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Geotechnical Evaluation
Borrow Source Assessment – Clinton Creek Area
Dawson, Yukon – 2015

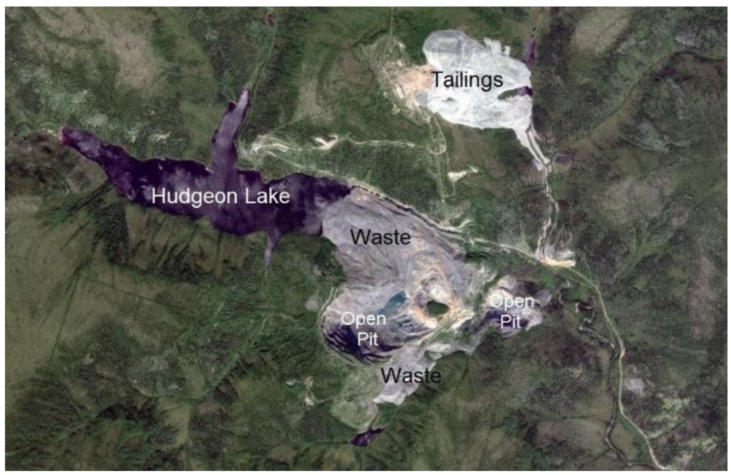
Prepared For: **Yukon Government**
Energy, Mines & Resources
Assessment and Abandoned Mines

Date : **January 8, 2016**

EXECUTIVE SUMMARY
Geotechnical Evaluation – Borrow Source Assessment
Clinton Creek Area – Dawson, Yukon – 2015

Chilkoot Geological Engineers Ltd. was retained by *Yukon Government – Energy, Mines and Resources - Assessment and Abandoned Mines (AAM)* to conduct a Geotechnical Evaluation to support the on-site care & maintenance and long-term site remediation of the abandoned Clinton Creek asbestos mine.

The former open pit mine site, located approximately 75 km northwest of Dawson, Yukon, was operated by the *Cassiar Asbestos Corporation Ltd.* between 1968 and 1978. During this time, approximately 1 million tons of asbestos fiber was extracted during the mining process. The mine produced 11 million tons of mine tailings and 63 million tons of waste rock which were deposited on nearby valley slopes. These mine tailings and waste rock piles progressively failed and resulted in the blockage of three creeks. Blockage of the primary tributary, Clinton Creek, led to the creation of a ~ 75 ha sized reservoir now referred to as Hudgeon Lake. As each of the blockages are the result of active failures due to creep mechanisms, the toe of the slope failures are undergoing progressive erosion due to the presence of the valley creeks. Overtopping of the Clinton Creek blockage has occurred from time to time, resulting in large scale erosion and flood events. Progressive head-cutting of the Clinton Creek channel is of concern as it may result in a full breach of Hudgeon Lake.



In order to reduce the impacts of the channel erosion, protection features consisting of a series of gabion drop structures were installed along the Clinton Creek channel. As these drop structures have since undergone disturbance as a result of the channel flow and flood events, there was a need to identify and assess potential nearby borrow sources to produce and extract various construction aggregates (such as rip-rap, filter media, structural fills, etc.) in order to achieve long-term solutions and fulfill ongoing maintenance requirements. As such, our firm was retained to identify and assess potential borrow sources along readily accessible areas of the mine site, Clinton Creek Road (CCR) and nearby quarries located along the Top-of-the-World Highway # 9 (ToW) through literature review and site reconnaissance methodologies. This work was supplemented through laboratory work programs which allowed for preliminary geotechnical characterization of the potential borrow sources.

In brief, our findings revealed that the geomorphology of the study area is uncommon relative to most regions in Canada due to its unglaciated nature. This presents unique challenges relative to the availability of standard borrow materials which are generally glacially derived. This lack of glaciation has had a direct impact on the regional quality of near surface bedrock which is in a state of decomposition due to weathering and periglacial processes. From a geological standpoint, the argillaceous nature of the Clinton Creek ore body and surrounding rock types increases their susceptibility to these processes. These processes are accelerated in the mine site area as the structural geology is dominated by weak and sheared assemblages.

Of twenty-seven (27) sites that were assessed during the course of our evaluation, only seven (7) were identified as harboring potential resources which may be suitable for structural applications. The potential sites were comprised of four (4) fluvial deposits and three (3) rock quarries.

- Of the four (4) fluvial deposits, only one site (Clinton Creek Road – Site 11) located ~ 14 kilometers from the mine site entrance, would likely harbor granular reserves of suitable high quality and adequate quantity to allow for long-term development. Some land use considerations may however be required as portions of this site coincide with Placer Prospecting Claim(s).

- Of the three (3) rock quarries, only one site (Top-of-the-World Highway - km 63 LHS) located ~44 kilometers from the mine site entrance, will yield Class III sized rip-rap.

While the waste rock piles were also identified as being a potential resource, the use of the materials would be limited to non-structural applications where deemed suitable.

Relative to recent Clinton Creek stabilization options proposed by *Worley Parsons*, the resources identified during our assessment should be sufficient to fulfill the material requirements. However, as many of the potential borrow locations coincide with mining claims and/or land dispositions, potential land use conflicts should be resolved/clarified during future work to verify their suitability for use.

As larger classed rip-rap (and potentially other materials) may need to be brought to the site from the Top-of-the-World Highway – km 63 quarry, sections of Clinton Creek Road may require upgrading in order to optimize haul operations.

Site specific geotechnical evaluations would be required to adequately characterize the potential borrow sources which were identified during our assessment prior to their use.

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1.0 INTRODUCTION

Chilkoot Geological Engineers Ltd. was retained by *Yukon Government – Energy, Mines and Resources - Assessment and Abandoned Mines (AAM)* through a Standing Offer Agreement to conduct a Geotechnical Evaluation to support the on-site care & maintenance and long-term site remediation of the abandoned Clinton Creek asbestos mine.

The purpose of the evaluation was to identify and assess potential borrow sources along readily accessible areas of the mine site, Clinton Creek Road (CCR) and nearby quarries located along the Top-of-the-World Highway # 9 (ToW). In addition to naturally occurring deposits, the onsite waste rock and mine tailings were to be characterized such that their use as potential borrow materials could be evaluated from a geotechnical perspective.

The former mine site is located approximately 75 km northwest of Dawson, Yukon as noted in Figure 1.

Our evaluation was preliminary in nature as it was limited to literature review and site reconnaissance methodologies. A geotechnical laboratory work program was however conducted to supplement our evaluation. These work programs were utilized in order to identify locations where more site specific sub-surface investigations could be conducted during future evaluations.

Authorization to proceed with the evaluation was granted by *AAM* on August 10th, 2015.

The findings of our assessment have been presented herein along with a description of our methodology.

1.1 Site History

Clinton Creek is the site of an abandoned asbestos mine that was operated by the *Cassiar Asbestos Corporation Ltd.* between 1968 and 1978. During this time, approximately 12 million tons of serpentine ore were extracted from three (3) open pits (Porcupine, Snowshoe and Creek). The serpentine ore was transported from the pit areas across the Clinton Creek valley via a cable tramway. Ultimately, 1 million tons of asbestos fiber was extracted during the milling process. The resulting (11 million tons of) mine tailings were deposited over the western slope of Wolverine Creek valley.

The extraction of the ore produced approximately 63 million tons of waste rock. Of this, approximately 3 million tons of the waste rock material was deposited over the western slope of Porcupine Creek. The remaining 60 million tons were deposited over the south slope of the Clinton Creek valley.

Movement of the waste rock materials resulted in the blockage of Clinton Creek in 1974 and led to the creation of a ~ 75 ha sized reservoir now referred to as Hudgeon Lake. Following the waste rock slope failure, the mine tailings above Wolverine Creek also underwent progressive failure. Initially the failure resulted in the blockage of Wolverine Creek through a soil mass now referred to as the 'southern lobe'. As mine operations continued, the tailings were deposited towards the north of this region. Subsequently, the tailings materials in this region also failed, creating a second blockage (referred to as the 'north lobe') upstream of the initial failure. The waste dump above Porcupine Creek has also failed, resulting in channel blockage and the creation of a small un-named reservoir located upstream of the blockage. Each of these blockages are undergoing progressive toe erosion as they continue to creep into the respective creek channels. In addition to the erosion, overtopping of the Clinton Creek blockage has occurred from time to time, resulting in large scale erosion and flood events.

In order to reduce the impacts of the channel erosion which incises into the blockage debris, protection features were installed along the Clinton Creek channel. These measures included the installation a series of small rock weirs as well as lining the channel with large boulders sourced from the open pits. The initial measures installed in 1981, were largely in-effective as the channel simply by-passed the weirs and channel lining. After being re-constructed twice by 1984, the channel works were generally successful in controlling the erosion until the spring of 1997 when a significant overtopping/flood event occurred. Following this, a series of gabion drop structures were constructed between 2002 and 2004 in an effort to control the gradient of the creek channel more effectively. These drop structure have since undergone disturbance as a result of the channel flow and flood events and were being repaired at the time of our assessment. Ultimately progressive head-cutting (or incising) of the Clinton Creek channel is of concern as it may ultimately lead to a full breach of Hudgeon Lake.

1.2 Scope-of-Work

The initial scope-of-work was established by *AAM* in their July 13th, 2015 outline. In brief, the outline indicated that a two phased approach (comprised of a desktop study and field investigation) would be required to identify borrow sources which would allow for both ongoing care and maintenance as well as long-term mine site reclamation work. Specifically, it was understood that the materials required during this work would be comprised of;

- Class I through III rip-rap and associated filter material.
    - comprised of durable and non-acid generating rock
- cover materials (silt, sand and gravel sources),
- concrete aggregate (sand and gravel sources); and
- road construction materials (gravel sources)

Our firm initially formulated a Proposal and Cost Estimate to allow for identification of the borrow sources through means of a literature review, test pit and laboratory work programs. However, as it was evident that extensive field investigation at this stage would become cost-prohibitive, the Proposal was modified to focus upon the literature review component and preliminary field reconnaissance and hand sampling programs.

The draft findings of the literature review were submitted to *AAM* on August 19th, 2015. A meeting was subsequently held on August 28th with *AAM* and *Aboriginal Affairs and Northern Development Canada (AANDC)* to review the initial findings and select sites which would yield the highest potential for harboring borrow resources suitable for use. During this time, *AAM* (and *AANDC*) indicated that the assessment was to focus upon identifying approximately 20,000 m^3 of Class III rip-rap. It was understood that the primary use of this material would be to allow for armoring of both Clinton and Wolverine Creeks to reduce the impacts of seasonal and long-term channel flow.

The gradational distribution for the rip-rap is described *by Yukon Government – Department of Highways and Public Works* (*HPW*) rip-rap specifications as;

Class I	**Class II**	**Class III**
100% < 450 mm	100% < 800 mm	100% < 1200 mm
20% > 350 mm	20% > 600 mm	20% > 900 mm
50% > 300 mm	50% > 500 mm	50% > 800 mm
80% > 200 mm	80% > 300 mm	80% > 500 mm
(Rip-Rap D_{50}) 300 mm	(Rip-Rap D_{50}) 500 mm	(Rip-Rap D_{50}) 800 mm

As such, our field reconnaissance component was modified to allow for additional characterization of the existing rock quarries and regional geological conditions. In addition, a more intensive laboratory work program was formulated to allow for more comprehensive characterization of retained soil and rock samples. This included conducting LA Abrasion analysis to better assess the durability of the potential rock quarry sources.

2.0 METHODOLOGY

Our methodology was comprised of a literature review, field reconnaissance and laboratory work programs. This work was conducted by the undersigned and our firms terrain specialist Mr.Wilbur Kofoed, M.Eng., P.Eng.

2.1 Literature Review

The literature review was comprised of data collation and memo compilation phases.

2.1.1 Data Collation Phase

The data collation phase involved evaluating satellite imagery, a selection of aerial photos, topographical data and other technical resources which were available for the study area.

Satellite Imagery

While satellite imagery of the study area dated April 9th, 2013 was available through *Google Earth,* other than for regional control purposes, the resolution of the imagery was too poor to allow for a detailed assessment of individual terrain features.

Aerial Photos

A selection of aerial photos were obtained from the *YG – Energy, Mines and Resources* library to allow for the identification of potential deposits. The locations of these potential borrow sources and areas of interest were illustrated on a selection of the air photos and have been attached as Appendix A. The following aerial photos were reviewed;

Flight Line	Photo No.	Date	Scale	Location
A27995	63-105	Aug.26, 1993	1:15,000	Clinton Creek Road km 0-end
A27874	59-100	Aug.19, 1977	1:15,000	Top of the World Highway km 50-62

Topographical Data

Information regarding local elevations was obtained from the *Yukon Government – Water Placer Atlas* website and from *Government of Canada – Energy, Mines and Resources* topographical maps to better assess the terrain.

The following *GSC* topographical maps were reviewed;

Title	**NTS**	**Scale**
Dawson, Yukon Territory	116 B&C (Edition 3)	1:250,000
California Creek	116 C/1 (Edition 2)	1:50,000
Clinton Creek	116 C/7 (Edition 2)	1:50,000
Cassiar Creek	116 C/8 (Edition 2)	1:50,000

Surficial Geology Map

While a surficial geology map of the study area has not been compiled by *Yukon Geological Survey* (*YGS*), a 1:25,000 scale surficial geology map, YGS - Open File 2014-12 – Surficial Geology of Dawson Region, Yukon (by McKenna, K.M. and Lipovsky, P.S.) was reviewed to provide insight into the regional geomorphology. In general, the surficial geology map noted that colluvial deposits dominated higher elevations on Top of the World Highway while fluvial deposits were encountered near lower valley bottom elevations. These deposits were at some locations modified through periglacial processes identified as;

(C) – cryoturbation,
(S) – solifluction,
(X) – permafrost processes, and
(Z) – general periglacial processes.

Bedrock Geology

A bedrock geology map, available through the *Yukon Geological Survey,* allowed for a more in-depth assessment of the regional bedrock types and characteristics within the study area. The map was entitled *Bedrock Geology – Yukon Territory* –

(*Geological Survey of Canada – Open File 3754* and *Exploration and Geological Service Division, Yukon – Indian and Northern Affairs Canada – Open File 2001-1 - 1:1,000,000 scale*) and was compiled by S.P.Gordey and A.J.Makepeace in 1999.

A section of this map, which illustrates the bedrock located in the region of the study area, has been attached as Figure 4. The potential borrow source locations which were assessed during our evaluation have been super-imposed on the map to illustrate their spatial distribution relative to the different types of bedrock.

It should be emphasized that as with all geological maps, the boundaries between the various geological units are not definitive given the scale of mapping and geological nature of formation and so this should be considered when viewing the figure.

YG – Assessment and Abandoned Mines - Reports

AAM provided our firm with a number of technical reports related to the Clinton Creek mine site and region.

These reports included;

An April 1st, 1978 report entitled Geotechnical Aspects of Mine Closure prepared by *Golder Brawner & Associates Ltd*. for the *Cassiar Asbestos Corporation Ltd*.

In brief, the report was prepared to discuss potential stabilization options for the waste rock and mine tailings piles which were undergoing movements so as to return the site to a condition acceptable to the *Yukon Territorial Water Board* as part of the mines closure.

A follow-up report prepared by *Golder Associates* dated July 1st, 1978 entitled Mine Waste Dump and Tailing Pile Clinton Creek Operations.

The report presented final mine closure options and contained appendices which included borehole logs for nineteen (19) boreholes which were advanced in the waste rock, tailings pile and other mine site locations. The appendices also included associated laboratory test results (grain size distribution analysis, moisture content analysis and direct shear tests) and included data which summarized the results of thermistor string, piezometer and horizontal movement observations.

A copy of the report has been attached in Appendix B.

A December 6th, 1978, letter and attached report entitled Rehabilitation and Stabilization – Clinton Creek Mine, Clinton Creek, Yukon Territory submitted to the *Cassiar Asbestos Corporation Ltd.* prepared by *Golder Associates*.

The letter was addressed to *R.M.Hardy and Associates Ltd*. to indicate that recent findings (as noted in *Golders* attached report) did not support *Hardy's* conclusions regarding the failure mechanisms associated with the mine tailings. The report indicated that they were in general agreement with *Hardy's* findings regarding the waste rock slope failure.

A thesis entitled Geology of the Clinton Creek Asbestos Deposit, Yukon Territory, prepared March 23rd, 1979 by Myat Htoon as partial fulfillment of a Master of Science Degree from *University of British Columbia's - Department of Geological Sciences*.

The purpose of the thesis was to describe the geology of the mine, the genesis of the deposit and the origin and emplacement of ultramafic rocks in order to develop concepts which could guide future exploration for chrysotile asbestos.

A compilation of technical bulletins entitled Yukon Exploration and Geology 1982 prepared by *Indian Affairs and Northern Development*. One of the bulletins was compiled by Grant Abbott of the Exploration and Geological Services Division (*D.I.A.N.D.* – Whitehorse) and was entitled Origin of the Clinton Creek Asbestos Deposits.

The report discussed the origins of asbestos in the Clinton Creek (and other) thrust complex regions as being a product of fracturing, metasomatism and thermal metamorphism of ultramafic rocks by Mesozoic intrusions. The report provided a geological cross section of the mine site area and described the local bedrock geology as being comprised of intensely deformed serpentine being interleaved with weakly deformed Triassic shale and younger calcareous sandstone. 'Brittle fracturing, hydration and asbestos formation likely occurred during final emplacement of the ultramafic rocks onto the wet miogeoclinal strata' (Abbott, 1982). Figure 1 of the report has been attached for reference purposes in Section 2.2.1 (Field Reconnaissance Mine Site).

A report entitled Abandoned Clinton Creek Asbestos Mine - Condition Assessment Report dated April 13th, 2000 conducted by *UMA Engineering Ltd.* for *Indian and Northern Affairs Canada*.

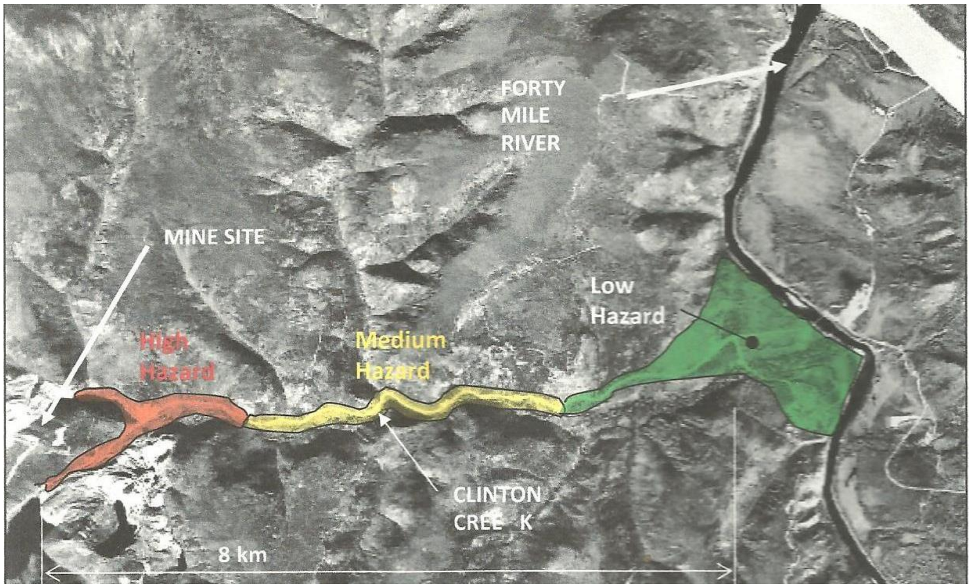
The report described the physical and environmental conditions at the site based upon (1998 and 1999) *UMA* and *Royal Roads University* investigations and a number of previous studies. The *Royal Roads* investigation obtained a total of 32 soil samples which allowed for geochemical assessment of the waste rock and tailings materials. Additional water and sediment samples were retained during the *Royal Roads* assessment from Hudgeon Lake, Wolverine Creek and other nearby regions.

A copy of the report has been attached in Appendix B.

A 2005 technical paper entitled Landslide Dams and Creek Stabilization at the Former Clinton Creek Asbestos Mine prepared by *UMA Engineering* (G.Robinson, P.Eng., K.Skaftfel, P.Eng. and R.Aslund, P.Eng.) and *Yukon Government* (H.Copland, P.Eng.). The paper was part of the Northern Latitudes Mining Reclamation Workshop held in Dawson City, Yukon.

The study summarized the design of the gabion drop structures and utilized risk assessment techniques to identify the risks associated with a full breach of the Hudgeon Lake outlet. In brief, the study identified downstream areas as having either a high, medium or low hazard potential, relative to the impacts of a failure.

Figure 10 from
Landslide Dams and Creek Stabilization at the Former Clinton Creek Asbestos Mine



A July 16th, 2015 draft report prepared by *Worley Parsons Canada* for *AAM* summarized laboratory test results of samples retained from the mine site and a granular quarry located at km 26.8 RHS of Clinton Creek Road on May 31st, 2015. The type of laboratory analysis included both chemical and physical analysis.

Specifically, six (6) samples were obtained from the mine site by *Worley Parsons* to allow for chemical analysis to determine the potential for metal leaching and acid rock drainage. Three (3) samples were retained from the waste rock and mine site entrance pit, respectively.

In brief, the results of the analysis indicated that the potential of ARD was very low. While a potential for metal leaching was identified, the report indicated that additional testing was required to determine if long-term leaching may occur and if so, whether the leaching would exceed allowable limits. The report did not specify the type of entrance pit rock which was analyzed.

In addition to the chemical analysis, two (2) soil samples were obtained by *TetraTech* from the mine site entrance pit and an existing granular quarry located at km 26.8 RHS of Clinton Creek Road to allow for geotechnical characterization through grain size distribution, moisture content and modified proctor analysis. These laboratory results have been summarized in Table II.

Worley Parsons initial findings were supported in their final report, which has been attached in Appendix B.

Four (4) soil samples were obtained by *CAP Engineering* for *Sidhu Trucking* during recent repairs to the drop structures in order to allow for geotechnical laboratory characterization.

The samples were retained on August 13th, 2015 from a region of waste rock located south of the drop structures. The laboratory analysis was comprised of grain size distribution and modified proctor analysis. The results for two (2) of these samples (which were provided to us by *AAM*), have been summarized in Table II and have been attached in Appendix B.

In brief, the results of the grain size distribution analysis would have characterized the material as silty gravel which contained a trace to some sand and the odd cobble.

YG – Department of Highways and Public Works - Reports

In addition to the above noted reports (supplied by *AAM*), our firm obtained three (3) geotechnical reports through *YG – Department of Highways and Public Works*. These reports summarized the finding of several geotechnical evaluations which were conducted on Top-of-the-World Highway (# 9).

The reports were entitled;

Subgrade Strength Evaluations – Top Of World Highway – kilometer 0.0 to kilometer 105, Yukon, 1995.

The report was prepared by *Hoggan Engineering & Testing (1980) Ltd*. This report was conducted for *YG - Community and Transportation Services – Transportation Engineering Branch* in order to sample near surface soils (~ 0.6 m) located on the roadway for each kilometer of the highway. The laboratory analysis included CBR testing to evaluate potential subgrade strengths, gradational analysis, consistency/limit determination and moisture/density (Proctor) relationships.

Proposed Upgrading Top of World Highway – km 60 to km 105 – Volume I – Geotechnical Report and Data, March, 1989.

This report was prepared by *Klohn Leonoff Yukon Ltd.* for *YG – Community and Transportation Services – Transportation Engineering Branch* in order to assess the feasibility of utilizing local materials to upgrade (and at some locations, re-align) the highway from the Clinton Creek turn-off (~km 60) to the Alaska Border (~km 105). The field work involved drilling 237 auger test holes along the highway at approximately 200 meter intervals to depths of 6 meters in cut regions and 1.5 meters in fill areas.

The report included the geotechnical discussions as well as test hole logs and laboratory data. Although not included, Volume II was described as containing the alignment drawings and approximate test hole locations.

In brief, the report indicated that upgrading of the highway would be feasible utilizing nearby existing borrow sources. The investigation described the materials encountered as being comprised of unglaciated, weathered bedrock which is overlain by non-plastic silt (which contains sand and angular gravel) and gravel (which is very dense and contains silt, sand and generally 100 mm minus angular cobble sized materials).

The bedrock was described as;

> 'grey-green micaceous quartzite, light and dark grey foliated quartz-mice schists with minor graphitic and chloritic schists', and
>
> 'dark grey-brown jointed, vesicular, andesite and basalts with minor shale, sandstones and conglomerates'.

The report indicated that upgrading of the highway would be feasible and that borrow materials could be derived from local side hill cuts into the weathered bedrock.

<u>Top of the World Highway – Granular Resource Development – km 30-km 60</u>, December, 1995.

This report was prepared by *EBA Engineering Consultants Ltd*. for *YG - Community and Transportation Services – Transportation Engineering Branch* summarized their summer work which was to identify sites to allow for the production of 'Granular A' (20 mm minus crushed base course) and bituminous surface treatment (BST) aggregates from either rock quarries or natural gravel occurrences. While only portions of the report were enclosed in the *YG* files, in brief, it indicated that naturally gravel occurrences are not present beyond km 8 along Top of the World Highway but that they are present in lower valleys in tributaries of the Sixtymile and Fortymile Rivers. The report described the quarry locations (km 11, 18, 32, 42, 60 and 64) as being comprised of 'fine grained weak schist type material or conglomerates with a fine grained matrix' which were deemed unsuitable for use as aggregate sources due to their fine grained nature and low durability. However, the report described a geotechnical investigation program which was conducted by *EBA* in August, 1995 which assessed ten (10) potential quarries through geological mapping and surficial sampling with the intent to identify sites where rock types suitable for 'Granular A' and BST production. Only portions of this report were attached in the *YG* file.

Table 1 of their summary (which presented the Preliminary Site Investigation Results) described their findings as follows;

Location	Material Type	Recommendation
km 27	interbedded felsic volcanic and chloritic schists	No further work – chloritic schist not suitable for aggregate production
km 31	augen gneiss	Recommended – hard durable material and significant volumes
km 34	micaceous augen gneiss	No further work – limited extent and micaceous nature not suitable for aggregate production
km 35	micaceous schist	No further work – micaceous schist not suitable for aggregate production
km 38	quartzite	Recommended – hard durable material and significant volume
km 42	chloritic schist overlying quartzites and limestone	No further work – chloritic schist not suitable for aggregate production, stripping ratio too great
km 45	quartzite	Recommended – hard material suitable for aggregate production
km 46	micaceous schist	No further work – micaceous schist no suitable for aggregate production
km 51	carbonaceous schist	No further work – carbonaceous schist not suitable for aggregate production
km 63	diorite	Recommended – hard durable material suitable for aggregate production

Secondary field testing through diamond drilling and bull-dozer excavation was subsequently completed at three of the four recommended locations (km 31, km 45 and km 63) to prove the quantity and quality of available quarry resources and to determine the overburden depth and composition in order to prepare development plans for aggregate production.

Table 2 of the August, 1995 report presented a summary of Laboratory (L.A.Abrasion) Test Results from the sub-surface investigation (and that of a km 38 surface sample) as follows;

Site	Sample	Rock Type	L.A.Abrasion (% loss) Specification	L.A.Abrasion (% loss) Actual [A]
km 31	1	augen gneiss	35	27.8
	DDH7	gneiss	35	24.6
	DDH9	augen gneiss	35	37.9
km 38	1	quartzite	35	24.6
km 45	2	micaceous quartzite	35	40.4
	DDH4	micaceous quartzite	35	27.9
	DDH6	micaceous quartzite	35	28.6
km 63	2	diorite	35	36.3
	DDH1	diorite	35	19.6
	DDH3	diorite	35	19.9

Note [A] - The LA Abrasion tests were completed on Gradation B, as per ASTM C131.

Of the four recommended sites (km 31, 38, 45 and 63), development requirements were discussed for km 31 and km 45 as they were selected by the *Yukon Government* to undergo development in 1996.

The geology of km 45 was described as a single geologic unit comprised of micaceous quartzite. The overburden was described as being comprised of between 1.0 and 1.2 meters of fine talus overburden mixed with a silt residual soil that coarsened downwards until fractured bedrock was encountered. They indicated that thicker zones of overburden may be encountered near the base of the slope. Their review of the test results suggested that aggregates of moderate to marginal hardness could be produced at the site. The quality of the surface sample (No.2) was noted to be less durable relative to the drilling samples (DDH4 & DDH6), likely as a result of weathering. As such, the report indicated that the surficial talus will perform poorly relative to the underlying rock which will provide acceptable performance.

The report recommended development of lower regions of the km 45 quarry (present day km 46 quarry) to minimize the visibility of the quarry from the highway. While higher regions along the ridge-line were considered suitable for development, access and visibility considerations made development in these regions less favorable. Long term development plans suggest that quantities are suitable to allow for up to 50 years of aggregate supply. The report indicated that this estimate is based upon a working face of 7-10 meters progressing south-easterly along the ridge spanning an area of approximately 4 ha.

While descriptions of the km 63 quarry were absent from the *YG* file, the higher % loss value of the surface sample (No.2) relative to the drilling samples (DDH1 and DDH3), suggests that weathering may also be responsible for the difference in the results, as per the km 45 observations.

Quartz/Placer Claims and Land Dispositions

A series of recent quartz and placer claim maps were obtained from the *YG – EMR - Mining Recorder* to determine whether or not any claims coincide with the proposed sites. In addition to the claims, the *Water Placer Atlas* website was utilized to verify the presence of various land dispositions (and other features) located within the study area. These claims and land dispositions were denoted on the map generated from the *Yukon Government – Water Placer Atlas* website which has been included as Figure 5. The approximate locations of the potential borrow sites have been illustrated on the map for reference purposes.

2.1.2 Memo

A memo was submitted to *AAM* on August 30th, 2015 upon completion of the literature review phase in order to identify potential (and previous) borrow sources located within the study area. A summary table was compiled (and supplemented following the site reconnaissance) as noted in Table I. In all, a total of twenty-seven (27) sites were identified. This included nineteen (19) sites which were located along Clinton Creek Road (CCR). The sites were numbered sequentially for reference purposes. Another two locations were identified on Top-of-the-World Highway # 9 (ToW). The remaining six (6) sites were comprised of borrow/sample locations located at the mine site. Maps which illustrate the approximate locations of the sites along CCR/ToW as well as the mine site area, have been attached as Figures 2 & 3, respectively.

A selection of airphotos, which illustrate the approximate limits of the potential deposits, has been attached as Appendix A.

2.1.3 Draft Report

A draft report was submitted to *AAM* on November 10th, 2015 in order to present the findings of our assessment. A meeting was subsequently held with the *AAM* Senior Project Manager, Ms.Joseè Perron, M.A.Sc. (Eng.), P.Eng. on December 10th, 2015 in order to discuss finalization of the report.

While a number of minor adjustments were identified, there were two aspects where additional engineering assessment was requested. Specifically, this included assessments of;

- development options at the Entrance Pit (Site MS1), and
- the availability of granular resources relative to a number of potential remedial option volumes which were estimated in *Worley Parsons* <u>Clinton Creek Site Lifecycle Cost Analysis for Remedial Options</u> dated March 28th, 2014.

As such, the adjustments to the report were made and discussions regarding the requested engineering assessments have been included in Sections 4.3.2 and 4.4, respectively

2.2 Field Reconnaissance

The field reconnaissance was conducted by the undersigned and Mr.W.Kofoed, P.Eng., M.Eng., between September 7 and September 14th, 2015.

The field reconnaissance focused upon three distinct regions;

Mine Site	Sites MS 1 through MS 6
Clinton Creek Road, and	Sites 1-17 & Airfield
Top-of-the-World Highway	km 46 RHS and km 63 LHS

Where possible, the reconnaissance involved traversing portions of the respective sites on foot to note relevant site features and collect soil, rock and stockpile samples. During this time, our observations were recorded in field-books, on maps and through digital photos. The retained samples were subsequently transported back to Whitehorse to allow for laboratory classification and analysis as described in Section 2.3, below.

A description of our field observations from each of the three regions has been summarized as follows;

2.2.1 Mine Site

Mine Site No.1 – Entrance Pit

Located on the right hand side of the entrance gate to the mine site (~ km 40.2 of Clinton Creek Road), the existing rock quarry harbors serpentine which overlies quartz-carbonate and shale rock.

Photo of Mine Site No.1 (Entrance Pit) facing north-east – Sept.11, 2015 (photo taken from road leading to Porcupine Creek Waste Rock)

Geological mapping of this area was conducted by G.Abbott in 1982 and was summarized in the *D.I.A.N.D.* paper entitled Origin of the Clinton Creek Asbestos Deposits. Figure 1 from the paper included an orthogonal view of the mine site and included a cross-section of the mine site. The geology at Mine Site No.1 can be seen at the right hand side of the west facing orthogonal photo at the confluence of Wolverine and Clinton Creek.

Figure 1 from Origin of the Clinton Creek Asbestos Deposits Abbott, 1982

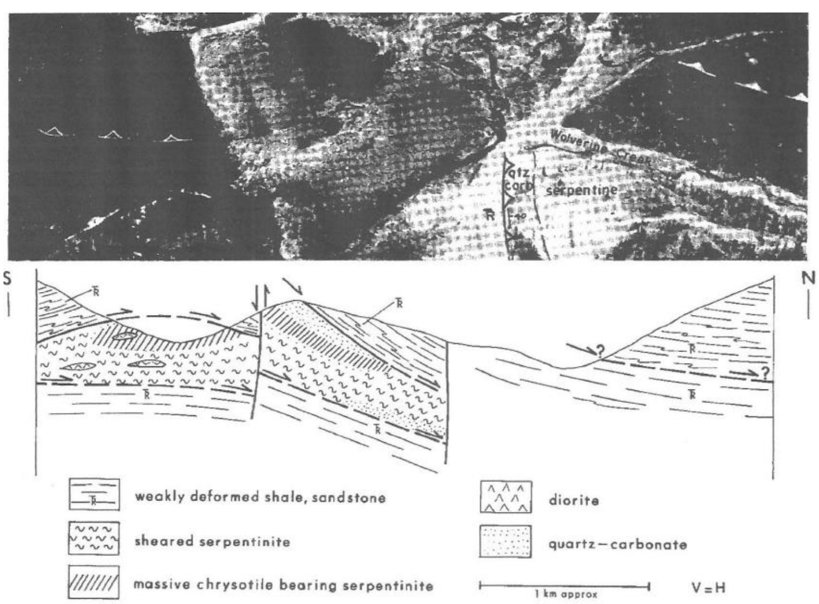


Figure 1. Looking west to the Snowshoe and Porcupine open pits. Thrust faults bound the asbestos bearing serpentinite. The lower thrust is shown with open teeth and the upper thrust is shown with solid teeth. Normal faults cut the thrusts.

Serpentine Unit

Much of the upper unit was comprised of 400 mm minus fractured pieces of moderate to high grade serpentine rock interspersed with colluvial materials. Rock outcrops were notably absent from much of the unit due to the weathered and disturbed nature of the serpentine rock and overall accessibility; however, one outcrop was encountered along the Wolverine Creek (west) side of the site.

Sept.10, 2015 - Serpentine Outcrop above the west side of Wolverine Creek

This outcrop was comprised of high grade serpentine which had fractured into 1 meter sized blocks. The spacing of general discontinuities within these blocks measured in the order of 0.2 to 0.3 meters.

Much of the talus present on the slopes of the serpentine unit appears to be slough resultant from the construction of higher (east-west trending) benches. These benches appear to have been incised into the hillside utilizing tracked equipment, possibly as part of expanding potential ore reserves during the later stages of mining operations.

Quartzite Unit

The quartzite unit was located beneath the serpentine throughout the majority of the quarry. The exception to this was the extreme eastern side where the underlying shale unit dominated the slope aspect.

The approximate bedding plane of the quartzite unit dips to the north at approximately 40˚ as was identified in Figure 1 of the Origin of the Clinton Creek Deposit by G.Abbott (1982). The figure notes the presence of a lower thrust fault located between the base of the quartzite unit and top of the weakly deformed shale and sandstone unit. The orange discoloration of the quartzite-carbonate unit is due to weathering. The common thickness of this unit was estimated to measure in the order of 30 meters (as was identified by G.Abbott, 1982). Alterations within the unit are present in the form of quartz veins, chalcedony, opal and magnesite (amongst others of lesser occurrence). The quartzite-carbonate unit is thought to post-date the 'penetrative deformation' of the serpentine.

Sept.10, 2015 – Mine Site No.1 (Entrance Pit – quartzite unit) facing east.

The exposed length of the quartz-carbonate rock measured in the order of 200 meters. The top of the quartz unit was estimated to be in the order of 15 meters high relative to the adjacent road elevation.

It was evident that the quartzite rock was being stockpiled for use in mine maintenance operations as several stockpiles of various rock sizes were present. These stockpiles were comprised of (approximately) 100 mm minus, 300 mm minus and ~ 1 m (nominal) sized materials. The spacing of discontinuities in the larger boulder size materials measured in the order of 0.3 meters, however, decrease to ~ 0.1 meters at some areas.

Shale Unit

The underlying rock unit was comprised of weakly deformed shale.

Sept.10, 2015 - Photo of Shale (foreground) facing west

Outcropping of this unit was difficult to identify as it was in a heavy state of disintegration and the rock face could not be approached due to the potential for rock-fall. Platy particles were however encountered throughout the eastern areas below the quartz-carbonate. The materials measured on average 35-40 mm in size. Maximum particle sizes of 100 mm were noted. The shale material was classified as sandy gravel with a trace of silt following grain size distribution analysis.

Mine Site No.2 – Waste Rock

The waste rock in this region was generally comprised of decomposed shale which contained the odd (low grade) serpentine and shale boulder in size to 2 meters. The boulders were highly weathered and in various stages of decomposition. The composition of the serpentine graded to a schist.

Photo of weathered serpentine (Sept.10, 2015)

Truck loads of fractured shale, the fragments of which measured in size to ~ 600-800 mm, were located in the southern realms of the waste dump. This material generally contained less than 3% cobbles (by volume) by visual estimate. The odd boulder was noted to be moderately to heavily fractured with discontinuities spaced in the order of 200 to 300 mm apart.

Mine Site No.3 – Waste Rock

The waste rock in this region was generally comprised of decomposed shale which contained the odd (low to moderately metamorphosed) serpentine and shale boulder in size to 1.5 meters and less than 2% cobbles (by volume) by visual estimate. The boulders were moderately to heavily fractured with discontinuities spaced between 200-300 mm apart.

Photo of erosion rill through Waste Rock (Sept.10, 2015)

Some regions of potentially more durable shale rock was also encountered at some locations as larger 300 mm to 400 mm cobble sized materials were also observed. The grain size distribution analysis of two samples classified the material as gravelly silty sand and sandy gravel which contained some silt.

Mine Site No.4 – Drop Structure No.4 Project – Temporary Stockpiles

A number of stockpiles were observed near the confluence of Hudgeon Lake and the inlet to the drop structures. These stockpiles were comprised of;

Clinton Creek Rock

Approximately 500 m^3 of higher grade greenish-yellow serpentine and grayish shale boulders which measured in size to 1.3 and 1.5 meters, respectively. Both types of boulders were rounded and appeared to have been previously located within the limits of Clinton Creek. On average, the serpentine boulders contained discontinuities (fracture planes) at 0.2 to 0.3 meter spacing. The spacing of discontinuities in the shale boulders was less than 0.1 meters.

Waste Rock Boulders
Approximately 500 m^3 of predominately serpentine boulders in size to 1.0 meters (with varying degrees of metamorphism) and the odd gneiss and quartz carbonate boulder in size to 700 mm.

Quartzite Rock
Approximately 300 m^3 of 300 mm minus quartz carbonate sourced utilizing a Link-Belt 250x[2] excavator from central regions of the mine site as noted in Figure 3 (Item A). The stockpiled material did not appear to contain particle less than 80 mm in size, and

A 300 m^3 stockpile of generally 80 mm minus quartz carbonate also sourced from the same location. The results of the grain size distribution analysis classified the material as sandy gravel with a trace of silt.

