



**REPORT**

**Report on**

*Tailings Review and Expansion Potential*

*Troilus Mine*

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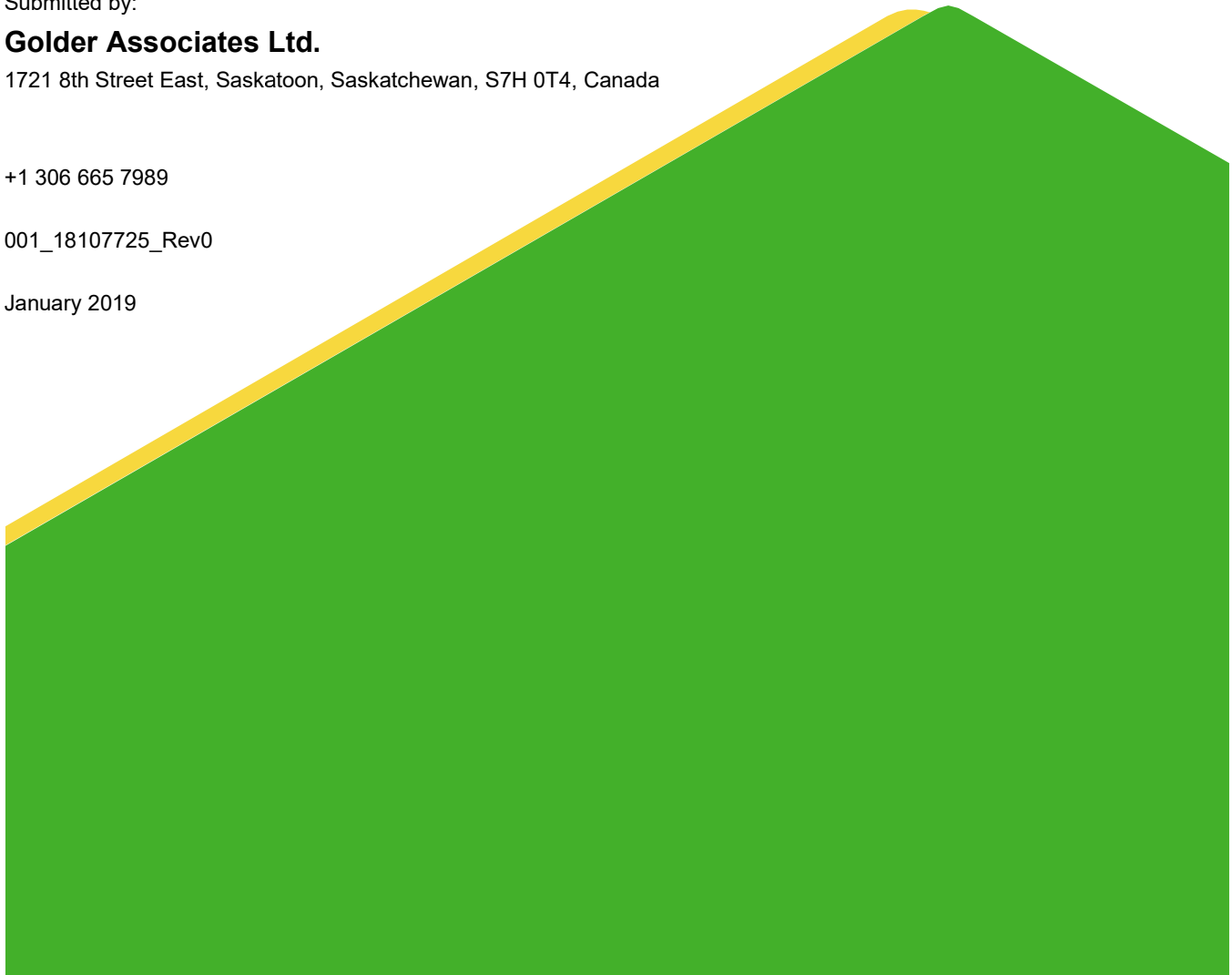
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## EXECUTIVE SUMMARY

This report summarizes a tailings area review and assessment of expansion potential for the Troilus mine site's tailings storage facility (TSF). The objective of the study was to evaluate the tailings storage options and in particular the potential to store additional tailings in the current facility. The evaluation was based on a review of existing background information for the property – no new investigations, analyses or designs were undertaken as part of the study.

The TSF was initially constructed with an embankment nominally at elevation 381 m along the west and south perimeter of the TSF footprint. The dyke is a till structure with a sand and gravel toe drain. The north and east perimeters were bounded by topographic highs. Thereafter, the facility was raised by the upstream construction method, with annual raises of approximately 1.5 m in height, until the elevation 401 m, which was reached in 2009. In 2005, a mine rock buttress was placed at the toe of the structure to improve stability. A south dyke was constructed in 2006 to elevation 401 m, in order to close off a limited drainage at this location. The dyke was a till-core, rock-shell structure.

Stability analyses were undertaken at various stages during the initial construction and raise construction. The factor of safety (FOS) against rotational instability was calculated to exceed the regulatory minima in force at the time of construction. Cone penetration testing (CPT) was undertaken to verify that the tailings were sufficiently resistant to liquefaction and that the upstream raise concept could be implemented safely.

The hydrotechnical analyses for the structure were carried out during operations and during the recent post-operation phase to define operational parameters (water levels, pumping and treatment rates) for the facility verify that the structure could safely manage long return period rainfall and/or snowmelt events required by the regulatory framework in effect at the time.

Since the end of the TSF operation in 2010, Mine Troilus managed excess runoff in the TSF by treatment by the ActiFlo plant for suspended solids and release to environment at the discharge point PR2. Mine Troilus tested in 2018 a new operational procedure to discharge untreated pond water directly into the emergency spillway and from there via a pipeline to discharge at a new final discharge point, PR-2.

A technical opinion of the potential to raise the facility beyond the current basis of design concluded that re-commissioning of the facility and further raises using the historic development design was technically feasible. Based on a high-level deposition model, it is estimated that the facility could be operated to store an additional 42.5 Mt of tailings with modest capital investments, whereas the natural containment within the basin could accommodate up to 95.2 Mt, albeit with some technical and economic constraints. The feasibility of this higher level storage capacity has not been established.

It is recommended that Troilus consider alternate tailings management strategies for the restart, in order to assess the optimum strategy. The report contains a synopsis of potentially applicable tailings dewatering approaches.

It is noted that the regulatory framework, and the engineering state of practice has evolved significantly since closure of the facility. Consequently, detailed technical analyses will be required to support an eventual request to re-commission the facility, with the following as a minimum:

- It will be necessary to review the design basis prior to restart of the facility, as both Directive 019 and the CDA Guideline have evolved since the closure of the mine. It would be recommended that the mine implement the risk-informed approach in the CDA Guideline, although it may in certain cases be more rigorous than Directive 019.
- The liquefaction assessment will have to be updated in conjunction with the restart of operations, as the regulatory framework has evolved since the closure of the mine. It will be necessary to verify the tailings properties for the new process/tailings.
- The stability analysis (static and seismic) for the facility should be reviewed when the mine plan is developed, as the regulatory framework has evolved since the closure of the facility.
- Consideration could be given to reducing the risk of embankment instability by disposing of neutral mine waste rock as a buttress against the embankment, as was done in 2005.
- The ultimate capacity of the facility will depend on the ultimate closure design, in particular the establishment of a permanent closure spillway. Standard practice is to establish closure spillways on natural ground to promote long term performance.
- New regulatory requirements lead to a recommendation to increase the water storage freeboard by approx. 1.0 m relative to the crest of the emergency spillway to provide for more operational flexibility of the pond water management. This recommendation will need to be verified by additional studies.
- The existing emergency spillway is wide enough to evacuate safely the probable maximum flood. An increase in the size of the erosion protection rocks on the upstream 35 m of the spillway channel is likely required.
- The management of the seepage water at the toe of the dykes depends on the observed water quality.
- Mine Troilus needs to verify that the Actiflo treated water meets all applicable water quality standards before release to the environment.
- When planning the future TSF development, an option comparison should be carried out to establish the optimal emergency and closure spillway location.
- A few hydrotechnical and hydrological studies are recommended before the re-start of the TSF operations including:
  - Verifying the wave run-up calculations based on recent extreme wind velocities statistics;
  - Confirming the required erosion protection rock size for the upstream segment of the emergency spillway channel.
  - Planning the pond water level operation by use of a water balance model to limit the risk of an environment spill and the risk of process water deficit for the mill.

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## 1.0 INTRODUCTION

This report summarizes Golder Associates Ltd.'s (Golder) tailings area review and assessment of expansion potential for the Troilus minesite's tailings storage facility (TSF). The work was performed pursuant to Golder's proposal P18103338 to Troilus Mines (Troilus) dated June 1, 2018.

## 2.0 SCOPE OF WORK

Troilus has purchased the inactive Troilus Mine site (the Site) with the objective of re-opening and operating the facility. The objective of the study is to evaluate the tailings storage options and in particular the potential to store additional tailings in the current facility. The study should answer the following questions:

- What is the history of development of the tailings facility?
- What is the remnant capacity of the facility (for the management of tailings, process water and naturally occurring precipitation) within the local topographical constraints?
- What is the potential to continue raising the perimeter embankment using upstream methods?
- Given that the state of practice with regard to the evaluation of tailings facility stability has evolved since the closure of the facility, what are the data gaps that need to be addressed in future phases of study?

The scope considers technical aspects related to facility expansion. It does not consider environmental permitting requirements to obtain any authorizations for the facility. We would be pleased to discuss environmental permitting issues with Troilus on request.

