anthracene/chrysene	ug/L		
C4 benzo(a)anthracene/chrysene	ug/L		
C1benzobjkfluoranthene/ benzoapyrene	ug/L		
C2benzobjkfluoranthene/ benzoapyrene	ug/L		
C1-Acenaphthene	ug/L		
1-Methylnaphthalene	ug/L		
NORM's (Radiological Parameter)			
Analyte	**Units**	**Laboratory Method**	**Analytical Method**
Lead-210	Bq/l	BQL SOP-00007	Gamma Spectrometry
Potassium-40	Bq/l		
Radium 226	Bq/l		
Radium-223	Bq/l		

Radium-228	Bq/l		
Thorium-227	Bq/l		
Thorium-228	Bq/l		
Thorium-230	Bq/l		
Thorium-234	Bq/l		
Uranium-235	Bq/l		

10.8 Tailings Asset Description Sheets

Fort Hills has provided a set of detailed descriptions in order to measure, analyze and report on required parameters for each tailings asset including:

- OPTA
- OPTA East (measurements to start in 2023)
- South Pit Tailings Area
- South DDA

Additional detail will be provided for new tailings assets as they become operational.

Each sheet is broken up into four main sections:

- Deposit Description – this section describes the FT materials stored or placed within the asset
- Measurement Reporting Requirements – this section describes the items reported in the *Annual Fluid Tailings Management Report*

Tailings Asset	OPTA		
Deposit Descriptions			
Asset will contain fluid tailings Asset will contain an operational water cap Asset will receive and hold Coarse Sand Tailings (CST) through dyke construction and beaching Asset will receive and hold Thickened Tailings (TT) Asset will receive and hold Tailings Solvent Recovery Unit (TSRU) Tailings			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Water cap Volume	Volume	n/a	
Water cap Quality	Routine Water Chemistry	n/a	Refer to *Appendix 10.7 "Water Quality Testing Guide"*
Total Containment	Volume	n/a	
FT Volume	Volume	n/a	
FT Volume Transferred	Volume	n/a	Treatment, pond storage location
Closed Circuit Water System	Inspection records	Operating as designed	Annual report on inspections of seepage collection system
Groundwater	Refer to Groundwater Monitoring Program		

Tailings Asset	OPTA East		
Deposit Descriptions			
Asset will contain fluid tailings Asset will contain an operational water cap Asset will receive and hold Coarse Sand Tailings (CST) through dyke construction and beaching Asset will receive and hold Thickened Tailings (TT)			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Water cap Volume	Volume	n/a	
Water cap Quality	Routine Water Chemistry	n/a	Refer to *Appendix 10.7 "Water Quality Testing Guide"*
Total Containment	Volume	n/a	
FT (TFT) Volume	Volume	n/a	
Closed Circuit Water System	Inspection records	Operating as designed	Annual report on inspections of seepage collection system
Groundwater	Refer to Groundwater Monitoring Program		

Tailings Asset	SPTA		
Deposit Descriptions			
Asset will contain fluid tailings Asset will contain an operational water cap Asset will receive and hold Coarse Sand Tailings (CST) through dyke construction and beaching			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Water cap Volume	Volume	n/a	
Water cap Quality	Routine Water Chemistry	n/a	Refer to *Appendix 10.7 "Water Quality Testing Guide"*
Total Containment	Volume	n/a	
FT (TFT) Volume	Volume	n/a	
Closed Circuit Water System	Inspection records	Operating as designed	Annual report on inspections of seepage collection system
Groundwater	Refer to Groundwater Monitoring Program		

Tailings Asset	SPDDA		
Deposit Descriptions			
Asset will contain PASS treated FT Asset will contain an operational water cap			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Expressed Water Volume	Water cap Volume	n/a	Expressed water mixed with precipitation
	Volume removed	n/a	Expressed water mixed with precipitation
Expressed Water Quality	TSS	*Annual average (TSS ≤ 500 ppm)*	Expressed water mixed with precipitation
	Routine Water Chemistry	n/a	Refer to *Appendix 10.7 "Water Quality Testing Guide"*
FT transported to PASS	Volume and Source Location	n/a	
PASS treated FT Volume	Volume	n/a	
PASS treated FT Composition	BMW[(1)]	n/a	
	CWR	*CWR > 0.3*	Threshold based on deposit sampling and modelling
Closed circuit water system	Notated air photo records of field operations	*Operating as designed*	To be reported in "*Fluid Tailings Management Report* " submitted annually to AER
Groundwater	Refer to Groundwater Monitoring Program		
Notes:			
[(1)] Fort Hills utilizes Dean Stark method to determine BMW, and Analytical Protocol for Pentane Content in Tailings by Coanda Research & Development Corporation.			