Serpentine (left) and Shale (right) boulders (2 m rod)

Quartzite (300 mm minus) stockpile

Mine Site No.5 – Former Granular Quarry

This site, which was once a former granular quarry likely sourced during mine operations, was located approximately 200 meters south off of the primary road which leads to the mine tailings and former mill area. The trail leading to the site is steep and partially overgrown. The deposit is comprised of a fluvial terrace which overlies bedrock.

A prominent working face, which extends ~ 100 meters east-west and is ~ 6 meter high, is located on the south side of the remaining deposit. A region which was originally cleared during the original quarry operations, but is now overgrown with birch trees, extends approximately 20-25 meters beyond the toe of the working face and suggests ~ 12,000 m^3 of remaining granular reserves within this area. Observations of the vegetation and road side-cuts suggests additional reserves may be located towards the north of the formerly cleared limits and along the northern side of the primary access road (which leads to the mine tailings area).

Photo of Mine Site No.5 (Sample 5-2) facing east (Sept.9, 2015)

The results of the grain size distribution analysis of three (3) samples retained from along the working face indicated the composition of the deposit is comprised of predominately sands which contained between 13.2 and 15.7 % silt (by weight). Some oxidation was noted. One of the samples (MS 5-3) was classified as sandy gravel with some silt. The (sub-angular to sub-rounded) gravel near this location measured in the order of 80 mm with only the odd cobble in size to 150 mm. The presence of cobble sized materials throughout the remainder of the visible working face was otherwise scarce. The gravel was comprised of predominately quartz however minor occurrences of gneiss and serpentine were also noted.

Mine Site No 6 - Mine Tailings

A total of six (6) samples were retained from the mine tailings on September 9th, 2015 as noted in Figure 3. Five (5) of the samples were collected from the upper realms of the primary discharge area located west of Wolverine Creek. The sixth sample was retained from what appeared to be a separate discharge pile comprised of predominately 100 mm minus high grade serpentine located south-west of the primary tailings pile.

Each of the five (5) primary tailings pile samples were composites of three (3) individual test pits which were hand shoveled to depths of 0.3 meters. Specifically, two (2) samples (No.1 and No.2) were retained from the upper realms of the northern lobe. Sample No.3 was retained from a central region located between the northern and southern lobe. The final two samples (No.4 and No.5) were retained from the upper realms of the southern lobe.

Although the color of each sample retained from the primary mine tailings pile was a similar yellow/green/brown color with grey shading and mottled zones of orange-brown oxidation, the composition and moisture contents varied.

Photo of Mine Site No.6 (Mine Tailings) - Sept.9, 2015
Photo taken from Sample No.6 location facing north (note Figure 3)

A progressive coarsening of the tailing materials was noted between the southern and northern lobes. In brief, the laboratory analysis revealed the gradation of the northern lobe was comprised of (28 mm minus) gravelly sand which contained 13.4 and 15.5 percent silt (by weight), respectively. The moisture contents were noted to be 8.9 and 8.3 percent. By contrast the southern lobe was comprised of (20 mm minus) gravelly sand, which contained 30.1 and 24.5 percent silt, respectively. Higher moisture contents of 12.6 percent were noted. The central area (Sample No.3) was classified as a (20 mm minus) gravelly silty sand. This material contained intermediate amounts of silt (23.9 %) and moisture content (10.3 %). The sample was retained from a region which exhibited polygons in size to 100 mm. Extension cracks up to 75 mm wide were located approximately 3 meters south-east of the sample location.

While the coarse fraction of the tailing materials was comprised of predominately serpentine, the odd fragments of quartz-carbonate and shale were also noted.

In addition to the silt, sand and gravel sized particles, each of the mine tailings samples contained asbestos fibers.

> The presence of these fibers, would have skewed the measured values of weight retained on the individual sieve sizes (to some degree) given the elongated nature of the asbestos fibers. Generally, the majority of the asbestos fibers were retained on sieve sizes greater than 0.315 mm.
>
> Observations made during the wash process generally noted the asbestos fibers tended to float and create what could be described as a cotton-like texture which exhibited hydrophobic tendencies. Below this mat, the fines fraction within the wash sieve appeared to congeal and form a paste-like consistency. Each of these characteristics were uncommon relative to standard soils which are processed during grain size distribution analysis and so some consideration is required relative to their classification utilizing the *Unified Soil Classification System*.

Regionally, trace amounts of miscellaneous waste metal, lumber, scrap wire, metal nuts and bolts, etc. were also noted throughout the surface of the mine tailings.

The secondary discharge pile of mine tailings, which was predominately comprised of a 100 mm minus high grade serpentine (low grade jade) with trace amounts of shale was classified as gravel. The odd oversize was noted. The nominal size of aggregate was in the order of 25 mm. The volume of the stockpile was estimated to be in the order of 30,000 m^3.

The results of the grain size distribution analysis of the primary and secondary tailings piles have been attached in Table II.

2.2.2 Clinton Creek Road Sites

Site 1 - CCR km 5.5 RHS (offset 500) *Colluvial Materials - rszCv/R*

The site was not assessed given poor access to the site.

Site 2 - CCR km 6.6 RHS *Colluvial Materials - rszCv/R*

This former borrow area was located off of Clinton Creek Road in a region which coincided with a sub-assemblage of the Nasina Assmblage (DMN2). While the rock types of this assemblage are described as graphitic quartzite and muscovitic quartz-rich schist with interspersed marble, marble was not observed. The depth of the borrow was relatively shallow and estimated to be in the order of 1.5 meters. A bedrock outcrop was noted 850 upchain from this site along Clinton Creek Road (RHS).

Site 3 - CCR km 9.1 RHS *Colluvial Materials - rszCv/R*

Rock cut face on the right-hand-side of Clinton Creek Road with 0.5 meter minus fractured micaceous (graphitic) serpentine rock grading to low grade muscovitic quartz/schist.

Site 4 - CCR km 9.6 LHS (offset 600-1000 m) *Colluvial Materials - rsvCv/R*

Poor site access prevented field reconnaissance of the site.

Site 5 - CCR km 10.1 RHS *Colluvial Materials - rszCv/R*

This site was cut into the hill side to depths of approximately 2 meters. Disturbed regions extended up to 50 meters from the road shoulder. A small stockpile (~100 m^3) was observed near the roadway. A smooth serpentine rock face was present with a dip of approximately 45˚ to the south-west. The rock type varied from the serpentine rock to a low grade micaceous schist.

Photo of CCR Site 5 facing north – Typical CCR side-cut borrow (Sept.12, 2015)

Site 6 - CCR km 11.7 RHS *Colluvial Materials - rszCv/R*

The site conditions were similar to those of Site 5 although the rock type varied from serpentine to a quartz-schist.

Site 7 - CCR km 13.2 RHS *Colluvial Materials - rszCv/R*

This former borrow site was developed utilizing a bull-dozer which pushed material down-slope to depths estimated to be in the order of 2 meters. The upper 0.5 meters would have been comprised of strippings. The rock type was classified as a platy, highly metamorphosed serpentine.

<u>Site 8 - CCR km 15.2 L&RHS</u> *Colluvial Materials - rsvCv/R*

The area on both sides of the road have been utilized as local borrow materials. While heavily overgrown, the left-hand-side was formally a knob which was identified on the (1993) airphotos of the site, but has since been utilized. The depth of borrow on the right-hand-side was estimated to be in the order of 1.5 meters. The rock type was classified as a low grade schist varied to a micaceous muscovitic (chloritic) quartzite.

<u>Site 9a - CCR km 18.1 RHS</u> *Colluvial Materials - Cv/R*

Heavy foliage and steep side-slopes prevented field reconnaissance of the site.

<u>Site 9b -CCR km 20.6 RHS</u> *Colluvial Materials – rszCv/R*

There was no visible access to the site. Overgrown remnants of a bench created by a bull-dozer were observed along the roadway. The materials were comprised of fractured colluvial materials with maximum particle sizes in the order of 150 mm.

<u>Site 10 - CCR km 24.9 RHS</u> *Fluvial Deposits - sgzFt/R*

This site was comprised of fluvial materials which were characterized as poorly graded gravelly sand which contained up to a trace of silt (< 10%). Some oxidation was noted. Large sized gravels and cobbles were notably absent from the deposit.

A prominent working face, which was estimated to be approximately 6 meters in height (relative to the elevation of Clinton Creek Road) was located approximately 30 meters from the road shoulder. The volume of the remaining reserves was estimated to be in the order of 14,000 m^3.

<u>Site 11 - CCR km 26.6 RHS</u> *Fluvial Deposits – sgzFt/R*

The deposit is comprised of a fluvial terrace which is partially located within a region designated as a Placer Prospector Claim (Grant No.00287 - Land Disposition No. 2008-2580). The south-eastern portion of the deposit has been developed as a granular quarry.

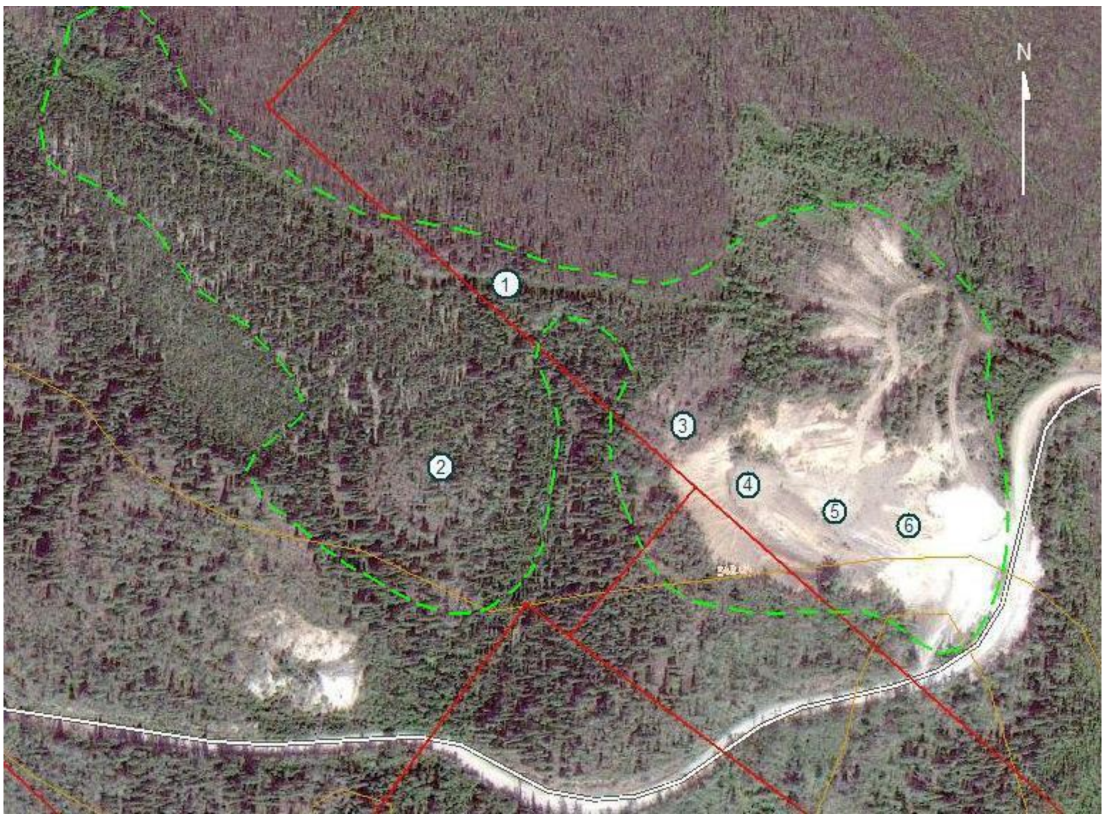
The deposit measures in the order of 800 meters long and 100 meters wide and was separated into what appeared to be four (4) areas by a series of gullies which trended to the south-west. A prominent working face located adjacent to Clinton Creek Road, was estimated to measure in the order of 10 meters in height. A second working face (approximately 6 meters in height) was located on the bench created during the initial phases of quarry development. A partially overgrown (cat) trail, which was located on what appeared to be the north-eastern limit of the granular deposit, allowed for reasonable (foot) access to the site.

Photo of Site 11 from CCR facing north-west (Sept.11, 2015)

As the south-easternmost area was partially cleared and stripped, visual inspection of the near surface materials noted granular materials throughout the exposed regions. Assuming the granular materials are continuous with depth, the volume of granular reserves which may be available in the south-eastern half of the site was estimated to be in the order of 100,000 m^3. The remaining areas likely harbor lesser amounts of granular reserves.

A total of nine (9) samples were retained during the field work program from six (6) hand excavated test pits. Three (3) of these samples were retained (from Test Pits 1-3) to classify the overburden which measured on average 0.2 meters thick. These soils were classified as silt to sandy silt and exhibited moisture contents ranging between 19.1 and 20.6%. The remaining samples were retained from the underlying granular materials (or else from the near surface of the cleared area). The results of the grain size distribution analysis classified the granular materials as predominately gravelly sand which generally contained a trace (<10%) of silt. The aggregated generally measured less than 80 mm in size although the odd cobble in size to 150 mm was noted.

Figure of CCR Site 11 - Approximate test pit locations, limits of Placer Claims (red lines) and granular deposit (green dash).



Site 12 - CCR km 30.4 L&RHS *Fluvial Deposits – Ft/R*

Three (3) separate areas were identified at the site. The primary region (located at km 30.4 LHS) is the remnants of a granular borrow area which was fluvial in origin. Laboratory classification of two samples retained from this region classified the material as sandy gravel which contained up to a trace of silt. Visually, the deposit contained less than 3-5 % of rounded cobble sized materials. A ~ 4 meter tall pit face noted overburden thickness ranged between approximately 0.3 and 1.2 meters. A 0.4 meter thick silt layer was also embedded within the granular deposit. Groundwater was noted approximately 100 mm below the prevailing pit floor.

Site 13 - CCR km 31.2 RHS *Fluvial Deposits - Ft/R*

This site was comprised of several deposits which were not readily accessible from the roadway. As such, direct field observations were not made. However, given the composition of aggregate located within Mickey Creek, it’s likely that the materials are of fluvial origin.

Site 14a - CCR km 33.2 RHS *Colluvial Materials – rszCv/R*

Colluvial deposits were encountered along a trail which bordered the north-western periphery of the deposit. A 1 to 2.5 meter tall cut face was noted on the upslope side of the trail as a result of the trails construction. Sample (No.3), retained from this side cut, was characterized as silty gravelly sand through laboratory analysis. Fractured cobbles in size to 300 mm were noted. A sample (No.1) retained from a hand excavated test pit located on the right-hand-side of the trail had a similar moisture content of 12% and was visually classified as the same type of material. The overburden at this location was comprised of approximately 200 mm of organics and organic silt.

Fluvial derived granular deposits may be located south-east of the site.

Site 14b - CCR km 33.2 LHS *Fluvial Deposits - Fp/R*

This deposit was located within the limits of the former town site and is located on both sides of the secondary road. The region north of the secondary road was the location of a former borrow area as remnants of a 1 meter deep cut into the level terrain was noted. Grain size distribution analysis conducted on a sample (No.1) classified the material as sandy gravel which contained a trace of silt. By visual estimate, the material also contained approximately 5 % of rounded cobbles which on average measured up to 150 mm in size. Groundwater would be expected at relatively shallow depths given the sites proximity to Clinton Creek. This deposit may extend to the north side of Clinton Creek Road.

Site 15 - CCR km 37.9 RHS *Fluvial Deposits - sgFp/R*

This site was not readily accessible from Clinton Creek Road and as quantities would be limited, a site reconnaissance was not conducted.

Site 16 – Offset 250 meters SW of Airfield *Colluvial Deposits – Cv/R*

Located on the south-west side of the former airfield, the deposit appeared to be comprised of predominately wet sandy silt of low plasticity. While the thickness of the deposit was undetermined, it is likely a thin veneer which overlies shallow bedrock.

The forest was comprised of spruce trees with interspersed birch. The forest floor was comprised of lichen and mosses where the thickness varied between 250 to 500 mm. The slope aspect varied between 5˚ to 7˚ and dipped to the south-west from the airfield with variations in the order of ~ 0.5 meters in the local relief.

Site 17– Offset 250 meters NE of Airfield *Colluvial Deposits – Cv/R*

Located on the north-east side of the former airfield, the deposit appeared to be comprised of predominately wet colluvial sandy silt to silty sands of low plasticity. Fractured chloritic schist was encountered near the 0.5 meter depth of the hand shoveled test pit. While the thickness of the deposit was undetermined, it is likely a thin veneer which overlies shallow bedrock.

The forest was comprised of spruce trees with interspersed birch. The forest floor was comprised of lichen and mosses where the thickness varied between 250 to 500 mm. The slope aspect varied between 10˚ to 15˚ and dipped to the north-east from the airfield with pronounced 2-3 meter drops in elevation at 10 to 20 meter intervals.

Airfield

Based upon laboratory analysis of a retained sample, the near surface materials at the airfield were comprised of gravelly sand which contained a trace of silt. While the upper 10-15 mm of the airfield surface had an oil coating to create a bituminous surface treatment, it was heavily weathered and so was easily susceptible to disturbance. Much of the surface had essentially disintegrated. The airfield was heavily overgrown with willow bush and interspersed birch trees.

2.2.3 Top-of-the-World Highway #9 Sites

km 46 RHS

A rock quarry, currently being utilized by *YG – HPW*, is located at the site. The quarry is located on the north side of a knob, the ridge of which ultimately trends east-west as noted in Figure 6. A stockpile area is located immediately north of the working face of the quarry. At the time of our reconnaissance, a single stockpile of Granular C and two stockpiles of Granular A were present.

The volumes of the stockpiles were visually estimated as follows;

Stockpile Description	Estimated Volume (m^3)
Granular A No.1 (20 mm minus)	20,000
Granular A – No.2 (20 mm minus)	2,000
Granular C (80 mm minus)	1,000

Beyond the stockpile area to the south-east lay a sparsely vegetated borrow source. A 0.5 ha area was stripped to allow for rock quarry operations. The stripping piles were placed along the south-west periphery of the working area. The primary working face of the quarry was developed in a series of two benches. The lower bench measured in the order of 7 meters in height. The upper bench was estimated to be ~ 5 meters tall in height.

The spacing of discontinuities in the rock was noted to vary. In general, they measured in the order of either 0.1 meter or else 0.5 meters, although some regions of more massive rock were also noted.

A third smaller (~ 2 meter high) bench was located on the upper realms south of the primary working face. This material in this region was comprised of more highly fractured rock and colluvial materials. The overburden thickness was estimated to be in the order of 1 meter.

Photo of km 46 quarry facing south-east (Sept.12, 2015)

The site lies in a region where the bedrock is comprised of the Nasina Assemblage (Gordey and Makepeace, 1999). Rock samples obtained from the site were classified as muscovitic quartz-rich schist, which varied to muscovitic (chloritic) quartzite. Graphitic quartzite may also be present. The muscovitic schist was crystalline in nature and may have exhibited some possible bedding, although this was hard to verify as it was heavily muted, possible due to the sites close proximity to nearby intrusive (plutonic) contacts. The odd quartz vein, one of which measured up to 600 mm thick, was also noted within the rock face.

km 63 LHS

The site is located within a sparsely vegetated land disposition (No.2006-0395) which is approximately 55 ha in size (750 m x 750 m) and is accessed via a 350 meter long trail from (km 63 LHS of) the Top-of-the-World Highway. At the end of the trail, a ~ 3 ha sized rock quarry (operated by *YG – HPW*) is located in the south-western quadrant of the land disposition. The rock quarry is comprised of two working benches which (combined) measure approximately 100 m x 100 m. Beyond this area to the north-east, lies a (200 m x 100 m) region which has been stripped with a heavy bulldozer.

Photo of km 63 quarry facing north-east (Sept.12, 2015)

The elevations in the region of the land disposition generally ranged between 1160-1220 meters. Swede Dome (peak elevation of 1265 m) was located approximately 900 meters to the south-west.

While the ground surface ascends to the north-east (at ~ 5˚) a working quarry face was not present. Instead, it appeared that colluvial and fractured rock materials had been removed from within the limits of the quarry to depths of approximately 2 meters until more competent rock prohibited further extraction.

Water Placer Atlas Imagery and approximate limits of land disposition

Granodiorite outcrop on quarry floor

The rock was classified as a granodiorite. A sample of the overburden (No.63-1) was classified as silty sand which contained a trace of gravel. Fractured detrital rock fragments in size to 80 mm were noted within the overburden.

Two oversize rock piles were located within the limits of the quarry. While the western pile was predominately buried with stripping and colluvial materials, (approximately twenty-five) intact fractured boulders in size to 1.4 meters were noted in the eastern pile.

Photo of eastern oversize pile facing north w/ 4 m survey rod (Sept.12, 2015)

2.3 Laboratory Work Program

A laboratory work program was conducted at our Whitehorse laboratory facilities and those of our sub-consultant, *Golder Associates*, in Surrey, British Columbia in order to characterize the index properties of the retained soil and rock samples.

2.3.1 Whitehorse, Yukon

The analysis conducted at our Whitehorse laboratory facilities occurred between September 15th and 25th, 2015. In brief, our analysis was comprised of the following;

Visual Classification	ASTM D 2288-00	44 Samples
Moisture Content	ASTM D 2216-92	44 Samples
Grain Size Distribution	ASTM D 422-633	36 Samples

The results of the grain size distribution analysis were utilized to classify the soils in accordance with the *Unified Soils Classification System*.

The results of the analysis have been summarized in Table II with the percent composition of fines (silt & clay), sand, gravel and moisture contents. Where test pits were hand excavated, the depths of the overburden and comments regarding the soil units were also noted.

The results of the individual grain size distribution analysis which denote the percent of material passing relative to standard sieve sizes have been attached in Table III.

In addition to the soil samples, the rock samples which were retained during the field work program were classified in the laboratory setting as follows;

Site	Assemblage [A]	Sample Classification / Comments
1	DMN	NA – Reconnaissance not conduct
2	DMN2	micaceous (graphitic) serpentine grading to low grade muscovitic quartz/schist.
3	DMN	micaceous (graphitic) serpentine grading to low grade muscovitic quartz/schist.
4	DMN	NA – Reconnaissance not conduct
5	DMN	low grade micaceous schist and serpentine
6	DMN	quartz-schist
7	DMN	platy, highly metamorphosed serpentine
8	DMN	low grade schist to micaceous muscovitic chloritic quartz
9a	CPA4	NA – Reconnaissance not conduct
9b	DMN	platy, highly metamorphosed serpentine
10	DMN	NA – Fluvial Deposits
11	DMN	NA – Fluvial Deposits
12	DMN	NA – Fluvial Deposits
13	DMN	NA – Fluvial Deposits
14a	CPA4	low grade serpentine
14b	CPA4	NA – Fluvial Deposits
15	CPA	NA – Reconnaissance not conduct
MS 1	CPA4	orange weathered quartz carbonate
MS 5	CPA	NA – No rock samples obtained or outcrops noted
16	CPA4	NA – No rock samples obtained or outcrops noted
17	CPA	muscovitic (chloritic) schist
km 46	DMN	quartz muscovite schist to muscovitic chloritic quartz
km 63	LKP	granodiorite

Note – [A] – As per Bedrock Geology map legend (Gordey and Makepeace, 1999).

2.3.2 Burnaby, BC – LA Abrasion and Specific Gravity Analysis

Four (4) bulk rock samples were analyzed by our sub-consultant *Golder Associates,* at their Burnaby, B.C. laboratory facilities between September 26th and November 4th, 2015, in order to assess their index properties and characteristics. In brief, their analysis was comprised of the following;

Specific Gravity	ASTM D 6473	25 Samples
LA Abrasion	ASTM C 535	3 Samples
Grain Size Distribution	ASTM D 422-633	3 Samples
Sulphate Analysis	CSA A23.1 – 3C	3 Samples

The specific gravity analysis was conducted to assess the relative density of the rock. The LA Abrasion tests were conducted to assess the hardness of the rock types. The grain size distribution analysis was subsequently conducted on the remnant LA Abrasion materials to better assess their breakdown performance. The purpose of the sulphate analysis was to assess the aggressiveness of the rock material relative to concrete use. A summary of the test results is as follows;

Sample No.	Location	Rock Type	LA Abrasion (% loss)	Apparent Relative Density	Absorption (%)	Total Sulphate Ion Content (%)
1	ToW – km 63 LHS	Granodiorite	14.7	2.719	0.39	0.03
2	ToW – km 46 RHS	Muscovitic Schist	18.2	2.647	0.31	0.05
3	MS 1 – Entrance Pit	Quarzite	22.6	2.899	0.91	0.01
4	MS 1 – Entrance Pit	Serpentine	A	2.630	1.72	NA

Note A – LA Abrasion analysis was considered to allow for comparison of the relatively weaker serpentine rock, however, the presence of the asbestos fibers prevented analysis due to health & safety concerns and so the analysis was not conducted.

The results of their analysis have been attached in Appendix C.

3.0 SITE CONDITIONS

3.1 Study Area

Relative to Dawson City (which is located at km 0 of Top-of-the-World Highway), the central regions of the mine site are located approximately 77 km to the north-west, as noted in Figure 1.

The study area encompassed a region bound by the limits of the mine site, along with regions located within approximately 1 km of both Clinton Creek Road (CCR) and Top-of-the-World Highway # 9 (between approximately km 44 and km 64).

Kilometer 0 of CCR is located at km 60 (RHS) of Top-of-the-World Highway # 9. From this intersection, CCR generally heads north-west, gradually dropping in elevation along a western spine of Cassiar Dome (peak elevation ~ 1340 m). The middle third of the road is bound by tributaries of Mickey Creek to the north and Maiden Creek to the south until crossing Forty Mile River at the Clinton Creek town site. The bridge crossing Forty Mile River near the Clinton Creek town site is located at CCR - km 32.3. The entrance to the mine site is located at approximately km 40.2 and the tailings at the far end of the mine site is located at approximately km 46.2.

3.2 Physiographic Region

The study area is part of the Boreal Cordillera Ecozone and lies within the Klondike Plateau immediately south-west of the Tintina Trench. The mountains in the region are of the Dawson Range, a sub-range of the Yukon (Mountain) Range which dominate much of central Yukon and eastern Alaska. These mountains rise to elevations in the order of 1500 meters. The terrain can be described as smooth, rolling, unglaciated terrain, which is incised by narrow, deep, V-shaped valleys.

The vegetation is predominately comprised of sparse boreal forest. Black spruce and birch dominate regions underlain by permafrost. The understory consists of a variety of mosses, willow and shrubs. Scrub birch and willows are also prevalent from low-lying regions to areas well above the treeline. Eutric brunisols soils developed on loamy colluvial materials which are prevalent throughout the region. Permafrost is extensive, discontinuous and overlain with turbic cryosols.

The elevations in the region of the study area vary. With respect to Clinton Creek Road, the highest elevations (~ 1020 m) are at the roads confluence with the Top-of-the-World Highway. The roads elevation gradually drops to near 290 meters, where it crosses the Forty Mile River. Following the crossing, the road parallels Clinton Creek and gains elevation where it terminates at the mine site where elevations vary between approximately 400 and 600 meters. The road crosses Clinton Creek within the limits of the mine site.

The Yukon River, which flows to the north, lies ~ 5 km east of the study area (relative to the bridge crossing at Forty Mile River) near elevations of ~ 290 meters.

3.3 Geomorphology

Glaciation

Regionally, the Dawson area is unglaciated. As such, glacially derived and segregated materials (which are commonly used for borrow sources) are notably absent from within the study area. Instead, the regional soils are predominately comprised of unsorted colluvial materials which are derived from weathered rock. These materials are incised by local and regional drainages where fluvial deposits can be found in the valleys near lower elevations.

Origin of Borrow Sources

Excluding the rock quarries, the materials encountered within the potential borrow source areas were identified as being derived from either fluvial or colluvial processes as follows;

ORIGIN	1	2	3	4	5	6	7	8	9a	9b	10	11	12	13	14a	14b	15	16	17	MS5
Fluvial											•	•	•	•		•	•			•
Colluvial	•	•	•	•	•	•	•	•	•	•					•			•	•	

Permafrost

Although the area lies within the zone of discontinuous permafrost, permafrost is widespread within the study area, particularly in regions which are low-lying, heavily shaded and located on northern slopes. Previous studies suggest permafrost may measure in the order of 60 meters thick. The active layer is thought to measure between 0.3 and 0.5 meters (Copland, 2005).

Watercourses

The study area is predominately located in the Forty Mile watershed. The central areas of Clinton Creek Road are bound by tributaries of Mickey Creek to the east and Maiden Creek to the west. Each of these creeks flows towards the north-west into the Forty Mile River. The Forty Mile River flows to the east and discharges into the Yukon River. North of the Forty Mile River, lies Clinton and Wolverine Creek. Wolverine Creek flows to the south into Clinton Creek. The confluence of the creeks is located at the entrance to the mine site (~ CCR km 40.2). The mine site itself is bisected by Clinton Creek up-gradient of the confluence. The Yukon River, which flows to the north, lies between 5 and 13 km east of the study area.

Groundwater

Groundwater would be expected near low lying regions of the valleys. Perched groundwater conditions would likely prevail at higher elevations due to the presence of underlying fine grained materials and other impermeable boundaries (i.e. bedrock, permafrost, etc.).

3.4 Surficial Geology

The surfical geology of the deposits noted within the study area are similar to those found in the Dawson region. Specifically, higher elevations are dominated by unsorted colluvial materials which are differentially weathered. Lower elevations, near valley (creek/river) bottoms, are predominately comprised of fluvial deposits which are derived from more recent depositional events. Both types of materials are geomorphologically modified through various mechanisms such as erosional, fluvial, mass movement and/or periglacial processes.

The surficial geology map of Dawson (Open File 2014-12) described these materials as follows;

Colluvium

"Material transported and deposited by down-slope, gravity driven processes such as creep, solifluction, landslides and snow avalanches. Colluvium is the dominant surficial material in the uplands north and south of the Klondike River and west of the Yukon River as most of these areas escaped Pleistocene glaciation. It commonly has a stratified structure with a highly variable texture and composition controlled by the parent material, transport mechanism and travel distance. Colluvium on uplands and slopes is generally derived from weathered bedrock and loess, resulting in a silt-rich diamicton containing angular, local bedrock clasts. On steeper slopes, colluvium is generally coarser grained, as it has been deposited by rapid mass wasting processes such as rock fall, debris flow and avalanches. Slower processes such as sheetwash, solifluction and creep occur on gentler slopes, which in conjunction with greater accumulations of loess and the presence of near-surface permafrost, result in finer grained colluvium. Colluvial aprons found on lower slopes and the uphill sides of terraces are commonly ice-rich and are primarily composed of re-sedimented loess and peat (muck). North of the Klondike River, Pre-Reid morainal deposits have been extensively modified by slope movement (colluviation) and solifluction and are mapped as complexes of colluvial and morainal deposits."

Fluvial

"Sediments transported and deposited by modern streams and rivers, found in floodplains, fans and terraces. Fluvial materials may be subject to occasional flooding, sudden stream migration and/or inundation. Fluvial deposits typically consist of well-sorted stratified sand and gravel comprising subangular to rounded clasts. Thicknesses up to 10 m are common. Low order streams in unglaciated areas are confined to very narrow V-shaped valleys and their fluvial deposits are generally not mapped due to scale limitations. Fluvial fans (Ff), or complexes of coalescing fan-shaped landforms (Fa) are found at the mouths of tributary streams. Where smaller streams enter the Klondike River Valley, fluvial deposits usually consist of large amounts of resedimented silt and sand primarily derived from loess with minor gravels derived from colluvial or glaciofluvial materials. These fans, though still active, likely formed relatively quickly after the McConnell glaciation. They may be ice-rich and contain ice wedges, especially where they are north-facing. Active fluvial (FA) materials primarily consist of sand and gravel and are subject to regular flooding."

3.5 Bedrock Geology

The bedrock in the study area is comprised of the Intermontane (Yukon-Tanana) Terrane. This terrane is described as being comprised of intensely deformed, variably metamorphosed and sheared sedimentary, volcanic and intrusive rocks of the Proterozoic to Mesozoic Age. The composition of the rock assemblages varied as noted in Figure 4. The rock assemblages are described in the legend for the *Bedrock Geology – Yukon Territory* (Gordey and Makepeace, 1999) as;

Anvil Assemblage

CPA – Dominantly oceanic assemblage of mafic volcanics, ultramafics, chert and pelite, limestone and gabbroic rocks.

CPA4 - Dunite, peridotite, gabbro, pyroxenite, hazburgite and minor diorite, hornblendite and diabase; serpentinite, orange weathering quartz carbonate rock with minor green chromian muscovite, talc-carbonate schist and carbonatized ultramafic rocks.

Nasina Assemblage

DMN – Graphitic quartzite and muscovitic quartz-rich schist

DMN2 – Graphitic quartzite and muscovitic quartz-rich schist with interspersed marble.

Prospectors Mountain Suite

LKP – grey, fine to coarse grained, massive, granitic rocks of felsic, intermediate, rarely mafic composition and related to felsic dykes.

The distribution of these assemblages varied. In general, assemblages comprised of predominately weaker argillaceous materials (Anvil Assemblage) were generally located in the region of mine site near the ore body. These rocks were encompassed by a matrix of rock of intermediate strength (Nasina Assemblage). The competence of the rock within the Nasina Assemblage varied. Specifically, based upon our observations, it was evident that the competency of the rock increased as one travelled further away from the mine site. The most competent assemblage within the study area (Prospectors Mountain Suite) was in general, located the furthest away from the mine site.

The regional geology in the area of the mine site are comprised of two complex assemblages. These consist of a sheared assemblage of ultramafic, igneous and metamorphosed rocks (which include serpentine, diorite, amphibolites and schist) and a weakly deformed assemblage comprised of shale, siltstone and sandstone with some phyllite. The ore body consists of jade grade serpentine which contains chrysolite asbestos veins. The very nature of asbestos formation requires the presence of serpentinized rocks where intense fracturing is common. The formation of the asbestos is thought to be a result of predominately fracture filling due to the proximity of granitic intrusions or else shearing and thrusting which caused the infilling by intrusion of aqueous solution. The structural geology of the mine site is intersected by numerous steeply dipping normal faults and low angle thrust faults.

Regionally, the near surface bedrock is fractured and in a state of decomposition due to weathering and periglacial processes. The degree of fracturing and decomposition varies depending upon the composition of the parent rock and local setting.

3.6 Land Use

The potential source (and sample) locations identified within the limits of the mine site are all located within the limits of (Land Disposition 2008-2580) and surveyed mineral claims.

Beyond the mine site, the locations of several of the potential borrow sites coincide with quartz and placer claims and/or land dispositions. These potential conflicts were noted as follows;

ORIGIN	1	2	3	4	5	6	7	8	9a	9b	10	11	12	13	14a	14b	15	16	17	km 46	km 63
Quartz								•	•						•	•		•	•		
Placer													•	•	•						
Placer Prospecting Lease												•					•				
Land Disposition																•					•

The distribution of the potential borrow sites relative to the mineral claims and land dispositions has been illustrated in Figure 5.

With respect to First Nations lands, although the project lies within the limits of Tr'ondëk Hwëch'in Traditional Territory, none of the sites coincided with (or were adjacent to) surveyed First Nations settlement lands. The locations of the surveyed settlement lands have been noted in Figure 1 for illustrative purposes.

4.0 DISCUSSIONS

4.1 General

The geomorphology of the study area is uncommon relative to most regions in Canada due to its unglaciated nature. This presents unique challenges relative to the availability of standard borrow materials which are generally derived through glacial mechanisms. This lack of glaciation has had a direct impact on the regional quality of near surface bedrock which is in a state of decomposition due to weathering and periglacial processes. From a geological standpoint, the argillaceous nature of the Clinton Creek ore body and surrounding rock types further increases their susceptibility to these processes. These processes are accelerated in the mine site area due to the structural geology where weak and sheared assemblages are present.

Historically, the supply of granular aggregate on Top-of-the-World Highway (beyond ~ km 8) has been accomplished by means of aggregate production at rock quarry locations or else through haul operations from naturally derived fluvial deposits which are located in the river valleys. The production of rip-rap along the Top-of-the-World Highway # 9 is generally restricted to smaller sizes (Class I and II) due to the origin and structural geology of the rock. The exceptions to this are near Swede Dome (km 63 area) and the Sixty Mile area where more massive igneous rock types are encountered. As such, considering these challenges, we have provided the following discussions regarding the development potential of the potential borrow sources which were identified within the limits of the study area.

4.2 Development Potential

The development potential of the potential borrow sites will vary with the project requirements and will be dependent upon the composition, quality and quantity of reserves, site access, field conditions, land use conflicts and distance to the mine site.

These factors were taken into consideration and the potential borrow sites were classified as having either a low, moderate or high development potential as follows;

Location	Source	Potential	Comments
Mine Site No.1	Rock Quarry	Moderate	Rip-rap production of quartz-carbonate rock will be limited to Class I sized materials given its highly fractured nature. Quantities may be limited due to the orientation of strata and presence of overlying Serpentine unit and colluvial materials.
Mine Site No.2	Waste Rock	Low	High fines content and poor site access.
Mine Site No.3	Waste Rock	Moderate	May be suitable for use as general purpose fill. Some rip-rap extraction may be possible although the rate is estimated to be at < 2% by volume. In general, overall durability will be poor due to the materials argillaceous nature.
Mine Site No.4	Stockpiles	High	Stockpiles being utilized for Drop Structure Project
Mine Site No.5	Fluvial	Moderate	High fines content may limit granular suitability. Poor site access may limit development.
Mine Site No.6	Tailings	NA	High fines content and presence of asbestos fibers will preclude use as borrow materials.
CCR - Site 1	Colluvial	NA	Poor site access.
CCR - Site 2	Colluvial	Low	May be suitable for CCR sub-base material.
CCR - Site 3	Colluvial	Low	May be suitable for CCR sub-base material.
CCR - Site 4	Colluvial	Low	Poor site access.
CCR - Site 5	Colluvial	Low	May be suitable for CCR sub-base material.
CCR - Site 6	Colluvial	Low	May be suitable for CCR sub-base material.
CCR - Site 7	Colluvial	Low	May be suitable for CCR sub-base material.
CCR - Site 8	Colluvial	Low	May be suitable for CCR sub-base material.
CCR - Site 9a	Colluvial	NA	Poor site access.
CCR - Site 9b	Colluvial	Low	May be suitable for CCR sub-base material.
CCR - Site 10	Fluvial	High	Good quality granular aggregate suitable for granular aggregate production and structural applications
CCR - Site 11	Fluvial	High	Good quality granular aggregate suitable for granular aggregate production and structural applications
CCR - Site 12	Fluvial	Low	Poor site access and limited quantities
CCR - Site 13	Fluvial	Low	Poor site access and limited quantities
CCR - Site 14a	Colluvial	Low	Poor quality material for structural applications. May be suitable for CCR sub-base use. Cover materials and fluvial granular aggregate may be located to the south-east.
CCR - Site 14b	Fluvial	Moderate	Good quality granular aggregate suitable for structural applications however coincides with mineral claims and existing land disposition.
CCR - Site 15	Fluvial	Low	Poor Site Access and limited quantities
CCR - Site 16	Colluvial	Low	High fines content and moisture contents will limit applications
CCR - Site 17	Colluvial	Low	High fines content and moisture contents will limit applications
ToW - km 46 RHS	Rock Quarry	Moderate	Reasonably sound rock however distance to mine site will require consideration. Production of rip-rap will be limited to Class I & II.
ToW - km 63 LHS	Rock Quarry	High	Hard rock suitable for a variety of structural applications (Rip-Rap (Class I to III), Concrete and Granular Aggregates)

4.3 Aggregates Sources

4.3.1 Granular Borrow Sources (cover, filter and road construction materials)

The fluvial deposits which were identified were comprised of both terrace and floodplain deposits. Each of these types of (granular) deposits will generally be suitable for use as cover, filter and road construction materials.

Additional evaluation would be required to verify their suitability for use in concrete applications. Specifically, the coarse fraction of the terrace deposits was noted to be comprised of predominately (weathered) quartz which may be susceptible to fracturing and thus limit their application. The (granular) floodplain deposits located at lower elevations, would likely be more suitable for use.

While the side-cut borrow sources along Clinton Creek Road would have been utilized for common fill, road sub-base and base materials to maintain the roadway, their poorly graded nature, weak aggregate and high fines content would limit their use in long-term structural applications.