## 3.0 PROJECT EXECUTION

### 3.1 Data Compilation

Golder has been a key contributor to the design, construction and operation of the TSF at Troilus, and as such many of the relevant background data reports exist within our files. We have been informed by the former owner of the site that Troilus may receive the information from Golder's files. The following table summarizes reports that Golder has used in the execution of this project:

Year	Project No.	Deliverable Title	Project Synopsis
1997	SNC-007595-41ET-401	EXPLOITATION MINIÈRE TROILUS, CONCEPTION DU PARC A RÉSIDUS MINIERS. NORD DE CHIBOUGAMOU, QUEBEC.	Initial site characterization and design of starter embankment
1997	971-7088	DEVIS TECHNIQUE REHAUSSEMENT DE LA DIGUE DU PARC À RÉSIDUS	Technical specifications
		EXPLORATION DE BANCS D'EMPRUNT	Borrow search
		RECHERCHE DE BANCS D'EMPRUNT	Borrow search
		MODIFICATION AU SCHÉMA DE DÉVELOPPEMENT DU PARC À RÉSIDUS DE LA MINE TROILUS, MUNICIPALITÉ DE LA BAIE-JAME	Modification of development strategy for TSF
1999	991-7034	ANALYSE DE RISQUES SYSTÈME DE REFOULEMENT DES EAUX DU PARC À RÉSIDUS MINE TROILUS	Water management risk analysis for the TSF.
1999	991-7076	DEVIS TECHNIQUE REHAUSSEMENT DE LA DIGUE DU PARC À RÉSIDUS (1999) PROJET TROILUS	Technical specifications
		RECHERCHE DE BANCS D'EMPRUNT ET AUTRES SONDAGES EXPLORATOIRES	Borrow search

Year	Project No.	Deliverable Title	Project Synopsis
2000	001-7014	MODÉLISATION DES DIFFÉRENTES ÉTAPES DE DÉPOSITION DES RÉSIDUS DANS LE PARC - MARS 2000 À AVRIL 2002, PROJET TROILUS	Deposition modelling - 2000 to 2002
		DEVIS TECHNIQUE REHAUSSEMENT DE LA DIGUE DU PARC À RÉSIDUS (2000) PROJET TROILUS	Technical specifications
		RAPPORT D'EXPLORATION BANC OUEST ET BANC C AOÛT 200	Borrow search
2001	011-7040	DEVIS TECHNIQUE REHAUSSEMENT DE LA DIGUE DU PARC À RÉSIDUS (2001) PROJET TROILUS	Technical specifications
		PLANS DE RÉFÉRENCE, TRAVAUX DE CONSTRUCTION, ÉTÉ 2001	Drawings for dyke raise
2002	021-7023	PLANS DE RÉFÉRENCE, TRAVAUX DE CONSTRUCTION, ÉTÉ 2002	Drawings for dyke raise
		DEVIS TECHNIQUE REHAUSSEMENT DE LA DIGUE PRINCIPALE DU PARC À RÉSIDUS (2002) PROJET TROILUS	Technical specifications
		INSPECTION ANNUELLE DU PARC À RÉSIDUS, PROJET TROILUS	Annual inspection report
2002	021-7044	REVUE DU CONCEPT DE REHAUSSEMENT PARC À RÉSIDUS DIVISION TROILUS	Review of dam raise concept
2003	03-1221-001	CONSIDÉRATIONS SUR LE REHAUSSEMENT DE LA DIGUE DU PARC À RÉSIDUS À PLUS DE 392,5 M, DIVISION TROILUS	Feasibility for dyke raising
		DEVIS TECHNIQUE REHAUSSEMENT DE LA DIGUE PRINCIPALE DU PARC À RÉSIDUS EN 2003 MINE TROILUS	Technical specifications
2003	03-1221-009	RECHERCHE DE BANCS D'EMPRUNT MAI 2003	Borrow search
2003	03-1221-016	PLANS DE RÉFÉRENCE TRAVAUX DE CONSTRUCTION 2003 - DIVISION TROILUS REHAUSSEMENT DE LA DIGUE - PARC À RÉSIDUS	Drawings for dyke raise
2003	03-1221-026	OUTIL DE GESTION DE L'EAU PARC À RÉSIDUS DIVISION TROILUS	Water management concept
2003	03-1221-027	INSPECTION ANNUELLE DU PARC À RÉSIDUS, PROJET TROILU	Annual inspection report
2004	04-1221-001	DEVIS TECHNIQUE REHAUSSEMENT DE LA DIGUE PRINCIPALE ET DE LA DIGUE NORD-EST DU PARC À RÉSIDUS EN 2004 MINE TROILUS	Technical specifications
		PLANS POUR CONSTRUCTION, TRAVAUX DE CONSTRUCTION 2004 - DIVISION TROILUS REHAUSSEMENT DE LA DIGUE - PARC À RÉSIDUS	Drawings for dyke raise
2004	04-1221-008	ÉTUDE DE LA MISE EN PLACE D'UN PAREMENT DE STÉRILES EN AVAL DE LADIGUE PRINCIPALE DU PARC À RÉSIDUS DIVISION TROILUS	Assessment of impact to stability for constructing a toe berm on the main dyke
2004	04-1221-016	OPINION TECHNIQUE ET MESURES DE REHABILITATION, DIGUE NORD-EST, PARC À RÉSIDUS, MINE TROILUS	Assessment of dyke rupture, northeast dyke.
2005	05-1221-002	PLANS POUR CONSTRUCTION, TRAVAUX DE CONSTRUCTION 2005 - DIVISION TROILUS REHAUSSEMENT DE LA DIGUE - PARC À RÉSIDUS	Drawings for dyke raise
		DEVIS TECHNIQUE REHAUSSEMENT DE LA DIGUE PRINCIPALE ET DE LA DIGUE NORD-EST DU PARC À RÉSIDUS EN 2005 MINE TROILUS	Technical specifications
2005	05-1221-016	INSPECTION ANNUELLE DU PARC À RÉSIDUS, DIVISION TROILUS	Annual inspection report
2005	05-1221-017	OPINION TECHNIQUE AU SUJET DE FAISABILITÉ D'UNE AUGMENTATION DE LA CAPACITÉ D'ENTREPOSAGE DU PARC À RÉSIDUS, DIVISION TROILUS	Memo which considered the feasibility of increasing the storage capacity in the TSF
2005	05-1221-018	RAPPORT FACTUEL INSTALLATION DE PIÉZOMÈTRES ÉLECTRIQUES SUR LE SITE DU PARC À RÉSIDUS DE LA MINE TROILUS	Vibrating wire piezometer installation
2006	06-1221-002	NOUVELLE DIGUE SUD, PARC À RÉSIDUS MINIER, DIVISION TROILU	Stability analysis for the South dyke
		PLANS POUR CONSTRUCTION, TRAVAUX DE CONSTRUCTION 2006 - DIVISION TROILUS Rehaussement de la digue - Parc à résidus	Drawings for dyke raise and new South dyke to El 402 m
		DEVIS TECHNIQUE REHAUSSEMENT DE LA DIGUE PRINCIPALE ET CONSTRUCTION DE LA DIGUE SUD DU PARC À RÉSIDUS EN 2006 MINE TROILUS	Technical specifications

Year	Project No.	Deliverable Title	Project Synopsis
2006	06-1221-004	ÉVALUATION DE LA CAPACITÉ DE REMPLISSAGE DU PARC À RÉSIDUS, DIVISION TROÏLUS	Assessment of remaining capacity
2006	06-1221-015	INSPECTION ANNUELLE DU PARC À RÉSIDUS MINIERS, DIVISION TROÏLUS	Annual inspection report
2006	061221-024	PLANS DE RÉFÉRENCE TRAVAUX DE CONSTRUCTION 2006 - DIVISION TROILUS REHAUSSEMENT DE LA DIGUE - PARC À RÉSIDUS	Drawings for dyke raise
2007	07-1221-002	PLAN DE FERMETURE RÉVISION 2007 LES MINES INMET, DIVISION TROILUS	Closure plan update
		PROGRAMME DE CARACTÉRISATION ENVIRONNEMENTALE DES SOLS ET DE L'EAU SOUTERRAINE EN VUE DE LA FERMETURE - PRÉLIMINAIRE	Environmental studies on soils and groundwater in support of closure
2007	07-1221-004	DEVIS TECHNIQUE REHAUSSEMENT DE LA DIGUE PRINCIPALE DU PARC À RÉSIDUS EN 2007 MINE TROÏLUS	Technical specifications
		PLANS POUR CONSTRUCTION, TRAVAUX DE CONSTRUCTION 2007 - DIVISION TROILUS Rehaussement de la digue - Parc à résidus	Drawings for dyke raise
		INSPECTION ANNUELLE DU PARC À RÉSIDUS MINIERS, DIVISION TROÏLUS	Annual inspection report
2008	08-1221-010	DEVIS TECHNIQUE REHAUSSEMENT DE LA DIGUE PRINCIPALE DU PARC À RÉSIDUS EN 2008 MINE TROÏLUS	Technical specifications
		PLANS POUR CONSTRUCTION, TRAVAUX DE CONSTRUCTION 2008 - DIVISION TROILUS Rehaussement de la digue - Parc à résidus	Drawings for dyke raise
		INSPECTION ANNUELLE DU PARC À RÉSIDUS MINIERS, DIVISION TROÏLUS	Annual inspection report
2008	08-1221-012	OPINION ON THE TAILINGS POND EXPANSION POTENTIAL, TROÏLUS MINE	Opinion on tailings pond expansion potential
2009	09-1221-001	PLANS DE RÉFÉRENCE TRAVAUX DE CONSTRUCTION 2009 - DIVISION TROILUS Rehaussement de la digue - Parc à résidus	Drawings for dyke raise
2009	09-1221-002	DEVIS TECHNIQUE REHAUSSEMENT DE LA DIGUE PRINCIPALE DU PARC À RÉSIDUS EN 2009 MINE TROÏLUS	Technical specifications
		PLANS POUR CONSTRUCTION, TRAVAUX DE CONSTRUCTION 2009 - DIVISION TROILUS Rehaussement de la digue - Parc à résidus	Drawings for dyke raise
		INSPECTION ANNUELLE DU PARC À RÉSIDUS MINIERS, DIVISION TROÏLUS	Annual inspection report
2009	09-1221-011	RÉSULTATS DE L'ÉTUDE D'ÉVALUATION DU POTENTIEL DE LIQUÉFACTION DES RÉSIDUS, PARC À RÉSIDUS, DIVISION TROÏLUS	Liquefaction potential assessment for tailings.
2010	10-1221-005	DEVIS TECHNIQUE - CONSTRUCTION DU SYSTÈME DE GESTION DES EAUX DE SURFACE DU PARC À RÉSIDUS DE LA MINE TROILUS, 2011	Technical specifications for surface water management system
		PLANS POUR CONSTRUCTION, TRAVAUX DE CONSTRUCTION 2007 - DIVISION TROILUS Système de gestion des eaux de surface	Drawings for surface water management system
		COMPTE RENDU –VISITE DU SITE DU PARC À RÉSIDUS LES 15 ET 16 JUIN 2010, MINE TROÏLU	Site inspection report
		RE: TROILUS MINE - FEASIBILITY STUDY OF A TAILINGS DIVERSION DITCH	Feasibility study for tailings diversion ditch
2010	10-1221-080	DEMANDE DE CERTIFICAT D'AUTORISATION POUR LA RESTAURATION DU PARC À RÉSIDUS	Request for certificate of authorization
2010	10-1221-109	ACTUALISATION DES NIVEAUX ET DÉBITS DE CRUE SUITE AUX CHANGEMENTS AU SYSTÈME DE GESTION DES EAUX -PARC À RÉSIDUS MINIERS TROÏLUS	
		INSPECTION ANNUELLE DU PARC À RÉSIDUS MINIERS, DIVISION TROÏLUS	Annual inspection report
		ÉTUDE DE FAISABILITÉ DU REGROUPEMENT DES POINTS D'ÉCHANTILLONNAGE DES EFFLUENTS DES EAUX DE SURFACE DU PARC À RÉSIDUS VERS L'ENVIRONNEMENT	Feasibility study for combining sampling points for surface water at the TSF

Year	Project No.	Deliverable Title	Project Synopsis
2012	12-1221-114	CONCEPTUAL STUDY OF EROSION PROCESSES AND EROSION PROTECTION SOLUTIONS ON THE TROILUS STORAGE FACILITY FOLLOWING THE END OF OPERATIONS	Erosion study
2013	13-1221-060	INSPECTION ANNUELLE 2013 DU PARC À RÉSIDUS MINIERS, DIVISION TROÏLUS	Annual inspection report
2014	1405806	INSPECTION ANNUELLE 2014 DU PARC À RÉSIDUS MINIERS, DIVISION TROÏLUS	Annual inspection report
2014	1410952	DEVIS TECHNIQUE - AMÉNAGEMENT D'UN FOSSÉ POUR LE REGROUPEMENT DES EFFLUENTS PR6 ET PR5, MINE TROÏLUS	Technical specifications for changes to surface water management system
		VUE EN PLAN ET COUPES DU FOSSÉ PR5-PR6	Detailed design
2015	1531075	INSPECTION ANNUELLE 2015 DU PARC À RÉSIDUS MINIERS, DIVISION TROÏLUS	Annual inspection report
2016	1655060	INSPECTION ANNUELLE 2016 DU PARC À RÉSIDUS MINIERS, DIVISION TROÏLUS	Annual inspection report
2017	1787327	INSPECTION ANNUELLE 2017 DU PARC À RÉSIDUS MINIERS, DIVISION TROÏLUS	Annual inspection report

### 3.2 History of Site Development

The initial design for the facility was carried out by SNC Lavalin Inc. (SLI) in a 1997 report:

« Exploitation minière Troilus, conception du parc à résidus miniers », notes techniques, rapport révisé de SNC-Lavalin Environnement, projet 007595-41ET-401, mai 1997.