4.3.2 Rock Quarries (Rip-Rap & Concrete Aggregate)

The results of the LA Abrasion and Sulphate Ion Content suggest that the rock located at each of the three quarries (MS 1 – Entrance Pit (quartzite), ToW - km 46 RHS and ToW - km 63 LHS) will be suitable for both rip-rap and concrete use. However, the nature of fracturing will limit the size of rip-rap in the MS 1 and km 46 quarries to Class I and II, respectively.

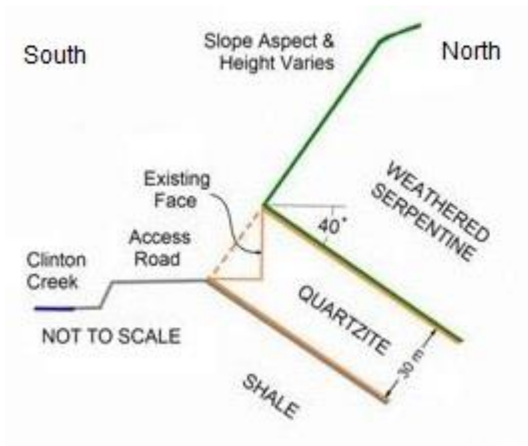
The July 16th, 2015, analysis conducted by *Worley Parsons Canada* suggests that rock from the entrance pit has limited potential for generating acid rock drainage (ARD).

Of the three (3) rock quarries, the analysis indicated that the km 63 quarry would be the most durable. In addition, based upon our field observations and literature review, it was evident that rock located at the km 63 quarry was more massive than either Mine Site No.1 or ToW - km 46 RHS.

The results of the sulphate analysis indicate that the potential that concrete would be subjected to sulphate attack from the respective rock types would be negligible.

Mine Site No.1

The degree of fracturing and discontinuities noted within the quartz-carbonate rock at Mine Site No.1 (Entrance Pit) was considerable and would limit the production of rip-rap to Class I sized materials (as was noted onsite). The results of the LA Abrasion and sulphate analysis indicated that crushed (quartz-carbonate) rock will be suitable for use as concrete aggregate. However, the aggregate will not be as competent as material sourced from either ToW – km 46 or ToW – km 63.



The attached cross section illustrates the approximate slope and stratigraphic conditions which are thought to be present at the entrance pit. As noted, the orientation (40° dip) and thickness (~30 m) of the quartzite strata relative to the overlying weathered serpentine rock unit (and colluvial materials) will limit the amount of available quartzite beyond what is readily accessible from the access road (in regions located south of the ‘existing face’). Specifically, removal of the overlying materials through mechanical means may prove to be cost prohibitive relative to the amount and quality of available quartzite. The weathered nature and configuration of the deposit would likely restrict or eliminate the need for blasting techniques if the available source is to be optimized. Additional assessment would be required to better characterize the configuration, quality and quantities of the remaining source.

ToW – km 46 RHS

The quarry at km 46 exhibited intermediate levels of fracturing and hardness relative to Mine Site No.1 and ToW – km 63. Rip-rap production would generally be limited to Class II sized materials.

ToW – km 63 LHS

The relatively massive nature of the granodiorite rock located at km 63 will allow for production of the required Class III sized rip-rap. While some of this material can be sourced from near surface materials located within the upper 2 meters of source areas (beyond the limits of the existing quarry) blasting may be required to more readily yield suitable quantities of material.

4.3.3 Fine Grained Deposits (Cover Materials)

Given the regional geomorphology, fine grained deposits within the study area were not readily abundant. While the low lying regions located adjacent to Forty Mile River (between approximately CCR Site 12 and Site 14) may harbor fine grained deposits, the presence of quartz and placer claims in this region may limit their development potential and so additional consideration may be required in this regard. The region located beyond the anticipated granular limits of CCR – Site 11, may also harbor fine grained materials, however, the presence of permafrost would need to be assessed along with land use considerations relative to the Placer Prospecting Claim(s).

4.4 Estimated Borrow Quantities

Although our assessment was preliminary in nature, we were able to estimate the volumes of the primary potential borrow sources based upon our observations. These estimated quantities have been summarized in Table I and in the table presented below. The noted values assume access to the reserves will be unfettered from both land use and geotechnical perspectives.

Borrow Source Volume Estimates

Site	Estimated Quantity (m^3)	Material Type	Comments
CCR - Site 10	~14,000	Granular (Sands & Gravels)	NA
CCR - Site 11	100,000 +	Granular (Sands & Gravels)	Portions of the deposit lie within existing Placer Prospecting Claims and so quantities may be partially restricted.
Mine Site - MS 1	~10,000 - 22,500	Rock Class I and smaller	Access to reserves may be limited due to overlying materials.
Mine Site - MS 5	~12,000	Granular (Sands & Gravels)	Quality of reserves may be variable and thus limit its application due to fines.
Top-of-the-World km 46	50,000 +	Rock – Class I or II	Existing YG-HPW quarry
Top-of-the-World km 63	100,000 +	Rock – Class I-III	Coincides with YG-HPW Land Disposition

The suitability of the individual borrow sites relative to the supply of structural materials for the stabilization of Clinton Creek will vary based upon the material types and quantities proposed in the remedial options. As per information retained during our December 10th, 2015 meeting with *AAM*, the types of materials and approximate required quantities (proposed by *Worley Parsons*) have been summarized as follows;

Worley Parsons - *Clinton Creek Site Lifecycle Cost Analysis for Remedial Options*

Option	**Gravel Resurfacing**	**Access Road**	**Rip-Rap** D50 = 500 mm	**Rip-Rap** D50 = 800mm	**Granular Filter**	**Granular Filter** Crushed Rock	**Blast Rock** 100 mm to 500 mm	**Cobbles** 25 mm to 100 mm	**Cobbles** 50 mm to 200 mm
B	960	NA	NA	NA	13,000	NA	31,000	NA	NA
C	960	NA	NA	2,900	NA	2,400	NA	2,500	NA
D	960	NA	NA	2,900	NA	2,400	31,000	2,500	NA
E	960	NA	NA	2,900	13,000	2,400	31,000	2,500	NA
F	12,000	NA	NA	NA	NA	NA	NA	NA	4,000
C3	12,000	1,350	8,500	NA	NA	NA	NA	NA	NA
D3	12,000	1,350	8,500	NA	NA	NA	NA	NA	NA
E3	12,000	1,530	6,100	NA	NA	NA	NA	NA	NA
I2	12,000	1,350	5,800	7,100	5,200	NA	NA	NA	NA

Note – Values noted are in m^3.

As such, based upon the noted material types and estimated quantities, the resources identified during our assessment should allow for implementation of the (*Worley Parsons*) options being considered by *AAM*. Additional consideration will however be required as the absence of large cobbles from the majority of the fluvial deposits may make fulfillment of the ‘Cobble’ component difficult (particularly if access to Site 14b is restricted due to land use conflicts). If required, larger cobbles could potentially be sourced from Site 12 or Site 13, however, these sites will have limited quantities and poor access, respectively. Another option would be to retain the larger cobbles directly from Clinton Creek or else the Forty Mile River floodplains. Regardless, there will likely be conflicts with mining claims and/or land dispositions where larger cobbles are known to be present (near the Forty Mile River Bridge) and so additional consideration will be required relative to potential land use requirements.

Where ‘Rip-Rap’ and ‘Blast Rock’ is required, the materials will need to be hauled to the project area from the Top-of-the-World Highway km 63 quarry as the ‘Entrance Pit’ quarry (MS 1) will not have sufficient quantities to fully meet the (volume and material size) requirements.

The fluvial deposits should allow for fulfillment of the ‘Granular Surfacing’ material requirements, however, depending on the material specifications, MS 5 materials may not meet the requirements given the higher fines contents which were initially encountered and potentially limited quantities.

While the gradation/composition of the ‘Granular Filter’ material was not specified, the fluvial deposits and rock quarries should allow for fulfillment of this component.

Site specific geotechnical evaluations would be required to adequately characterize the potential borrow sources to prove the quantity and quality of the reserves prior to their use as discussed in Section 5.3, below.

5.0 RECOMMENDATIONS

5.1 General

The following recommendations have been provided with the intent to identify borrow sites which may yield reserves most suited to fulfill *AAM* requirements. In addition, we have outlined general project requirements which will need to be conducted during the course of borrow source development. These would include;

- conducting geotechnical evaluations to verify the quantity, quality and characteristics of the resource,
- formulating pit development plans to maximize use of the resource, and
- providing quality control and construction monitoring during borrow source development to document the conditions and optimize extraction.
- clarifying potential land use conflicts

5.2 Recommended Sites

Of the twenty-seven (27) sites that were assessed during the course of our evaluation, only eight (8) sites were identified as harboring potential resources which will be suitable to fulfill portions of the *AAM* material requirements. These sites and their potential use are presented in the table below;

Site	Source	Potential Use
Mine Site No.1	Rock Quarry	Rip-Rap (Class I) and Filter Materials
Mine Site No.3	Waste Rock	General purpose non-structural fill
Mine Site No.5	Fluvial Deposit	Filter, Cover and Road Construction Materials
CCR - Site 10	Fluvial Deposit	Filter, Cover and Road Construction Materials
CCR - Site 11 [A, B]	Fluvial Deposit	Filter, Cover and Road Construction Materials
CCR – Site 14b [E]	Fluvial Deposit	Cobbles and Road Construction Materials
ToW - km 46 [C]	Rock Quarry	Rip-Rap (Class I & II and supplement portions of Class III) and Concrete Aggregates
ToW - km 63 [C, D]	Rock Quarry	Rip-Rap (Class I to Class III) and Concrete Aggregates

Notes – [A] – Surrounding areas should be assessed for the presence of potential fine grained deposits.
[B] – Additional consideration will be required relative to the existing Placer Prospecting Claims which coincide with the southern portion (existing cleared borrow area) of the site.

[C] – Although these sources may also allow for production of filter, cover and road construction materials, their distance from the site may limit their use for aggregate supply in this regard.
[D] – Additional consideration will be required relative to the (assumed) *YG – HPW* Land Disposition which encompasses the site.
[E] – Additional consideration will be required relative to the mining claims and land dispositions which coincide with the site.

5.3 Geotechnical Evaluations

Site specific geotechnical evaluations should be conducted at selected locations to verify the composition, quality and quantity of the potential borrow resources and identify geotechnical liabilities (ie groundwater, permafrost, overburden thickness, etc.) which may restrict development. The evaluations should be conducted through field reconnaissance as well as sub-surface test-pit and drilling methodologies. Sub-surface samples should be retained to allow for comprehensive laboratory analysis. The laboratory analysis should assess the acid rock drainage potential of the materials along with characterizing the physical traits of the material.

A geotechnical report, which details the findings of the evaluation and provides recommendations for pit development, should be prepared following the work. The source material (and surrounding areas) should be well characterized such that pit development can be optimized.

Subsequent evaluations should be conducted to ascertain the risk potential associated with natural hazards at selected sites. These hazards may include, but are not limited to mass wasting/creep, slope stability, debris flows, liquefaction, flooding and other similar type hazards.

5.4 Pit Development Plans

A site specific Pit Development Plan should be formulated prior to the borrow source development in order to maximize the use of available materials. The plan should take into account the findings of the geotechnical evaluation and anticipated individual remedial project requirements and consider the following;

Permafrost

Due to widespread presence of discontinuous permafrost and depositional variability, the suitability of potential borrow source areas would have to be assessed on a case-by-case basis. The development potential would decrease on terrain features located on north facing slopes, where the potential for permafrost is higher.

Surface and Groundwater

The surface and groundwater regimes may vary considerably depending upon the time of season and variations in the local conditions. Consideration should be given to potentially perched groundwater and inflow rates that may limit development. Site dewatering may be required to allow for extraction of additional materials from potential borrow areas if resources are proven and extraction is deemed to be cost effective.

Deleterious Materials

Consideration should be given to the presence of deleterious materials that may be found in the fluvial (or other) deposits, given their geomorphology. This may include the presence of organics, boulders, ice lenses and other deleterious materials. Additional care will be required in regions where fine grained soils are encountered as pit development is commonly challenging due to difficulties in material extraction, handling and placement.

5.5 Quality Control & Construction Monitoring

Quality control testing and construction monitoring services should be provided by qualified geotechnical personnel in order to confirm the quality of the material and document the conditions during borrow source development.

5.6 Additional Considerations

As larger classed rip-rap (and potentially other materials) may need to be brought to the site from the Top-of-the-World Highway – km 63 quarry, sections of Clinton Creek Road may require upgrading in order to optimize haul operations.

Our recommendations have been provided without consideration to land use (mining claims and land disposition) conflicts and so these potential issues should be resolved/clarified during future work.

6.0 CONCLUSIONS

The geomorphology of the study area is uncommon relative to most regions in Canada due to its unglaciated nature. This presents unique challenges relative to the availability of standard borrow materials which are generally glacially derived. In addition, this lack of glaciation has had a direct impact on the regional quality of near surface bedrock which is in a state of decomposition due to weathering and periglacial processes. From a geological standpoint, the argillaceous nature of the Clinton Creek ore body and surrounding rock types increases their susceptibility to these processes. These processes are accelerated in the mine site area due to the structural geology where weak and sheared assemblages are present.

Hence, of the twenty-seven (27) sites that were assessed during the course of our evaluation, only eight (8) of the sites may harbor resources which will be suitable to fulfill (structural applications) portions of the *AAM* material requirements. Specifically, these sites and their potential use include;

Site	Source	Potential Use
Mine Site No.1	Rock Quarry	Rip-Rap (Class I and supplement Class II & III) and Filter Materials
Mine Site No.3	Waste Rock	General purpose non-structural fill
Mine Site No.5	Fluvial Deposit	Filter, Cover and Road Construction Materials
CCR - Site 10	Fluvial Deposit	Filter, Cover and Road Construction Materials
CCR - Site 11	Fluvial Deposit	Filter, Cover and Road Construction Materials
CCR – Site 14b	Fluvial Deposit	Cobbles and Road Construction Materials
ToW - km 46	Rock Quarry	Rip-Rap (Class I & II and supplement Class III) and Concrete Aggregate
ToW - km 63	Rock Quarry	Rip-Rap (Class I to Class III) and Concrete Aggregate

Of the four (4) fluvial deposits, CCR – Site 11 would likely yield the highest quality and largest quantities of granular aggregate to allow for long-term development, although some land use considerations will be required as portions of the site coincide with Placer Prospecting Claim(s).

Of the three (3) rock quarries, ToW – km 63 LHS will be the only one which will yield Class III sized rip-rap. The rock at this location is the most durable relative to the others. Discussions with the land disposition holder (assumed to be *YG – HPW*) will be required as the deposit lies within their limits.

Further assessment of the waste rock would be required to identify regions which may be suitable for non-structural and common fill applications.

As many of the potential borrow locations coincided with mining claims and/or land dispositions, potential land use conflicts should be resolved/clarified during future work.

Site specific geotechnical evaluations would be required to adequately characterize the potential borrow sources identified herein to prove the quantity and quality of the reserves prior to their use as discussed.

7.0 LIMITATIONS

This report is intended for the sole use of *Yukon Government*. No portion of this report may be used as a separate entity; it is intended to be read in its entirety. Any use of this report by a third party is the responsibility of such third party.

The comments contained herein reflect our best judgment in light of the information available to our firm at the time of our assessment and report preparation. Our comments are based upon our collation of available literature, recognition of geomorphic features, current construction techniques and generally accepted engineering practices. Given the nature of our assessment and scale of mapping, the information contained herein will not be sufficient to assess all factors that may have an effect upon borrow source development. Our assessment was limited due to the time available in which to conduct the field reconnaissance and scope of field work and laboratory testing. As such our findings should be confirmed (or refuted) through site specific geotechnical evaluations.

The presence, quality and quantity of borrow materials within selected areas, should be confirmed (or refuted) through supplementary site reconnaissance, sub-surface investigations and comprehensive laboratory analysis. This work should be undertaken by qualified personnel in order to confirm borrow source suitability, pit development options and geotechnical material parameters.

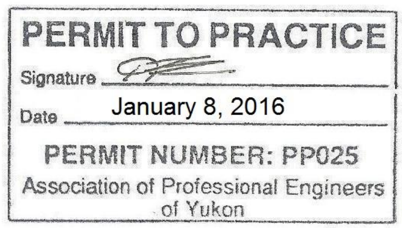
Due to the dynamic geological and geomorphological nature of the deposits located within the study area, interpolations of the conditions, between the compiled information, has not been made or been implied. Should newly found geologic and/or geomorphic conditions be encountered, our firm should be notified in order to confirm the suitability of our recommendations and conclusions, which may be altered or modified by the undersigned.

8.0 CLOSURE

We trust that the information we have provided will be suitable for your purposes. However, if you should have any questions or concerns, please feel free to contact the undersigned at your convenience.

Respectfully Submitted,

CHILKOOT GEOLOGICAL ENGINEERS LTD.



Tares Dhara, P.Eng.

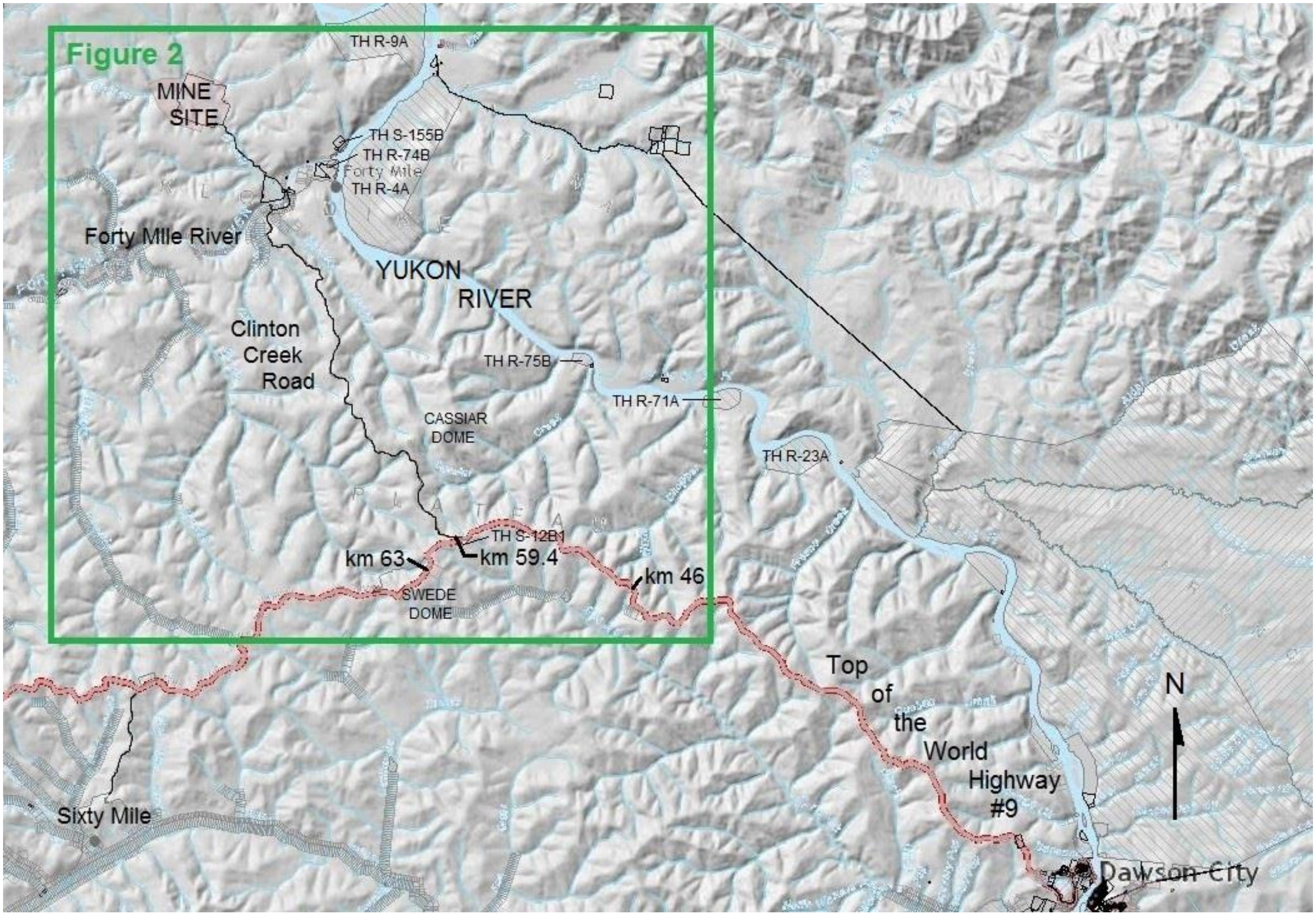
Senior Geotechnical Engineer

TD/td

FIGURES 1-5

Geotechnical Evaluation - Borrow Source Assessment - Clinton Creek Area – Dawson, Yukon – 2015

Figure 1 – Site Location

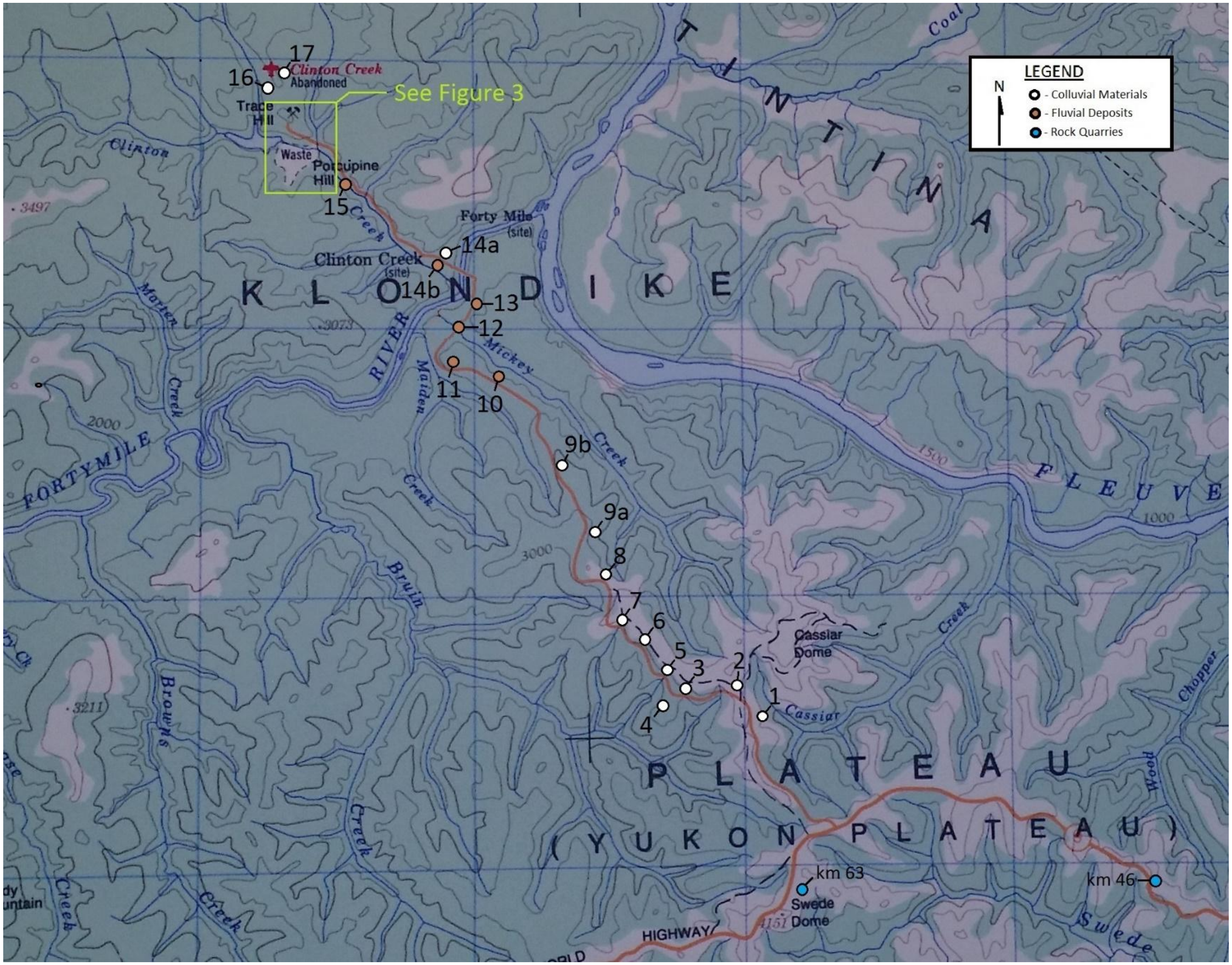


Based map from *Yukon Water Placer Atlas* website – Locations are approximate

Compiled December 29, 2015 by T.Dhara

Geotechnical Evaluation - Borrow Source Assessment - Clinton Creek Area – Dawson, Yukon – 2015

Figure 2 – Potential Borrow Locations



Based map from *GSC* 1:250,000 Scale Topographical Map

Compiled Oct.31, 2015 by T.Dhara

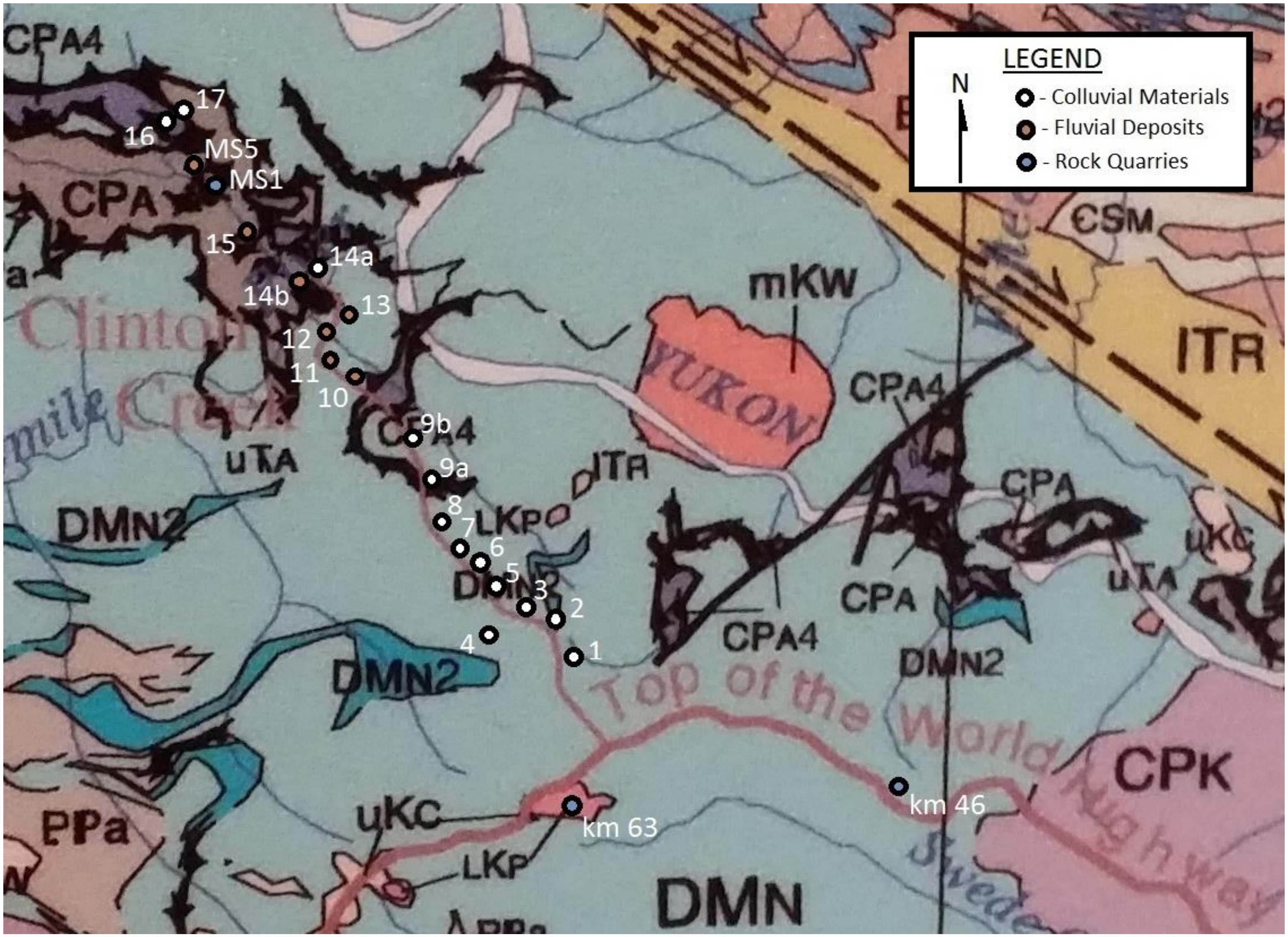
Geotechnical Evaluation – Borrow Source Assessment - Memo
Clinton Creek Area, Yukon – 2015
FIGURE 3 – Mine Site Locations

Based map modified from Water Placer Atlas
Locations are approximate – Not to Scale

Compiled Sept. 25, 2015 by T.Dhara, P.Eng.

Geotechnical Evaluation - Borrow Source Assessment - Clinton Creek Area – Dawson, Yukon – 2015

Figure 4 – Bedrock Geology

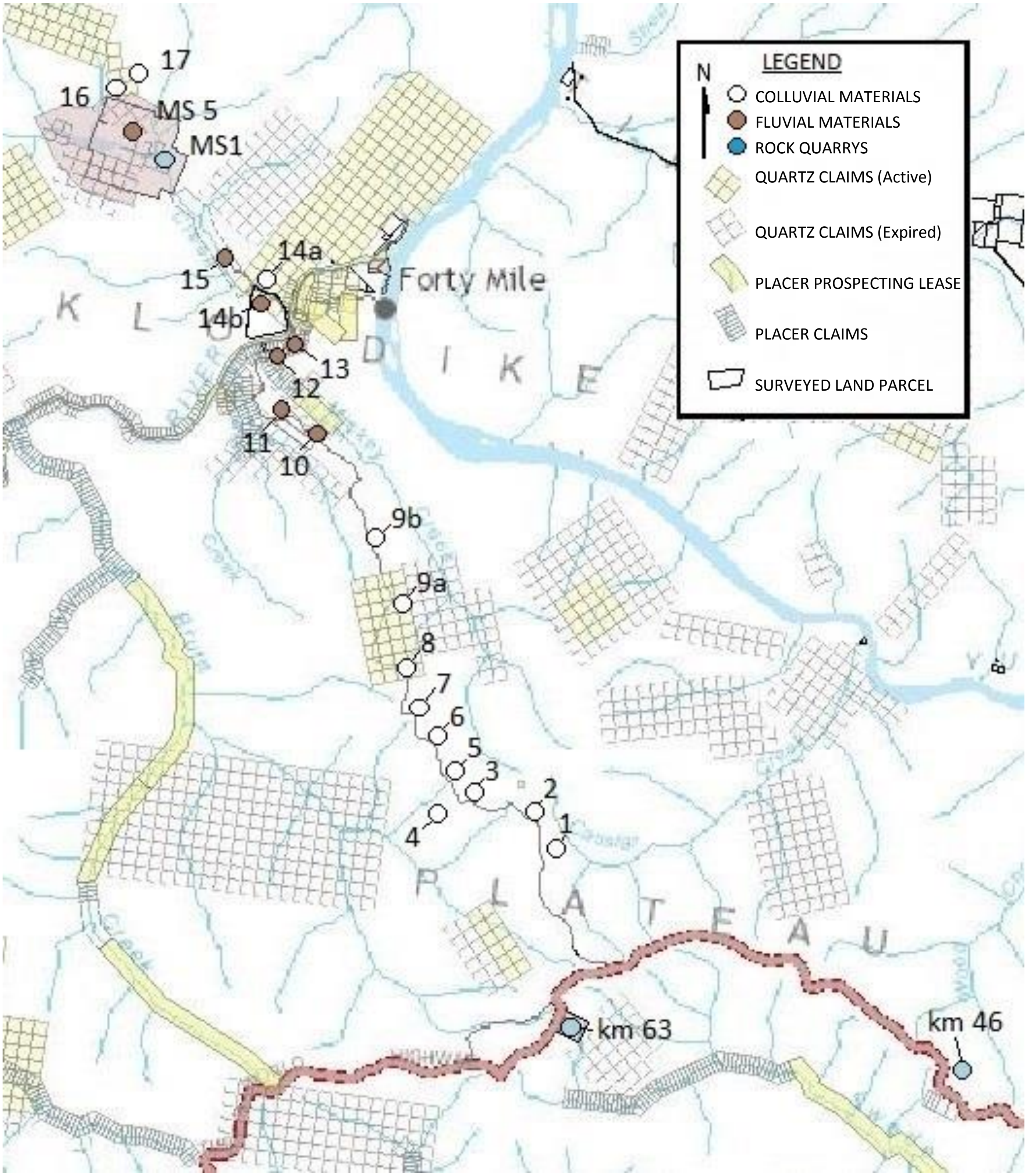


Based map from *Bedrock Geology – Yukon Territory* – (*GSC* -Open File 3754 and *GSYukon* – Open File 2001-1), 2001

Not to Scale – Locations are approximate

Compiled September 26, 2015 by T.Dhara

Geotechnical Evaluation - Borrow Source Assessment
Clinton Creek Area – Dawson, Yukon – 2015
Figure 5 – Mineral Claims & Land Dispositions



Based map from *Water Placer Atlas*
Not to Scale – Locations are approximate

Compiled December 29, 2015 by T.Dhara

TABLES I - III

CHILKOOT GEOLOGICAL ENGINEERS LTD.

5b Bennett Road, Whitehorse, Yukon

GEOTECHNICAL EVALUATION - BORROW SOURCE ASSESSMENT

CLINTON CREEK AREA - DAWSON, YUKON - 2015

TABLE I - SUMMARY OF RECONNAISSANCE AREAS

TOP-OF-THE-WORLD HIGHWAY # 9 (ToW)

Pit [B] ToW	km [C] (approx.)	LHS/RHS	Offset (m)	Terrain Classification	Previous Borrow	Estimated [A] Quantity (m^3)	Comments
km 46	44	RHS	300	Cv/R	YES	50,000 +	Existing YG - HPW Quarry
km 63	63	LHS	400	Cv/R	YES	100,000 +	Coincides with YG - HPW Land Disposition

CLINTON CREEK ROAD LOCATIONS (CCR)

Pit (CCR)	km (approx.)	LHS/RHS	Offset (m)	Terrain Classification	Previous Borrow	Estimated [A] Quantity (m^3)	Comments
1	5.5	RHS	500	rszCv/R	NO	Limited	Relatively Inaccessible
2	6.6	RHS	NA	rszCv/R	YES	Limited	Limited quantities relatively far from Mine Site.
3	9.1	RHS	NA	rszCv/R	YES	Limited	Limited quantities relatively far from Mine Site.
4	9.6	LHS	600-1000	rszCv/R	YES	Limited	Relatively Inaccessible
5	10.1	RHS	NA	rszCv/R	NO	Undetermined	Potentially limited quantities relatively far from Mine Site.
6	11.7	RHS	NA	rszCv/R	YES	Limited	Limited quantities relatively far from Mine Site.
7	13.2	RHS	NA	rszCv/R	YES	Limited	Limited quantities relatively far from Mine Site.
8	15.2	L&RHS	NA	rszCv/R	YES	Limited	Limited quantities relatively far from Mine Site.
9a	18.1	RHS	500	Cv/R	NO	Undetermined	Potential Rock Outcrops - Poor access
9b	20.6	RHS	NA	rszCv/R	YES	Limited	Overgrown access. Relatively far from Mine Site.
10	24.9	RHS	NA	rszCv/R or sgzFt/R	YES	14,000	Limited Granular Reserves
11	26.6	RHS	NA	rszCv/R or sgzFt/R	YES	100,000 +	Portions of the deposit are located within Placer Prospecting Claim(s).
12	30.4	RHS	NA	Ft/R	YES	Limited	Isolated fluvial terrace deposits - Relatively Limited Quantities
13	31.2	RHS	NA	Cv/R or Ft/R	NO	Limited	Difficult access. Highly variable depositions.
14a	33.2	RHS	NA	Ft/R	NO	Limited	Located on flood plain. Deposit may be discontinuous due to channel incising.
14b	33.2	LHS	275	Fp/R	YES	Undetermined	Located within limits of former townsite (Lot 103 REM - Group 1101 - Clinton C
15	37.9	LHS	100	sgFp/R	NO	Limited	Relatively Inaccessible small discontinuous fluvial deposits adjacent to Clinton C
16	Airfield	LHS	NA	Cv/R	NO	Undetermined	Limited overall potential
17	Airfield	RHS	NA	Cv/R	NO	Undetermined	Limited overall potential

MINE SITE LOCATIONS (MS)

Pit (MS)	km (approx.)	LHS/RHS	Offset (m)	Terrain Classification	Former Borrow	Estimated [A] Quantity (m^3)	Comments
1	40.2	RHS	NA	Cv/R	YES	10,000 - 22,500	Current Rock Borrow
2	NA	NA	NA	Waste Rock	NA	NA	Porcupine Creek - Waste Rock
3	NA	NA	NA	Waste Rock	NA	NA	Clinton Creek - Waste Rock
4	NA	NA	NA	Misc.Stockpiles	NA	NA	Potential Stockpiles
5	NA	NA	NA	Ft/R	YES	12,000	Former Borrow Area
6	NA	NA	NA	Mine Tailings	NA	NA	Mine Tailings

Terrain Classification - Legend

Texture	Material Origin	Surface Expression
z - silt	A - Anthropogenic	v - veneer
s - sand	C - Colluvial	t - terrace
g - gravel	F - Fluvial	p - plain
r - rubble	R - Rock	

Notes -

[A] - Based upon site observations and as per report discussions.

[B] - kilometer reading refers to location of site access relative to the Yukon River.

[C] - kilometer reading refers to location of borrow source based upon truck odemeter.

Prepared Sept.30, 2015 by T.Dhara, P.Eng.

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GEOTECHNICAL EVALUATION - BORROW SOURCE ASSESSMENT
CLINTON CREEK AREA - DAWSON, YUKON - 2015
TABLE II - SUMMARY OF LABORATORY RESULTS AND TEST PITS

Site	Test Pit	Sample	Depth (m)	Moisture (%)	Fines (%)	Sand (%)	Gravel (%)	(USCS) Description	USCS	Comments
10	1	1	0.3	7.1	5.7	75.7	18.6	Gravelly Sand trace Silt	SP-SM	Top of Terrace
	2	2	0.3	3.5	2.8	53.8	43.3	Gravelly Sand	SP	Top of Terrace
	3	3	0.5	3.5	2.1	53.7	44.2	Gravelly Sand	SP	Base of Slope
11	Tetra Tech	SA01	NA	7.4	11	53	37	Gravelly Sand some Silt	NA	Tetra Tech analysis for Worley Parsons
11	1	NA	0.0 - 0.1	NA	NA	NA	NA	Organics and Organic Silt	ORG	Overburden
		1	0.0-0.1	19.1	64.2	32.5	3.3	Sandy Silt	ML	Overburden
		2	0.2-0.4	4.7	6.4	74.8	18.8	Gravelly Sand trace Silt	SP-SM	Granular Source
	2	NA	0.0 - 0.1	NA	NA	NA	NA	Organics and Organic Silt	ORG	Overburden
		3	0.1-0.2	20.6	80.8	18.9	0.2	Sandy Silt	ML	Overburden
		4	0.2-0.4	5.2	11.0	74.5	14.5	Sand some Silt and Gravel	SP-SM	Granular Source
	3	NA	0.0 - 0.1	NA	NA	NA	NA	Organics and Organic Silt	ORG	Overburden
		5	0.1-0.2	19.8	83.7	14.3	2.0	Silt some Sand	ML	Overburden
		6	0.2-0.4	3.9	6.4	61.1	32.5	Gravelly Sand trace Silt	SP-SM	Granular Source
	4	7	0.3	2.5	2.0	51.6	46.4	Gravelly Sand	SP	Granular Source
	5	8	0.3	2.6	2.0	51.5	46.5	Gravelly Sand	SP	Disturbed granular source materials pushed overbank.
	6	9	0.3	2.7	1.6	38.1	60.3	Sandy Gravel	GP	Granular Source
12	1	1	See Comments	3.6	8.6	37.7	53.6	Sandy Gravel trace Silt	GW-GM	Obtained 2 up a 4 meter tall working face.
	2	2	See Comments	4.0	1.7	48.6	49.7	Sandy Gravel	GW	Obtained from 0.2 meters below pit floor at groundwater.
14a	1	NA	0.0 - 0.2	NA	NA	NA	NA	Organics and Organic Silt	ORG	Organics
		1	0.2 - 0.3	12.0	NA	NA	NA	Silty Gravelly Sand	SM	Test Pit RHS of trail
	2	2	Side cut	8.7	NA	NA	NA	Gravelly Silty Sand	SM	Trail Sidecut
	3	3	Side cut	12.7	34.1	42.0	23.9	Silty Gravelly Sand	SM	Trail Sidecut
14b	1	1	0.6	4.3	6.0	39.1	54.9	Sandy Gravel trace Silt	GW-GM	Former Borrow
16	1	NA	0.0 - 0.3	NA	NA	NA	NA	Organics and Organic Silt	ORG	Spruce w/ interspersed Birch - lichen and moss floor
		1	0.3 - 0.4	25.8	NA	NA	NA	Sandy Silt	ML	Slope Aspect 5° to 7° dipping to the north-east
		2	0.4 - 0.75	27.4	NA	NA	NA	Silt trace fine Sand - low plasticity	ML	Local relief of 0.5 meters
17	1	NA	0.0 - 0.25	NA	NA	NA	NA	Organics and Organic Silt	ORG	Spruce w/ interspersed Birch - lichen and moss floor
		1	0.25 - 0.35	18.6	NA	NA	NA	Detritus - moist Sandy Silt trace rootlets	ML	Slope Aspect 10° to 15° dipping to the north-east
		2	0.35 - 0.5	11.0	NA	NA	NA	Detritus - wet Sandy Silt to Silty Sand - Fractured Rock	SM/ML	'chloritic' schist - increasing plasticity
Airfield	1	1	0.0	4.8	7.0	52.7	40.3	Gravelly Sand trace Silt	GW-GM	10-15 mm of BST
km 46	stockpile	1	NA	3.3	6.2	33.4	60.4	Sandy Gravel trace Silt	NA	20 mm minus crushed surfacing agg
	stockpile	2	NA	1.1	2.7	25.6	71.7	Sandy Gravel	NA	3" Minus Sub-base Aggregate
km 62	1	1	0.1	8.5	17.6	74.5	7.9	Silty Sand trace Gravel	SM	Overburden
MS 1	1	1	0.2	4.8	6.5	44.0	49.5	Sandy Gravel trace Silt	GW-GM	Shale
	stockpile	2	NA	4.3	4.3	18.7	77.0	Sandy Gravel	GW	100 mm minus rip-rap
MS 1	Tetra Tech	SA02	NA	1.5	6	31	63	Sandy Gravel trace Silt	GW	Tetra Tech analysis for Worley Parsons
MS 2	1	1	0.0	6.5	NA	NA	NA	weathered serpentine	NA	Waste Rock - weathered serpentine
	2	2	0.0	6.2	NA	NA	NA	weathered serpentine	NA	Waste Rock - weathered serpentine
	3	3	0.2	5.5	24.7	62.6	12.7	Silty Sand some Gravel	SM	Waste Rock - weathered shale
	4	4	0.2	3.5	16.1	36.8	47	Sandy Silty Gravel	GM	Waste Rock - weathered shale
MS 3	1	1	0.3	5.2	18.0	42.4	39.6	Gravelly Silty Sand	SM	Waste Rock - shale
	2	2	0.3	7.5	14.4	37.4	48.3	Sandy Gravel some Silt	GM	Waste Rock - shale
South of Drop Structure	CAP	1	NA	7.0	NA	NA	NA	Proctor Analysis	NA	CAP analysis for Sidhu Trucking - Waste Material
	CAP	1	NA	8.1	17.2	14.8	68.0	Silty Gravel some Sand	NA	CAP analysis for Sidhu Trucking - Waste Rock
	CAP	4	NA	5.9	20	8	72	Silty Gravel trace Sand odd Cobble	NA	CAP analysis for Sidhu Trucking - Waste Rock
MS 4	stockpile	1	NA	8.3	8.8	28.0	63.2	Sandy Gravel trace Silt	GW-GM	80 mm nominal quartzite stockpile
MS 5	1	1	0.4	7.5	14.7	71.1	14.3	Sand some Silt and Gravel	SM	Former Borrow Area - West Side
	2	2	0.4	8.3	15.7	80.0	4.3	Silty Sand	SM	Former Borrow Area - Central Area
	3	3	0.4	4.4	13.2	35.0	51.8	Sandy Gravel some Silt	GM	Former Borrow Area - East Side
Tailings	1	1	0.3	8.9	13.4	52.6	34.0	Gravelly Sand some Silt with Asbestos fibers	SM	Mine Tailings - Northern Lobe
	2	2	0.3	8.3	15.5	53.8	30.6	Gravelly Silty Sand with Asbestos fibers	SM	
	3	3	0.3	10.3	23.9	41.0	35.0	Gravelly Silty Sand with Asbestos fibers	SM	Mine Tailings - Central Area
	4	4	0.3	12.6	30.1	49.4	20.6	Silty Gravelly Sand with Asbestos fibers	SM	Mine Tailings - Southern Lobe
	5	5	0.3	12.6	24.5	58.1	17.4	Silty Gravelly Sand with Asbestos fibers	SM	
	stockpile	6	0.2	1.6	0.8	1.8	97.4	Gravel with Asbestos fibers	GP	Mine Tailings - (nominal) 25 mm minus Serpentine waste pile

Prepared by T.Dhara, P.Eng. - October 15, 2015

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GEOTECHNICAL EVALUATION - BORROW SOURCE ASSESSMENT
CLINTON CREEK AREA - DAWSON, YUKON - 2015
TABLE III - SUMMARY OF GRAIN SIZE DISTRIBUTION ANALYSIS

Site/Sample		10-1	10-2	10-3	11-1	11-2	11-3	11-4	11-5	11-6	11-7	11-8	11-9	12-1	12-2	14A-3	14B-1
Sieve Size (mm)	80	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	56	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	40	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	28	94.7	97.6	100.0	100.0	100.0	100.0	100.0	100.0	92.1	92.7	100.0	94.5	84.5	92.0	95.2	88.8
	20	94.7	83.5	92.2	100.0	100.0	100.0	96.9	100.0	92.1	76.2	94.7	65.2	79.6	90.5	91.2	72.8
	12.5	91.2	71.3	78.1	100.0	93.5	100.0	91.1	100.0	81.3	66.9	74.7	59.3	66.1	81.5	87.5	62.8
	10	89.3	68.5	72.0	98.7	91.5	100.0	90.2	100.0	78.2	63.4	69.9	54.6	61.5	73.8	83.7	58.1
	5	81.4	56.6	55.8	96.7	91.2	99.8	85.5	98.0	67.5	53.6	53.5	39.7	46.4	50.3	76.1	45.1
	2.5	68.9	41.2	42.3	94.1	68.3	98.5	80.5	96.5	58.4	44.9	42.0	27.6	34.7	28.8	66.7	35.0
	1.25	47.3	20.5	28.5	90.6	51.8	96.3	69.7	94.7	51.3	36.7	32.8	16.7	26.7	13.2	57.9	26.8
	0.63	23.7	8.5	12.5	83.0	33.2	92.7	45.8	92.5	40.7	18.8	20.9	7.4	20.1	6.4	50.1	21.4
	0.315	13.3	5.1	4.7	70.6	16.0	89.0	23.1	89.2	15.5	5.7	6.4	3.5	14.6	3.5	44.5	13.9
	0.16	8.4	3.8	2.9	66.7	9.1	85.6	14.6	86.6	8.7	2.8	2.9	2.2	11.0	2.3	39.3	8.3
	0.08	5.7	2.8	2.1	64.2	6.4	80.8	11.0	83.7	6.4	2.0	2.0	1.6	8.6	1.7	34.1	6.0
Moisture		7.1	3.5	3.5	19.1	4.7	20.6	5.2	19.8	3.9	2.5	2.6	2.7	3.6	4.0	12.7	4.3
Fines		5.7	2.8	2.1	64.2	6.4	80.8	11.0	83.7	6.4	2.0	2.0	1.6	8.6	1.7	34.1	6.0
Sand		75.7	53.8	53.7	32.5	74.8	18.9	74.5	14.3	61.1	51.6	51.5	38.1	37.7	48.6	42.0	39.1
Gravel		18.6	43.4	44.2	3.3	18.8	0.2	14.5	2.0	32.5	46.4	46.5	60.3	53.6	49.7	23.9	54.9
USCS		SP-SM	SP	SP	ML	SP-SM	ML	SP-SM	ML	SP	SP	SP	GP	GP-GM	GP	SM	GP-GM
Description		Gravelly Sand trace Silt	Gravelly Sand	Gravelly Sand	Sandy Silt	Gravelly Sand trace Silt	Sandy Silt	Sand some Silt and Gravel	Silt some Sand	Gravelly Sand trace Silt	Gravelly Sand	Gravelly Sand	Sandy Gravel	Sandy Gravel trace Silt	Sandy Gravel	Silty Gravelly Sand	Sandy Gravel trace Silt

Compiled Dec.29, 2015 by T.Dhara, P.Eng.

CHILKOOT GEOLOGICAL ENGINEERS LTD.
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GEOTECHNICAL EVALUATION - BORROW SOURCE ASSESSMENT
CLINTON CREEK AREA - DAWSON, YUKON - 2015
TABLE III - SUMMARY OF GRAIN SIZE DISTRIBUTION ANALYSIS

Site/Sample		Airfield	MS 1-1	MS 1-2	MS 2-3	MS 2-4	MS 3-1	MS 3-2	MS 4-1	MS 5-1	MS 5-2	MS 5-3
Sieve Size (mm)	80	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	56	100.0	100.0	69.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	40	100.0	100.0	62.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	28	85.3	100.0	60.7	100.0	76.5	84.6	75.6	100.0	100.0	100.0	88.8
	20	80.9	96.8	50.4	100.0	74.2	80.4	75.6	84.1	100.0	100.0	74.0
	12.5	75.6	81.7	40.5	98.0	70.4	74.5	66.1	64.8	95.5	97.7	64.8
	10	73.3	71.9	35.2	95.1	66.6	71.2	61.6	52.8	93.2	97.5	61.1
	5	59.7	50.5	23.0	87.3	53.0	60.4	51.7	49.3	85.7	95.7	48.2
	2.5	45.2	34.8	15.9	77.3	44.0	49.4	41.8	36.8	73.5	90.8	38.6
	1.25	28.4	23.4	11.7	64.3	36.1	39.0	33.4	30.5	51.8	61.4	31.2
	0.63	14.7	15.5	8.9	51.2	29.3	31.5	26.6	24.8	33.3	34.2	26.2
	0.315	9.8	11.0	6.9	39.4	23.6	25.6	21.3	19.9	24.3	25.3	20.6
	0.16	8.0	8.2	5.3	30.5	19.2	20.8	17.2	15.8	18.4	19.8	16.0
	0.08	7.0	6.5	4.3	24.7	16.1	18.0	14.4	12.0	14.7	15.7	13.2
Moisture		4.8	4.8	4.3	6.5	6.2	5.5	3.5	5.2	7.5	8.3	4.4
Fines		7.0	6.5	4.3	24.7	16.1	18.0	14.4	12.0	14.7	15.7	13.2
Sand		52.7	44.0	18.7	62.6	36.8	42.4	37.4	28.0	71.1	80.0	35.0
Gravel		40.3	49.5	77.0	12.7	47.0	39.6	48.3	63.2	14.3	4.3	51.8
USCS		GP-GM	GP-GM	GP	SM	GM	SM	GM	GP-GM	SM	SM	GM
Description		Sandy Gravel trace Silt	Sandy Gravel trace Silt	Sandy Gravel	Silty Sand some Gravel	Sandy Silty Gravel	Gravelly Silty Sand	Sandy Gravel some Silt	Sandy Gravel trace Silt	Sand some Silt and Gravel	Silty Sand	Sandy Gravel some Silt

Compiled Dec.29, 2015 by T.Dhara, P.Eng.

CHILKOOT GEOLOGICAL ENGINEERS LTD.
5b Bennett Road, Whitehorse, Yukon - Y1A 5Z4

GEOTECHNICAL EVALUATION - BORROW SOURCE ASSESSMENT
CLINTON CREEK AREA - DAWSON, YUKON - 2015
TABLE III - SUMMARY OF GRAIN SIZE DISTRIBUTION ANALYSIS

Site/Sample		T 1	T 2	T 3	T 4	T 5	T 6	km 46	km 46	62-1
Sieve Size (mm)	80	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	56	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	40	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	28	100.0	100.0	100.0	100.0	100.0	72.0	90.0	100.0	100.0
	20	93.9	100.0	100.0	100.0	100.0	53.9	73.5	100.0	97.5
	12.5	82.5	92.6	82.3	97.7	100.0	17.0	52.5	76.5	94.1
	10	79.6	89.6	78.5	94.6	96.2	7.2	42.5	68.4	93.3
	5	66.0	69.4	65.0	79.4	82.6	2.6	28.3	39.6	92.1
	2.5	50.3	51.2	54.3	60.6	64.6	2.0	19.6	26.7	89.4
	1.25	41.2	40.7	45.5	52.9	61.1	1.7	14.1	18.3	75.4
	0.63	33.1	31.6	37.1	48.2	55.3	1.4	9.8	13.2	54.2
	0.315	25.0	24.2	30.8	42.8	45.2	1.2	6.9	10.1	39.0
	0.16	17.1	18.4	26.3	35.0	31.0	1.0	4.4	8.0	25.9
	0.08	13.4	15.5	23.9	30.1	24.5	0.8	2.7	6.2	17.6
Moisture		8.9	8.3	10.3	12.6	12.6	1.6	1.1	3.3	8.5
Fines		13.4	15.5	23.9	30.1	24.5	0.8	2.7	6.2	17.6
Sand		52.6	53.8	41.0	49.4	58.1	1.8	25.6	33.4	74.5
Gravel		34.0	30.6	35.0	20.6	17.4	97.4	71.7	60.4	7.9
USCS		SM	SM	SM	SM	SM	GP	Gran C	Gran A	SM
Description		Gravelly Sand some Silt	Gravelly Silty Sand	Gravelly Silty Sand	Silty Gravelly Sand	Silty Gravelly Sand	Gravel	3" Minus Sub-base	20 mm Crush	Silty Sand trace Gravel

Notes - T = Tailings

Compiled Dec.29, 2015 by T.Dhara, P.Eng.

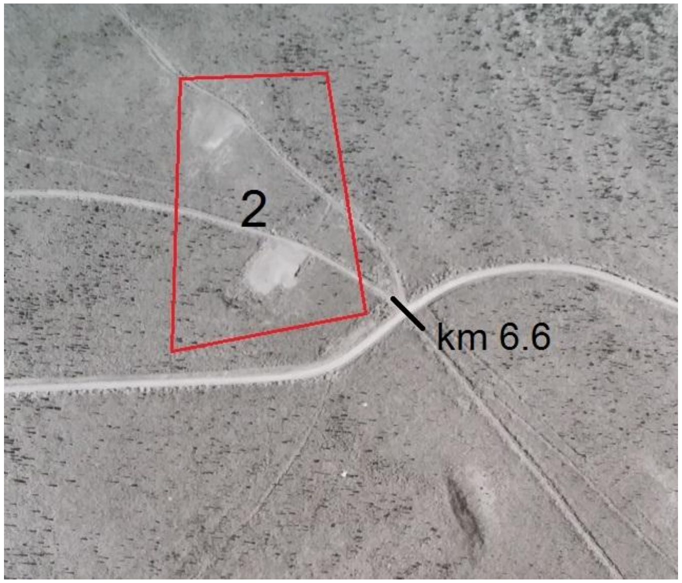
APPENDIX A

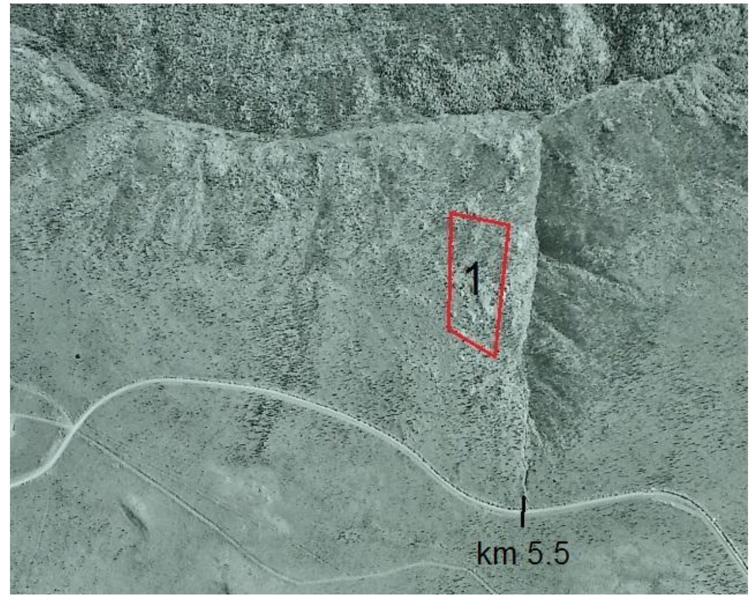
Selection of Airphotos and

Borrow Source Limits

Geotechnical Evaluation - Borrow Source Assessment - Clinton Creek Area – Dawson, Yukon – 2015

Appendix A – Airphotos of Potential Borrow Sites – Clinton Creek Road (Pg 1 of 3)





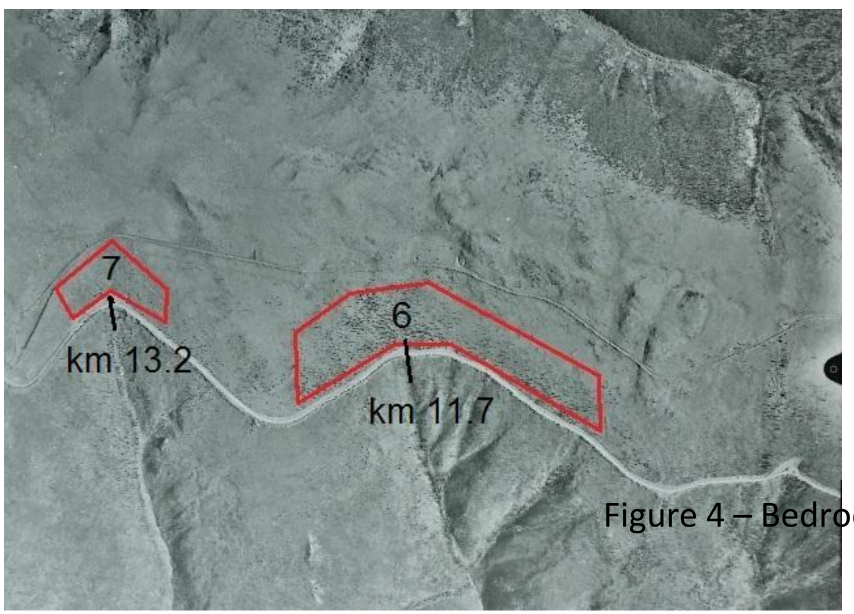
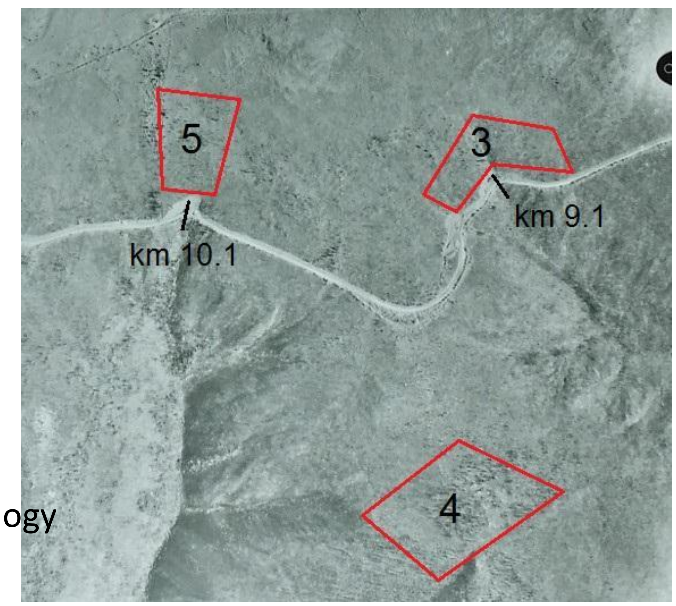


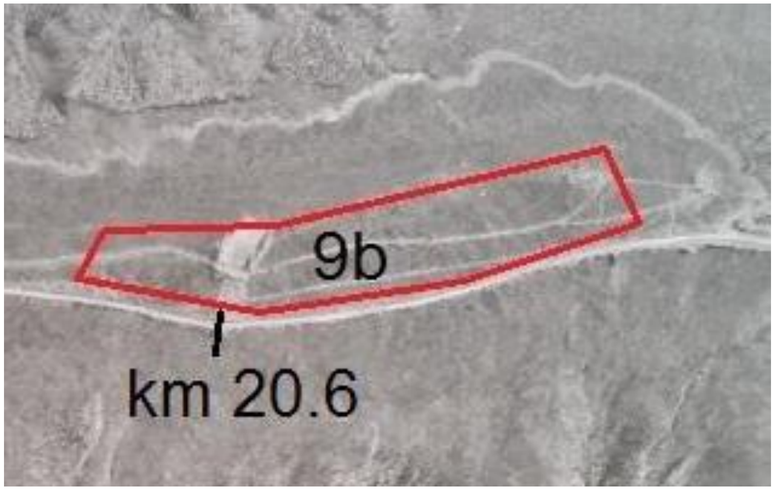
Figure 4 – Bedrock Geology

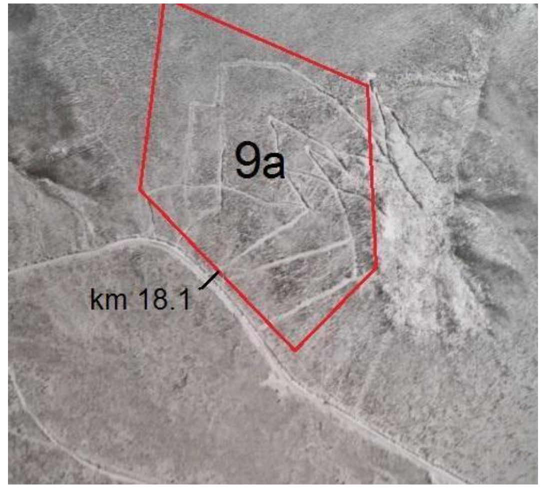


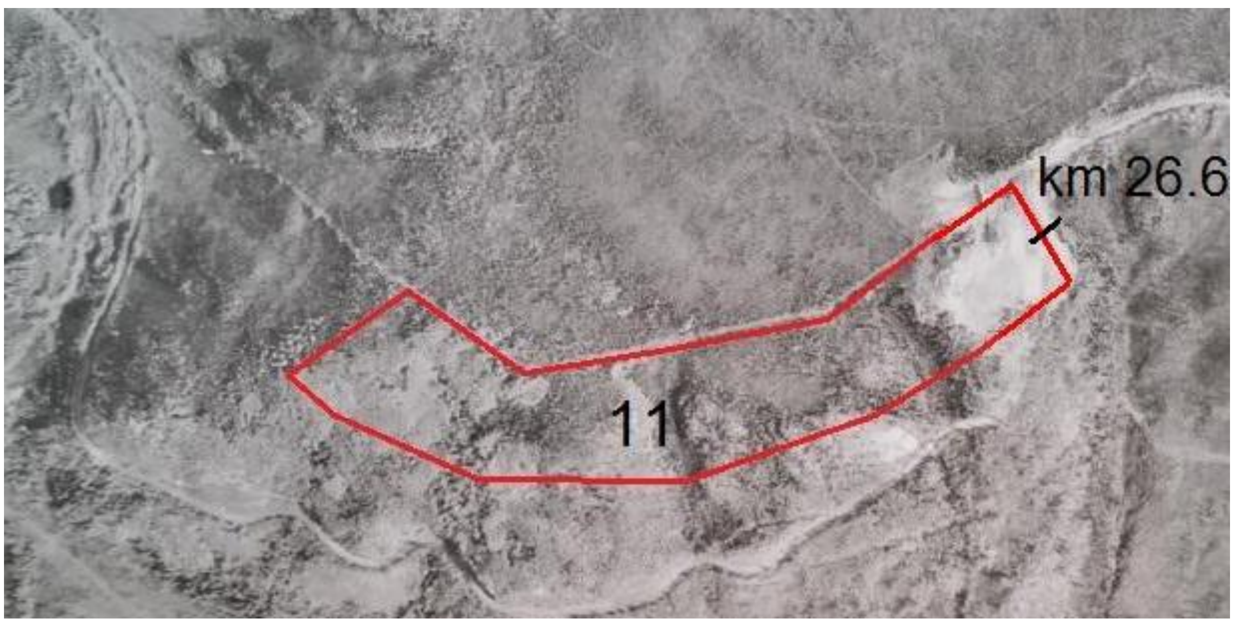
Not to Scale – Boundaries are approximate

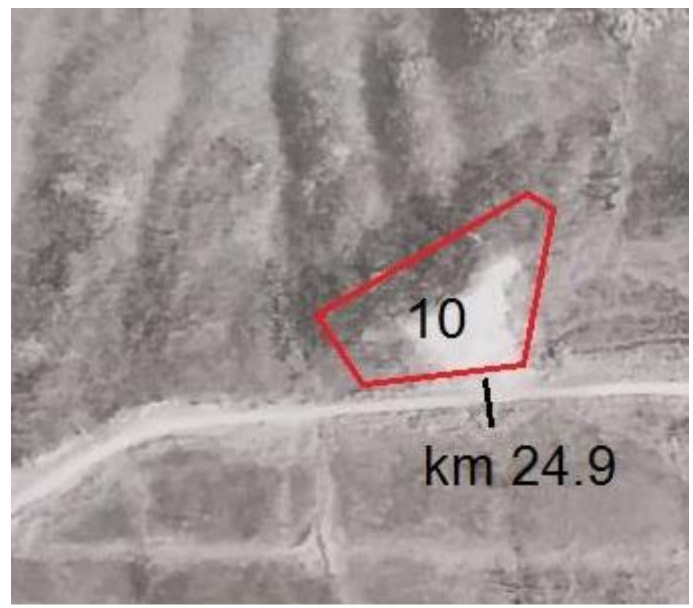
Compiled September 26, 2015 by T.Dhara, P.Eng.

Geotechnical Evaluation - Borrow Source Assessment - Clinton Creek Area – Dawson, Yukon – 2015
Appendix A – Airphotos of Potential Borrow Sites – Clinton Creek Road (Pg 2 of 3)



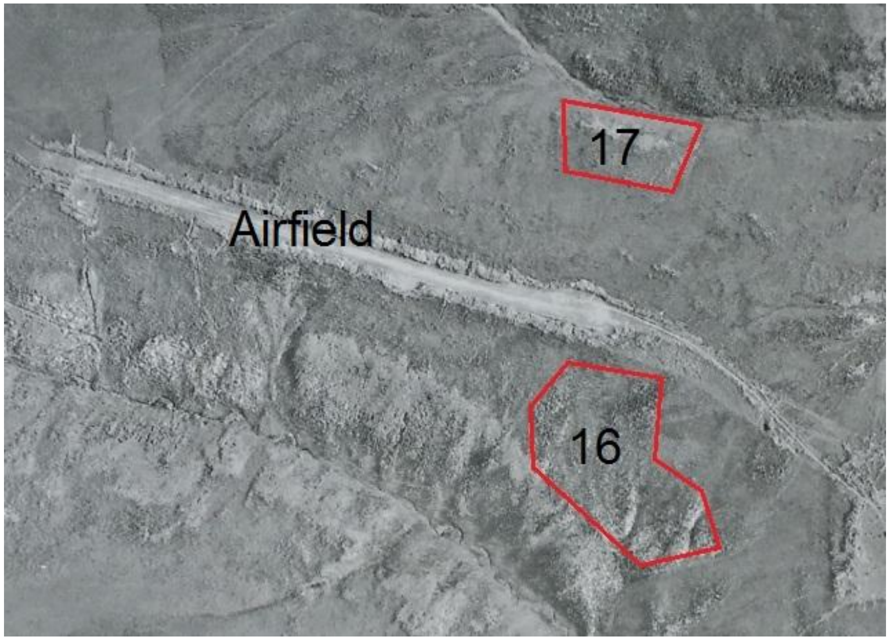


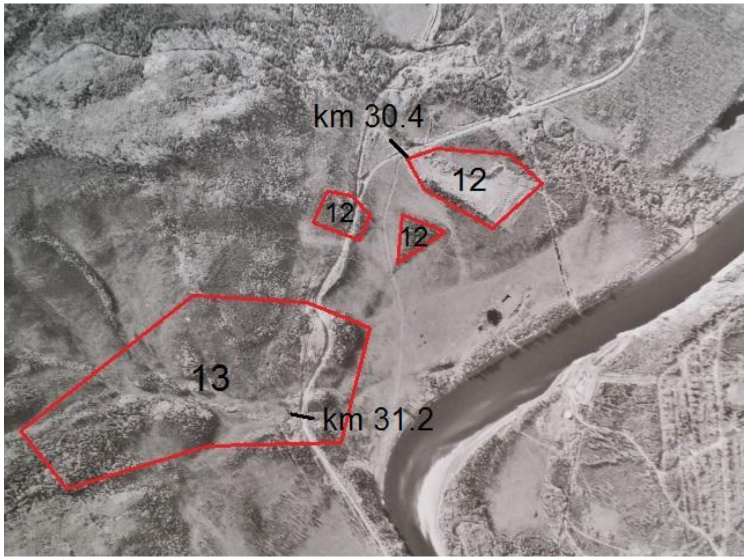




Not to Scale – Boundaries are approximate

Compiled September 26, 2015 by T.Dhara, P.Eng.





Not to Scale – Boundaries are approximate

Compiled September 26, 2015 by T.Dhara, P.Eng.

APPENDIX B

Selection of Technical Reports

- Mine Waste Dump and Tailing Pile - Clinton Creek Operations prepared by *Golder Associates* – July, 1978

- Abandoned Clinton Creek Asbestos Mine – Condition Assessment Report, prepared by *UMA Engineering Ltd.* – April, 2000

- *CAP* – Laboratory Test Results – August, 2015
  - Proctor Analysis – Sample No.1
  - Grain Size Distribution Analysis – Sample No.1
  - Grain Size Distribution Analysis – Sample No.4

- Clinton Creek Lab Test Results, prepared by *Worley Parsons Canada Services Ltd*. – September 22, 2015 ωυ 221 08

Golder Associates
CONSULTING GEOTECHNICAL ENGINEERS

REPORT TO
CASSIAR ASBESTOS CORPORATION LTD.
RE
MINE WASTE DUMP AND TAILING PILE
CLINTON CREEK OPERATIONS

CLINTON CREEK YUKON TERRITORY

DISTRIBUTION:

2 copies - Cassiar Asbestos Corporation Ltd.
Clinton Creek, Yukon Territory

1 copy - Cassiar Asbestos Corporation Ltd.
Vancouver, British Columbia

1 copy - Yukon Territory Water Board
Whitehorse, Yukon Territory

1 copy - R.M. Hardy & Associates
Calgary, Alberta

2 copies - Golder Geotechnical Consultants Ltd.
Vancouver, British Columbia

July 1978 V77016

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1.0 INTRODUCTION

Since 1968 Cassiar Asbestos Corporation Ltd. have operated an asbestos mine and a mill at Clinton Creek in the Yukon Territory. The economically recoverable asbestos ore reserves at the Clinton Creek operations are now exhausted and the operators are preparing to cease mining and milling operations. As part of the mine closure, Cassiar Asbestos propose to carry out certain improvements so that the site will be left in a condition acceptable to the Yukon Territory Water Board, the government regulatory agency responsible for environmental control of land use in the Yukon.

Cassiar Asbestos Corporation Ltd. have requested Golder Associates to provide geotechnical assistance on matters relating to the Clinton overburden waste dump, and to the tailing pile. This report presents the results of geotechnical investigations that have been carried out at the site, interpretations regarding the nature and mechanisms of earth movements that have been occurring at the waste dump and the tailing pile over the past several years, and a description of possible earth work construction to ameliorate potential erosion problems associated with the earth movements.

2.0 SUMMARY

2.1 Clinton Dump

The Clinton waste dump has crept across the valley bottom of Clinton Creek, and now forms a dam which impounds Hudgeon Lake. The present discharge channel from Hudgeon Lake is located at the northern perimeter of the dump where the surface of the dump contacts the natural hillside of the north valley wall. Over most of its length, the present channel is incised into in situ material, including bedrock. As a result, the invert of the channel is below original ground surface.

The foundation area of the dump prior to its development was underlain by permafrost. The permafrost beneath the dump is degrading and, as a result, high pore water pressures have developed within the foundation soils beneath the base of the dump. These high pore water pressures reduce the shearing resistance of the foundation soils and permit the dump to creep as a result of base sliding.

Considering its ability to serve as a dam, the waste dump has a generously large factor of safety. Nevertheless, within the region of the northern boundary of the dump, creep movements are currently developing at an average of approximately 3.6 ft. per year. Since the channel remains open it must be concluded that, on an annual basis, stream erosion removes a 3.6 ft. wide slice of dump material from the right hand side of the channel. The Yukon Territory Water Board has expressed concern regarding water quality degradation and sedimentation in the drainage course attendant with erosion of material from the right hand side of the channel.

To arrest the problem of erosion, installation of a coarse rock, erosion-resistant channel lining and energy dissipating weirs would be required. However, unless the creep movements within the northern limit of the dump are first stopped, the right side of the channel lining would become displaced toward the centerline, thereby destroying the design cross-section of the rock-lined channel. Therefore, before a permanent channel lining is installed, the movements within the toe region of the dump should be stopped. The only practicable means of stopping the dump movements at the present time is placement of stabilizing fill along the northern perimeter of the dump. To achieve a factor of safety of 1.25 would require raising the lake to elevation 1370, 25 ft. above its present level, in order to accommodate placement of approximately 450,000 cu. yds. of stabilizing fill. The estimated cost for placement of the stabilizing fill, placement of rock to form an erosion-resistant channel lining, and ancillary works is estimated to be approximately $590,000.

Waste rock materials were last consigned to the Clinton dump in the summer of 1977. Disposal of waste rock at the Clinton dump is now complete, and 1978 represents the first year since the inception of its development that waste rock has not been consigned to the dumps. The survey data for reference points 19 to 23 inclusive, on the surface of the Clinton dump, show that since the fall of 1977 the rates of horizontal displacement have decreased by 50 per cent or more. This trend of decreasing rate of movement is expected to continue in future. In lieu of placement of the stabilizing fill to stop the movements, we suggest that observations be continued to indicate the rate at which the movements develop in future. This data may show that within the space of a few years the rate of horizontal movement adjacent to the channel has decreased to an acceptably slow rate.

In the meantime, we suggest that a 150 ft. long section of rock-lined channel be constructed commencing approximately 275 ft. downstream from the downstream end of the existing culverts. This segment of rock-lined channel would be designed to remain stable in the event of a 100-year flood occurrence, and would serve to preserve the channel grade and thereby preclude the possibility of rapid lowering of the level of Hudgeon Lake, and the danger of attendant flooding downstream. The remainder of the channel section would receive a modest application of rock fill to protect the invert of the channel against further lowering, and to guard against further undercutting of in situ rock and soil along the left side of the channel.

2.2 Tailing Pile

The principal concern with respect to the mill tailing pile is the transport by water of asbestos fibre and other fine-grained materials from the pile in those areas where the tails encroach, or may encroach upon Wolverine Creek, and the subsequent deposition of these sediments in the drainage courses of Wolverine and Clinton Creeks and thence in the Forty Mile and Yukon Rivers.

Field observations have shown that:-

a) The 1974 failure lobe at the south end of the pile continues to move slowly downslope, tending to result in lateral constriction of that segment of Wolverine Creek which extends from the upstream to the downstream limits of the toe of the failure lobe, resulting in erosion of tails and downstream sedimentation.

b) The lobe to the north of the 1974 failure is moving downslope at a current rate of approximately 77 ft. per year. If this rate were to continue, tails in this segment of the pile would reach Wolverine Creek in approximately 4-1/2 years.

Stability analyses, using data gathered in the field and laboratory, have shown that trimming of some portions of the 1974 failure lobe upslope from its toe, together with appropriate grading and lining of the Wolverine Creek channel where it bypasses the toe of the slope, will increase the factor of safety to a sufficient degree to stop further downslope movements. Construction of a rock-lined channel and weir system downstream of the failure lobe to conduct Wolverine Creek in a competent channel, and return it to its natural course will also be required. The cost of this work is estimated to be approximately $57,000.00.

Stability analyses carried out on the north lobe of the tailing pile indicate that removal of material from the surface of this segment of the pile will enhance its factor of safety with respect to downslope movement. The removal of approximately 20 ft. of tails from the surface of the more rapidly moving portion of the pile will increase its factor of safety from 1.0 to approximately 1.3. The cost of this work is estimated to be approximately $75,000.00.

A second environmental concern related to the tailing pile is the problem of wind-blown (fugitive) dust from the surface of the pile. The majority of fugitive dust has originated in the course of the belt conveyor transport of tails from the mill, and deposition on the tailing pile. When milling operations cease, this source will be eliminated. The materials at the surface of the tailing pile have formed an erosionresistant crust as a result of slight cementing of the particles. Except in those areas where active movements of the pile result in exposure of fresh material, no dust is raised by wind. When measures to stop the downslope movements of the pile are completed, no further exposure of loose fines on the surface of the pile will occur. It is our opinion that fugitive dust originating from the surface of the tailing pile is not a problem, and that placement of a waste rock cover on the surface of the pile is not required. Such a cover would have only aesthetic value.

3.0 PHYSICAL ENVIRONMENT

The Cassiar Asbestos Corporation Ltd. Clinton Creek operations are located within the triangle bounded by the Yukon-Alaska boundary, the Forty Mile River, and the Yukon River, at latitude 64° 30' N, longditude 141° 45' W, approximately. Local relief at the site is approximatley 800 ft., varying between elevation 1200 and 2000 ft., approximately.

Although the area was unglaciated during the last (Wisconsin) glacial period, the site is located within an area of wide-spread permafrost distribution. The maximum thickness of permafrost is of the order of 200 ft.

Based on records maintained by Cassiar Asbestos during the period 1965 to present, the mean annual temperature at the site is approximately -2.5 degrees C. Average maximum and minimum temperatures vary from +15 degrees C during the month of July, to -32 degrees C during the month of January.

The six-year period of records, 1972 to 1977 inclusive, indicate an average annual precipitation of 14.1 inches per year (360 mm/yr). During this period, the driest year was 1973 when measured total precipitation was approximatley 260 mm. The wettest year was 1975 when total precipitation was 430 mm.

An anemometer was installed at the site in early 1976. The records for the two-year period 1976 and 1977 indicate that the average annual wind speed is approximately 5 miles per hour (8 kmh). The maximum recorded wind speed is 20 mph (32 kmh).

4.0 CLINTON WASTE DUMP

4.1 Brief History

The Clinton waste dump comprises waste rock overburden consisting predominantly of argillite removed in the course of open pit mining operations at the Porcupine Pit. Development of the Clinton waste dump commenced approximately 1970. Overburden materials were excavated from the Porcupine Pit, loaded into trucks, and hauled to the Clinton dump. Development of the dump commenced by end-dumping of materials near the crest of the north-facing slope that forms the valley wall on the south side of Clinton Creek. Shortly after development of the Clinton dump commenced, a segment of the face of the dump began to slump, and the toe of the dump began to spread northward onto the flat valley floor of Clinton Creek. These creep movements of the dump materials continued to develop with continued consignment of overburden material to the dump, with the result that the waste rock overburden advanced northward across the valley bottom, resulting in blockage of the drainage course of Clinton Creek. The Clinton waste dump now constitutes a dam which impounds the water of Hudgeon Lake. The surface elevation of Hudgeon Lake is approximately 1345 ft., the surface area is approximately 180 acres, and the maximum water depth is approximatley 85 ft. The drainage outlet from the lake is via an open channel located along the junction of the northern limit of the waste dump and sloping surface of the north valley wall on the left hand side (left with respect to the viewer facing in the downstream direction) of the Clinton Creek valley.