The design concept proposed by SNC was to construct a dam initially to elevation 381 m, subsequently to be raised to elevation 385 m and 390 m. Tailings were intended to be deposited on the upland areas to the northeast of the dyke and that the supernatant water would rest against the embankment. We understand that the starter dyke for the main embankment of the facility was constructed up to nominal elevation 381 m on the basis of this report.

The concept for the development of the TSF was revised by Golder in 1997 (971-7088). The concept selected was to raise the tailings facility by constructing upstream raises 2 to 2.5 m high using tailings placed on top of the tailings beach. A filter zone was constructed to allow the passage of exfiltrating water, and mine waste was used for erosion protection. The TSF was raised incrementally using this concept, except that the annual raises were typically 1.5 m high.

Whereas the raise construction methodology was largely successful, issues were experienced with high levels of suspended solids in the water pond, which had implications in terms of water management. Several iterations of dyke raise heights and pond size were considered during the operational phase to manage water quality issues.

In 2004, a study was undertaken (04-1221-008) to assess the potential to construct a toe berm along the main embankment using mine waste rock. This study demonstrated the beneficial effect of the toe berm, and the berm was constructed in 2005. The berm crest elevation varied from 394 m to 397 m, which corresponded to the crest of the 2005 raise.

In 2006, the South Dyke was constructed up to a crest elevation of 402 m. This dyke is a till core, rock shell dam with a sand and gravel filter between the till core and the downstream rock shell. Upstream and downstream slopes for this structure are 2H:1V and 2.5H:1V respectively.

Subsequently, the facility was raised annually until 2009. The crest elevation varied between 400 m and 402 m. This was the last raise for the facility. In 2010, the mine applied for, and received a certificate of authorization for a closure plan of the facility.

## 4.0 GEOTECHNICAL DATA REVIEW

### 4.1 Site Classification and Design Basis

Mining dams in Quebec are governed according to Directive 019, which outlines applicable controls for the design, construction and operation of tailings storage facilities. The Directive 019 approach is a proscriptive, standards-based approach to the assessment of design flood events, seismic events and required factors of safety.

Many operators, and particularly operators who have investments in jurisdictions outside of Quebec, choose to further consider their structures within the framework of the Canadian Dam Association (CDA), Dam Safety Guidelines 2007 (2013 Edition) – (Guideline). The Guideline proposes a risk-informed approach to dam management. Within this approach, the consequences of failure are analyzed and then the basis of design is developed for a particular risk category for the structures. A formal classification according to the Guideline has not been undertaken for this facility. In 2014, the CDA published an update to the Guideline focussing specifically on tailings dams.

It will be necessary to review the design basis prior to restart of the facility, as both Directive 019 and the CDA Guideline have evolved since the closure of the mine. It would be recommended that the mine implement the risk-informed approach in the CDA Guidelines, although it may in certain cases be more rigorous than Directive 019.

### 4.2 Foundation Conditions

The SNC report (SNC-007595-41ET-401) reported that a total of 8 standard boreholes, 32 exploration wells, 16 dynamic penetration testholes, 6 hollow stem auger holes, 14 coreholes and 5 test pits were advanced at the site. A program of laboratory testing including water contents, grain size and hydrometer, Proctor compaction, triaxial permeability and direct shear testing was carried out. This geotechnical information formed the database to support the design of the facility.

The record of borehole sheets, and a site plan showing the locations of the various investigation points, were not included in the copy of the SNC report provided for review. The key strata encountered at the site include:

- topsoil layer
- peat bog
- glacial till – generally silty sand and gravel containing cobbles and boulders
- glaciofluvial sand and gravel (esker)
- alluvial silt to silty sand
- bedrock outcrop (limited).

In general, the embankment is founded on glacial till, and Table 1 summarizes the observed foundation conditions along the chainage of the embankment:

**Table 1: Interpreted Foundation Conditions (after SNC)**

Stationing along dyke (m)	Main surficial deposit	Ground surface elevation (m)
0+100 – 0+170	Rock outcrop	378 - 384
0+170 – 0+245	<1m peat on silt and sand	378 – 384
0+245 – 0+300	Esker sand and gravel	378 – 384
0+300 – 0+475	<2m peat on silt and sand	376 – 378
0+580 – 1+200	Till and/or silt	378 - 386
1+200 – 1+300	Silt and/or till	374 – 376
1+300 – 1+515	Till	372 - 379
1+515 – 1+615	Thin till over rock	372 – 374
1+615 – 1+710	Silt/sand over till	372 – 376
1+710 – 1+825	>5m sand over till	376 – 378
1+825 – 1+930	Till and/or silt	374 – 378
1+930 – 2+210	Sand over till	374 – 387
2+210 – 2+270	<2m sand over till with thin peat	373 – 374
2+270 – 2+940	<2m sand over till without thin peat	374 – 390

The groundwater table was observed between 0 and 4 m below ground in boreholes drilled at the site, corresponding to elevation 365.5 to 368.0 m.

One borehole was drilled on the tailings beach by Golder in 2009, which extended into the foundation below the tailings. The soils encountered in this borehole consisted of cobbly gravel to gravelly sand (interpreted to be glacial till) extending at least 9 m below the contact with the tailings mass.

### 4.3 Tailings Properties

Golder's archives contain some data on the properties of the tailings. A 1997 study was used to develop several design basis assumptions, as listed in Table 2.

**Table 2: Select Tailings Design Basis Values**

Parameter	Value	Source
Beach slope (0-500m)	2%	971-7088
Beach slope (500-1800m)	0.3%	971-7088
Beach slope (underwater)	3%	971-7088
Specific gravity	2.7	Mine
Water content, deposited tailings	26.3%	971-7088
Dry density, deposited tailings	1.58 t/m <sup>3</sup>	971-7088
Bulk density, deposited tailings	1.99 t/m <sup>3</sup>	971-7088

A study in 2000 presented grain size curves for deposited tailings deposited close to, and far away from the point of deposition. These results are summarized in Figure 1. The data indicates that the tailings are generally classified as silty sands. Near the deposition point the materials average 41% passing the #200 sieve, whereas the deposits further from the deposition point have on average 47% passing the #200 sieve. The data indicates moderate segregation with distance from the deposition point.

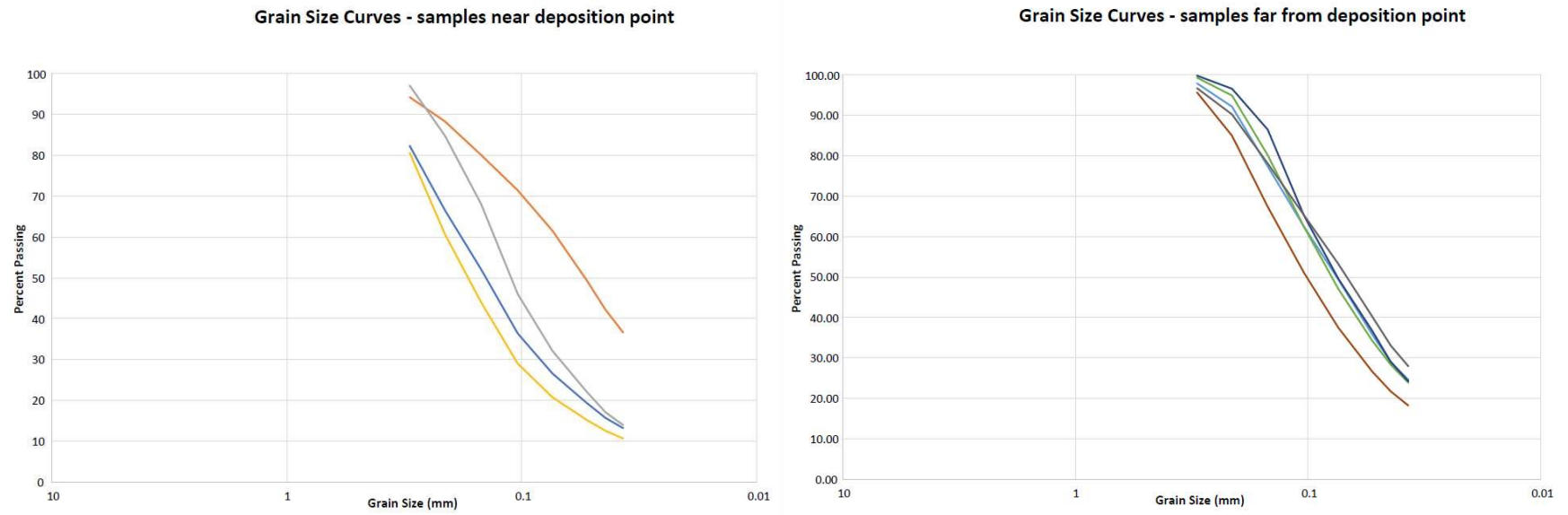


Figure 1: Tailings Grain Size Curves

The most comprehensive assessment of the properties of the tailings is contained in the 2009 report (09-1221-0011 RF Rev0). A series of five cone penetration tests with pore pressure measurement (CPTu) and one borehole with standard penetration test (SPT) were carried out on the tailings near the crest of the main embankment. Some conclusions of this study were:

- The tailings exhibited behaviour generally of clean sands, silty sands and sandy silts. Thin bands exhibiting behaviour of silty clay were observed randomly.
- The phreatic surface was observed at a depth between 10.0 and 14.6 m below the tailings beach.
- SPT N values (blows per 0.3 m of penetration) varied between 4 and 24
- Calculated against a seismic event corresponding to a 1:476 year return period, the tailings were calculated to be non-liquefiable.

Mining records indicate that a total of 75 Mt of tailings were produced over the life of mine.

It is likely that the liquefaction assessment will have to be updated in conjunction with the restart of operations, as the regulatory framework has evolved since the closure of the mine.