4.2 Statement of Problem

The Clinton dump continues to experience creep movements. The movements on the surface of the dump have components northward in a direction transverse to the Clinton channel, as well as westward toward Hudgeon Lake.

Prior to development of the Clinton dump, the grade of the natural channel of Clinton Creek was approximately 0.075 per cent within the area now occupied by the dump. The present average grade of the Clinton channel between the upstream and downstream limits of the dump is approximately 5 per cent. Owing to the presence of Hudgeon Lake, peak instantaneous flows in the Clinton Creek channel are reduced somewhat compared to the conditions that existed prior to development of the dump, because the lake has the effect of reducing peaks, and smoothing the stream discharge curve. However, owing to the significant increase in the channel grade, a given discharge flows at higher velocity, and therefore has increased erosion capability.

Subsequent to the advance of the dump across the valley floor and impoundment of the stream flows, Clinton Creek channel has become incised in both waste dump material and in situ bedrock along the contact between the northern limit of the dump and the hillside that formed the north valley wall of Clinton Creek. The waste dump material contains scattered fragments of hard, durable rock which have accumulated within the channel bottom, and provide resistance to erosion of the bottom of the channel during normal flow conditions (e.g. Photo 5, Appendix A).

While downcutting of the channel does not appear to be a particularly serious problem, the Yukon Territory Water Board have expressed concern about stream siltation as a result of erosion of the right hand bank of the channel which keeps pace with creep movements of the dump in a direction transverse to the channel. That is, as the creep movements occur and tend to decrease the width of the channel, side channel erosion maintains the channel width. Clinton Creek discharges into the Forty Mile River at the townsite, and the Forty Mile in turn discharges into the Yukon River. Photograph No. 6 of Appendix A shows the point at which the Forty Mile River discharges into the Yukon.

4.3 Field Investigations

Instrumentation installed at the Clinton dump includes reference points for determining horizontal and vertical movements on the surface of the dump, thermistor installations to permit measurement of subsurface ground temperatures, and piezometers.

4.3.1 Surface Movements

Eight reference points have been established on the surface of the dump to permit measurement of horizontal and vertical movements using an EDM survey instrument. In addition, five cross-channel reference lines have been established to permit measurement of the apparent rate of lateral closure of the channel. The locations of these reference points are shown on Figure 2. Reference points 19 to 23 inclusive were established in November 1976, and reference points 66 to 69 inclusive were established in April 1978.

The azimuth of the horizontal movement vectors and rates of horizontal movement in units of feet per year at each of the reference points is indicated by the arrows marked on Figure 3. The data indicate that, in general, surface movements are occurring in directions radially outward from the central region of the dump. Movements toward Hudgeon Lake are also occurring as evidenced by the pressure ridge that developed on the ice surface parallel to the elevation 1345 contour on the western face of the dump during the winter of 1977-78 (see photo No. 1 of Appendix A). In general, the rates of horizontal movement are greater near the perimeter of the dump than they are within the central regions of the dump. Also, the rates of horizontal movement decrease proceeding in the downstream direction.

As indicated on Figure 3, reference points 66, 67, and 69 are located between the northern limit of the dump and the position of the toe of the north valley wall prior to dump development. Thus, the original ground surface beneath the position of these movement gauges slopes upward toward the north. The data for these reference points show that upward vertical movements are occurring currently with development of the horizontal movements. At reference point 66 and 69, the movement vectors are inclined upward toward the north at approximately 12 degrees, which is approximately parallel to the slope of the original ground surface at these locations. The indicated inclination of the surface movement vector at reference point 67 is approximately 6 degrees. This reference point is influenced by localized shear movements within the dump materials adjacent to the right hand side of the Clinton channel. As a result, the indicated rate of horizontal movement is considered to be somewhat greater, and the indicated inclination of the movement vector is somewhat less than the true dump movements that are occurring at this location.

In May 1978, five reference lines were established transverse to the Clinton channel between coordinate lines 108000 E and 107250E, approximately. The locations of these cross-channel reference lines are indicated on Figure 2. The northern end of each of these reference lines is located on the surface of the natural hillside beyond the northern side of the Clinton channel. The southern end of each of the reference lines is located on the surface of the dump near the northern edge of the main access roadway. The purpose of these cross-channel reference lines is to provide an indication of the rate of horizontal movement of the dump adjacent to the channel, which is an indication of the rate at which the dump movements tend to constrict the channel. The rates of horizontal movement, as based on records which extend over a period of approximately 2 weeks, are indicated on Figure 3. The data indicate that over this segment of the channel the dump movements tend to constrict the channel at an average rate of 3.6 ft. per year. As is the case for movement reference points 66, 67, and 69, the data for cross-channel reference lines AA to DD inclusive, show that the horizontal movements of the dump on the right hand side of the channel are accompanied by upward vertical displacements.

Although the horizontal movement data for reference points adjacent to the channel indicate that the dump movements tend to constrict the channel at rates varying from 3.5 and 4 ft. per year, field observations show that Clinton Creek is capable of maintaining the width of its channel, and that the invert of the channel has not increased in elevation as a result of the vertical component of the movement vectors within the toe region of the dump. It must, therefore, be concluded that on an average, a 3.5 to 4 ft. wide slice of dump material is lost from the right hand side of the channel on an annual basis. Most of this material is lost as a result of erosion during spring run-off. Over most of the remainder of the summer (Clinton Creek ceases to flow in the winter) the channel flows remain clear, and there is no visible evidence of reduction in water quality as a result of increase in suspended solids between the outlet from the lake and the downstream end of the channel.

4.3.2 Thermistors

Thermistors were installed at four locations within the boundaries of the Clinton dump to permit measurement of subsurface ground temperatures, and to determine whether permafrost is aggrading or degrading within the base of the dump. Each thermistor installation consists of a set of nine individual thermistors spaced at 5 ft. intervals, as shown on the schematic drawing included in Appendix D. Thus, at each thermistor installation, ground temperatures can be measured over a 40 ft. interval of depth.

The locations of the thermistor installations at the Clinton dump were selected to satisfy the following requirements:-

i. The waste dump at the location of the installation should have been in place for a minimum period of 4 to 5 years to provide sufficient time for changes to occur in the thermal conditions at the base of the dump.

ii. The thickness of the dump should be less than 80 ft. to permit drilling of the thermistor holes, using Cassiar's 40R drill.

iii. At each location, permafrost was to have been extant prior to commencement of dump development.

The subsurface temperatures, as determined by the thermistor readings, are summarized on the data sheets included in Appendix D. The data show that at thermistor installations T1 and T2, ground temperatures at the base of the dump are below 0 degrees C, indicating that at these locations permafrost has aggraded into the base of the dump.

At location T3, the data indicate that ground temperatures are above 0 degrees C to a depth of 30 ft. below original ground surface. At the location of T3, the original ground surface formed part of a north aspect slope that examination of aerial photographs shows to have been underlain by extensive permafrost prior to development of the dump. Thus, at the location of T3 the permafrost has apparently degraded to a depth of approximately 30 ft. below original ground surface.

Thermistor installation T4 is located near the northern edge of the dump, approximately coincident with the position of the toe of the north valley wall prior to dump development. During the installation at this location, the hole caved before the lower end of the cable had been lowered to the bottom of the hole. As a result, the thermistor installation at T4 does not extend into the in situ native materials beneath the base of the dump. The subsurface temperature fluctuations recorded at this location (see Appendix D) suggest that the thermistor is probably registering the temperature of the seepage water within the base region of the dump. As indicated on the data sheet for T4, the temperatures are within the range +1 to +2 degrees C below a depth of 35 ft. below surface. The temperature profile suggests that the phreatic surface at this location is at approximately elevation 1300 ft. This is approximately 10 ft. above the invert of the adjacent Clinton channel. Assuming that the temperatures below elevation 1300 ft. as recorded at thermistor installation, are indicative of the temperature of the seepage water within the base of the dump, it may be concluded that the seepage waters are applying heat to the original ground surface at the base of the dump, and that the permafrost within this region is degrading.

4.3.3 Piezometer Installations

Five Casagrande-type piezometers were installed along the south side of the main roadway that traverses the northern limit of the dump. Their locations are shown on Figure 2. The piezometers were placed in drilled holes, and sealed with bentonite. After placement of the bentonite seals, the segment of each hole within the dump material above the seal was permitted to collapse around the piezometer casing. None of the piezometers have functioned properly, and these installations have yielded negligible useful data.

4.4 Mechanism of Movement

The pattern of cracking on the surface of the Clinton dump, as well as the dump movement survey data, indicate that the dump movements are the result of horizontal spreading on its base. The results of direct shear tests on a representative sample of the 1/4 inch minus fraction of argillite comprising the Clinton dump are included in Appendix B. The test results indicate that the material has an angle of internal friction which varies from slightly greater than 40 degrees for the effective normal stress range 0 to 25 psi, to 33.5 degrees at an effective normal stress of 200 psi. The face of the Clinton dump, near the point where the tramline crosses the Clinton channel, has a maximum height of approximately 125 ft., and this face stands at an angle of slightly greater than 40 degrees. Since the angle of repose for cohesionless material is numerically equal to the angle of internal friction for that material under low stress, the angle of repose as observed in the field, and the angle of internal friction as determined by the laboratory tests, are in agreement.

The geometry of the Clinton dump, together with the angle of internal friction of the dump material, preclude the possibility that the horizontal movements of the dump are occurring as a result of shearing within the dump materials. The dump is sliding on its base as a result of shear displacements within the in situ native foundation soils beneath the base of the dump.

The in situ foundation soils beneath the flat valley bottom of Clinton Creek prior to development of the dump were beyond the reach of the drilling equipment available at site at the time that the 1978 subsurface investigations at the dump were underway. For this reason, samples of the native foundation soils within the region of the original flat valley bottom beneath the Clinton dump have not been sampled. However, discussions with personnel who were engaged in construction activities on the valley bottom during the initial stages of development of the Clinton dump, together with observations within the valley bottom downstream of the dump, indicate that the foundation soils were ice-rich. For example, at locations on the valley bottom downstream of the Clinton dump, where surface vegetation has been disturbed by the tracks of a bulldozer, this disturbance has resulted in development of water-filled thermo-karst depressions. These features are indicative of the presence of ice-rich permafrost soils at shallow depth below surface.

Prior to development of the dump, the site experienced approximately 3240 degrees C days of frost annually. The foundation area of the dump is now covered by waste rock up to 240 ft. in thickness. The dump now serves as an effective insulator which isolates the foundation from the ambient temperatures. More important, ground water seepage from Hudgeon Lake toward the eastern limit of the dump provides a continuous source of heat at the base of the dump. As a result, the permafrost beneath the dump is melting. As thawing occurs, water is changed from the solid to the liquid phase and, under the weight of the dump, this results in the generation of high pore water pressures within the foundation soils. Stability analyses of the present conditions indicate that the pore water pressures in the foundation soils are between 70 and 90 per cent of the pressures at the base of the dump due to the weight of the dump materials. These pore water pressures reduce the shearing resistance of the foundation soils beneath the base of the dump and, as a result, the Clinton dump is subject to horizontal spreading on its base. These spreading movements were responsible for development of a pressure ridge on the ice surface of Hudgeon Lake during the winter of 1977-78 (see Photo 1 of Appendix A), and they are also responsible for development of the cracks on the surface of the dump as illustrated on Photos 2 and 3. The mechanism of crack development, the orientation of the cracks, and the implied stress conditions within the dump are discussed in Appendix E.

4.5 Treatment of the Clinton Dump

4.5.1 Consequences of No Treatment

The horizontal movement vectors on the surface of the dump, shown on Figure 3, indicate that the northern perimeter of the dump is advancing toward the Clinton channel at rates varying between 3.5 and 4 ft. per year. The plots of horizontal displacement versus time for reference points 19 to 23 inclusive, see Appendix C, show that the rate of movement has decreased by greater than 50 per cent since the autumn of 1977. Materials were last consigned to the dump during the summer of 1977, and no further consignment of materials to the dump will take place. Under these circumstances, we expect that the rates of horizontal movement will continue to decrease in future.

Although the dump movements tend to result in lateral confinement of the Clinton channel, removal of dump material from the right side of the channel by stream erosion has maintained the channel cross-section. A major portion of the dump materials consist of fragments of a size that can be eroded by the stream. However, the dump also contains scattered large fragments which the stream is not capable of moving. Thus, if nothing were done to the Clinton channel, the bottom of the channel would eventually become paved with large boulders that would accumulate on the channel bottom through the process of advancement of the toe region of the dump into the channel cross-section, and removal of the finer fraction of the material by erosion.

4.5.2 Transverse Groynes

The Yukon Territory Water Board have expressed concern regarding the problem of suspended solids in Clinton Creek as a result of continued erosion of the dump, as well as concern about the possibility of continued downcutting of the channel, and headward erosion of the channel bottom which might eventually result in rapid lowering of the level of Hudgeon Lake, leading to flooding downstream.

In an interim report to Cassiar Asbestos Corporation Ltd., dated April 1978, we suggested that rock groynes constructed transverse to the channel, and extending approximately 200 ft. south of the channel, would be effective in maintaining the invert elevation of the channel at each of the groynes. This would preclude the possibility of rapid lowering of Hudgeon Lake and attendant flooding downstream. For rock groynes extending 200 ft. south of the channel, and considering a current rate of movement of 3.5 to 4 ft. per year at the edge of the channel, the rock groynes would continue to maintain the channel grade for a period of 50 to 60 years. If the current trend of reducing rate of horizontal displacement continues in future, the 200 ft. long groynes would provide protection for a period much greater than 50 to 60 years. Periodic field observations over the next few years would indicate whether or not the groynes should be extended in order to provide for permanent grade protection.

4.5.3 The Cadillac Treatment

4.5.3.1 General Requirements

Following submission of the interim report dated April 27, 1978, in which the rock groyne proposal was presented, the Yukon Territory Water Board expressed concern regarding the potential for erosion of dump materials from the right hand side of the channel between adjacent groynes, and the attendant problem of water quality degradation as a result of an increase in suspended solids. It is apparent that the problem of suspended solids would apply to that segment of the drainage course between the downstream limit of the Clinton dump, and the mouth of the Yukon River during spring run-off only. Inspection of photograph 6, Appendix A, suggests that a relatively small additional contribution of suspended solids to the Yukon River during spring run-off should not be considered as a serious problem.

If erosion during spring run-off within the Clinton channel must be completely stopped, installation of an erosion-resistant channel lining extending to the downstream limit of the dump will be required. If erosion within the Clinton channel is arrested, the movements of the dump must first be stopped, otherwise continued dump movements would result in lateral shifting of the right hand side of the channel toward the north, as well as in upward vertical displacement of the channel invert. The lining materials would eventually be displaced upward and to the left hand side of the channel, and the stream would again proceed to erode and to remove dump material.

The only practicable means of stopping the movements within the region within the northern limit of the dump, adjacent to the existing

Clinton channel, is to increase the resistance to movement by placement of additional fill. Since movement of the dump is occurring at the present time, it follows that the factor of safety of the dump with respect to sliding on its base is 1.0. That is, the sum of the forces tending to produce base sliding are just balanced by the forces that resist base sliding. The resistance to base sliding is governed primarily by the pore water pressures that are generated as thawing takes place within the foundation soils. As concluded by Morgenstern and Nixon, 1971, the distribution of excess pore water pressure, and the degree of consolidation within the foundation soils, are independent of time. Thus, the excess pore water pressures which govern the resistance to shearing at the base of the dump cannot be expected to decrease to any significant degree within the near future. Thus, at least for the next few years, the shearing resistance at the base of the dump can be expected to remain essentially the same as it is at present.

Stability analyses indicate that if the existing Clinton channel were backfilled, and a channel provided at a higher elevation, but on the same alignment as the existing channel, the factor of safety of the dump with respect to base sliding would be increased to approximately 1.1.

4.5.3.2 Design Discharge - Clinton Channel

In 1974, Sigma Resource Consultants Ltd. undertook a study of the hydroelectric power potential of the Yukon Territory. As part of that study, an investigation was made of the maximum recorded rates of discharge for drainage systems in the Yukon. The study considered drainages east and north of the Yukon main stem, and drainages west of the Yukon, including the main stem of the Yukon and Teslin Rivers. Clinton Creek falls within this latter classification.

The upper limit of the data points for drainages west of the Yukon, including the main stem, can be expressed by the equation:-

$$Q = 10^{(0.927 \text{ Log } A + 1.15)}$$

where:

Q = the maximum recorded discharge in cubic feet per second

A = the area of the drainage basin in square miles.

The drainage area of Clinton Creek above the Cassiar Asbestos operations is 106.2 sq. km or 41 sq. miles. Applying the above equation, Q for Clinton Creek is 442 cfs. In their report, Sigma Resource Consultants suggest that the maximum discharge in any of the drainages could be twice the maximum discharge on record. Thus, the maximum discharge in the Clinton channel could be as high as approximately 880 cfs. According to analyses carried out by the Whitehorse office of the Canada Department of Indian Affairs and Northern Development, the 50-year peak discharge for Clinton Creek is calculated to be 882 cfs, and the 100-year peak discharge is calculated to be 968 cfs. Thus, the predicted maximum discharge using the data contained in the Sigma report, and the predicted peak discharge rates provided by DIAND are in close agreement.

4.5.3.3 Channel Lining

If erosion of dump material and of the in situ bedrock as exposed on the left hand side of the existing Clinton channel is to be prevented in future, the channel must be lined with material that will remain stable during anticipated peak discharges. The channel cross-section and lining materials required are essentially the same, whether the design is based on the predicted 50-year peak discharge, or on the predicted 100-year peak discharge.

Rock rip-rap is the only practicable material available for construction of the channel lining. Rock rip-rap is capable of adjusting to minor movements that may occur following completion of construction of the improved channel. Rigid or semi-rigid control structures or energy dissipators are considered unsuitable because of their inability to adjust to the earth movements that may occur subsequent to their installation.

To accommodate the maximum anticipated discharge, a permanent 'fail-safe' channel lining would require approximately 21,000 cu. yds. of rip-rap, at an estimated cost of between $50,000 and $75,000. The rock would be placed in a manner which would form a series of energy dissipating weirs. Details of the rock lining and weirs are included on Figure 5. As noted above, filling of the existing Clinton Creek channel, and provision of a new channel above the existing channel, will increase the factor of safety to approximately 1.1. We are of the opinion that this low factor of safety does not justify the capital expenditure of $50,000 to $75,000 for the channel lining. For a capital expenditure of this magnitude, the factor of safety with respect to base sliding of the dump should be not less than 1.25.

4.5.3.4 Toe Fill to Stop Lateral Movements

To provide a factor of safety of 1.25 with respect to base sliding of the dump toward the Clinton channel, placement of approximately 460,000 cu. yds. of fill would be required along the northern boundary of the dump. This would necessitate raising the level of Hudgeon Lake to elevation 1370, 25 ft. above its present level.

The fill that would be required to increase the factor of safety with respect to dump movement toward the channel to 1.25 is illustrated on Figure 4. Extending for a distance of approximately 540 ft. downstream from the existing culverts, fill would not be placed, with the result that the elevation 1370 contour would form the perimeter of a wide forebay extending to the upstream end of the new channel. A segment of the new channel would extend approximately level for a distance of 500 ft., to the upstream end of the rip-rap section. The rip-rap section would form a series of energy dissipating weirs at an average channel grade of 8 per cent. Each weir would provide for a 2 ft. net drop in head, and the weirs would be spaced at 25 ft. on center. Details of the rock weirs are illustrated on Figure 5.

4.5.3.5 Timing and Sequence of Construction

Stream discharge records for Clinton Creek are available only for the year 1977 and part of 1978. The 1977 records show that the average discharge during the 3-month summer period (July, August, and September 1977) was approximately 14 cfs. For purposes of planning and scheduling, it would be prudent to assume that during any particular year, the average discharge during the summer period (July, August, and September) could be as high as 21 cfs. In order to carry out the construction work, discharge from the lake must be controlled. It would therefore be necessary to construct a cofferdam to a height sufficient to provide for impoundment of the Clinton Creek flows during the construction period. Based on an average stream discharge of 21 cfs, and a lake surface area of 180 acres, the lake could rise 21 ft., i.e. to elevation 1366 during the 3-month summer period. Placement of 460,000 cu. yds. of common fill in 60 working days, would require placement at an average rate of between 7000 and 8000 cu. yds. of fill per day.

We expect that the rock could be placed into the winter season. However, all of the 460,000 cu. yds. of common fill would have to be in place before freeze-up.

The overall sequence of construction would be approximately as follows:-

1. Construct a cofferdam to elevation 1372, approximately, immediately upstream of the existing culverts.

2. Place mill overs to form a pervious granular drain on the invert of the existing channel.

3. Place common fill (approximately 460,000 cu. yds. of waste dump material) to form the stabilizing toe fill. Shape the new Clinton channel to receive mill overs.

4. Place a 1 ft. thick layer of mill overs (approximately 4600 cu. yds. of material).

5. Place rock rip-rap to form rock weirs (approximately 21,000 cu. yds. of material).

6. Remove, replace, and backfill the four 60-inch diameter metal culverts to provide access over the new channel.

7. Breech the cofferdam.

4.5.4 Suggested Treatment

Horizontal movement data for reference points 66 to 69, and for the cross-channel reference lines AA to EE inclusive, have been in operation for a period which is too short to permit a meaningful assessment of the trend in the rates of horizontal movement at these locations. The data included in Appendix C for reference points 19 to 23 inclusive, show the average rates of movement over various intervals of time since the autumn of 1977. These data indicate that the rates of horizontal movement at reference points 19 to 23 inclusive, have decreased by 50 per cent or more over the last 9 months. We expect that this trend of decreasing rate of horizontal movement will continue in future.

Over virtually all of its length, the invert of the existing Clinton channel is below original ground surface, and over a considerable portion of its length the invert of the channel is located on in situ bedrock. Typical examples of the position of the existing channel in relation to the original ground surface are shown on Figure 4. With continued creep movements of the dump toward the north, the invert of the channel is not subject to lateral upward displacements. The dump movements result in advancement toward the channel centerline of the upper portion of the right hand bank, with the result that dump materials are fed into the channel by ravelling of the upper right bank.

The "Cadillac" treatment outlined in the foregoing section would be a very expensive undertaking, and would result in a degree of erosion protection which is incompatible with that provided by nature. In the event of an occurrence of a 50-year or 100-year flood, significant erosion could be expected to take place within natural undisturbed areas located beyond the perimeter of the dump. Thus, provision of a new channel complete with rock lining to provide complete security against erosion in the event of the 50-year or 100-year flood appears to be an unnecessarily severe requirement. However, security should be provided to preclude the possibility of rapid downcutting of the channel which could result in lowering of the level of Hudgeon Lake.

We suggest that the existing culverts should be left in place at their present location. Commencing at a point approximately 275 ft. downstream of the downstream end of the culverts, a 150 ft. long rock-lined channel section should be constructed. This section would consist of a series of five rock weirs with a net drop of 2 ft. of head across each weir. In longitudinal section, the weirs would be as illustrated on Figure 5. To accomodate the lateral crowding of the right hand side of the channel that may take place over the next few years as a result of continued dump movements, the weirs should have a crest width of 50 ft. This series of five weirs would be capable of remaining stable in the event of a 100-year flood occurrence. Thus, this rock-lined segment of the channel will preclude possible downcutting of the channel, and will therefore provide protection against rapid lowering of the level of Hudgeon Lake.

Over the remainder of the Clinton channel, we suggest that a modest application of rock rip-rap be applied to provide protection against downcutting of the channel invert, and undermining of the left hand bank.

Periodic measurements should be continued in future on the movement reference points that have been established. These data may show that horizontal displacements within the toe region of the dump have reduced to an acceptably slow rate. If the records show that the rate of movement in future does not decrease progressively, then further protective measures can be undertaken at that time.

4.6 The Function of Clinton Dump as a Dam

The Clinton waste dump, which has blocked the natural drainage course of Clinton Creek and resulted in impoundment of Hudgeon Lake, now serves as a dam which must remain secure in future.

We have carried out analyses to check the stability of the dump under the influence of the forces imposed by the self-weight of the dump materials, and the forces imposed by the hydrostatic pressures due to the impounded waters of Hudgeon Lake. Using conservative shear strength parameters, and values for the foundation pore water pressures as determined by back analyses, the indicated factor of safety of the dump with respect to gross movement in the downstream direction, is approximately 4.3.

The horizontal distance between the upstream and downstream limit of the Clinton dump is approximately 3000 ft. The water impounded in Hudgeon Lake has a maximum depth of 85 ft., and the topographic slope on the original valley bottom drops approximately 40 ft. between the western and eastern limits of the dump. Thus, the total head loss between the upstream and downstream limits of the dump is approximately 125 ft.

Empirical observations indicate that piping does not occur even in fine sands and silts, provided the creep ratio is equal to or greater than about 18 (reference page 305 Terzaghi and Peck, 1948). The maximum head loss between the upstream and downstream limits of the Clinton waste dump is approximately 125 ft., and the horizontal distance over which this head is dissipated is approximately 3000 ft. Thus, the creep ratio for the overburden dump is approximately 24, approximately 1-1/3 times greater than the value above which empirical observations show that piping does not occur. Under these circumstances, we conclude that there is no danger of failure of the waste dump dam by piping.

In our opinion, the Clinton waste dump will continue to serve as a dam for impoundment of the water in Hudgeon Lake. In spite of the creep movements that the dump is experiencing, as a dam, it exhibits a high degree of stability.

4.7 Estimated Costs

Following is a summary of the estimated quantities of materials, mine prices, and costs for the various schemes and items of work related to treatment of the Clinton Dump.

4.7.1 Transverse Groynes

The scheme for placement of rock groynes transverse to the channel is described in Section 4.5.2.

Placement of quarry-run rock to form 15 groynes 30 ft. wide, and extending 200 ft. south of the existing channel, each containing 1420 cu. yds. of material = 21,300 yd^3 of material.

21,300 yd^3 @ \$1.70/yd^3 = \$36,210.00 say \$40,000

4.7.2 The Cadillac Treatment (Ref. Section 4.5.3)

a)	Place common waste dump fill 460,000 cu. yds. @ \$1.00	\$460,000
b)	Place 4600 cu. yds. of mill overs @ \$1.00	\$ 4,600
c)	Rock rip-rap for channel lining and weirs 21,000 cu. yds. @ \$2.75	\$ 57,750
d)	Construct cofferdam 10,000 cu. yds. @ \$1.00	\$ 10,000
e)	Relocate culverts	\$ 4,000
f)	Contingencies 10% of sum of total	\$ 53,650
	TOTAL	\$590,000

4.7.3 Suggested Treatment (Ref. Section 4.5.4)

a)	Coarse rock rip-rap for 150 ft. long lined channel complete with weirs 2500 cu. yds. @ \$2.75	\$ 6,875
b)	Mill overs at base of rip-rap lined channel section 800 cu. yds. @ \$1.00/yd.	\$ 800
c)	Quarry run rock downstream of rip-rap contact section 10,000 cu. yds. @ \$2.00	\$ 20,000
d)	Contingencies 8.4% of sum of total	\$ 2,325
	TOTAL	\$ 30,000

5.0 TAILING PILE

5.1 Brief History

The separation of asbestos fibre at the Clinton Creek operation is a dry process. Tails are transported from the mill by belt conveyor and have been deposited in the form of a large pile located to the east and the northeast of the mill on the west slope of the Wolverine Creek valley. A photograph of the tailing pile is included as Photo 7 in Appendix A.

In 1974, a segment of the tailing pile, near its southern extremity, moved downslope and blocked Wolverine Creek. This failure occurred at the location of a small draw in the hillside on the west side of Wolverine Creek. According to aerial photographs of the area taken during 1970, the surficial earth materials in this draw were wetter than those in the surrounding area. It is probable that as the tailing pile advanced onto these materials, the shear stresses induced in them by the loads applied by the tails exceeded the available shear resistance, and failure occurred. No confirmed observations are available with regard to the length of time it took the tails to reach Wolverine Creek. Hence, it is not possible to define the type of failure in terms of velocity of movement.

Water from the Wolverine Creek drainage basin ponded upstream of the dam formed by the failure lobe of the tailing pile. The impounded water overtopped the failure lobe in July 1974 and the resulting flows eroded a large quantity of tails in a short period of time, downcutting a channel through the tails to approximately its present level and position. Serious flooding of Clinton Creek, to which Wolverine Creek is tributary, occurred at this time. In the process, substantial amounts of tails were deposited in the Wolverine Creek and Clinton Creek drainage courses.

Shortly after the failure of the southern segment of the tailing pile, the belt conveyor system was shifted and the disposal of tails continued to the north of the failed mass. No further sudden or catastrophic failures have occurred in the tailing disposal area since 1974. However, slow downslope movement in the failed mass continues to occur.

As the new disposal area north of the 1974 failure was developed and the pile expanded, downslope movement in this area also began to take place. No sudden or catastrophic failures have occurred in this segment of the tailing pile, but its continuous movement has extended the toe of this portion of the pile to within 350 ft. of Wolverine Creek as of mid-June 1978.

Disposal of tails from the mill is now being carried out in the northwest section of the disposal area and the pile is being extended in a northerly direction. The terrain in this area is much flatter than that over which previous disposal operations were carried out. No perceptible mass movements of the pile in this area have been noted.

5.2 Statement of Problem

The principal concern with respect to the mill tailing pile is the transport by water of asbestos fibre and other fine-grained materials from the pile in those areas where the tails encroach, or may encroach, upon Wolverine Creek, and the subsequent deposition of these sediments in the drainage courses of Wolverine and Clinton Creeks and thence the Forty Mile and Yukon Rivers.

In the case of the 1974 failure lobe, the tails are already in contact with Wolverine Creek. The lake created by the failure lobe has a maximum depth of approximately 25 ft. and the change in head between the lake and the downstream end of the failure lobe, a distance of approximately 750 ft., is approximately 45 ft., or an average gradient of 6.0 per cent. The tongue of the failure lobe continues to move eastward tending to close the channel cut through it by the stream. The rate of closure of the channel was approximately 4 ft. per year as of mid- June 1978. This rate appears to be slowing with time. Undercutting and erosion of the tails takes place as a result of both this continued movement and the high velocities attained by the stream as it travels past the failure lobe.

0.011 ft/d

In order to deal with the basic problem of the downstream transport of tails from the failure lobe, it will first be necessary to halt the movement of the tailing pile in this region. If this is accomplished, then a permanent channel can be constructed in such a way that Wolverine Creek can be conducted past the failure lobe in a controlled manner. The problems of the water transport of asbestos fibre, erosion, and downstream sedimentation will then be eliminated.

The potential environmental problems associated with the more rapidly moving segment of the tailing pile to the north of the 1974 failure are basically the same as for the failure lobe. Contact of this portion of the tailing pile with the water in Wolverine Creek would lead to downstream transport of sediment, including asbestos fibre. If the tails from this source were to reach a higher elevation in the valley than that at

Wolverine Creek of the upstream end of the 1974 failure lobe, rapid erosion of the tails, and possibly downstream flooding, could occur.

As of June 1978, the rate of downslope movement of the faster moving segment of the pile was approximately 77 ft. per year. At this rate the tails will not reach the water line in the lake formed by the 1974 failure lobe before 1983. This rate of movement is significantly less than the 160 ft. per year average measured in 1977. Moreover, the rate now appears to be slowing continuously with time.

In order to prevent contact of tails in this region of the tailing pile with Wolverine Creek, measures to stop or significantly impede the downslope movement of the tailing pile will be required.

A further concern with respect to the tailing pile is the potential for wind transport of asbestos fibre from the surface of the pile. By far the most significant portion of fines susceptible to wind transport is from the belt conveyors as the tails are being transported from the mill to the disposal areas. When milling ceases, this source will no longer be of concern. The texture of the exposed tails on the pile is coarser than the material below the surface since most of the fines have already been removed by wind or cemented to form a crust on the surface of the pile. It is only in those areas of the pile which are moving at significant rates, and hence exposing fresh material, or in those areas where new tails are being deposited, that fines are susceptible to wind transport. The problems associated with wind-blown fibre will be accommodated when milling operations cease and by the measures to be recommended for stopping the movements in the tailing pile. No continuing or long term environmental problems with regard to fugitive dust are forseen.

5.3 Field Investigation

5.3.1 Site Observations

A number of on-site inspections of the tailing pile at the Clinton Creek mine have been carried out by Golder Associates personnel since May 1976. The principal observation concerning the 1974 failure lobe made during these inspections is the fact that this portion of the pile is continuing to move and to encroach upon the channel cut through it by Wolverine Creek in July 1974. Photograph 8 shows the effects of this continuing movement in terms of undercutting and erosion of the tails in the channel as well as erosion of the argillite bedrock along the toe of the east valley wall of Wolverine Creek. The crack patterns noted on the tongue of the failure lobe, and shown in Photos 9 and 10, indicate that the tails are also spreading toward the lake formed by the damming of the creek.

Observations on the lobe to the north of the 1974 failure have also indicated that movements in this area of the tailing pile continue to occur. The principal features in this area, noted during the field inspections, are concerned with the mechanisms of the movements as related to the behaviour of the foundation soils. As shown in Photos 11, 12 and 13 substantial amounts of the surficial foundation soils have been displaced and bulldozed ahead of the tailing pile as it has continued to move downslope. This phenomenon is believed to be related to both the soil type and permafrost conditions in the surficial deposits that mantle the slope in this area, and is discussed in detail in Section 5.5 of this report.

The region at the northwest extremity of the disposal area, in which mill tails have been disposed of most recently, is on relatively flat ground. No mass movement or creep of the pile in this region has been noted. However, small localized failures as a result of oversteepening of the pile as it is developed may occur. A photograph of this portion of the pile is included as Photo 14 principally to illustrate the segregation of the coarse fraction of the tails as they roll down the face of the pile forming a highly pervious layer at the bottom of the pile.

5.3.2 Drilling Program

A drilling program was carried out in May 1978 to identify the subsoils in the vicinity of the tailing pile, to recover samples for testing in the laboratory, and to install thermistors in the tailing pile and foundation soils in order to assess the ground temperature regimes in various parts of the tailing disposal area. A total of eight boreholes were made and thermistor cables were installed in four of them. The locations of these boreholes are shown on Figure 6 and their logs are included in Appendix F.

Briefly, the principal soil types encountered beneath the tailing pile and/or beneath the surface organic layer were a fluvial-lacustrine deposit of silty sandy gravel, overlying weathered argillite which, in turn, overlies unweathered argillite bedrock. In general, the fluvial-lacustrine deposit becomes thinner with decreasing elevation down the west valley wall of the Wolverine Creek valley, varying in thickness from greater than 40 ft. near the top of the slope to being virtually absent on the bottom portions of the slope.

5.3.3 Thermistor Installations

Thermistor cables were installed at three locations in the tailing pile and at one location in undisturbed ground about 200 ft. beyond the perimeter of the pile. Each cable included nine thermistors at 5 ft. intervals. The locations of these installations are shown on Figure 6 and records of the data collected from them are included in Appendix D.

Thermistor T-5 is located in the southwest corner of the tailing pile where the tails have been in place for an estimated 4 to 5 years. The data show that both the tails and the foundation soils, to a depth of at least 20 ft. beneath the tails, are unfrozen at this location.

Thermistor T-6 is in undisturbed ground near the northwest corner of the disposal area. The ground at this location is frozen from the surface downward, except during the summer months when thaw in the surface active layer occurs. The lowest temperature recorded at this location is at a depth of 15 ft. below the ground surface where measurements indicate a value of approximately -1.6 degrees C. The ground temperatures increase from this point downward to values in the order of -1 degrees C at depths of 35 and 40 ft.

Thermistor T-7 was placed in the tailing pile upslope of the moving north lobe of the pile. It is estimated that the tails have been in place at this location for between 1 and 2 years. The data indicate that both the tails and the foundation soils at this location are frozen with the coldest temperatures near the tailing/foundation soil interface. The temperatures of the foundation soil appear to increase with depth at this location to a value of 0.0 degrees C at a vertical distance of 25 ft. beneath the tails.

Thermistor T-8 was installed in the 1974 failure lobe at a location estimated to be close to the centerline of the draw in which the failure occurred. The temperature data gathered from this installation show that the tails and the foundation soils to a depth of between 5 and 10 ft. beneath the tails are unfrozen. Below this depth, for a further 10 to 15 ft., the data indicate temperatures of -0.1 degrees C.

5.3.4 Movement Observations

Survey monitors to determine the horizontal and vertical displacements on the surface of the tailing pile were installed in late 1976. Additional monitors were installed during the spring of 1978 to provide additional information with regard to these movements. Two lines of monitors were installed. One of these, located close to grid line 113500 N, is approximately along the centerline of the 1974 failure. The second, along grid line 114500 N, is close to the locus of the maximum rates of movement on the segment of the tailing pile to the north of the 1974 failure. The locations of all of the survey monitors on the tailing pile are shown on Figure 6.

a) 1974 Failure Lobe

Survey monitors 24 and 25 were established on December 23, 1976. Plots of the magnitudes and rates of horizontal displacements of these points on the tailing pile are included in Appendix A. The recorded movements at the locations of monitors 24A, 24B, 24C and 25A havve been small and erratic, since their installation on March 30, 1978. Plots of their horizontal movements are shown on Figure C-8 in Appendix C.

Table 5.3.1 is a summary of the rates of horizontal movements at each of the monitors on the failure lobe. The data for monitors 24 and 25, established since December 23, 1976, indicate that the movements in this segment of the tailing pile are slowing with time.

The data in Table 5.3.1 also indicate that the movements in the failure lobe involve a downslope "stretching" of the materials in this segment of the pile except in the vicinity of monitor 25A. This reflects the fact that this monitor is located above the east slope of the Wolverine Creek valley and movements in this area can, therefore, only occur if the tails are pushed up the valley side. As a result of the forces required to move the tails upslope, some relative compression of the materials takes place in this area.

Table 5.3.2 summarizes the rates of vertical movements in the 1974 failure lobe. These rates reflect four components of vertical displacement. These are: (1) vertical displacements corresponding to the horizontal movements of the tailing pile; displacements as a result of (2) spreading and consequent thinning of the tails; (3) displacements caused by thawing of, and subsequent consolidation of, the foundation soils beneath the tails; and displacement due to (4) consolidation of the tails under self weight. The measurements of vertical displacement at the locations of monitors 24 and 25, which have been in place since December 23, 1976, indicate that their rates are decreasing with time.

b) North Lobe of Tailing Pile

Survey monitor 26 was established December 23, 1976 and monitor 29 was established June 10, 1977. Monitors 26A, 26B, and 29A were installed on March 30, 1978. Plots of the rates and magnitudes of the horizontal displacements at these locations are included in Appendix C.

Table 5.3.3 is a summary of the rates of horizontal movement for various time-spans for each of the survey monitors on this segment of the tailing pile. The data for monitors 26 and 29 indicate a substantial slowing down of their rates of movement with time. The records included in Appendix C also show this deceleration and the continuance with which it is occurring. The data for the more recently installed monitors provide the same indication.

The data in Table 5.3.3 for all of the monitors indicate that, in general, the tailing pile along the grid line on which the monitors have been placed is tending to "stretch". (The data relating monitors 26 and 26A are somewhat misleading in this regard insofar as the movement vector at the location of monitor 26 has a dominant component toward the north, whereas the dominant direction of movement for all of the other monitors on this grid line is toward the east, as shown in Figure 3. The net downslope movements for the monitors in this area definitely indicate "stretching" of the tailing pile). If the present rate of movement were to continue, the toe of the tailing pile would reach Wolverine Creek in approximately 4-1/2 years.

Table 5.3.4 provides a summary of the rates of vertical movements on the north lobe of the tailing pile. The same comments made in paragraph a) above, with regard to the components of changes in the vertical locations of the monitors on the 1974 failure lobe apply to this segment of the tailing pile. Also, it can be seen from Table 5.3.4 that the rates of vertical movement are tending to decrease with time in this region.

5.4 Laboratory Investigation

The laboratory investigation consisted of natural moisture content, unit weight and specific gravity determinations, grain size analyses, and direct shear tests on selected samples of the tails and foundation soils recovered during the field investigation.

The moisture content of the fluvial-lacustrine material sampled at the location of Borehole No. 13, which was made in undisturbed ground away from the tailing pile, varied between 28.2 and 40.6 per cent. The moisture contents of the same materials recovered from the boreholes made in the tailing pile were all within the range of 13.5 to 19.5 per cent. The difference in the moisture contents of this material between areas which have been subjected to the loads of the tailing pile, and those which have not, provides a clear indication of the effects of thaw consolidation of the foundation materials.

The natural moisture contents in the weathered argillite sampled at the location of Borehole No. 15 near the toe of the north lobe of the tailing pile varied between 5.2 and 11.4 per cent.

The specific gravity determinations indicated values of 2.64 for the fluvial-lacustrine soils and 2.72 for the weather argillite. The saturated unit weights of the fluvial-lacustrine materials varied between 112 pcf in the undisturbed ground away from the tailing pile to 138 pcf for the same class of material in areas surcharged with the tails. The unit weight of the weathered argillite varied between 145 and 156 pcf.

The results of the grain size analyses are included in Appendix B. The analyses of the fluvial-lacustrine soil were done on samples with the greater than 3/8 inch diameter particles removed. The material is classified as a silty sandy gravel and is frost-susceptible. The weathered argillite on which a grain size analyses were done indicates a particle size distribution equivalent to a sandy gravel of relatively high permeability.

Direct shear tests were carried out on samples of the mill tails, the fluvial-lacustrine gravels and the weathered argillite bedrock recovered during the field investigation. The results of these tests are included in Appendix B and are summarized in Table 5.4.1.

The direct shear tests were all performed on unfrozen samples and each sample was allowed to consolidate and drain, or, conversely to absorb water, under each increment of normal load before any shear stress was applied to it. (An exception was the sample of mill tails which was tested at its original moisture content.)

The test results are somewhat misleading in terms of the indicated shear strengths of the fluvial-lacustrine materials relative to those of the weathered argillite. The tests indicate that under drained conditions the shear strength parameters for the fluvial-lacustrine soils are slightly greater than those for the weathered argillite. However, as discussed in Section 5.5 of this report, the operative conditions leading to failure in the foundation soils under the tailing pile can involve undrained conditions. This will be reflected in a build-up of greater excess pore water pressures in the fluvial-lacustrine soils than in the weathered argillite due to the higher natural moisture content and lower permeabilities of the fluvial-lacustrine soils in their undisturbed state. Under similar conditions of temperature and loading, these larger excess pore water pressures will lead to significantly lower effective shear strengths in the fluvial-lacustrine soils than in the weathered argillite.

5.5 Mechanisms of Movement

5.5.1 Introduction

The observations made and the data collected from the site inspections and the field and laboratory investigations have provided insight into the mechanisms of failure which have been operative in the tailing disposal area. These mechanisms are discussed in the following paragraphs for the two segments of the tailing pile which are of concern.

5.5.2 1974 Failure Lobe

Only sparse information is available on the failure which occurred at the southern extremity of the tailing pile in 1974. However, it is possible to reconstruct the probable sequence of events which led to the failure.

The slope over which the tails were being placed prior to the 1974 failure was, in general, frozen. The vegetation on the slope, shown on aerial photographs taken in 1970, as well as field observations, confirm this point. The thickness of the active layer on the slope is not known with certainty but, judging by the vegetation, it is unlikely that it would normally be in excess of 2 to 3 ft. A localized exception to these observations was probably extant in the draw on the slope into which tails at the southern extremity of the disposal area were being placed prior to the failure. The 1970 aerial photographs show that the surficial soils in the draw were wetter than those on the remainder of the slope. It is therefore probable that the active layer in this localized area extended to a greater depth than elsewhere on the hillside. The dominant soil type on the upper portion of the slope is a fluvial-lacustrine deposit of silty sandy gravel and it is likely that this material was also the principal surficial deposit in the draw. This material was noted during the field investigation to be frost-susceptible with as much as 40 per cent, by volume, of ice in the form of lenses. ?

According to mine personnel, the tails at the southern extremity of the pile moved downslope in the draw on a continuous basis from soon after disposal began in this area until the failure occurred in 1974. No information is available regarding the configuration of the tailing pile immediately prior to the failure. However, the quantity of the material in the failure lobe at present suggests that even prior to the failure the toe of the pile must have extended a substantial distance downslope in the draw.

The mechanism of failure for this segment of the tailing pile probably involved the build-up of excess pore pressures within the active layer of the foundation soils beneath the tails in the draw to the point of incipient failure throughout the period of the continuous slow downslope movement of the pile before the 1974 failure. When the toe of the pile reached the break in grade on the slope where more resistant foundation materials were encountered, it is possible that the movements slowed at the toe to a sufficient degree to allow increased loads from newly deposited tails to accumulate upslope. This would induce still higher pore water pressures in the foundation soils in the draw which would, in turn, lead to an overall failure of the mass of tails in that segment of the pile.

Since the failure, the tails in the failure lobe have continued to creep downslope and to encroach on the Wolverine Creek channel. There is also spreading of the tails at the tongue of the failure in a direction toward the lake formed by the damming effect of the tails. The spreading of tails into the lake is probably due to thawing of the original soils in the bottom of the valley caused by the year-round presence of water at above- freezing temperatures in the lake. The continued downslope movement of the tails along the length of the failure lobe is slow and becoming slower with time. The movements themselves are likely related to the thaw-consolidation process taking place in the permafrost beneath the tails as observed at the thermistor installation in this segment of the pile, as well as to the continuous removal of support from the toe of the failure by erosion in the Wolverine Creek channel. The slowing down of these movements suggests that temperature equilibrium between the tails and the foundation soils is approaching, and that the excess pore pressures induced as a result of the thaw-consolidation process are dissipating with time.

5.5.3 North Lobe of Tailing Pile

Following the failure of the southern portion of the tailing pile in 1974, disposal of tails was shifted northwards. As this new area was developed and the pile extended, the tails in this area began slowly to move downslope. In this instance, no localized weak areas, such as the draw in which the 1974 failure occurred, exist. The segment of the pile that is moving, is doing so on a front of the order of 1000 ft. wide which is much greater the width that of the 1974 failure which is estimated to have had a maximum frontal width of approximately 400 ft.

The mechanism of this failure is related to thaw-consolidation phenomena in the permafrost foundation soils. In general, each year thawing takes place to some depth in the soils on the slope. As the thaw front advances, excess pore water pressures build-up in this active layer due to the presence of excess water and the self weight of the soil. Expulsion of this excess water and the consequent dissipation of excess pore pressures takes place at a rate which depends upon the permeability of the soil, the depth of thaw and the loads applied to the thawing soil. When freeze-back begins, it commences at the ground surface and proceeds downward, forming an upper impermeable barrier to further exit of water from the unfrozen saturated soil sandwiched between this frozen surface layer and the underlying permafrost. Depending upon the relative severities of seasons, or changes in surface conditions, such as the presence of a layer of tails, freeze-back may or may not reach the bottom of the unfrozen soil stratum each year. Clearly, if loads in addition to the self weight of the soil, such as those of the tailing pile, are applied when a layer of saturated unfrozen soil is sandwiched between frozen and, therefore, relatively impermeable soil strata, excess pore water pressures will be induced and will result in a significant reduction in the shear strength of the soil. In the case of the north lobe of the tailing pile, it is believed that these phenomena have led to its downslope movement.

The presence of a weak layer of soil confined at some depth below the ground surface would also allow the bulldozing of slabs and masses of earth ahead of the pile as it moved downslope. Photographs 11, 12 and 13 show this phenomenon at the toe of the north lobe of the tailing pile. wouldn't this happen in any case

The rate of downslope movement of the pile is related to the magnitude of the loads applied to the foundation soils by the tailing pile and the pore water pressures induced by these loads. The pore water pressures are, in turn, related to the moisture contents and permeabilities of the soils in the foundation of the tailing pile. As noted in Section 5.3, the rates of movements of this segment of the tailing pile are slowing with time. It is probable that this slowing of the rate of movement is due to two factors. First, a reduction in the normal loads applied to the foundation soils because of the thinning of this portion of the pile as it continues to move downslope, to spread laterally on its base, and to cover a progressively larger area; and second, the thickness of the frost-susceptible fluvial-lacustrine foundation soils beneath the tailing pile diminishes in the downslope direction causing a reduction in the potential for high pore water pressures. (At several locations checked at the toe of the north lobe of the tailing pile the fluvial-lacustrine stratum was either absent or only a few inches thick. The foundation material in this region, and downslope from the toe of the pile, is predominantly weathered argillite which has a higher permeability and lower ice contact. content? The weathered argillite is therefore less susceptible to build-ups of excess pore water pressures). ? lower

5.6 Analyses

5.6.1 Introduction

Stability analyses of both the 1974 failure lobe and the lobe to the north of the failure have been carried out. The analyses show that trimming of some portions of the lobe upslope of the toe of the failure lobe, together with appropriate treatment of the Wolverine Creek channel, as it bypasses the toe of the slope, will increase the factor of safety to a sufficient degree to stop further downslope movements in this area. The analyses carried out on the north lobe of the tailing pile indicate that removal of materials from the surface of the pile in that area will bring the downslope movements to a halt.

5.6.2 1974 Failure Lobe

A section through the 1974 failure lobe is shown on Figure 7. This section was analyzed using the indicated geometry, together with the strength parameters and unit weights determined for the tails and foundation soils at the site. It was assumed that in its present condition the failure lobe has a factor of safety against failure of 1.0. The analysis provided a pore pressure distribution along the tails/foundation interface for these conditions, i.e. for the condition of incipient failure. Various altered geometries for the surface of the failure lobe were then assessed, using the calculated pore water pressure, which was appropriately adjusted in each case for the effects of the new geometries. A tabulation of the factors of safety for several possible slope configurations, which would lead to improved stability of the failure lobe is given on Figure 7. The analyses lead to the conclusion that trimming of the "knob" upslope from the toe of the failure lobe, as shown on Figures 6 and 7, together with appropriate grading and lining of the Wolverine Creek channel at the toe of the lobe, will provide an adequate safety against further downslope movement of the failure lobe. The factor of safety against downslope movement attendent with this solution is 1.20. Details of the measures required to effect this solution are given in Section 5.7 and 5.8 of this report.

5.6.3 North Lobe of Tailing Pile

Figure 8 shows a section through the north lobe of the tailing pile which is moving downslope. This section has been analyzed using the indicated geometry, together with the soil properties determined for the tails and the foundation soils at the site. A factor of safety of 1.0 against downslope movement was assumed for the tailing pile in its present condition. The analyses yielded a pore pressure distribution along the bottom of the pile for this condition of incipient failure. This pore pressure was then used in analyses of the north lobe of the tailing pile to determine factors of safety against downslope movement for altered geometries of this segment of the pile. Figure 8 shows these geometries and the graphical relationship between factor of safety and geometry of the pile.

The analyses indicate that removal of material from the surface of the moving segment of the tailing pile enhances its stability. As shown on the graph in Figure 8, removal of approximately 20 ft. of tails from the surface of the pile in this area will increase the factor of safety against downslope movement from 1.0 to 1.3. Details of the measures required to effect this solution are given in Sections 5.7 and 5.8 of this report.

5.7 Recommended Treatment

5.7.1 1974 Failure Lobe

The analyses outlined in Section 5.6 with regard to the 1974 failure lobe indicate that the most economical and practicable solution to the problem of continuing movements in this region of the pile will involve the removal of some material from the surface of the pile upslope from its toe, grading and lining of the Clinton Creek channel where it bypasses the toe of the failure lobe, and construction of a channel and weir system downstream of the failure lobe to conduct Wolverine Creek in a competent channel to return it to its natural course.

The required work in the sequence in which it should be done is as follows:-

a) The knob between coordinate lines 109200 E and 109500 E on section 113500 N should be trimmed according to the contours shown on Figure 6 and the profile denoted as (4) on Figure 7. Survey monitors should be established on the recontoured slope between approximately coordinates 109200 E and 109700 E on gridline 113500 N and checked periodically to assess any slope movements which may occur.

b) The Wolverine Creek channel, where it bypasses the toe of the failure lobe, should be straightened and graded at 0.3 per cent from approximately elevation 1322 ft. at coordinate 113950 N - 109800 E to elevation 1320.2 ft. at coordinate 113350 N - 109880 E, a distance of approximately 600 ft., as shown on Figure 6. The channel must be suitably lined to prevent erosion of tails by the stream in this reach of the channel. The bottom of the existing channel should be filled with mill overs to provide an underdrain at the toe of the slope in those areas where the creek channel will be raised to meet the required gradient. The materials used for fill above the drain rock and below the bottom of the channel lining can consist of tails taken from the excavation required to widen and contour the channel sides. Figure 9 shows a typical section through the Wolverine Creek bypass channel. The dimensions, gradient and material size requirements are based on a flow of 358 cu. ft. per sec., which is the 100-year flow taken from the flood frequency analysis provided to Golder Associates by the Department of Indian Affairs and Northern Affairs.

c) From the downstream end of the bypass channel at coordinate 113350 N to 109880 E, the stream must be conducted in a rock-lined channel and weir system at an overall gradient of 8 per cent to meet the existing Wolverine Creek channel at approximately elevation 1257 ft. at coordinate 112650 N - 110080 E. This portion of the channel will be approximately 800 ft. long and will accomodate a decrease in head in the stream of approximately 63 ft. Continuation of the coarse tails underdrain in the bottom of the existing channel for the full length of this construction will be required. Materials needed to raise the ground surface to the required gradient above the drain rock can consist of tails taken from those areas of the tailing pile where excavation is required. Figure 10 shows a typical section through this portion of the channel, as well as a profile of the channel with details of the weir construction, channel gradients and material size requirements. The specifications for the channel were determined on the basis of the DIAND flood frequency analyses for Wolverine Creek.

d) It is recommended that this work be carried out during the months of August and September 1978, when stream flows can be expected to be low and problems contingent with construction in freezing temperatures can be avoided. In the event that flows in Wolverine Creek are too high to allow construction of the proposed system, a cofferdam to contain the run-off from this drainage basin during the construction period can be constructed at the upstream end of the failure lobe.

5.7.2 North Lobe of Tailing Pile

The analyses carried out on the north lobe of the tailing pile, shown on Figure 8, indicate that removal of material from the surface of the more rapidly moving segment of the pile will enhance its factor of safety against downslope movement. Therefore, it is recommended that approximately 20 ft. of material be removed from the surface of the pile, according to the limits and contours shown on Figure 6. The analyses indicate that the factor of safety against further downslope movement of the pile, if this work is performed, will be approximately 1.3.

The excavated material can be moved onto undisturbed ground to the north of this segment of the pile. The thickness of the excavated tails should not exceed 20 ft. in their new location.

It is recommended that this work be performed during the months of September and October 1978, when the thickness of the active layer in the undisturbed ground is at its maximum. Dissipation of excess pore water pressures within the foundation soils can then proceed throughout the winter months, since the insulating effect of the tails will prevent freeze-back in the active layer.

Survey monitors should be established on the recontoured surface of this segment of the tailing pile and checked periodically so that any movements that do occur can be assessed with regard to their significance.

5.7.3 Fugitive Dust from the Tailing Pile

The majority of wind-blown dust from the tailing disposal area originates from the belt conveyor as the tails are being transported from the mill to the tailing pile. When milling operations cease, this source of fugitive dust will be eliminated.

The materials at the surface of the tailing pile have formed a crust as a result of cementing of the particles and, except in those areas where active movements of the pile are occurring, and fresh materials being exposed, no dust is raised by wind. When measures to stop the downslope movements of the pile are completed, further exposure of loose fines on the surface of the pile will be precluded.

As a result of these considerations, it is our opinion that no specific measures regarding control of fugitive dust from the surface of the tailing pile are required.

5.8 Summary of Estimated Quantities and Costs

The following is a summary of the estimated material quantities and costs involved in the proposed work for stabilization and stream control in the tailing disposal area:-

a) 1974 Failure Lobe

i)	excavation of knob on failure lobe approximately 30,000 cu. yds. @ $0.50/cu. yd.	$15,000.00
ii)	coarse tails underdrain in Wolverine channel approximately 1500 cu. yds. @ $1.70/cu. yd.	$ 2,550.00
iii)	tails for general backfill to raise channel to required grade approximately 30,000 cu. yds. @ $0.50/cu. yd.	$15,000.00
iv)	coarse rock (30% greater than 3 inch diameter) for bypass channel lining approximately 4500 cu. yds. @ $1.70/cu. yd.	$ 7,650.00
v)	rock for channel lining and weirs downstream of failure lobe approximately 6500 cu. yds. @ $2.50/cu. yd.	$16,250.00
		$56,450.00

b) North Lobe of Tailing Pile

i)	excavation and removal of tails from surface of pile approximately 150,000 cu. yds. @ $0.50/cu. yd.	$75,000
	TOTAL ESTIMATED COST FOR STABILIZATION AND STREAM CONTROL IN TAILING DISPOSAL AREA	$131,450.00

TABLE 5.3.1

Horizontal Movements on 1974 Failure Lobe of Tailing Pile

Monitor	Date Established	Rate of Horizontal Movement (ft./day) Overall Average to June 16/78	March 78 - June 78
24	December 23/76	0.0023	0.0011
24A	March 30/78	0.0012	0.0012
24B	March 30/78	0.0072	0.0072
24C	March 30/78	0.0100	0.0100
25	December 23/76	0.0205	0.0104 (0.020 May 78 - June 78)
25A	March 30/78	0.0049	0.0049

TABLE 5.3.2

Vertical Movements on 1974 Failure Lobe of Tailing Pile

Monitor	Date Established	Rate of Vertical Movement (ft./day) Overall Average	March 78 - June 78
24	December 23/76	0.0020	0.0015
24A	March 30/78	0.0044	0.0044
24B	March 30/78	0.0047	0.0047
24C	March 30/78	0.0053	0.0053
25	December 23/76	0.0071	0.0051
25A	March 30/78	0.0004	0.0004

TABLE 5.3.3

Horizontal Movements on North Lobe of Tailing Pile

Monitor	Date Established	Rate of Horizontal Movement (ft./day) Overall Average to June 16/78	March 30/78 to May 5/78	May 5/78 to June 16/78
26	December 23/76	0.159	0.030	0.016
26A	March 30/78	0.020	0.017	0.014
26B	March 30/78	0.207	0.242	0.177
29	June 10/77	0.389	0.274	0.207
29A	March 30/78	0.249	0.295	0.210

TABLE 5.3.4

Vertical Movements on North Lobe of Tailing Pile

Monitor	Date Established	Rate of Vertical Movement (ft./day) Overall Average	March 78 - June 78
26	December 23/76	0.141	0.022
26A	March 30/78	0.013	0.013
26B	March 30/78	0.119	0.119
29	June 10/77	0.164	0.098
29A	March 30/78	0.087	0.087

TABLE 5.4.1

Shear Summary of Laboratory Direct Shear Tests

LOCATION	DEPTH	SOIL TYPE	NATURAL MOISTURE CONTENT W (%)	MOISTURE CONTENT BEFORE TEST	MOISTURE CONTENT AFTER TEST	EFFECTIVE ANGLE OF INTERNAL FRICTION Ø'
		Mill Tailings	1.9	1.9	1.9	35° - 45°
BH 13 (T-6)	15' - 20'	Fluvial Lacustrine Gravel	40.6	21.8	18.2	29°
BH 13 (T-6)	32' - 34'	Fluvial Lacustrine Gravel	32.9			27.5°
BH 14 (T-7)	46' - 48'	Fluvial Lacustrine Gravel	19.5	16.3	11.8	32°
BH 16 (T-8)	66' - 68'	Fluvial Lacustrine Gravel	13.5	13.4	13.0	27.5° - 32.5°
BH 15 (ST-8)	6' - 9'	Weatherd Argillite	5.2	15.8	12.9	26°
BH 15 (ST-8)	20' - 21'	Weathered Argillite	11.4	13.6	13.0	27°

6.0 PORCUPINE DUMP

The location of the Porcupine dump is indicated on the reproduction of the aerial photograph, Figure 1. This dump was developed on the sloping surface of the west valley wall of the Porcupine Creek. As in the case of the Clinton dump, the Porcupine dump has experienced downslope displacements which have interrupted the drainage course of Porcupine Creek. The Porcupine catchment area is smaller than the catchment area of Clinton Creek, and only minor ponding of water on the upstream side of the dump has occurred.

A field examination has been made of the toe region of the Porcupine dump, along the line where its limit contacts the sloping surface of the east valley wall of Porcupine Creek. Some segments along this contact zone at the toe of the Porcupine dump consist of serpentine rock to a maximum size of approximately 5 ft. These rock fragments are durable, and are not subject to degradation in the manner which is characteristic of the argillite that constitutes the majority of the waste rock materials which the dump comprises. Other segments along the toe of the Porcupine dump consist of highly degraded argillite bedrock. At these locations, the creek flows on a surface within a channel formed by the toe of the dump and the right valley wall of Porcupine Creek. At the locations where the material within the toe region of the dump consists of coarse serpentine rock, the creek dissapears into the waste dump and flows beneath the surface.

Examination of the area where the Porcupine Creek flows exit the toe of the dump showed that the discharge water is clear. On the basis of our field examinations, we conclude that the Porcupine dump does not present any environmental problems relating to erosion or degradation of water quality.

Yours very truly

GOLDER GEOTECHNICAL CONSULTANTS LTD.

David B Campbell

Per: David B. Campbell, P. Eng.

EB Fletcher

E.B. Fletcher, P. Eng.

DBC/EBF:rme

V77016

LIST OF REFERENCES

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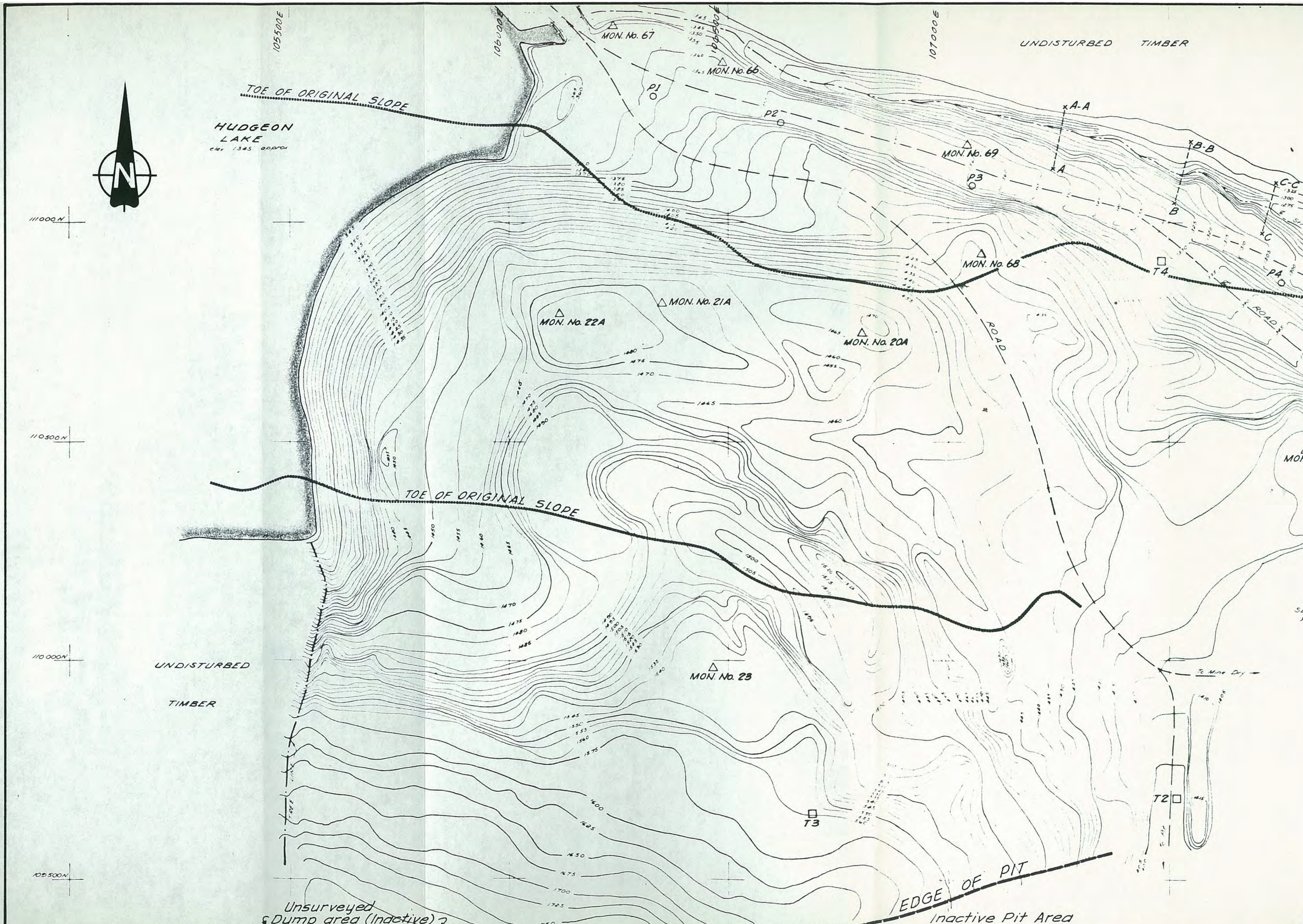
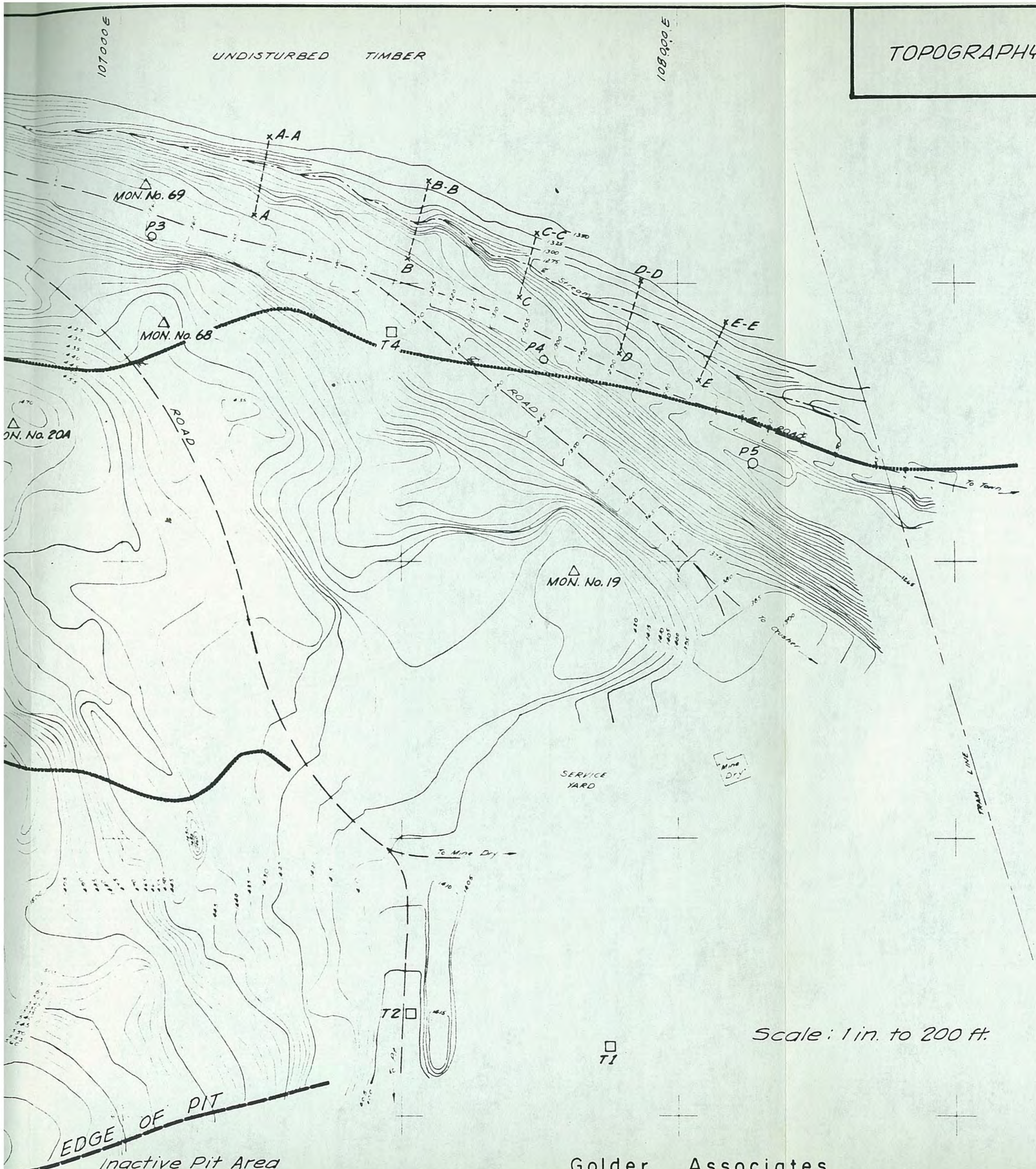
Sigma Resource Consultants Ltd. - The Development of Power Potential in the Yukon, Addendum to, Hydrology, January 1975, Document prepared for the Northern Canada Power Commission.

Terzaghi and Peck - Soil Mechanics and Engineering Practice, John Wylie and Sons, 1st Addition, 1948.



HUDGEON
LAKE
elev 1345 approx
TOE OF ORIGINAL SLOPE
MON. No. 67
MON. No. 66
MON. No. 69
MON. No. 68
MON. No. 21A
MON. No. 22A
MON. No. 20A
MON. No. 23
UNDISTURBED TIMBER
UNDISTURBED
TIMBER
A-A
B-B
C-C
P1
P2
P3
P4
T2
T3
T4
ROAD
To Mine Dry
105500E
106000E
106500E
107000E
111000N
110500N
110000N
109500N
Unsurveyed
Dump area (Inactive)
EDGE OF PIT
Inactive Pit Area

TOPOGRAPHY - CLINTON DUMP | FIGURE 2



LEGEND:

MON. No. 19 Surface movement survey reference point.

A-A / A Cross-channel reference line.

T2 Thermister installation

P4 Piezometer.

REFERENCE:

Topo. plan of Inactive Waste Dump for Clinton Cr. Mine by Underhill Engineering Ltd. - Mar. 30, 1978. Coordinate grid from Cassiar Asbestos Corp. Grid Origin.

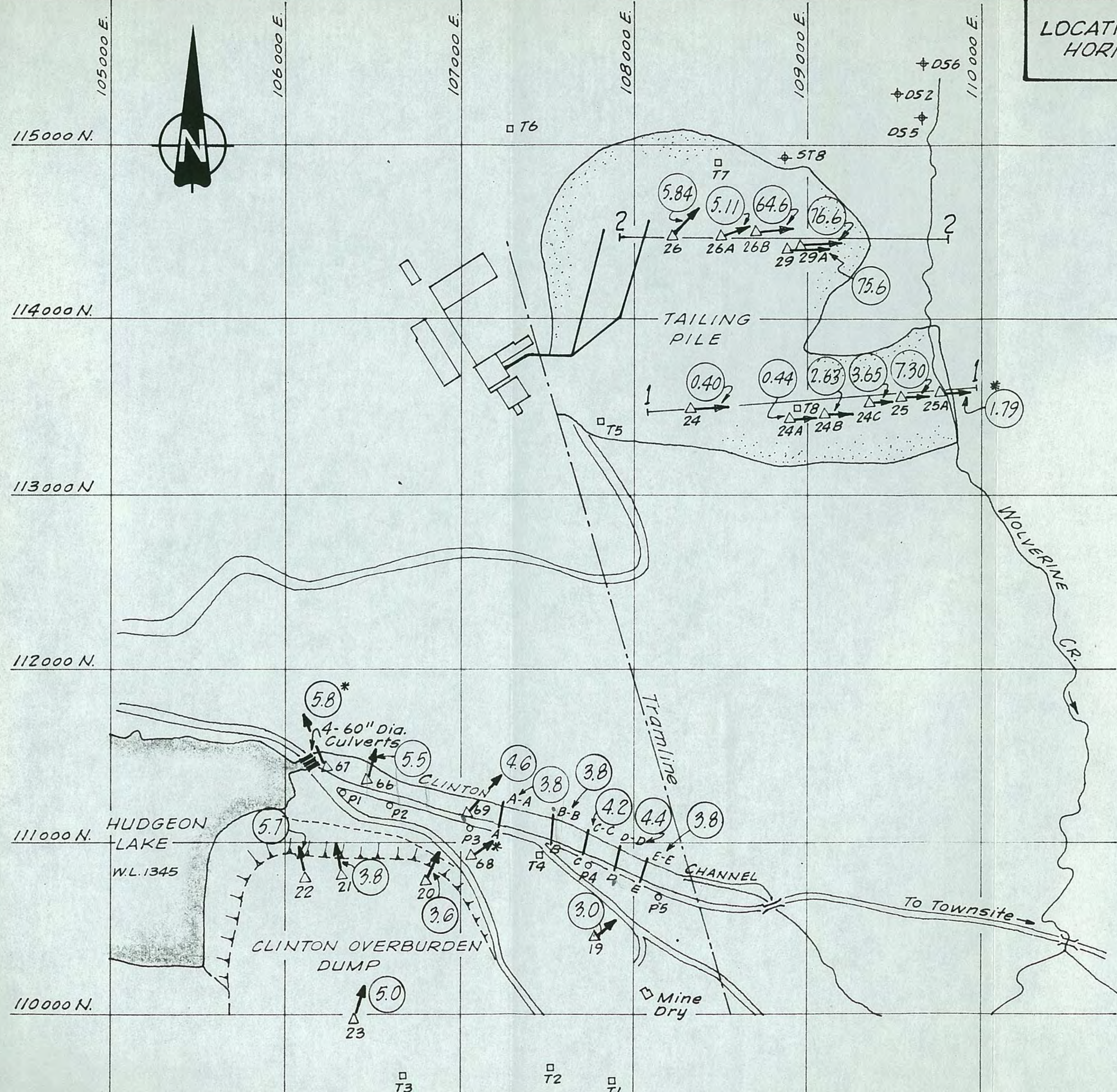
Scale: 1 in. to 200 ft.

Golder Associates

Drawn Ing.
Reviewed
Date June '78

LOCATION OF INSTRUMENTATION AND HORIZONTAL MOVEMENT VECTORS

FIGURE 3



LEGEND:

- △ Surface movement reference point.
- □T4 Thermister installation.
- ○P5 Piezometer
- ⌖ D52 Borehole
- (5.84) Indicates azimuth of horizontal movement vector and rate of horizontal movement (feet/year).
- *Reference point subject to localized horizontal movements.