#### 4.4 Design of Starter Embankment

The design of the starter embankment varied depending on the inferred foundation conditions listed in Table 1. In general, the starter embankment, to elevation 381 m, was designed as a till embankment with a sand and gravel toe drain. Upstream slopes of 2H:1V and downstream slopes of 3H:1V, and an 8 m wide crest were proposed. Rock rip rap was placed on the upstream face and a thin granular traveling layer was placed on the crest. Key differences in the starter embankment related to the key-in measures into the foundation, as follows:

- Where the foundation was comprised of rock or till, the dyke was keyed in a minimum of 0.5 m.
- Where the foundation was comprised of peat, the peat was excavated completely.
- Where the foundation was comprised of thin alluvial sand or silt over till, the dyke was keyed in through the sand/silt and at least 0.5 m into the till.
- Where the foundation was comprised of thick alluvial sand or silt over or rock, the dyke was not keyed in, but a cement-bentonite cutoff wall was constructed under the embankment, and keyed into competent foundation.
- Where the foundation was through the esker sands and gravels, a till cutoff was excavated at 1.5H:1V slopes, through the esker materials and into the competent foundation (inferred as rock).
- The sand hill which was observed at chainage 1+930 – 2+210 was at an elevation greater than 381 m. In this location, a till cutoff was proposed at 1.5H:1V slopes, through the sand and keyed in 1 m into the till foundation. The cutoff was to be constructed up to elevation 381 m in preparation for future raises.

#### 4.5 Upstream Raise Design

After construction of the starter embankment, the design concept for the facility was revised, outlined in Golder report (971-7088) and consisted of raising in an upstream direction instead of downstream. The concept included constructing bi-annual compacted embankments, approximately 2.0 to 2.5 m high directly on the sub-aerially deposited tailings beach. In reality, the mine opted to construct approximate 1.5 m high raises annually. The raises were proposed for construction using compacted tailings, with a mine rock protective layer upstream and downstream, and sand filter zone/geotextile between the tailings and the mine rock. A typical sketch from the 2009 raise design is included below.

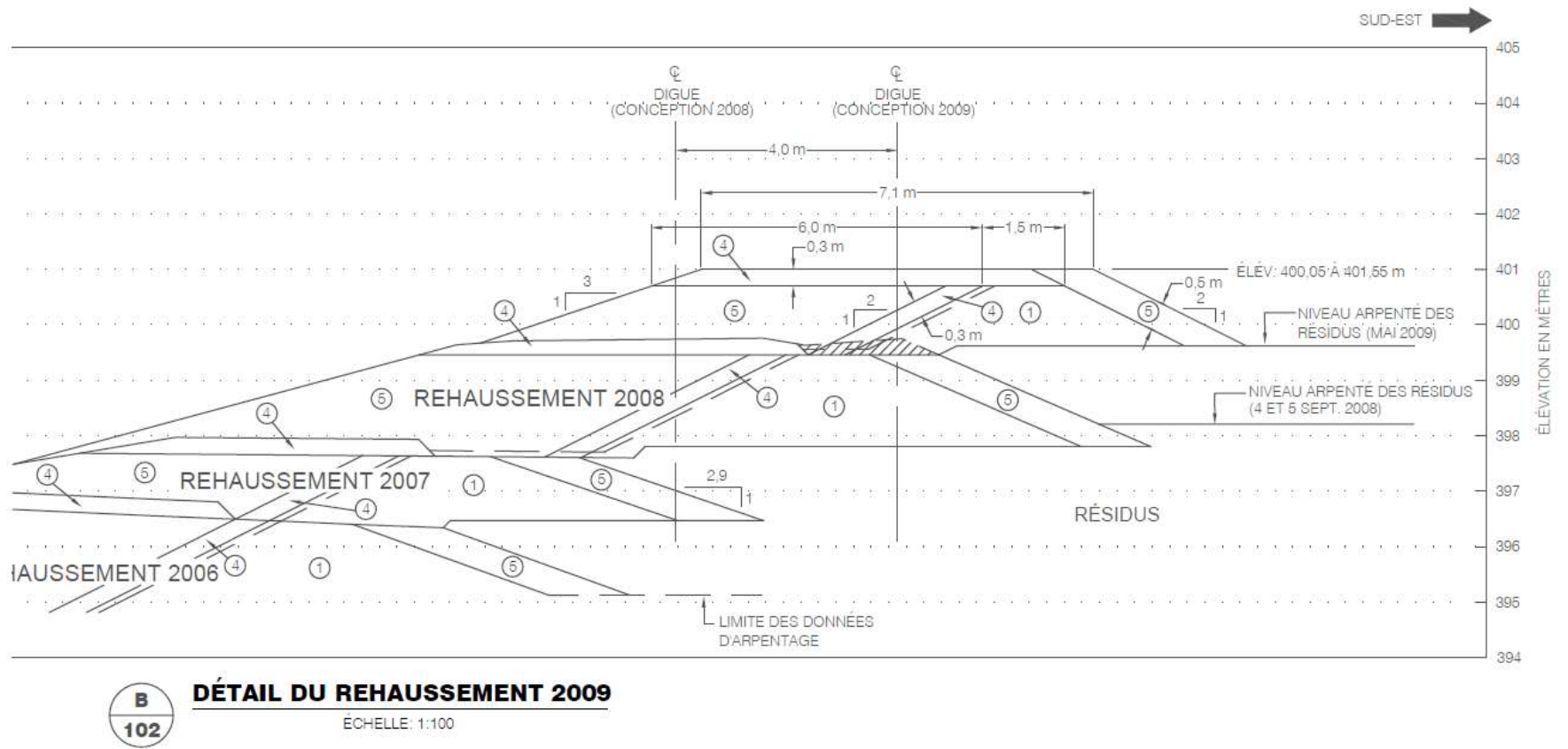


Figure 2: Sketch of typical raise design – 2009

Stability analyses carried out in connection with the design were referenced to the geotechnical parameters in the initial SNC Lavalin report. No new investigations were carried out in support of this concept.

## 4.6 Toe Berm Design

In 2004, the Mine expressed an interest to dispose of mine waste rock at the toe of the main embankment. This had a dual objective to stabilize the embankment and to economically dispose of waste rock. Under the original concept, it was proposed that the 30 m wide buttress would be constructed up to the elevation of the crest of the 2005-era main embankment and then raised in 2 m increments as the main embankment was raised. Golder assessed the stability of this concept (04-1221-008) and found that even for a conservative assumption of complete liquefaction of the tailings, that the revised embankment section met or exceeded the regulatory objectives for stability in place at that time.

The toe berm was constructed in 2005, up to the current dam crest elevation, however the toe buttress was not raised in subsequent years. In subsequent years, a smaller buttress constructed mainly of mine waste rock was added to flatten the downstream slope of the embankment.

## 4.7 Stability Analysis

### 4.7.1 Static and Seismic Analysis

Numerous slope stability analyses were conducted as the facility evolved. The geotechnical parameters used in the original SNC Lavalin report were generally carried forward in all subsequent analyses (Table 3). These parameters were derived by SNC Lavalin either from laboratory testing or from engineering judgment and experience with similar materials.

**Table 3: Soil Geotechnical Parameters (After SNC 007595-41ET-401)**

Soil	Description	Saturated unit weight (kN/m <sup>3</sup> )	Moist unit weight (kN/m <sup>3</sup> )	Cohesion (kPa)	Friction angle (deg)	Pore pressure coefficient, $r_u$
1	Tailings	22.0	22.0	0	25	0.45
2	Compacted till	20.5	20.0	0	37	0.4
3	Granular	20.5	20.0	0	37	0
4	Glacial till	20.0	19.5	0	35	0.2
4'	Alluvial silt	18.5	18.0	0	30	0.2

The seismic criteria applied for analysis of the structures was a horizontal ground acceleration of 0.05g, which corresponded to an earthquake with a 10% probability of exceedance in 50 years.

The analyses generally confirmed that the structures demonstrated factors of safety meeting or exceeding the regulatory minimums.

It is likely that the stability analyses will have to be redone in conjunction with the restart because the regulatory framework has evolved since the closure of the facility.

### 4.7.2 Liquefaction Susceptibility

A liquefaction susceptibility assessment was carried out in 2009 (09-1221-0011), to support the closure of the facility. Five cone penetration tests were advanced within the tailings. The resistance to liquefaction is interpreted as a cyclic resistance ratio (CRR) based on the results of the CPT testing. The cyclic susceptibility ratio (CSR) is calculated based on the designated earthquake acceleration and stress state within the tailings. The CSR for this study was calculated based on a seismic event with a 10% probability of exceedance in 50 years (1:476 year event).

The CPT profiles thus generated showed that generally the CRR was well above the CSR, indicating an acceptable factor of safety against liquefaction. A sensitivity analysis was carried out to assess liquefaction potential in the event that the tailings became saturated, and again the CRR generally exceeded the CSR.

The closure stability analyses therefore considered the intact strength of the tailings, and both static and seismic stability were re-evaluated. The calculated factors of safety exceeded regulatory requirements on this basis.

It is possible that current regulatory and industry guidelines will require a re-analysis of seismic and static stability in conjunction with the restart of operations. The provided data does not account for any improvements in density (and cyclic resistance) which may have occurred since 2009.

### 4.8 Implications for Future Raises

In 2008, Golder provided an opinion (08-1221-012) on the potential to expand the capacity of the current TSF to accommodate 17 Mt of tailings from a proposed underground development. It was concluded that such a change would require a raise of 5 to 6 metres above the original planned elevation of 402.0 m. This study concluded that the raise concept could be feasible, subject to additional technical studies, including a revised filling scheme/deposition plan, liquefaction assessment and stability re-assessment.

Whereas liquefaction and stability were re-assessed in 2009 (09-1221-0011), it is possible that current regulatory and industry guidelines will require a re-analysis of seismic and static stability in conjunction with the restart of operations.

## 5.0 HYDROTECHNICAL DATA REVIEW

The mine's TSF water management plan has been fairly simple: drainage from the approx. 2.8 km<sup>2</sup> tailings beach and from the approx. 2.3 km<sup>2</sup> mountain slope are collected by gravity to the TSF pond. The drainage includes both natural runoff and water exfiltrating from the deposited tailings. The pond water is evacuated by pumping for recirculation to the mill and, if there is surplus, for discharge to the environment after treatment for total suspended solids (TSS) removal at the existing Actiflo station.

The TSF water management system must meet the following operational requirements:

- 1) The operational pond water depth must be sufficiently high to allow water pumping out of the pond without strong resuspension of the fine particles on the pond bottom. The resuspension would increase the TSS concentration of the water and would limit the treatment efficiency. The issue can become a challenge in winter when the ice cover decreases the available liquid water depth. Based on historical operational experience (971-7088), a minimum 3 m water depth is required. For the current TSF topography, this is equivalent to a minimum operational water level at 396.0 m.

- 2) The available water storage capacity between the maximum operational water level and the spillway crest elevation (currently at 399.0 m) must accommodate without spilling the project flood event (“cru de projet” in the French original) as defined by the Directive 019 (MDDELCC, 2012): the sum between the 1:100 year snow cover melting over 30 days and the 1:1,000 year or the 1:2,000 year 24-hour rainfall. The rainfall’s frequency is chosen based on the tailings characteristics: 1:2,000 year if the tailings contain cyanide, are acid generating, or are otherwise classified as high risk, and 1:1,000 year otherwise. Troilus Mine tailings have historically fallen under the second category, for which the 1:1,000 year rainfall event applies.