SCALE - FEET

0 500 1000

Drawn ____

Reviewed ____

Date July '78

Golder Associates

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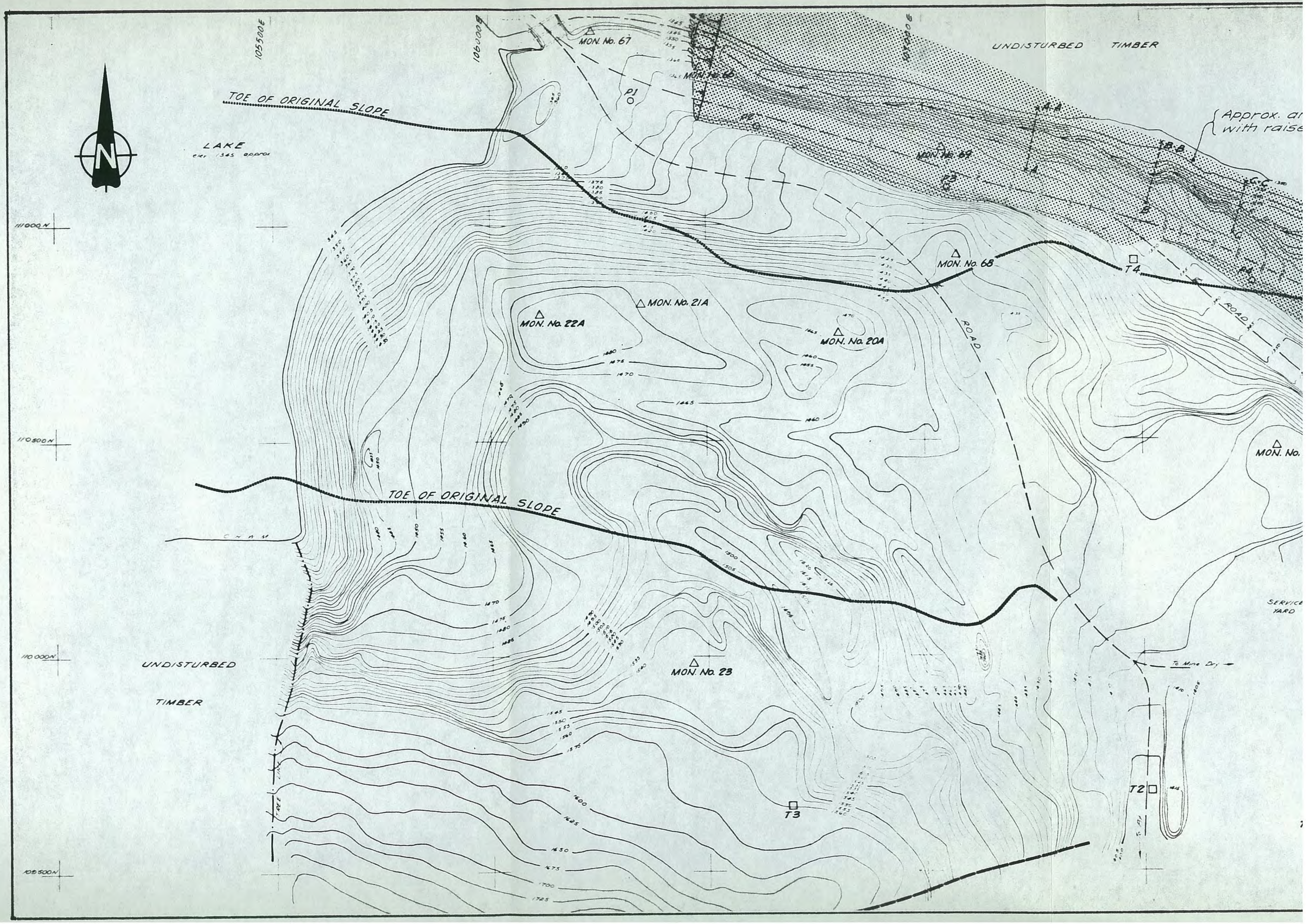
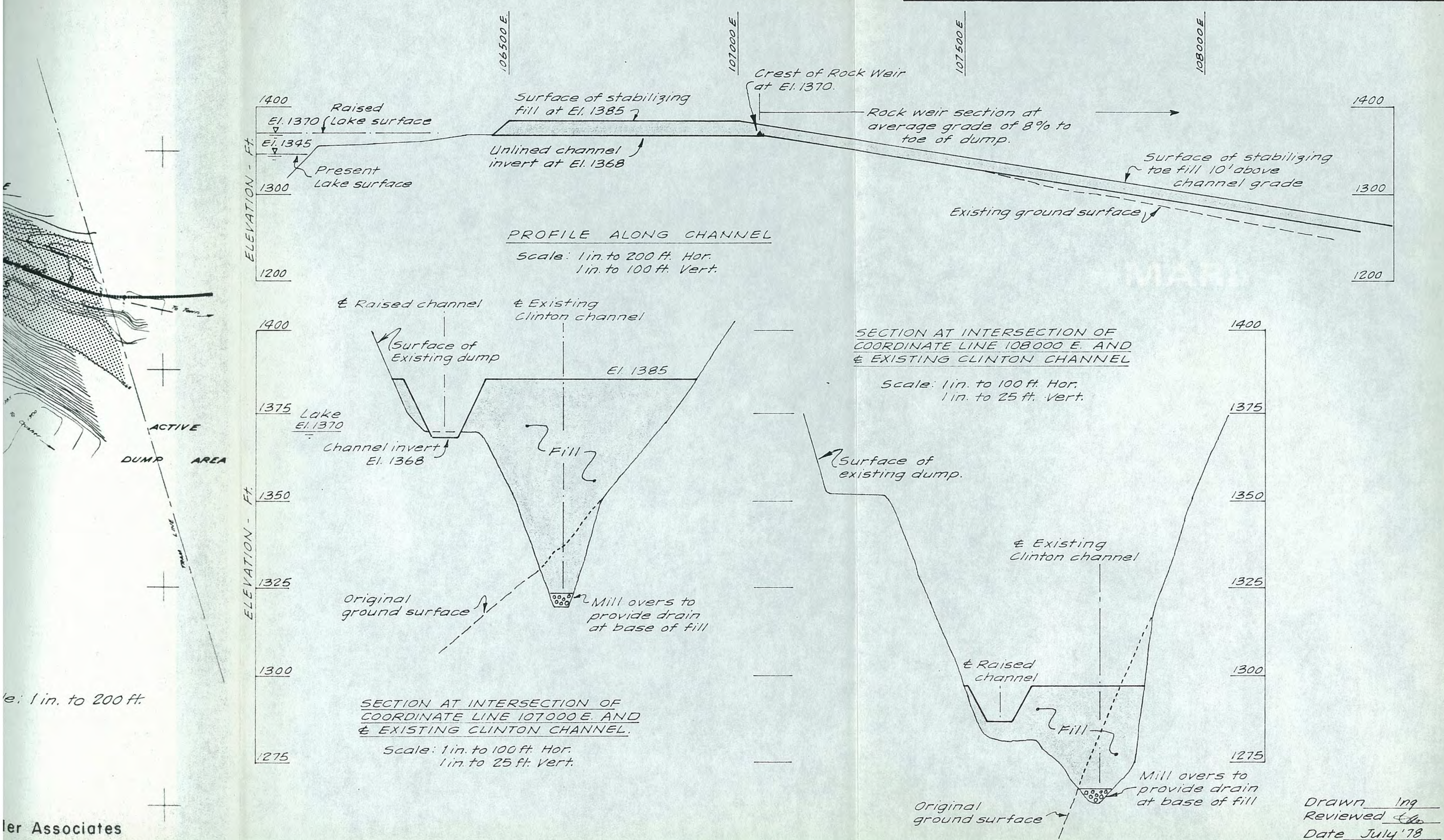


UNDISTURBED TIMBER
MON. No. 67
MON. No. 66
P1
P2
TOE OF ORIGINAL SLOPE
LAKE
MON. No. 69
P3
A-A
B-B
C-C
Approx. a
with raise
MON. No. 68
T4
P4
ROAD
MON. No. 21A
MON. No. 22A
MON. No. 20A
ROAD
MON. No.
TOE OF ORIGINAL SLOPE
SERVICE YARD
UNDISTURBED
TIMBER
MON. No. 23
To Mine Dry
T3
T2
105500E
106000E
111000N
110500N
110000N
109500N

CLINTON DUMP
STABILIZING TOE FILL AND RAISED CHANNEL

FIGURE 4



Drawn ___ Ing
Reviewed ___
Date July '78

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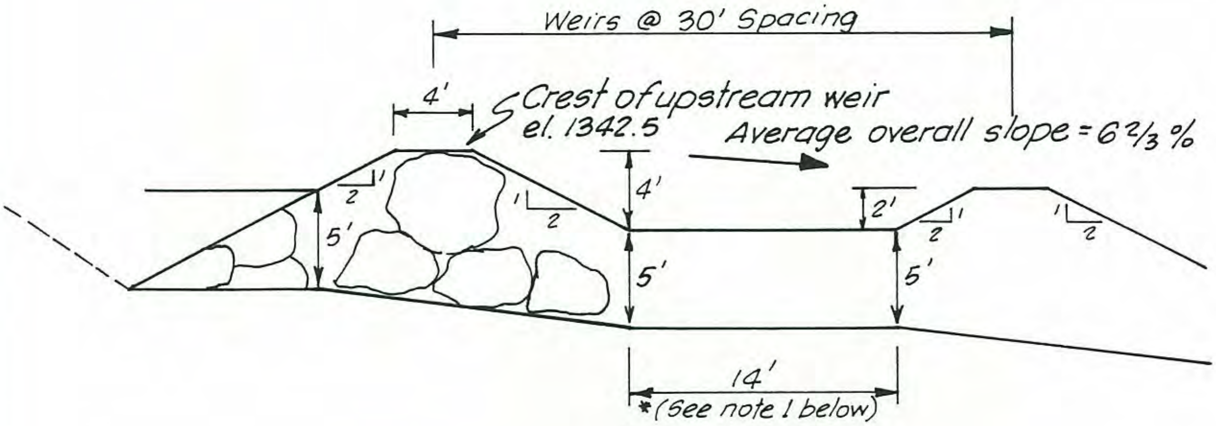
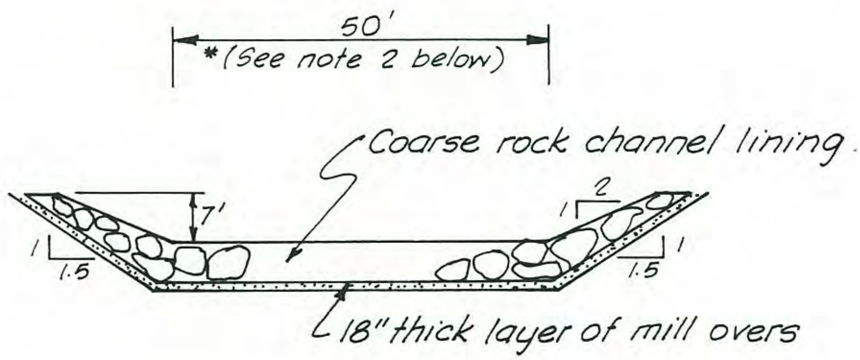
CLINTON CHANNEL
EROSION RESISTANT ROCK LINING

Figure 5



LONGITUDINAL SECTION
Scale : 1 inch to 10 feet



For the coarse rock channel lining,
20% of fragments by weight should be > 5500 lbs. size
50% of fragments by weight should be > 4300 lbs. size
80% of fragments by weight should be > 2700 lbs. size

TRANSVERSE SECTION
Scale: 1 inch to 25 feet

*Notes : 1. For the 'Cadillac' scheme, this dimension is 9 ft. which increases the overall average grade to 8%.

2. For the 'Cadillac' scheme, this dimension is 30 ft.

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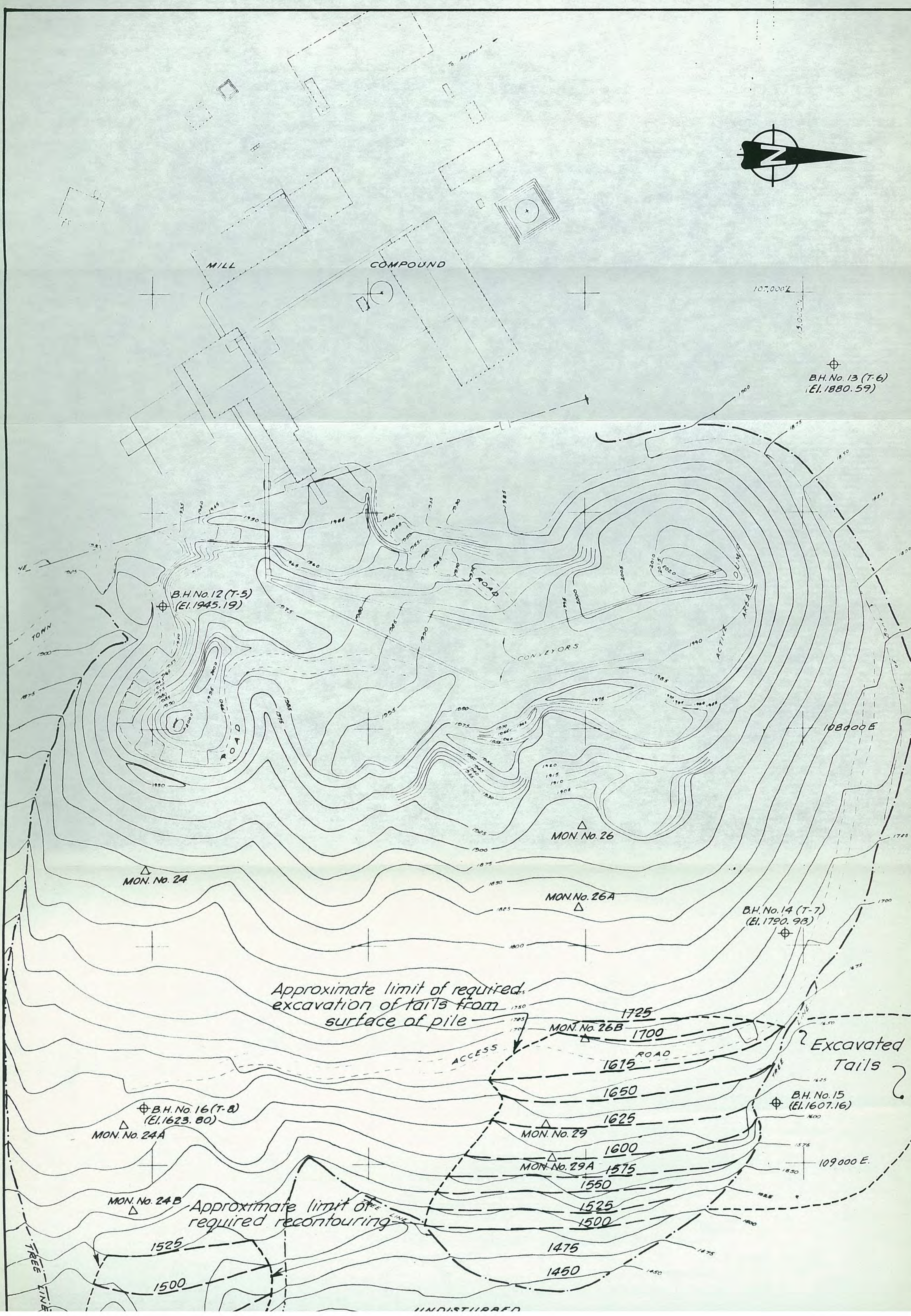
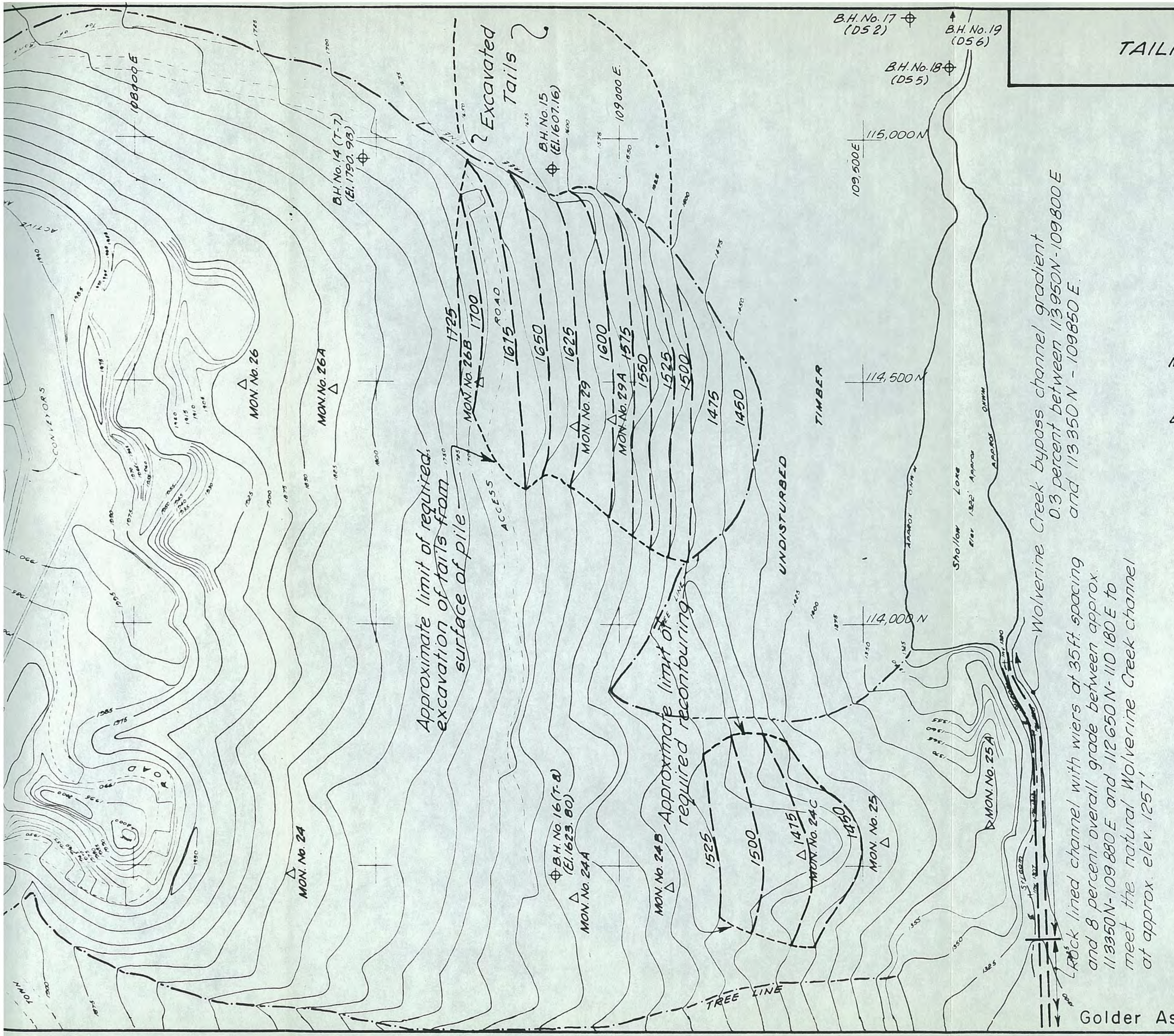

MILL
COMPOUND
107,000 E.
B.H. No. 13 (T-6)
(El. 1880.59)
B.H. No. 12 (T-5)
(El. 1945.19)
ROAD
CONVEYORS
ACTIVE AREA
TOWN
108000 E.
MON. No. 26
MON. No. 24
MON. No. 26A
B.H. No. 14 (T-7)
(El. 1790.98)
Approximate limit of required excavation of tails from surface of pile
MON. No. 26B
ACCESS ROAD
Excavated Tails
B.H. No. 15
(El. 1607.16)
B.H. No. 16 (T-8)
(El. 1623.80)
MON. No. 24A
MON. No. 29
MON. No. 29A
109000 E.
MON. No. 24B
Approximate limit of required recontouring
TREE LINE
1725
1700
1615
1650
1625
1600
1575
1550
1525
1500
1475
1450
UNDISTURBED

TAILING PILE

FIGURE 6



LEGEND:

△ MON. No. 19 — Surface movement survey reference point.

⊕ B.H. No. 12 — Borehole

REFERENCE:

Topo. plan of Mill Tailings Pile for Clinton Creek Mine, by Underhill Engineering Ltd. - April 29, 1978. Coordinate grid from Cassiar Asbestos Corp. Grid Origin.

Scale: 1 in. to 200 ft.

Drawn: Ing
Reviewed: [illegible]
Date: June '78

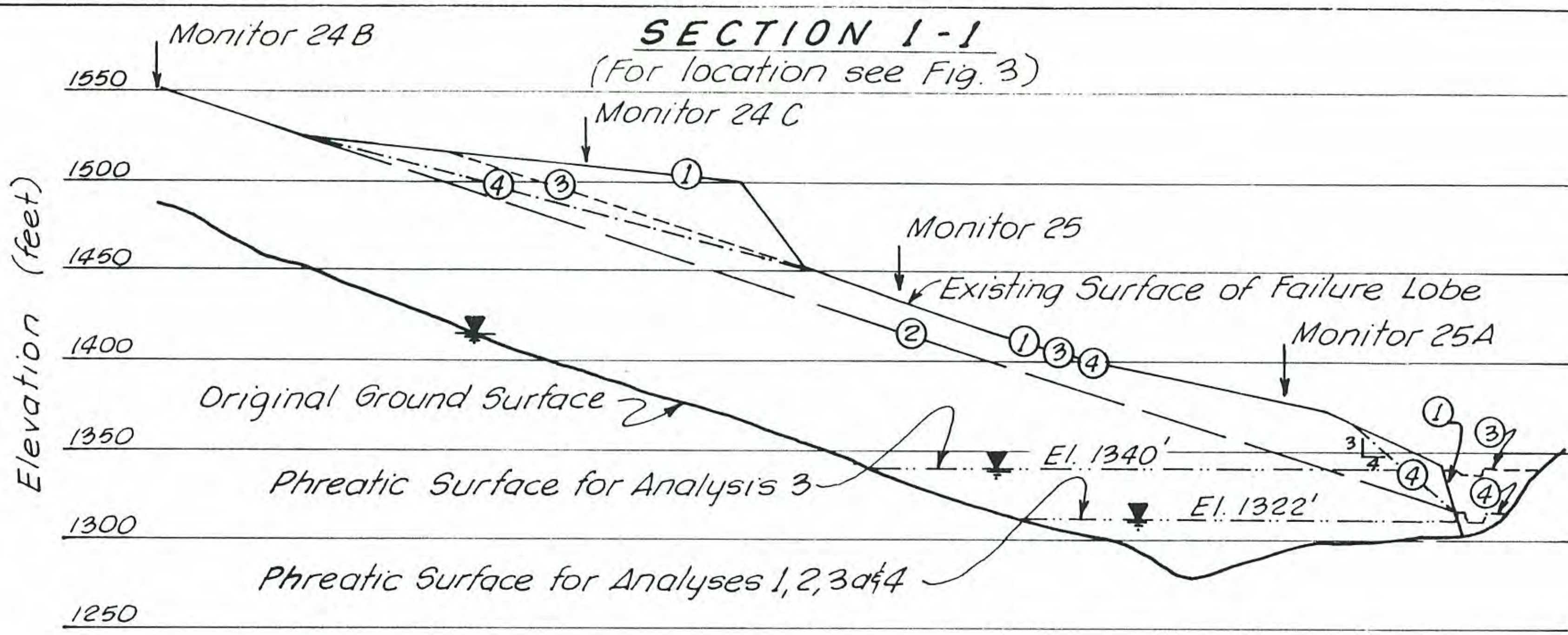
Y-77016 E.O.F. July '78

TAILING PILE - 1974 FAILURE LOBE

Figure 7

SECTION 1-1

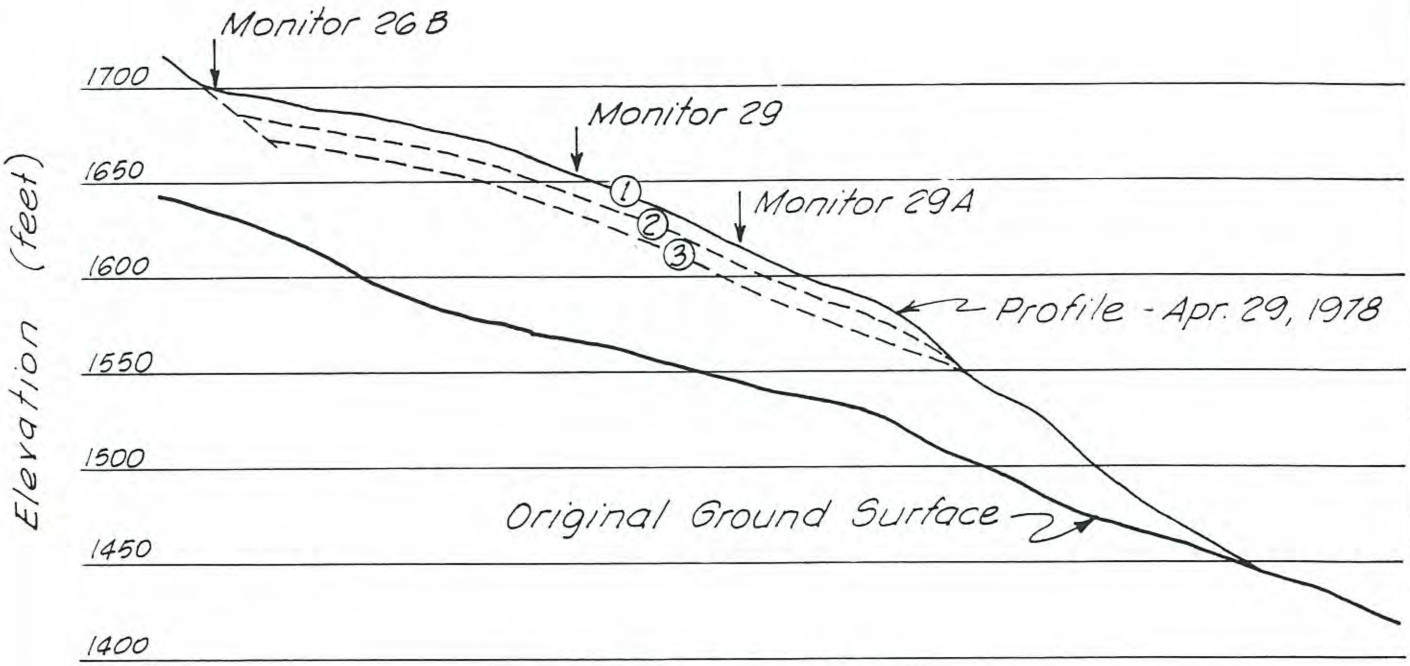
(For location see Fig. 3)



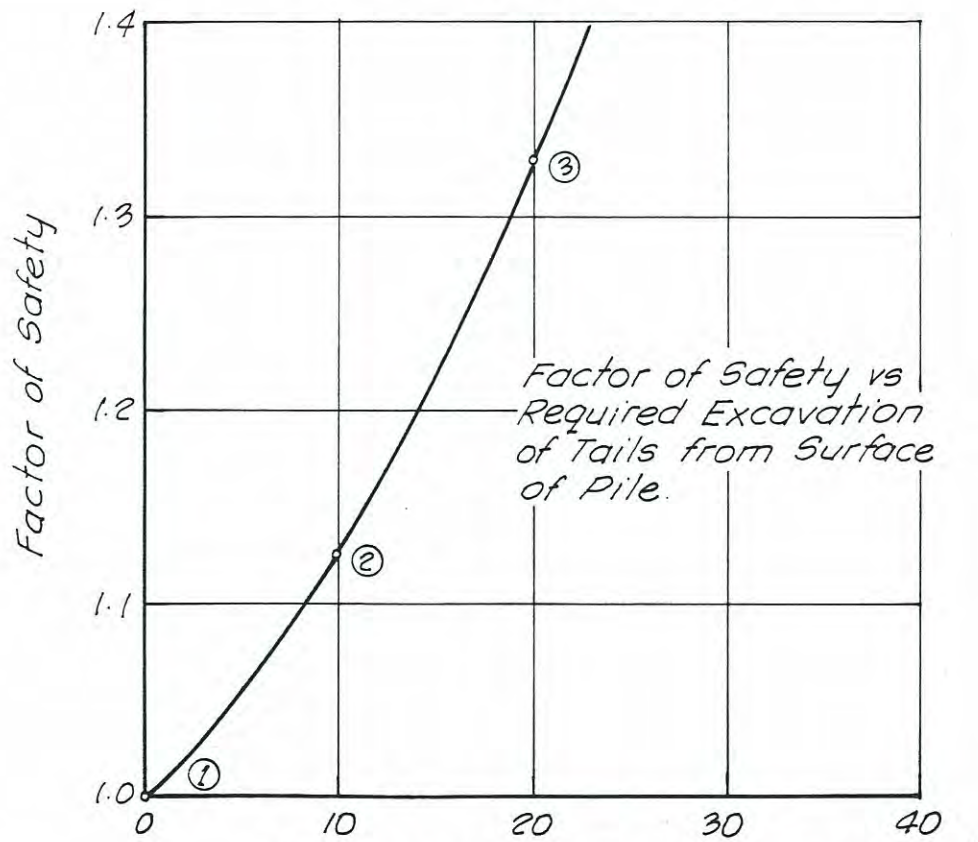
Profile	Notes	Factor of Safety
1	Existing Slope	1.00
2	Slope trimmed to approximately 18° from Wolverine Channel	1.57
3	Wolverine Channel filled to elevation 1340'; phreatic surface in tails raised to elevation 1340'; upslope knob removed	1.04
3a)	Wolverine Channel filled to elevation 1340'; phreatic surface maintained at elevation 1322'; upslope knob removed	1.21
4	Wolverine Channel trimmed and armed against stream erosion; upslope knob removed	1.20

TAILING PILE - NORTH LOBE

Figure 8



SECTION 2-2
(For location see Fig. 2)



July '78

V-77016

Golder Associates

TYPICAL CROSS-SECTION OF WOLVERINE CREEK BYPASS AT TOE OF 1974 FAILURE LOBE

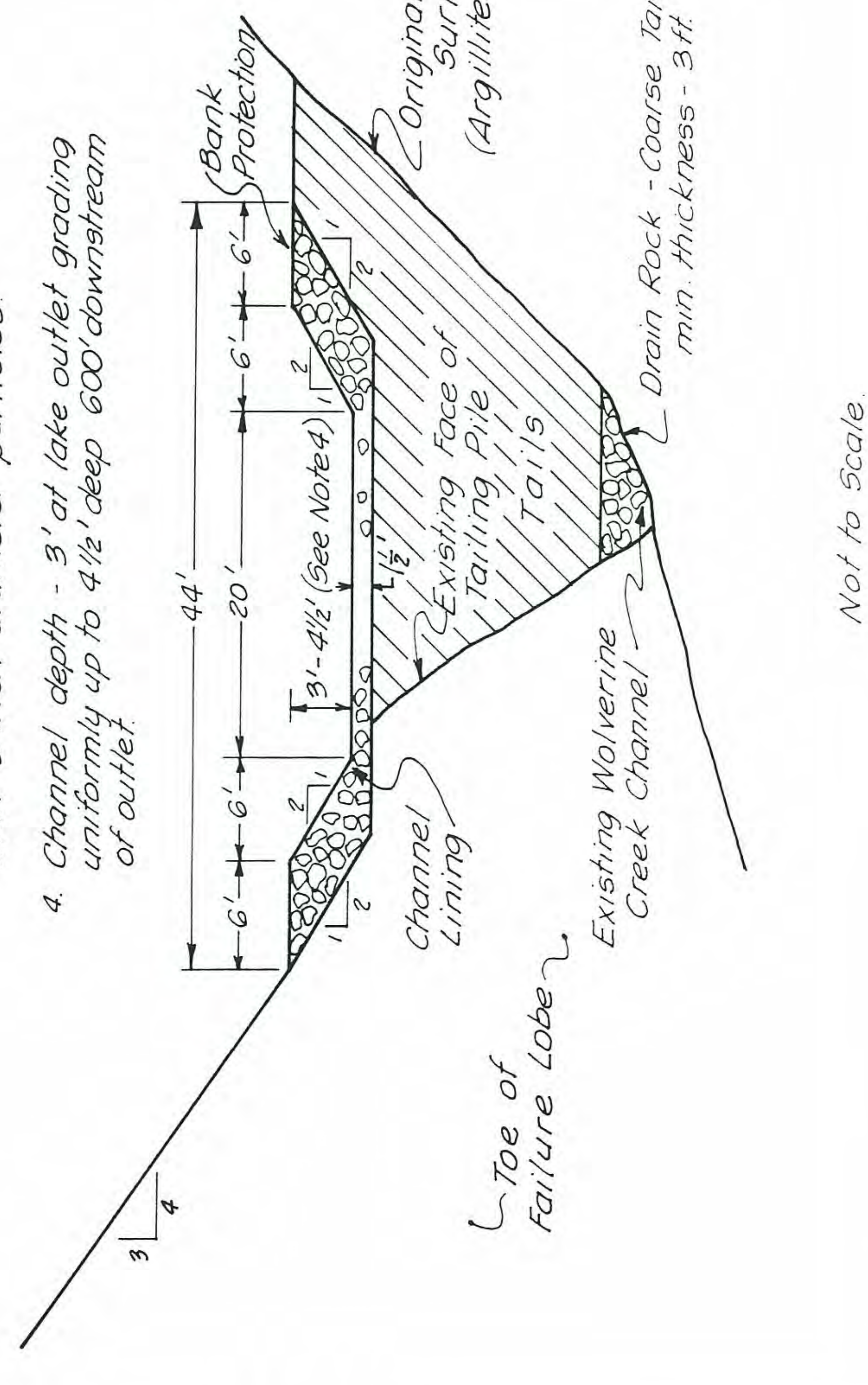
Figure 9

Notes: 1. Channel outlet from lake at El. 1322'.

2. Channel gradient 0.3 percent.

3. Channel lining built with material consisting of 30 percent greater than 3 inch diameter particles.

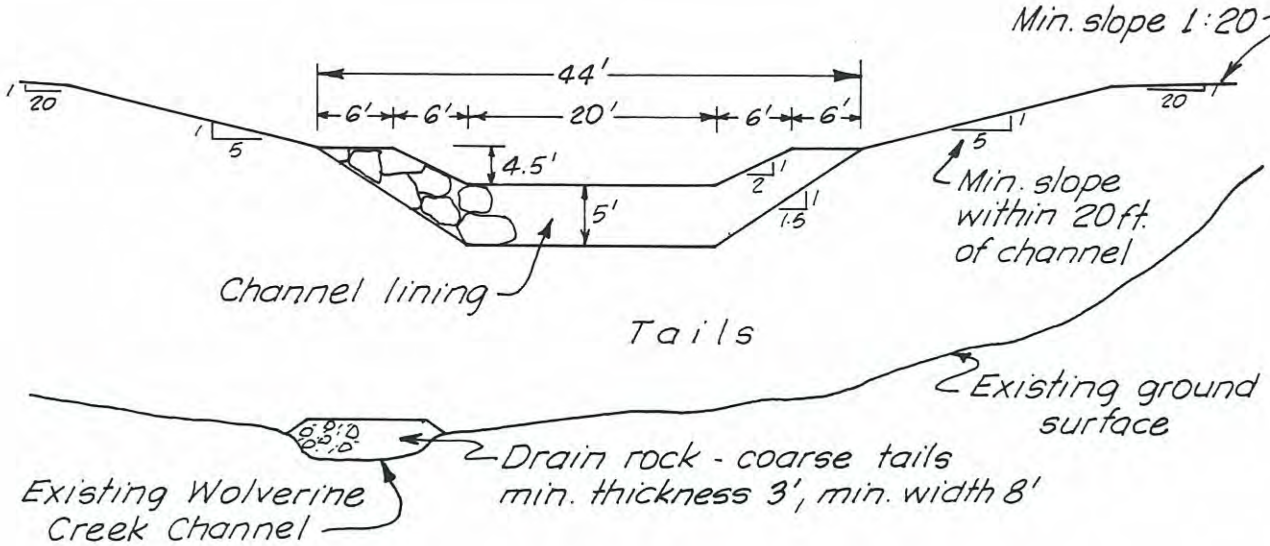
4. Channel depth - 3' at lake outlet grading uniformly up to 4½' deep 600' downstream of outlet.



1-77016 July '78

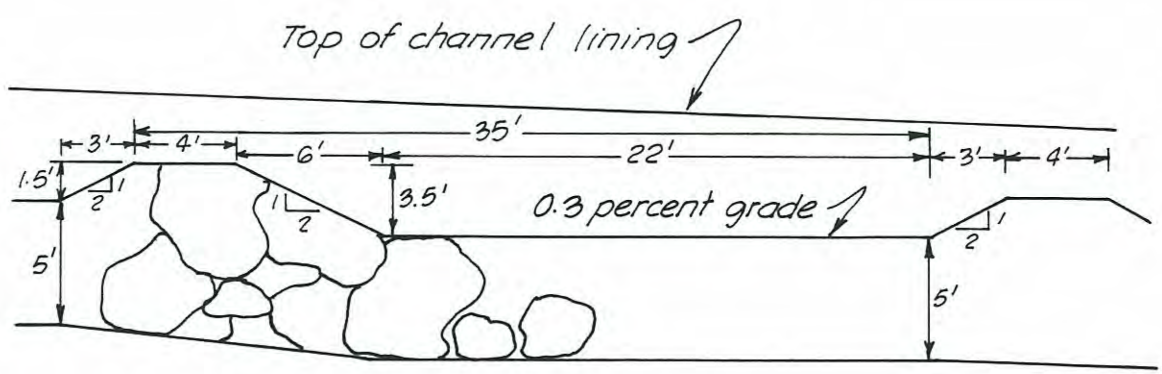
WOLVERINE CREEK CHANNEL DOWNSTREAM OF FAILURE LOBE

Figure 10



Note: 1. Channel lining and wier materials must conform to:
20 percent greater than 48 inch diameter (~5500 lbs.)
50 percent greater than 40 inch diameter (~4300 lbs.)
80 percent greater than 30 inch diameter (~2700 lbs.)

TYPICAL SECTION



Note: 1. Crests and downstream toes of weirs must be constructed of heavy rocks.

PROFILE OF WEIR SYSTEM

Not to Scale

Project No. V-77016 Drawn [initials] Reviewed EBF Date July '78

PHOTO 1

View of Clinton Dump looking downstream, and showing pressure ridge on ice surface as a result of creep movements during the winter of 1977-78. Date of Photo, March 9th, 1978.

PHOTO 2

Tension cracks on surface of Clinton Dump as a result of horizontal movements due to shear of the dump on its base.

PHOTO 3

Tension crack aligned approximately perpendicular to Clinton Channel.

PHOTO 4

Showing bedrock exposed on left side of Clinton Channel at a point midway between cross channel reference lines B-B and C-C (see Figure 2 for location).

PHOTO 5

View of Clinton Channel looking upstream showing exposed bedrock on north side. Bedding dips at approximately 20 degrees toward the channel, and well developed cross joints are aligned perpendicular to the bedding joints. Large rocks on left side of photo are remnants from the waste dump.

PHOTO 6

The junction of the Forty Mile river and the Yukon river. Clinton creek joins the Forty Mile just beyond the upper edge of the photo. Date of photo June 5th, 1978.

PHOTO 7

View of tailing pile-facing north

PHOTO 8

View of Wolverine Creek channel at toe of 1974 failure lobe showing the effects of stream erosion on the tailings.

PHOTOS 9 & 10

Aerial views of the 1974 failure lobe. Note the crack pattern at the toe of the failure.

PHOTO 11

Toe of north lobe of tailing pile showing foundation soils bulldozed ahead of the pile.

PHOTOS 12 & 13

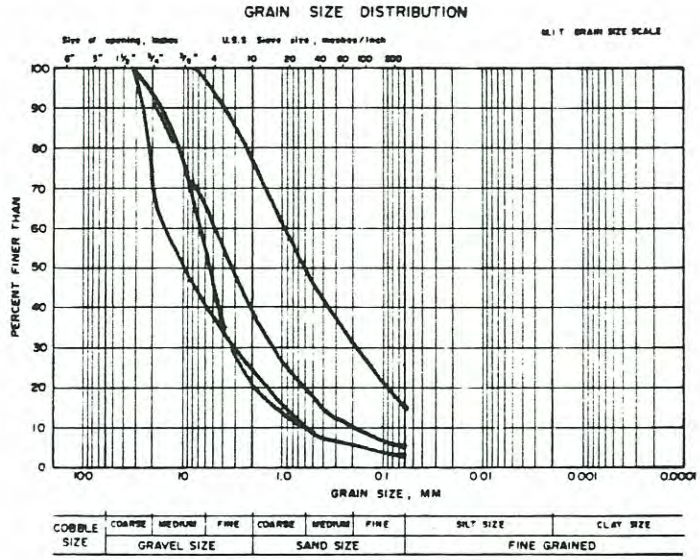
Views of slabs of foundation soils pushed ahead of the tailing pile. These soil exposures are approximately 60 ft. in front of the toe of the tailing pile.

PHOTO 14

Northwest corner of tailing pile. Note the segregation of particle sizes as the tails travel down the face of the pile.