Based on previous studies (10-1221-0005), the 1:1,000 year 24 rainfall has a depth of 125 mm. The 1:100 year snow cover has a depth of 464 mm. The total project flood event has a depth of 589 mm, which is equivalent of a water volume of approx. 3.0 M m<sup>3</sup>, when account for limited losses to evaporation and infiltration.

When using an Actiflo treatment capacity of 1,200 m<sup>3</sup>/hour or 650,000 m<sup>3</sup>/30 days, the TSF must be able to store approx. 2.3 M m<sup>3</sup> water without spilling. Using the beach stage-storage curve (10-1221-0005), this requirement is equivalent to a maximum operational water level at 396.9 m.

The described analysis neglected input of water due to tailings deposition and consolidation and return of groundwater seepage to the TSF, and output of water for recirculation to the mill. These combined fluxes are typically negative to the pond (i.e. more water is pumped to the mill than released from tailings) and as such they “help” empty the pond faster. Assuming an extreme spring month without operational fluxes is a more conservative scenario.

Operating the pond between 396.0 m and 396.9 m (0.9 m operational margin) is likely feasible, but is not practical because of the lack of flexibility to varying climate conditions. The Directive 019 project flood is a new requirement (since 2012) for the Troilus Mine. Increasing the crest of the containment dykes to add a minimum 1.0 m of operational freeboard is likely required. In addition, a detailed water balance decision making support tool would increase the operational flexibility by allowing to operate at higher water levels during the summer and fall seasons. Also, if the actual Actiflo treatment capacity is less than 1,200 m<sup>3</sup>/hr, the required water storage in the TSF increases.

- 3) The emergency spillway (currently at 399.0 m, 1.0 m below the 400.0 m dyke crest) must safely evacuate the probable maximum flood (PMF) (requirement from Directive 019). The freeboard above the maximum PMF must be sufficient to prevent the waves generated by a 1:2 year wind to overtop the dyke (recommendation from CDA guidelines).

The PMF conveyance requirement is new (since 2012) and the current 25-m wide spillway have not been verified for it in the past. According to SNC Lavalin (2004), the probable maximum flood (PMP) for the Troilus Mine region is approx. 340 mm/24 hour. Assuming an initial water level at the spillway crest, which is very conservative, the 25 m wide spillway is sufficient to maintain the PMF water level below 399.6 m; for this statement, Golder re-ran a hydrological model developed during a previous project (10-1221-0005). The remaining 0.4 m freeboard is also likely sufficient to accommodate the 1:2 year wave run-up; extreme wind velocities for the mine site have not been extracted in the past, but Golder estimated the run-up of a 30 km/h wind to 0.35 m. This has to be verified in future studies.

The rock size of the erosion protection material (D<sub>50</sub> of approx. 300 mm for the upstream segment) was not verified in the current analysis, but it is estimated that larger rocks are needed to withstand PMF flows.

An additional water management aspect to consider for the TSF development is the location of the emergency spillway during the future TSF life:

- Currently, the spillway is located in the south-west TSF corner. The downstream spillway channel is built partially on the downstream face of the dyke (from elevation 394.0 m to 399.0 m at a slope of approx. 3H:1V) and partially on the waste rock berm, which is placed downstream of the dyke (from elevation 378.5 m to 394.0 m at a slope of 4.5% to 17.3%).

The mine tested in 2018 where the excess pond water could be discharged without treatment, directly into the TSF emergency spillway and allowed to flow via a pipeline to the discharge point PR-2. The test results indicated that the pond water met discharge water quality objectives in terms of iron content and suspended solids. Troilus is preparing a request for certificate of authorization to implement this practice on a routine basis. Appropriate controls will be implemented to verify discharge water quality, and provisions in place to either recycle the effluent back to the TSF pond or through the ActiFlo plant. This procedure has the advantages of reducing water treatment requirements and reducing the gradual accumulation of iron-rich water in the facility. This operational practice should be re-evaluated under an operating mine scenario, as the suspended solids in an operating pond will likely be higher than in the current, post-operation pond.

- As the TSF height increases, increasing the length of the emergency channel, which is built on the downstream face of the dyke, might not be the optimal solution in terms of costs (very large rock size would be required) and residual risks. Two alternatives are:
  - Shifting the emergency spillway towards south, where a natural terrain high point, would allow to build the channel directly on natural ground. The terrain slope is steep (>25%) and a significant volume of fill would be required to flatten it.
  - Building the emergency spillway channel along the mountain slope, from the east end of the pond towards south. This option might require the creation of a new effluent point to the environment. The option was studied in the past and was rejected because of the challenge to excavate a wide channel into the steep (up to 100%) mountain slope. However, the option should be re-evaluated for a higher TSF configuration.

The final aspect addressed in this review related to the water quality of the seepage water collected at several collection points (PR2, PR5, and PR7) at the toe of the containment dyke. From our experience at Mine Troilus between 2010 and 2016, high iron concentrations in the seepage water prevented direct release to the environment. We understand that passive iron removal measures were implemented, but we don't have a confirmation of their effectiveness. Mine Troilus will need to verify this aspect:

- If the currently observed concentrations satisfy the applicable effluent water quality guidelines, Mine Troilus will be able to discharge the water through-out the operational period.
- If the above is not true, Mine Troilus will need to return the water to the TSF pond.
- It is important to verify the Actiflo treated water meets the applicable effluent water quality guidelines.

In summary, there seem to be no major, water management flaws for restarting the operation of the Troilus Mine TSF. The main observations resulting from this review include:

- New regulatory requirements lead to a recommendation to increase the water storage freeboard by approx. 1.0 m relative to the crest of the emergency spillway to provide for more operational flexibility of the pond water management.
- The existing emergency spillway is wide enough to evacuate safely the probable maximum flood. An increase in the size of the erosion protection rocks on the upstream 35 m of the spillway channel is likely required.
- When planning the future TSF development, an option comparison should be carried out to establish the optimal emergency spillway location.
- A few hydrotechnical and hydrological studies are recommended before the re-start of the TSF operations including:
  - Verifying the wave run-up calculations based on recent extreme wind velocities statistics;
  - Confirming the required erosion protection rock size for the upstream segment of the emergency spillway channel.
  - Planning the pond water level operation by use of a water balance model to limit the risk of an environment spill and the risk of process water deficit for the mill.

## 6.0 DEPOSITION MODELLING

Based on a digital surface model provided by Troilus, and supplemented where required by existing contour data, a deposition model was constructed. The following basis of design assumptions were used for the deposition model:

**Table 4: Basis of Design for Deposition Model**

Parameter	Design Basis
Production Rate	10,000 tpd @ 365 days per year = 3.65 Mt/year
Deposited Dry Density	1.5 t/m <sup>3</sup>
Beach slope 0-500 m	1.5%
Beach slope 500-pond	0.3%
Beach slope underwater	3%
Minimum pond depth	3 m
Water plant treatment capacity	800 m <sup>3</sup> /hr
Raise strategy	Annual perimeter dyke raises

For the purpose of high level stage-storage modelling, no design basis was used to establish required freeboards, and these will have to be revised in detailed design. Rather, the deposition model was assumed to essentially mirror the conditions at the end of mine life. Therefore, beach slopes, freeboard and pond size were assumed to mirror the end of mine-life contours as the facility was raised.

Figure 3 shows a stage storage curve for the facility, which is obtained by raising the perimeter embankment at an approximate 4H:1V slope, and maintaining beach slopes, freeboard and pond size constant. Whereas the natural topography to the east could support significant TSF expansion (estimated 63.5 Mm<sup>3</sup>) by raising the main and south embankments, there may be economic constraints that make such expansion unfavorable. These scenarios and constraints are discussed in this section.

## 6.1 Year 1-2 Model

A model was constructed to demonstrate the conditions at the end of the first stage of deposition. This model is useful to estimate:

- The volume of material required to effect an upstream raise. For the raise embankment, Golder used a somewhat larger area section compared to historic dam raises (see Figure 4). This was done in anticipation of potentially more aggressive seismic loading conditions relative to the initial design.
- The annual rate of rise for the proposed production rates.
- The available capacity for each raise.

Figure 5 shows a plan view of the tailings basin at the end of year 2. To construct a nominal 2 m high raise, a volume of 220,000 cubic metres of material would be placed. This volume would be partially composed of tailings, and partially of granular drainage aggregate. Such material would require controlled placement and compaction, possibly with geotextile separation and rip rap slope/erosion protection. For CAPEX/sustaining CAPEX planning, a similar volume can be estimated bi-annually.

The annual rate of rise is estimated at 0.85 m per year (i.e., 3.65 Mt/year). It follows that a 1.5 m raise would be required every 1.76 years. Consideration would be given to constructing raises in the order of 1.7 (nominally 2 m) m at a time, such that construction campaigns would be required only every second year. Alternately, nominally 1 m raises every year would be an option.

Although it is not an exact figure, the geometry of the basin suggests that these parameters can serve as a high level estimate of earthworks requirements for bi-annual construction programs.

## 6.2 Year 11 Model

Bi-annual raises to the main and south embankments would be constructed as production advances. At year 11, the main perimeter embankment crest reaches the elevation of the natural topographic high between the main embankment and the south embankment (~411.5 m). This height of natural ground is considered a prime candidate to establish a permanent closure spillway for the facility. In addition, the access road to the current pumphouse could likely be operated until year 11, but would be flooded thereafter.

Figure 6 shows a plan view of the facility at year 11. Available storage is estimated at 28.3 Mm<sup>3</sup> (42.5 Mt).

## 6.3 Year 25 Model

If the mine wishes to expand beyond elevation 411.5 m (i.e., year 11, or 42.5 Mt), then the main embankment and south embankment would be joined, and it may be necessary to construct a new closure spillway, to the east of the south embankment, as well as raising the access road to the pumphouse. Such a concept was considered in the past and was judged to be very expensive and could require a significant change to the environmental permitting for the facility.

The natural containment afforded by the topographic ridge to the east of the facility could support expansion up to approximate elevation 423 m. In this scenario, a permanent closure spillway could be established to the east of the south embankment. Figure 7 shows a sketch of the facility footprint at year 25. Estimated storage volume is 63.5 Mm<sup>3</sup> (95.2 Mt). The technical and economic feasibility of this option has not been established.

## 7.0 OPTIONS FOR TAILINGS MANAGEMENT

There are many options which could be considered for the restart of operations at Troilus Mine. The establishment of secure and permanent storage of mine tailings satisfies the following objectives:

- Minimize cost.
- Minimize environmental impacts.
- Minimize societal impacts and concerns.
- Minimize additional land disturbance.
- Avoid schedule delays to the resumption of operations.

Many options can only be considered in conjunction with overall mine development considerations, such as fines/coarse segregation, or storage in mined out pits or underground workings. Assessment of these options is outside the scope of this study. There are also other special considerations (i.e., potential for acid generation, presence of highly sensitive environments, dust control issues), and these also are not considered in this analysis.

It is useful to discuss typical strategies related to tailings dewatering, which could be considered as the project moves forward into feasibility study. Tailings dewatering has been adapted to produce tailings of variable consistency, from slurry (like water), to thickened (like molasses) to paste (like toothpaste) to filtered (like soil), see Mend 2017<sup>1</sup>.

The following sections provide a brief synopsis of tailings dewatering options which could be applicable for this site.

### 7.1 Slurry Tailings Management

The historic operating principle for the facility, consisting of slurry tailings spigotting from the south, west and north perimeter, accumulation of supernatant water in an operational pond at the east edge, and re-use or pump/treat/discharge of the supernatant water remains technically feasible, and is used widely in the industry. The storage of supernatant against a natural topographic high is beneficial in terms of embankment stability, and the demonstrated performance of an upstream raising concept is encouraging. Slurry disposal uses conventional equipment and typically has the lowest capital and operating cost per tonne for transport and placement.

Slurry tailings deposition typically requires significant up-front capital expenditure, but the costs of transportation and placement are subsequently low. For the Troilus TSF, high up-front cost is less of a consideration as the starter facilities have been constructed. Operationally, water management can be problematic because of the high volumes of surplus water; also suspended solids in the supernatant pond have caused operational difficulties in the past. Low transportation and deposition costs are somewhat offset by higher water treatment costs.

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<sup>1</sup> Mine Environment Neutral Drainage, 2017, “*Study of Tailings Management Technologies*”, MEND report no 2.50.1, October 2017.

With this approach, the coarsest tailings settle close to the discharge point while the fines settle in the middle of the facility. The fines portion in particular can take a long time to consolidate and may be untrafficable for an extended period after cessation of operation. Implementation of effective closure strategies may be complicated and have an undefined schedule. Seepage from the facility will continue for a long period post-closure. In relative terms, post-closure costs and schedule are highest/longest for a slurry deposition facility.

## 7.2 Thickened Tailings

The solids content of the tailings stream is increased at the plant in a deep bed thickener. The underflow is pumped and deposited hydraulically, while the overflow is re-used as process water. Thickening uses conventional equipment for dewatering, pumping and placement. The resulting tailings mass resembles a viscous fluid, and will exhibit segregation and water bleed after deposition.

The key advantage of this method is improved management of water, as a significant portion of the process water is reclaimed at the plant. The result is a smaller supernatant pond and lower water treatment costs. Some supernatant water is to be expected, and the evaluation of this option must be made in consideration of the overall water balance of the mine.

Thickened tailings management may reduce, but not eliminate post-closure issues of contaminant seepage, consolidation time and available closure technologies. Typically, the time required for closure may be somewhat less than for a slurry tailings facility.

No technical issues have been identified which would preclude or disfavor thickened tailings management.

## 7.3 Paste Tailings

Tailings are dewatered more aggressively (~70-75% solids by weight) at the mill such that they do not segregate upon placement. Paste provides a great benefit in terms of water management, reduced water treatment costs and results in a more stable (physically and chemically) tailings deposit. Non-segregating tailings have low water bleed in the disposal facility and financial and schedule risks post-closure are reduced. It is typically possible to reshape, cover and close paste tailings facilities a few years after end of operations.

The disadvantage of paste technology is higher capital and operating cost. Specialized equipment is required (paste thickener, vacuum filtration, positive displacement pumps) and energy costs are increased due to pumping requirements.

No technical issues have been identified which would preclude or disfavor paste tailings management at this site.

## 7.4 Filtered Tailings

Tailings are aggressively dewatered at the mill (80-85% solids by weight) using pressure filtration equipment, then hauled for disposal using conveyors or trucks. All free process water is managed at the mill, and this option requires the least amount of water to be managed in the tailings facility. The tailings material behaves like a soil, and as such can be stacked at steeper slopes and at higher densities, resulting in efficient use of airspace. Under certain environmental conditions, the tailings can be compacted and used as structural fill. There is little water exfiltration from the tailings body after placement. Generally, filtered tailings facilities can be designed to achieve a closure configuration during operation, such that the schedule and cost post-closure is limited.

The main disadvantage of this option is high capital and operating cost. Specialized equipment, high manpower requirement, high maintenance and high energy costs must be considered against the environmental and closure benefits.

No technical issues have been identified which would preclude or disfavor filtered tailings management at this site.

## **7.5 Summary of Tailings Management Strategies**

Slurry tailings deposition has been proven at this site and we have identified no technical issues, which would preclude continued application of this technology. Meanwhile, we recommend that it is in Troilus' best interests to consider alternative strategies that implement increased tailings dewatering as the feasibility study is advanced. Current tailings management practice globally is moving towards increased tailings dewatering in order to facilitate closure of the facility and reduce overall environmental impacts.

Based on our current understanding of the site and of the proposed mining plan, we cannot assess whether alternative strategies (such as underground disposal) could also be viable.

Table 1 provides a more comprehensive comparison of the benefits and drawbacks of the various technologies.

**Table 5: Comparison of Tailings Storage Options**

Category	Slurry 30 - 60 wt% solids	Thickened Tailings segregating and non-segregating 60 - 70 wt% solids	Paste 70 - 75 wt% solids	Filter Cake 75 to 80 wt% solids
<b>Environment</b>				
Process water pond, recycling	Large water pond. Recycle from pond, not mill. Highest volume of fresh water make up if no recycling.	Between slurry and paste, lower use of fresh water make-up than slurry.	Very small water pond, high recycle rate at the mill.	No pond, 100% recycle at the mill
Chemical stability	ARD: Saturated tailings minimizes ARD except for exposed beaches.	ARD: saturated tailings minimize ARD except for desiccated surface.	ARD: saturated tailings minimize ARD except for desiccated surface. Tailings should be covered shortly after deposition	ARD: unsaturated tailings allow ARD onset. Tailings must be covered shortly after deposition
	ML: leachable tailings will contaminate large water body. Prevention of exfiltration required	ML: leachable tailings will contaminate smaller water body. Prevention of exfiltration required	ML: porewater contaminated but minimal water bleed results in smaller release.	ML: Depends on flushing rate (climate). Tailings must be covered to minimize dispersion of leachable particulates to receiving environment.
Potential effect on receiving environment - groundwater, surface water	Risk of contamination to groundwater and/or surface water through infiltration and seepage. Both tailings area and water ponds need to be lined.	segregating materials are similar to slurry, non-segregating material more similar to paste	Little free water and water bleed. Minimal exfiltration of pore water to ground or through containment structure	Little exfiltration of tailing water.
Water treatment needs	High: Large volume of water may require ongoing treatment before discharge to receiving environment. May require additional sedimentation/polishing ponds.	Variable: Segregating materials release lower water volume than slurry, possibly lower discharge frequency. Non-segregating material are similar to paste.	Low: Low volumes of free water.	Minimal: runoff water of exposed tailings only
Wind and water erosion	Low for bulk of tailings, high for exposed beach	between slurry and paste	lower erosion except for (if) desiccated surface which could be deeper than slurry	Moderate to high. Needs to be covered shortly after deposition.
<b>Technical</b>				
Stability of containment	Water stored against dam, requires more robust dams with impermeable core	Similar slurry for segregating material although typically lower volume of water. Similar to paste for non-segregating (higher solids content).	Non-segregating tailings placed against dams: more stable than slurry or thickened. Smaller dams or berms.	Highest stability, minimal to no berms or dams.
Tailing thickening /transport equipment	Slurry pumps.	Conventional thickener and centrifugal pumps.	Paste thickener and positive displacement pump. Filtration of part of stream may be required to get desired consistency.	High rate thickener and disc or belt filter. Conveyor or haulage trucks. Mobile equipment for placement.
Distance between mill and deposition area	any	any, may require booster pump	Dewatering/paste plant close to tailings impoundment if distance is over about 4km.	any but increased haulage cost if far.
Under ground backfill	Limited to hydraulic fill, slimes on surface. May require additional coarse fill.	Hydraulic fill possibly thickened full tailings stream, high water volume may require high binder addition.	Same stream for u/g and surface	May partly dewater u/g stream for backfill.
<b>Financial</b>				
Dewatering and thickening (major equipment)	Capital Cost: base case  Operating Cost: base case	Capital Cost: Low. Dewatering plant: thickener centrifugal pumps.  Operating Cost: Low: Some additional power, maintenance and reagent costs.	Capital Cost: High: Dewatering plant: paste thickener, vacuum filtration, positive displacement pumps.  Operating Cost: High: Additional manpower (operation and maintenance). Increase in power, maintenance and reagent costs.	Capital Cost: Highest: Dewatering plant, thickeners, vacuum disc or belt filters; conveyors, load out systems.  Operating Cost: Highest: Additional manpower (operation and maintenance). Higher increase in power than paste, maintenance and reagent costs.
Tailings transportation	Capital Cost: base case (low) Pipeline would be larger than other options.  Operating Cost: base case (low).	Capital Cost: Low Similar to slurry, smaller pipeline.  Operating Cost: Low, similar to slurry.	Capital Cost: High Bigger pumps, higher pressure rated pipeline. Large increase in cost with pumping distance.  Operating Cost: High: Pumps will require more maintenance.	Capital Cost: Possibly Highest Conveyor or fleet of haulage truck and quality road  Operating Cost: Highest Manpower, maintenance and energy costs.
Tailings placement	Capital Cost: Base case (low)  Operating Cost: base case (low)	Capital Cost: Moderate Similar to slurry. Would require more discharge points, longer pipeline to go around tailings.  Operating Cost: Low, however larger power requirement than slurry.	Capital Cost: Moderate May need disposal tower  Operating Cost: Moderate-low Manpower for more frequent move of discharge points, pipeline inspections.	Capital Cost: Possibly Highest Road maintenance equipment and material placement in tailings area.  Operating Cost: Possibly Highest Continued manpower, maintenance and energy to operate and maintain mobile fleet.
Tailings containment and water treatment	Capital Cost: High Liner, dams design and construction costs.  Operating Cost: Moderate Frequent inspections; water management and treatment, maintenance of water treatment plant.	Capital Cost: Moderate Closer to paste than slurry. May require additional holding capacity for recycled water at mill. Smaller water recycling system from TMF  Operating Cost: Moderate. Less water to pump around.	Capital: Significantly lower than thickened tailings and slurry. Small containment.  Operating: Low Frequent inspections; lower water management.	Capital Costs: Low  Operating Cost: Very low
<b>Closure</b>				
Environment / risk	Continued risk of contaminant seepage and dam failure. Long post-closure monitoring period.	Continued risk of contaminant seepage, possible lower risk of dam failure in time. Long post-closure monitoring period.	Smaller period for closure, little risk to water quality (minimal seepage). Lower risk of long-term failure. Must maintain cover.	No seepage, little risk of water contamination. Must maintain cover.
Technical	Slimes take a long time to consolidate, difficult to cover, reshaping and contouring difficult. Likely require long term treatment and dam maintenance	Consolidation time better than slurry and similar to paste. Slightly longer time than paste to reshape and contour at closure. Similar to paste with regards to water treatment and dam maintenance	Easier to reshape and contour for closure within a few years after tailings deposition as ceased.	Material can be stacked and place to get required final topography.
Economic	Highest: Costs incurred at and post-closure. Long period of care & maintenance before (if) possible to cover. Long period of water collection and treatment.	Moderate: Similar to paste, slightly longer time prior to placing cover. Costs incurred at and post-closure.	Lower: Costs incurred during operation or at closure. Possible progressive rehabilitation.	Lowest: Costs incurred during operation or at closure. Reclamation can be nearly complete at closure.

Note: Items under each criteria need to be verified via additional, more detailed studies

**Relative rating of options**

most desirable
intermediate
least desirable

## 8.0 CONCLUSIONS AND CONSIDERATIONS FOR DEVELOPMENT

The historic information reviewed suggests that the foundation conditions for the main embankment generally consist of relatively dense and over consolidated glacial till and/or bedrock. The nature of the deposited tailings appears to support upstream raising of the facility. The TSF water management consists mainly in controlling the pond water level and maintaining sufficient storage capacity for large flood events; also in having an emergency spillway that can evacuate safely extreme peak flows.

Re-commissioning of the facility and further raises using the historic development design would appear to be technically feasible. The report has assessed at a very high level some technical, economic and environmental constraints that require evaluation prior to restart. The following considerations are presented:

- It will be necessary to review the design basis prior to restart of the facility, as both Directive 019 and the CDA Guideline have evolved since the closure of the mine. It would be recommended that the mine implement the risk-informed approach in the CDA Guideline, although it may in certain cases be more rigorous than Directive 019.
- The liquefaction assessment will have to be updated in conjunction with the restart of operations, as the regulatory framework has evolved since the closure of the mine. It will be necessary to verify the tailings properties for the new process/tailings.
- The stability analysis (static and seismic) for the facility should be reviewed when the mine plan is developed, as the regulatory framework has evolved since the closure of the facility.
- Consideration could be given to reducing the risk of embankment instability by disposing of neutral mine waste rock as a buttress against the embankment, as was done in 2005.
- The ultimate capacity of the facility will depend on the ultimate closure design, in particular the establishment of a permanent closure spillway. Standard practice is to establish closure spillways on natural ground to promote long term performance.
- New regulatory requirements lead to a recommendation to increase the water storage freeboard by approx. 1.0 m relative to the crest of the emergency spillway to provide for more operational flexibility of the pond water management. This recommendation will need to be verified by additional studies.
- The existing emergency spillway is wide enough to evacuate safely the probable maximum flood. An increase in the size of the erosion protection rocks on the upstream 35 m of the spillway channel is likely required.
- The management of the seepage water at the toe of the dykes depends on the observed water quality.
- Mine Troilus needs to verify that the Actiflo treated water meets all applicable water quality standards before release to the environment.
- When planning the future TSF development, an option comparison should be carried out to establish the optimal emergency and closure spillway location.
- A few hydrotechnical and hydrological studies are recommended before the re-start of the TSF operations including:
  - Verifying the wave run-up calculations based on recent extreme wind velocities statistics.

- Confirming the required erosion protection rock size for the upstream segment of the emergency spillway channel.
- Planning the pond water level operation by use of a water balance model to limit the risk of an environment spill and the risk of process water deficit for the mill.
- Raising the facility to nominal elevation 411.5 m can likely be achieved without major changes to the previous operating permit.
- We recommend that Troilus' consider alternative strategies for tailings management that implement increased tailings dewatering as the feasibility study is advanced.

## 9.0 CLOSURE

We trust that this report is consistent with the objectives set out for the project and that it meets the current needs of Troilus. We thank you for the opportunity to be of service and welcome any comments or questions you may have.

**Golder Associates Ltd.**

<Original signed by>



Vlad Rojanschi, Ph.D., ing.  
*Associate, Senior Water Resources Engineer*

LFG/VR/rd

<Original signed by>

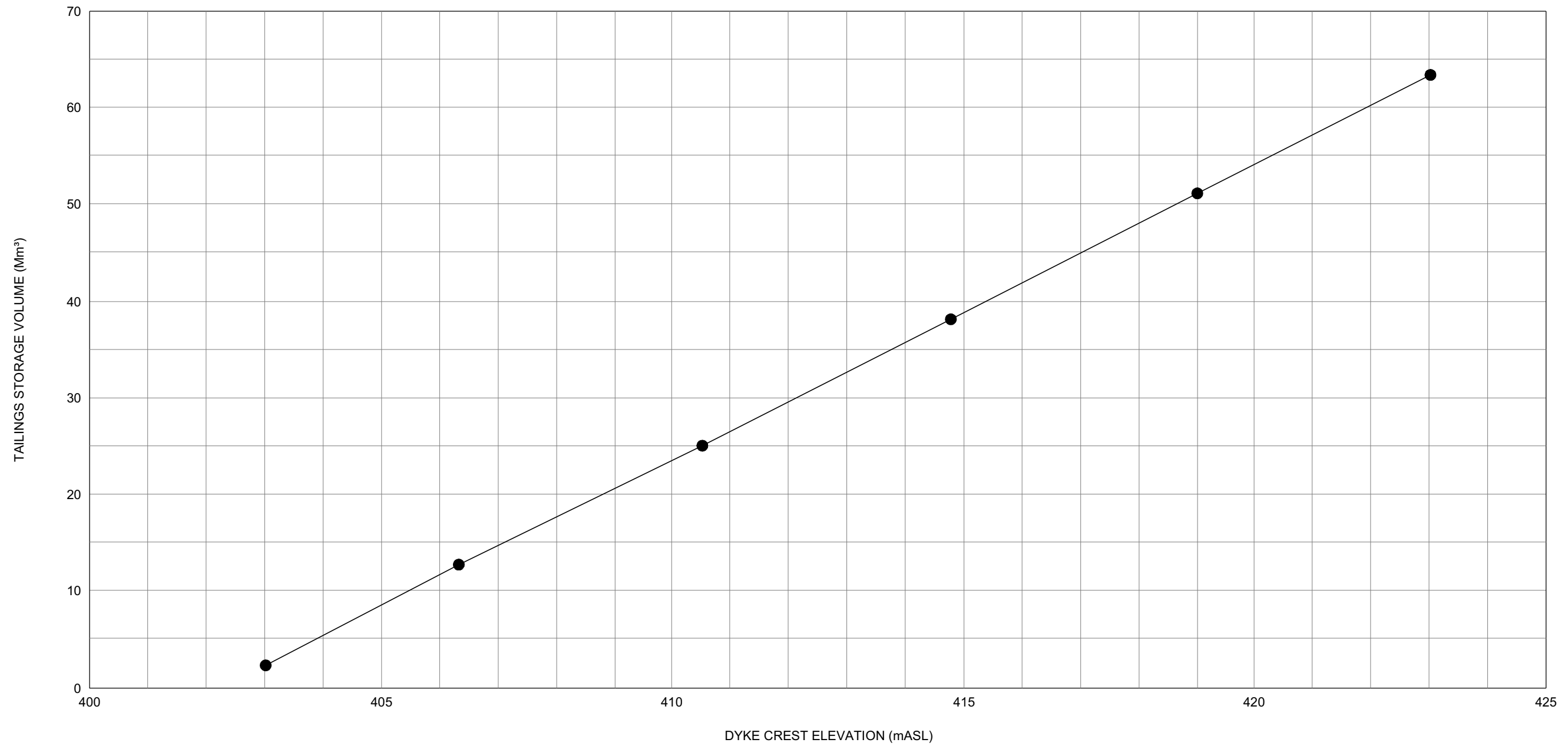
Laurent Gareau, M.Sc., ing.  
*Principal, Senior Geotechnical Engineer*

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[https://golderassociates.sharepoint.com/sites/31886g/preparation of deliverables/001-18107725 report final.docx](https://golderassociates.sharepoint.com/sites/31886g/preparation%20of%20deliverables/001-18107725%20report%20final.docx)

**FIGURES**

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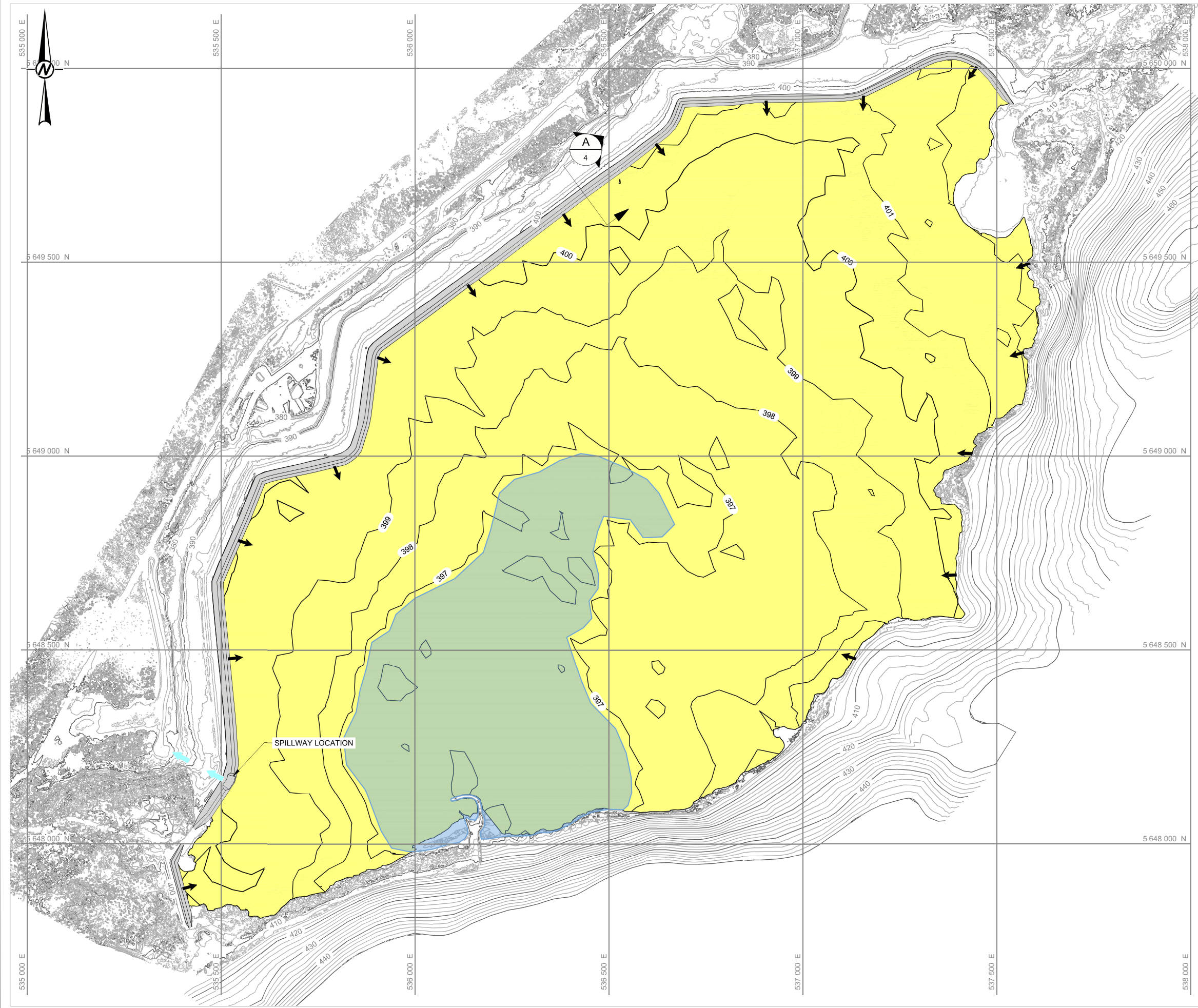
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TROILUS GOLD CORPORATION			
PROJECT			
TROILUS GOLD CONCEPTUAL DEPOSITION PLAN			
TITLE			
STAGE-STORAGE CURVE			
CONSULTANT	YYYY-MM-DD	2019-01-22	
	DESIGNED	JDS	
	PREPARED	JDS	
	REVIEWED	LFG	
	APPROVED	VR	
PROJECT NO.	PHASE	REV.	FIGURE
18107725	5000	0	3



IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANS B 28 mm

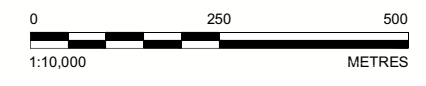


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**LEGEND**

- DEPOSITION BEACH
- APPROXIMATE POND AREA
- EXISTING GROUND CONTOUR (2m INTERVAL)
- DEPOSITION SURFACE CONTOUR (1m INTERVAL FOR CLARITY)
- DEPOSITION LOCATION



CLIENT  
TROILUS GOLD CORPORATION

PROJECT  
TROILUS GOLD  
CONCEPTUAL DEPOSITION PLAN

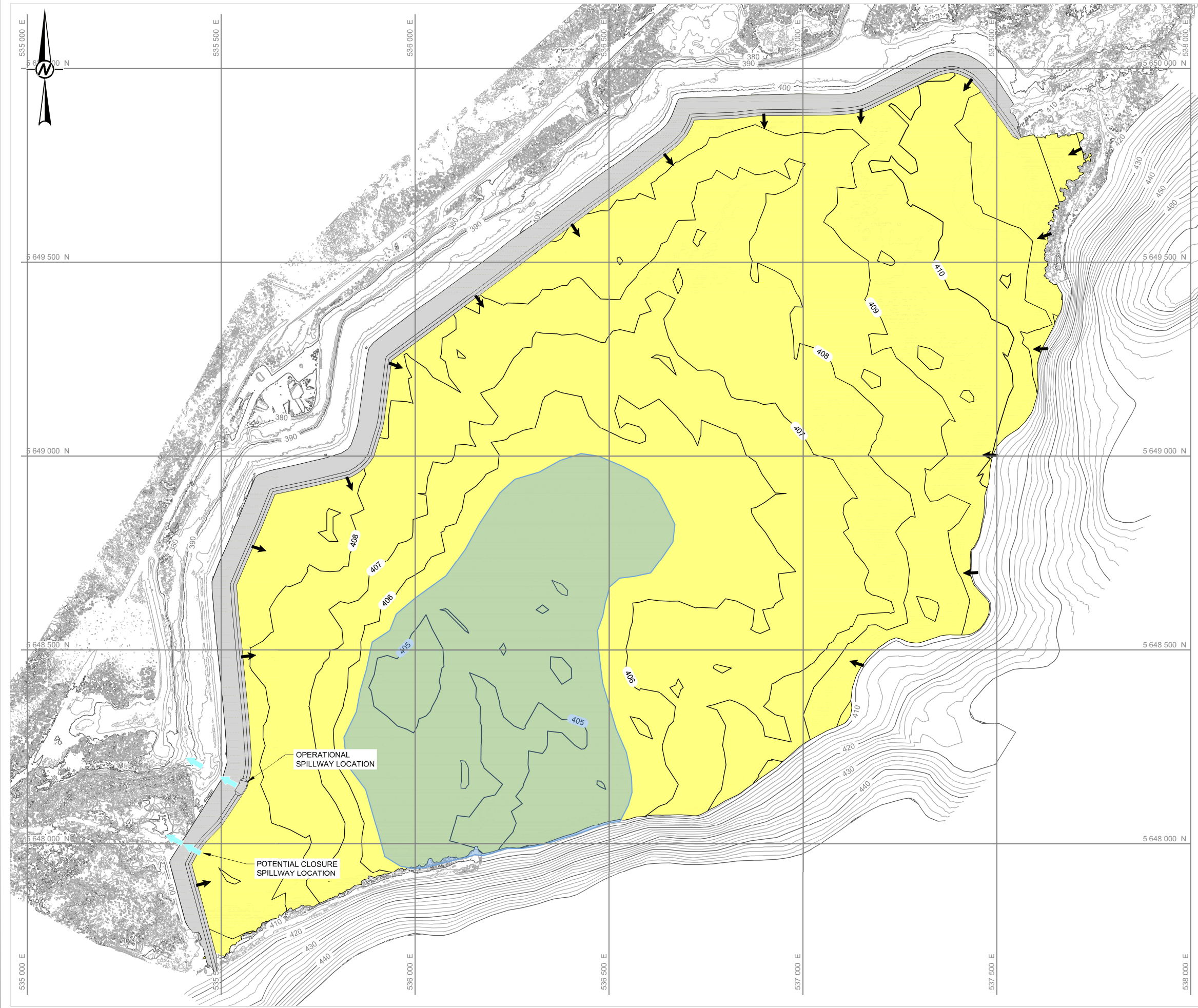
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CONSULTANT	YYYY-MM-DD	2019-01-22
	DESIGNED	JDS
	PREPARED	JDS
	REVIEWED	LFG
	APPROVED	VR

PROJECT NO. 18107725      PHASE 5000      REV. 0      FIGURE 5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANS B

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**LEGEND**

- DEPOSITION BEACH
- APPROXIMATE POND AREA
- EXISTING GROUND CONTOUR (2m INTERVAL)
- DEPOSITION SURFACE CONTOUR (1m INTERVAL FOR CLARITY)
- DEPOSITION LOCATION



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PROJECT  
TROILUS GOLD  
CONCEPTUAL DEPOSITION PLAN

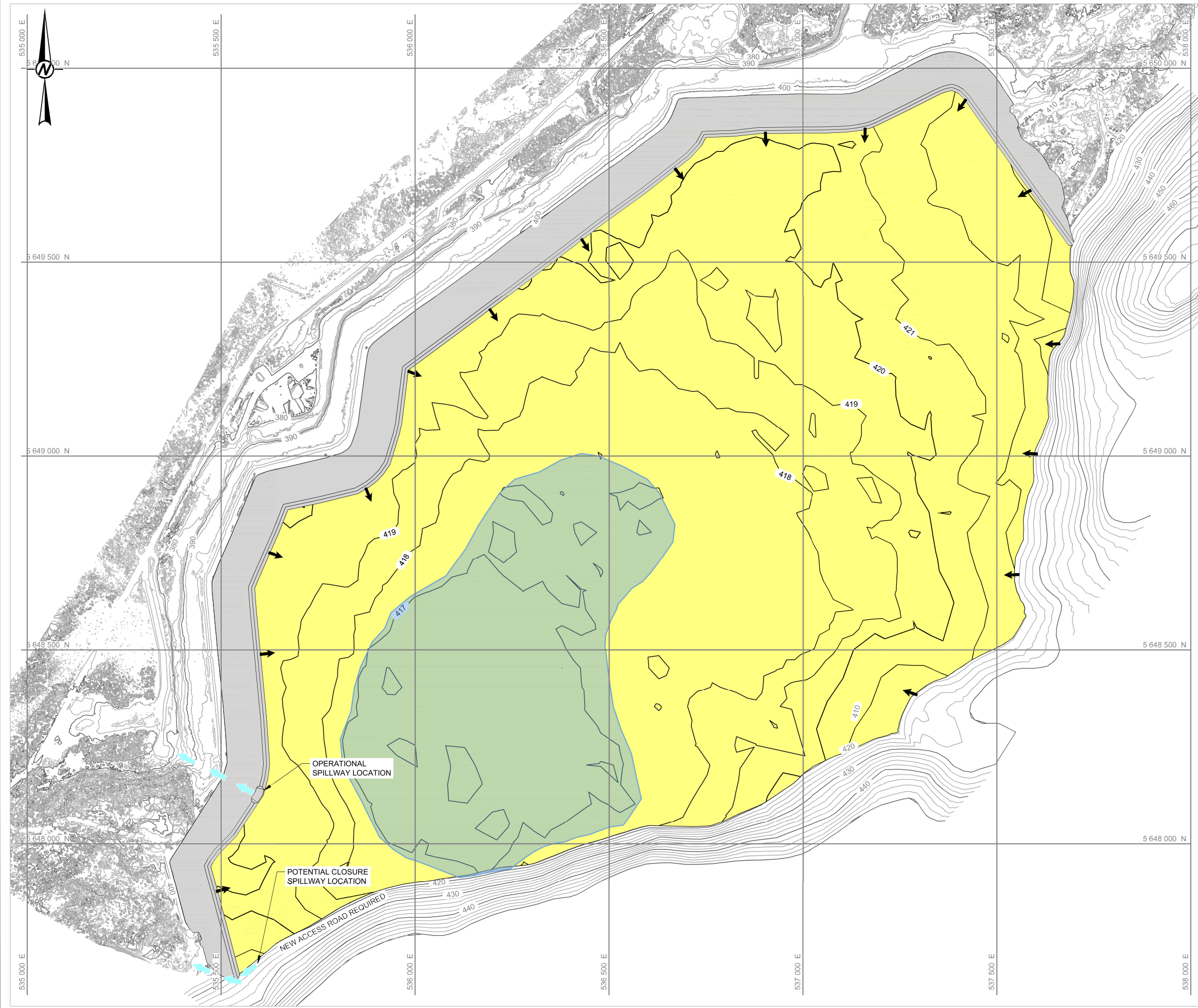
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DEPOSITION PLAN - YEAR 11

CONSULTANT	YYYY-MM-DD	2019-01-22
	DESIGNED	JDS
	PREPARED	JDS
	REVIEWED	LFG
	APPROVED	VR

PROJECT NO. 18107725      PHASE 5000      REV. 0      FIGURE 6

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANS B

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**LEGEND**

- DEPOSITION BEACH
- APPROXIMATE POND AREA
- EXISTING GROUND CONTOUR (2m INTERVAL)
- DEPOSITION SURFACE CONTOUR (1m INTERVAL FOR CLARITY)
- DEPOSITION LOCATION



CLIENT  
**TROILUS GOLD CORPORATION**

PROJECT  
**TROILUS GOLD  
CONCEPTUAL DEPOSITION PLAN**

TITLE  
**DEPOSITION PLAN - YEAR 25**

CONSULTANT	YYYY-MM-DD	2019-01-22
	DESIGNED	JDS
	PREPARED	JDS
	REVIEWED	LFG
	APPROVED	VR

PROJECT NO. <b>18107725</b>	PHASE <b>5000</b>	REV. <b>0</b>	FIGURE <b>7</b>
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANS B 28 mm



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