GRAIN SIZE DISTRIBUTION

Figure B - 1



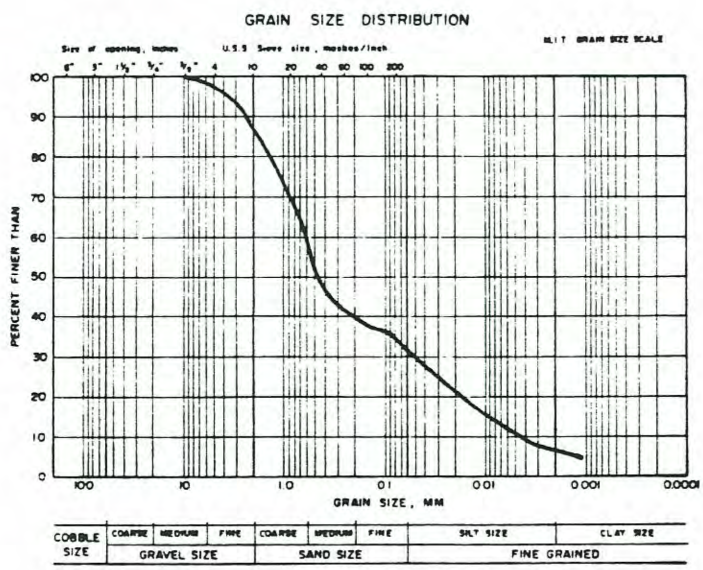
Borehole No. ________

Location CLINTON WASTE DUMP

Sample No. ________

Depth ________

Soil Type WASTE ROCK FROM CLINTON DUMP



Borehole No. 12 (T-5)

Location TAILING PILE

Sample No. 1

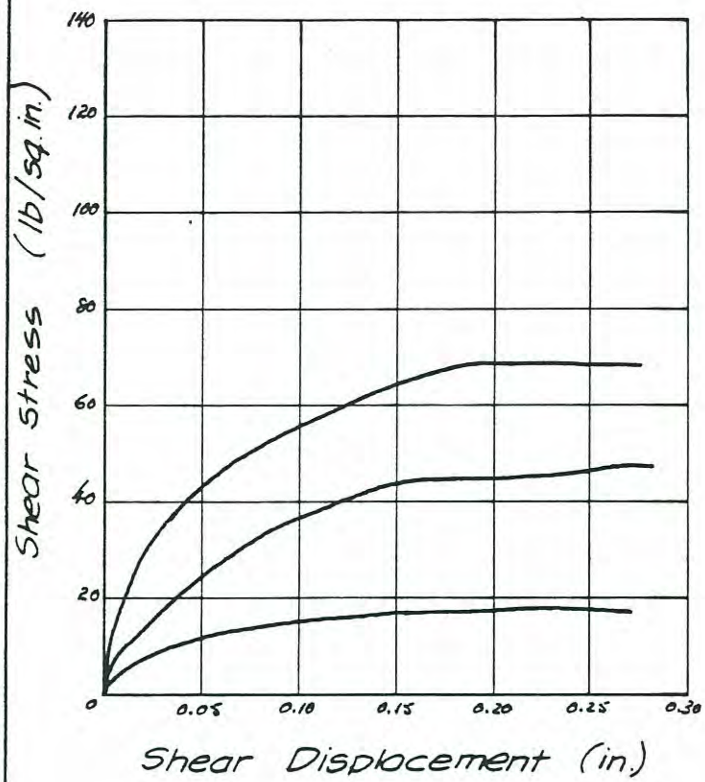
Depth 36.5' - 39'

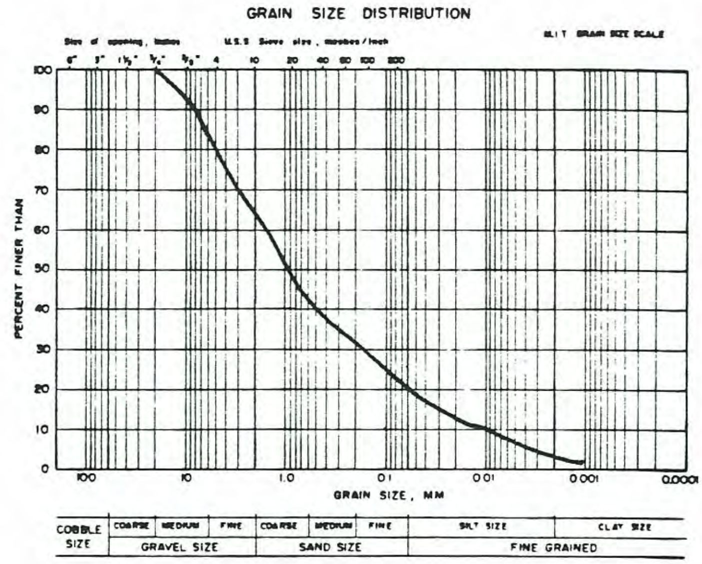
Soil Type FLUVIAL LACUSTRINE GRAVEL

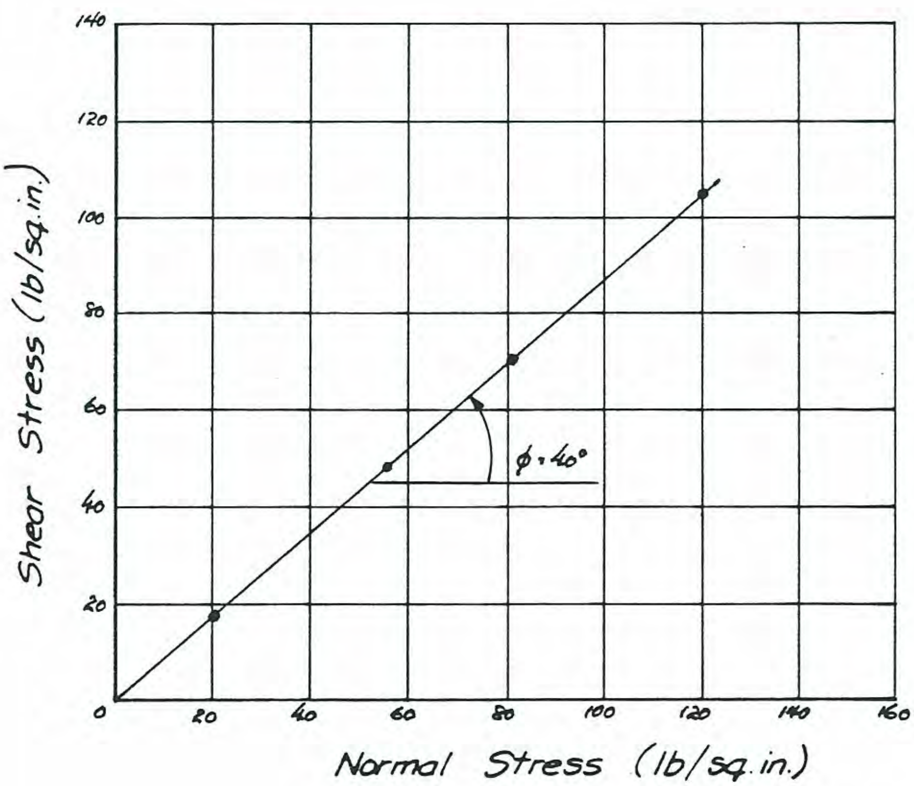
Project No. V77016 Drawn R.D. Reviewed EBF Date JUNE '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 2







Borehole No. ________

Location CLINTON WASTE DUMP

Sample No. ________

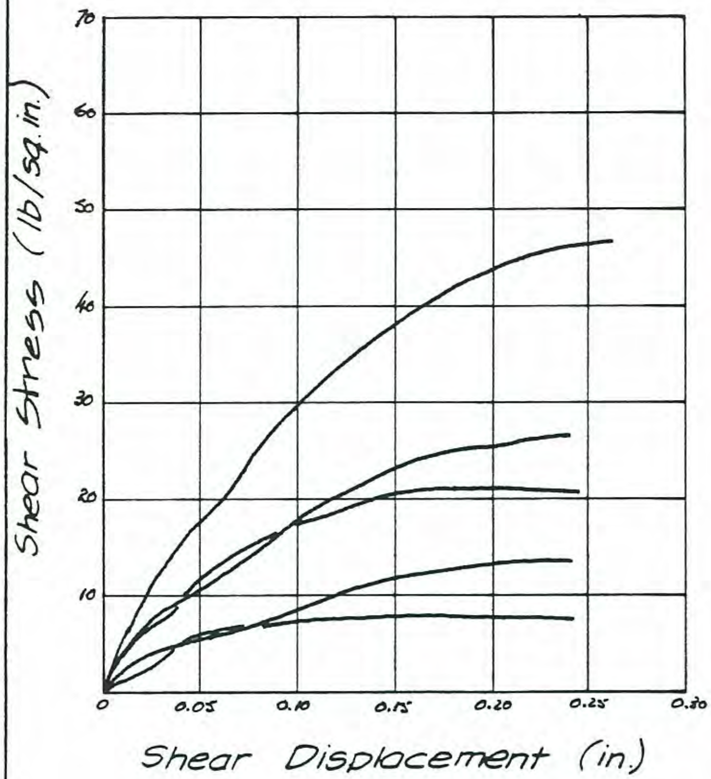
Depth ________

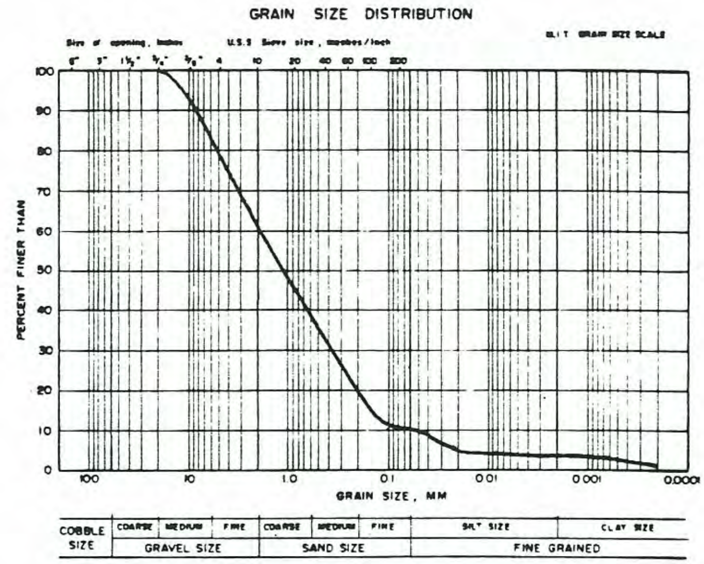
Soil Type Weathered Argillite Bedrock

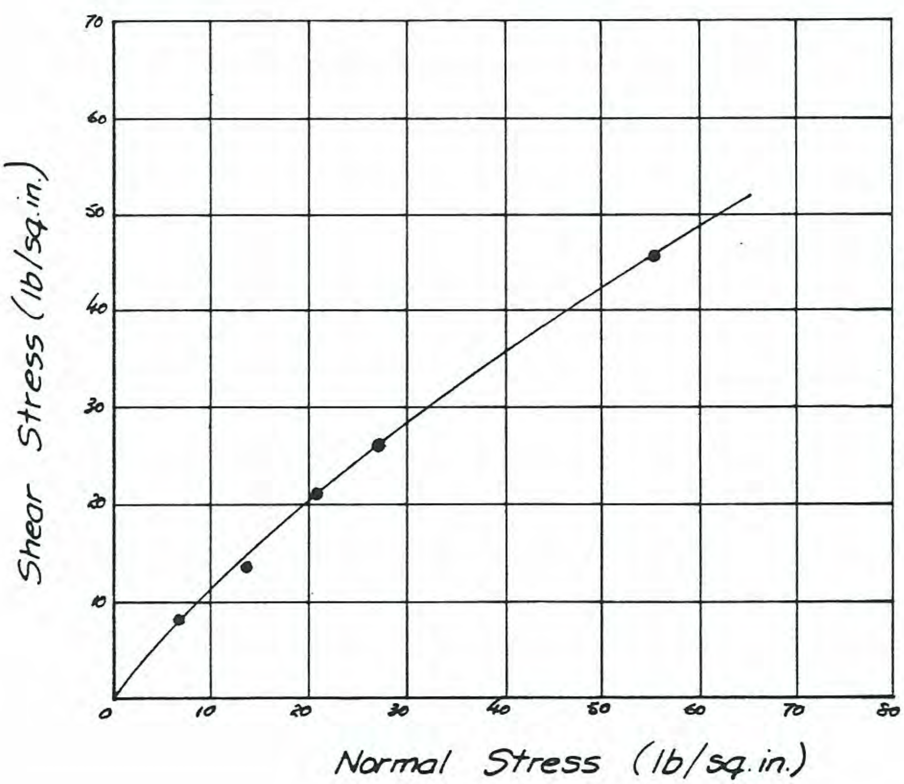
Project No. V77016 Drawn R.D. Reviewed EBF Date June '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 3







Borehole No. __________

Location __________

Sample No. __________

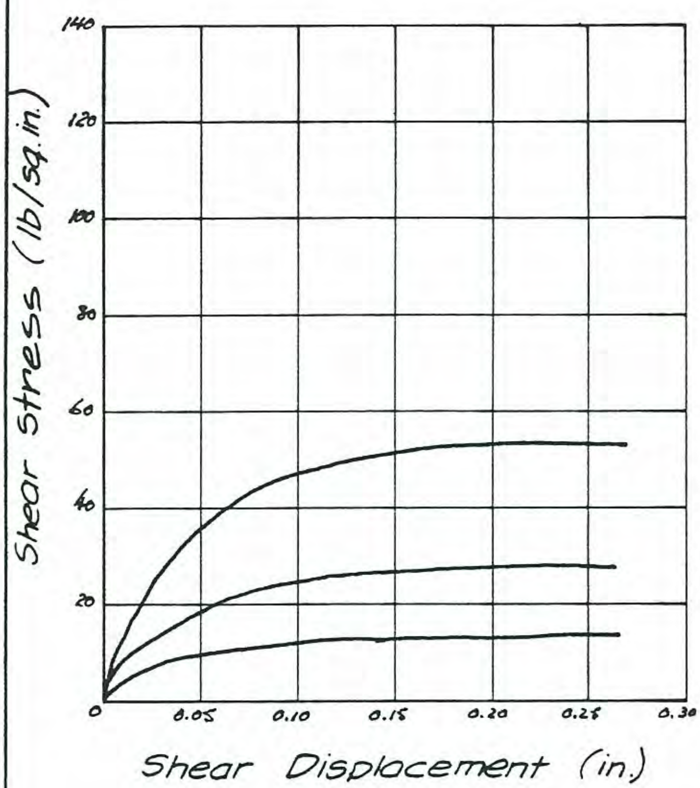
Depth __________

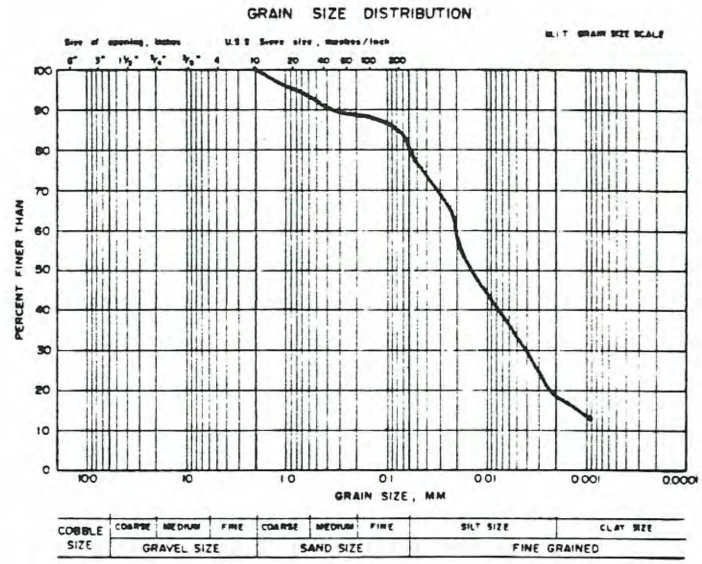
Soil Type MILL TAILINGS

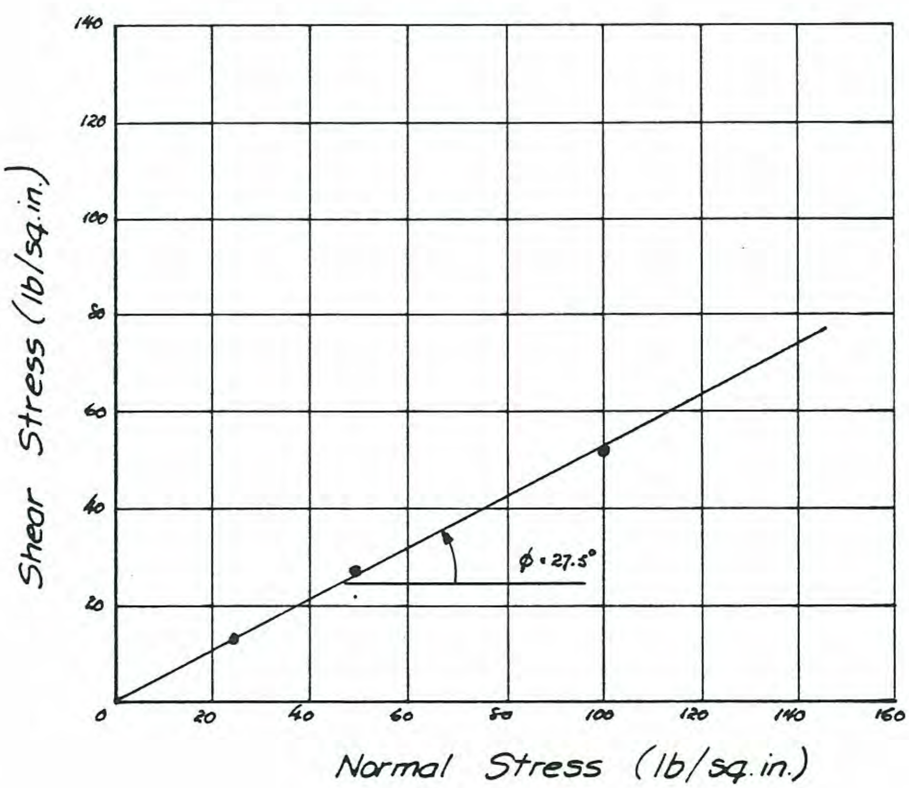
Project No. V77016 Drawn R.D. Reviewed E.B.F. Date June '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 4





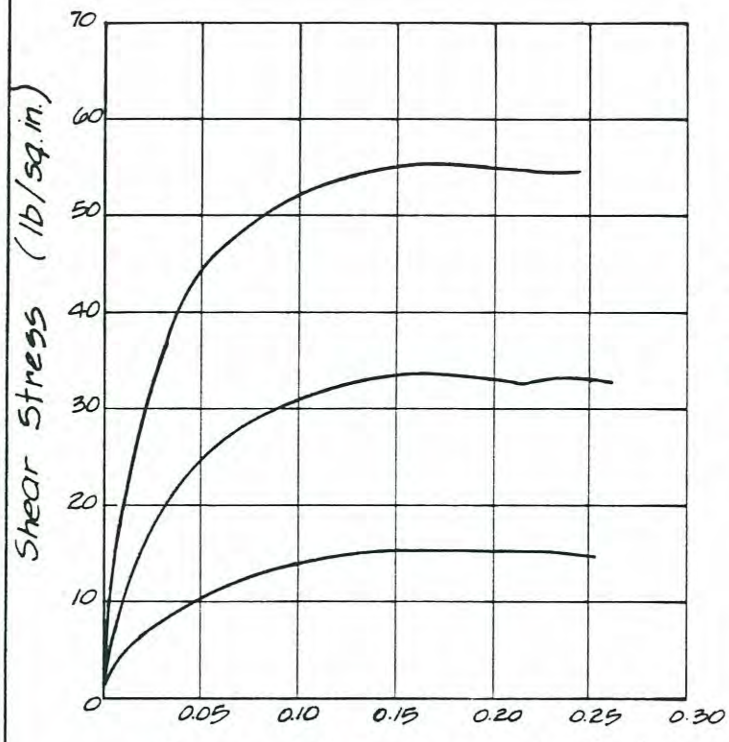


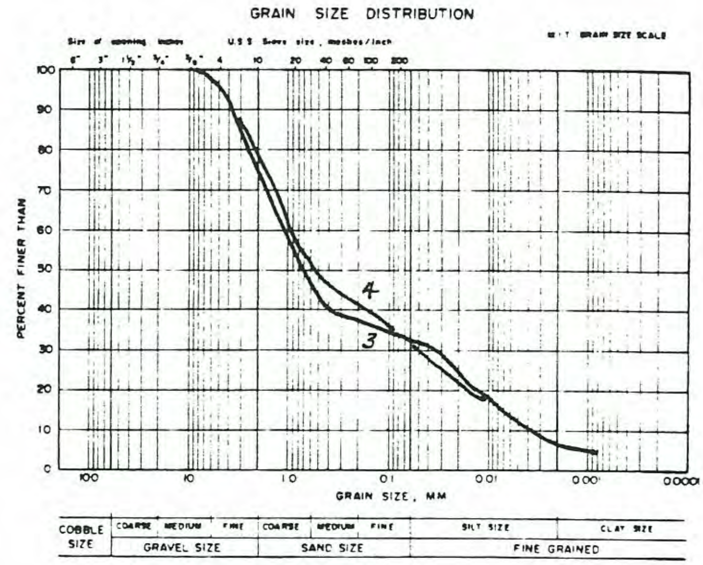
Borehole No. 13 (T-6)
Location North of Tailing Pile
Sample No. 2
Depth 15'-20'
Soil Type Fluvial-Lacustrine Gravel

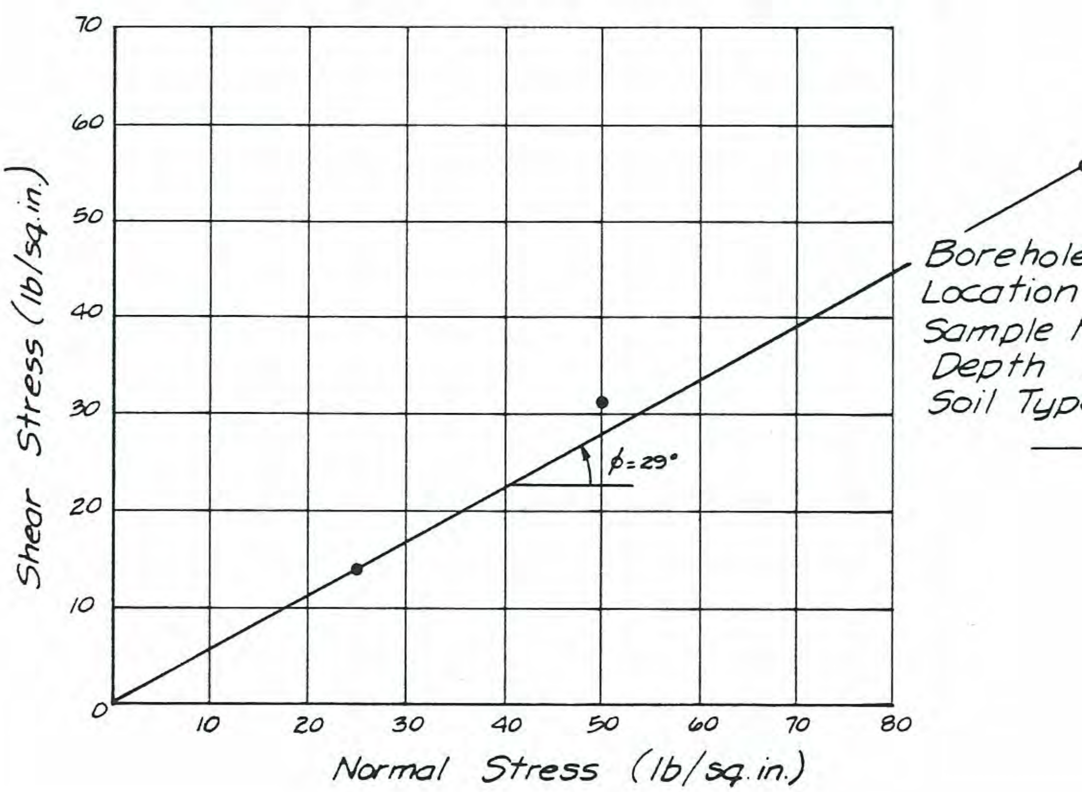
Project No. V77016 Drawn R.D. Reviewed E.B.F. Date June '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 5





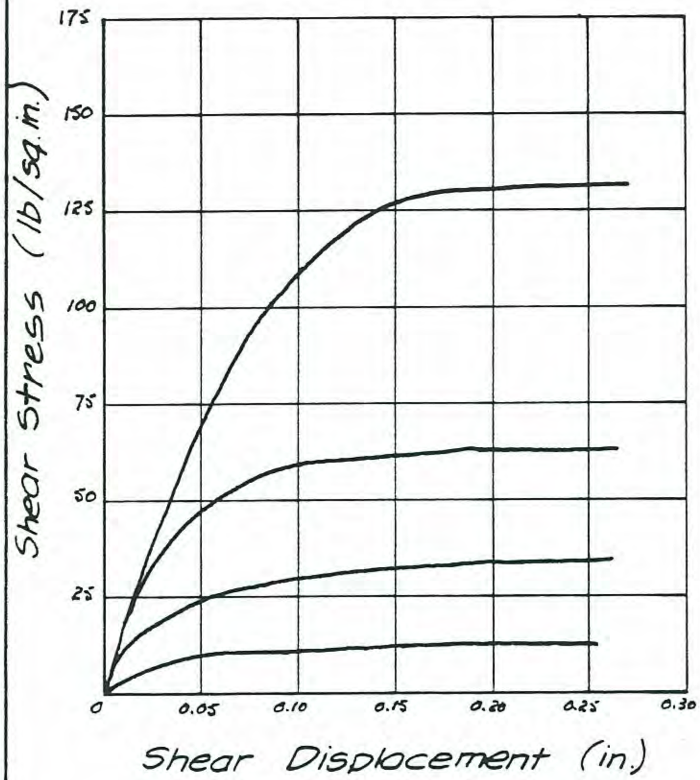


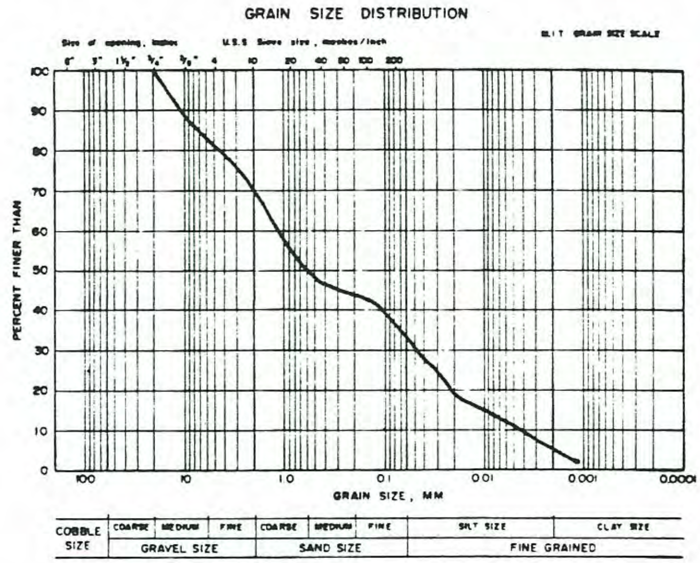
Borehole No. 13 (T-6)
Location NORTH OF TAILING PILE
Sample No. 3 & 4
Depth 23-25' & 32-34'
Soil Type FLUVIAL - LACUSTRINE GRAVEL

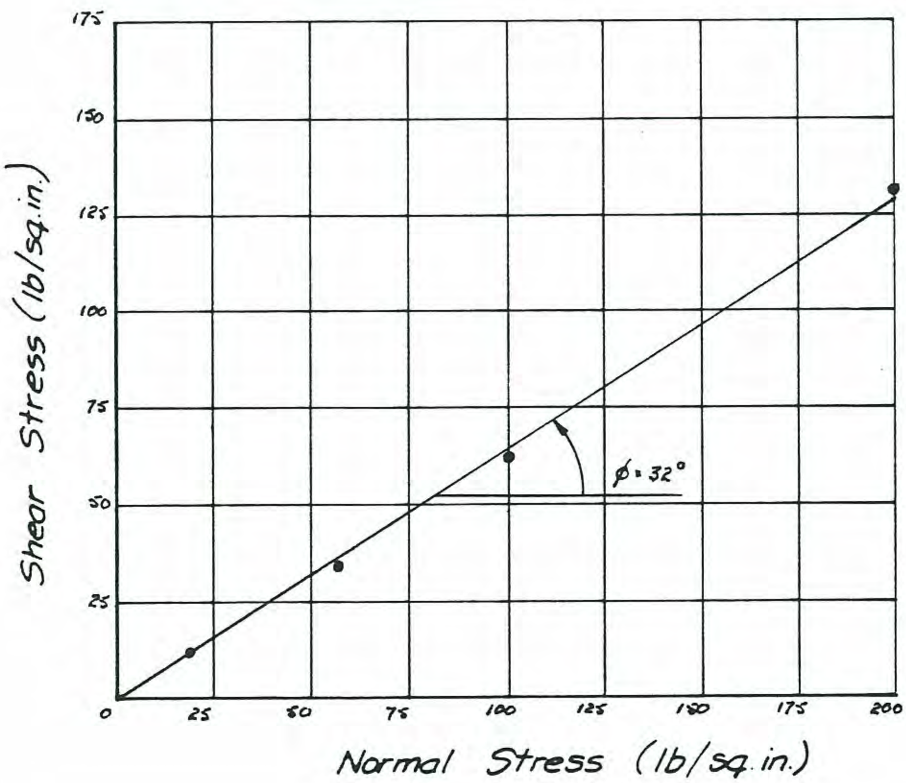
Project No. V77016 Drawn R.D. Reviewed EBF Date June '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 6





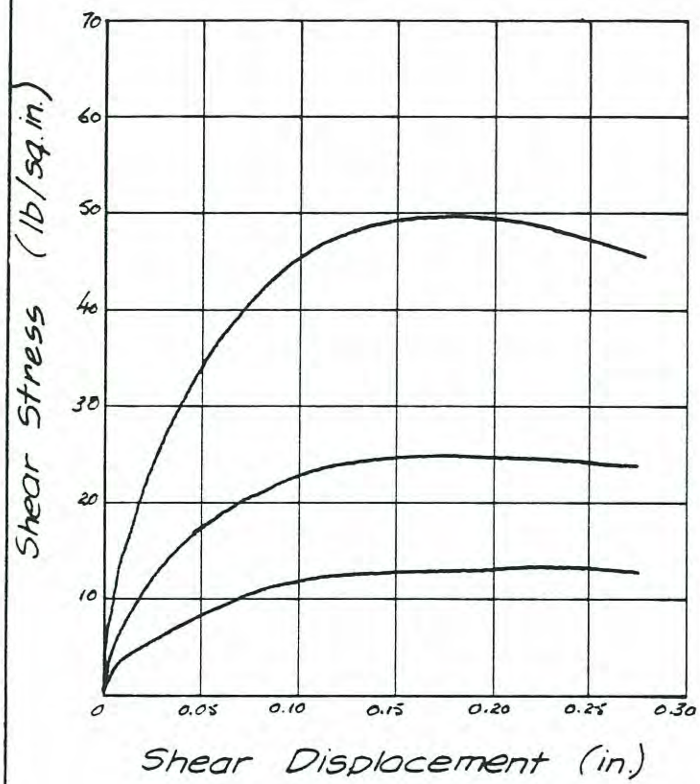


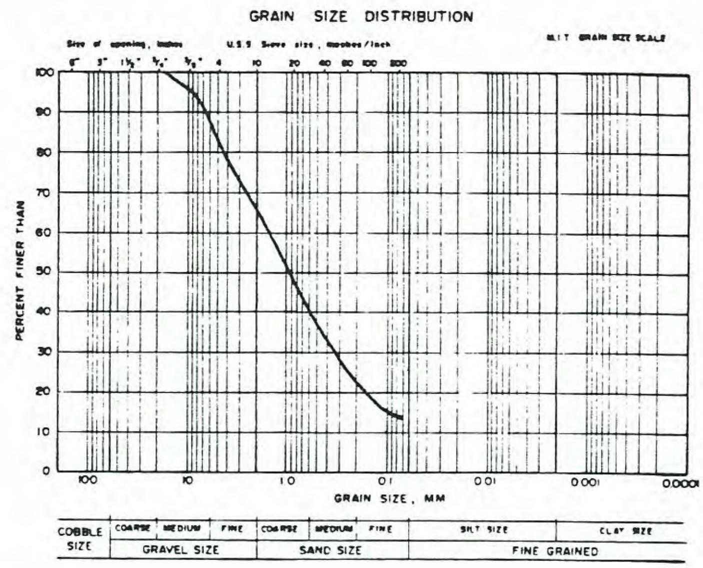
Borehole No. 14 (T-7)
Location TAILING PILE
Sample No. 1
Depth 46'-48'
Soil Type FLUVIAL-LACUSTRINE GRAVEL

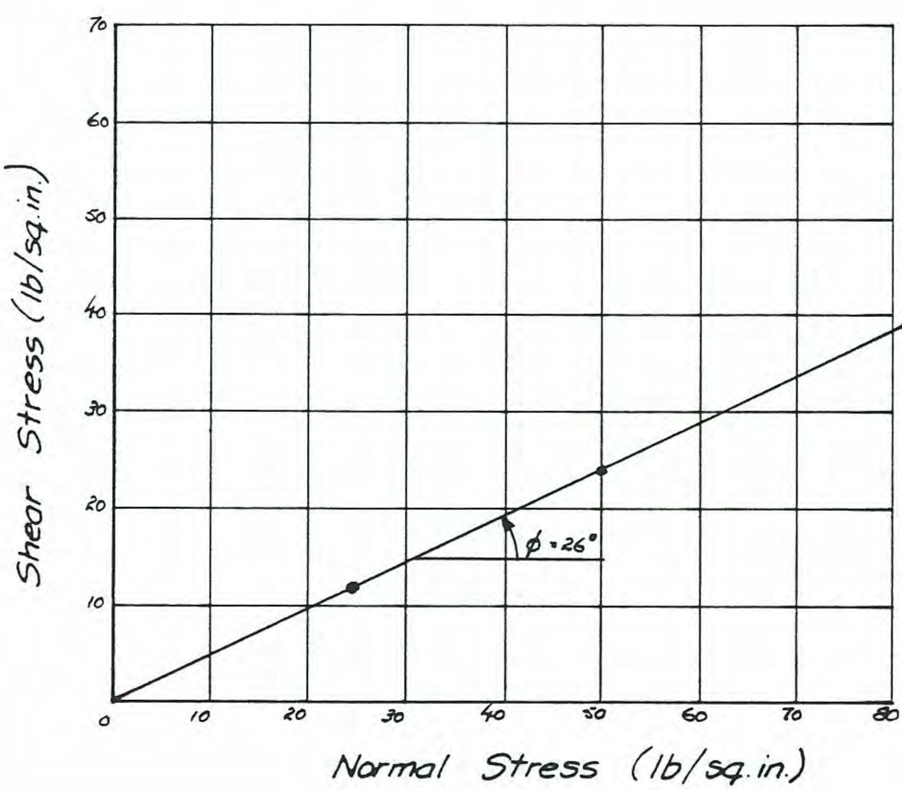
Project No. V77016 Drawn R.D. Reviewed EBF Date June '78.

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 7





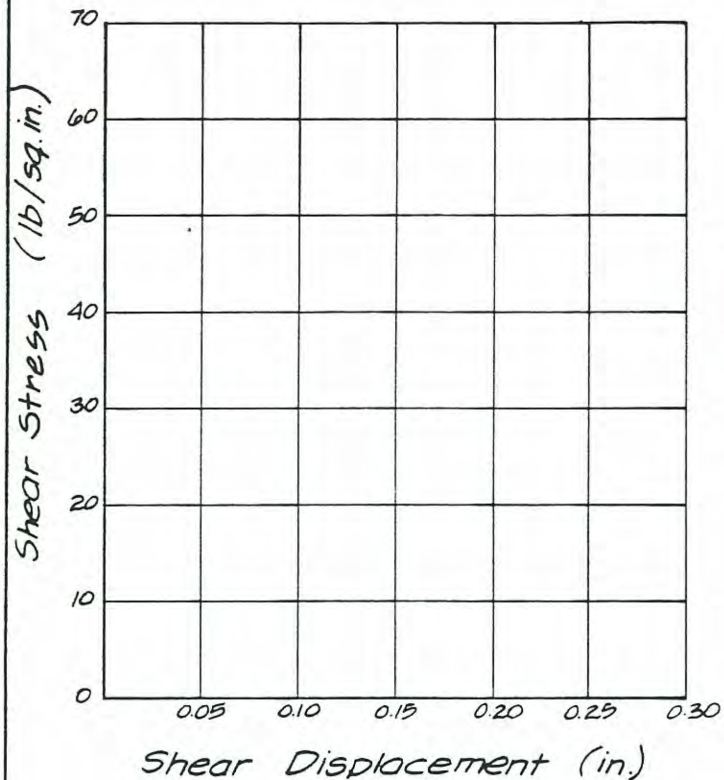


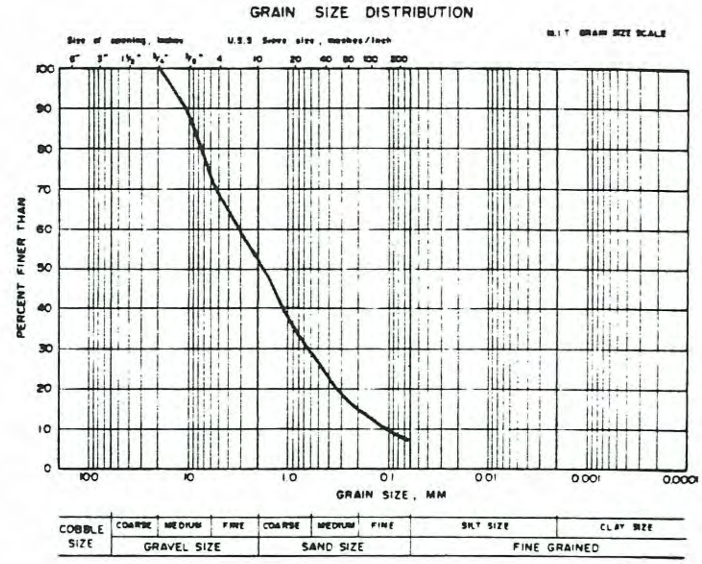
Borehole No. 15 (ST-8)
Location TAILING PILE
Sample No. 1
Depth 6'-9'
Soil Type WEATHERED ARGILLITE

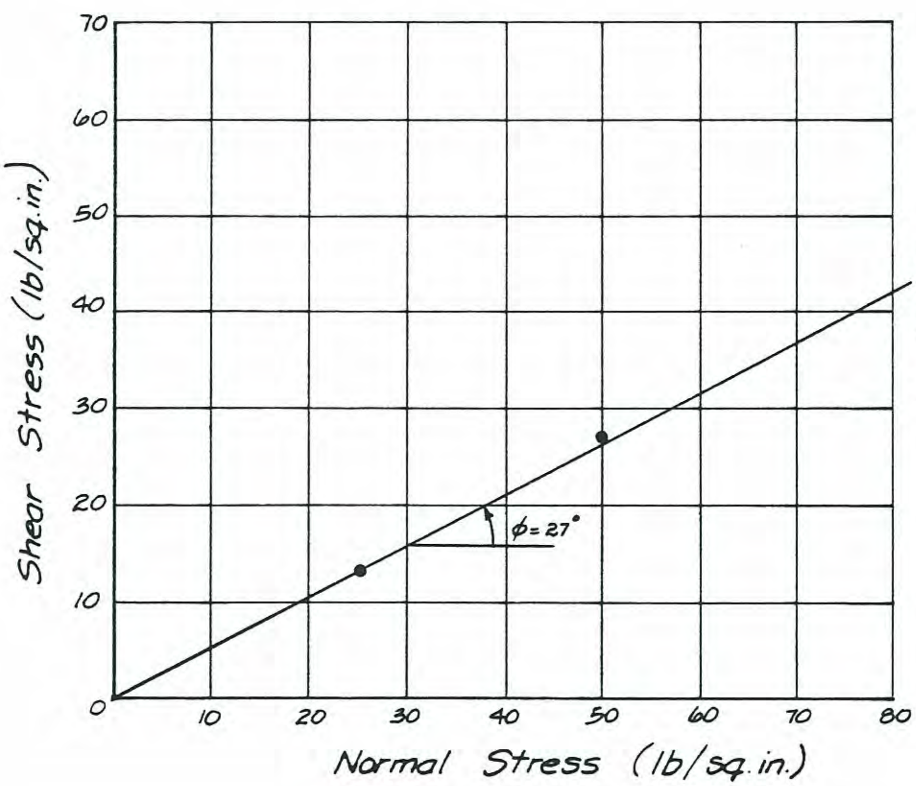
Project No. V77016 Drawn R.D. Reviewed EBF Date June '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B-8





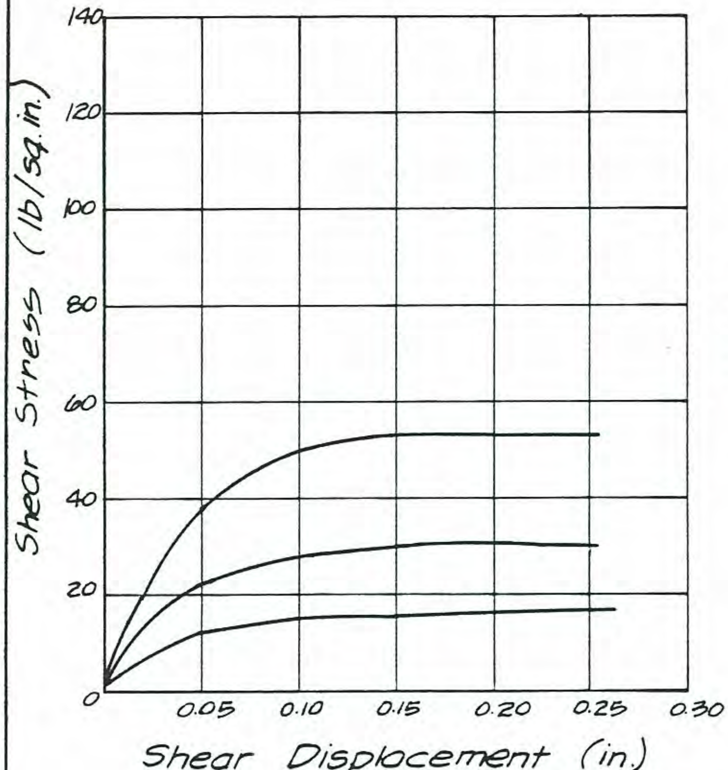


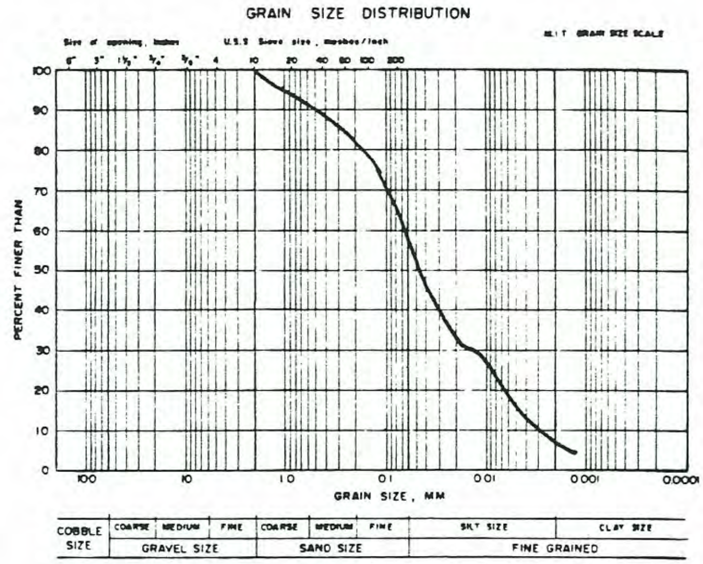
Borehole No. 15
Location TAILING PILE
Sample No. 2
Depth 20'-21'
Soil Type WEATHERED ARGILLITE

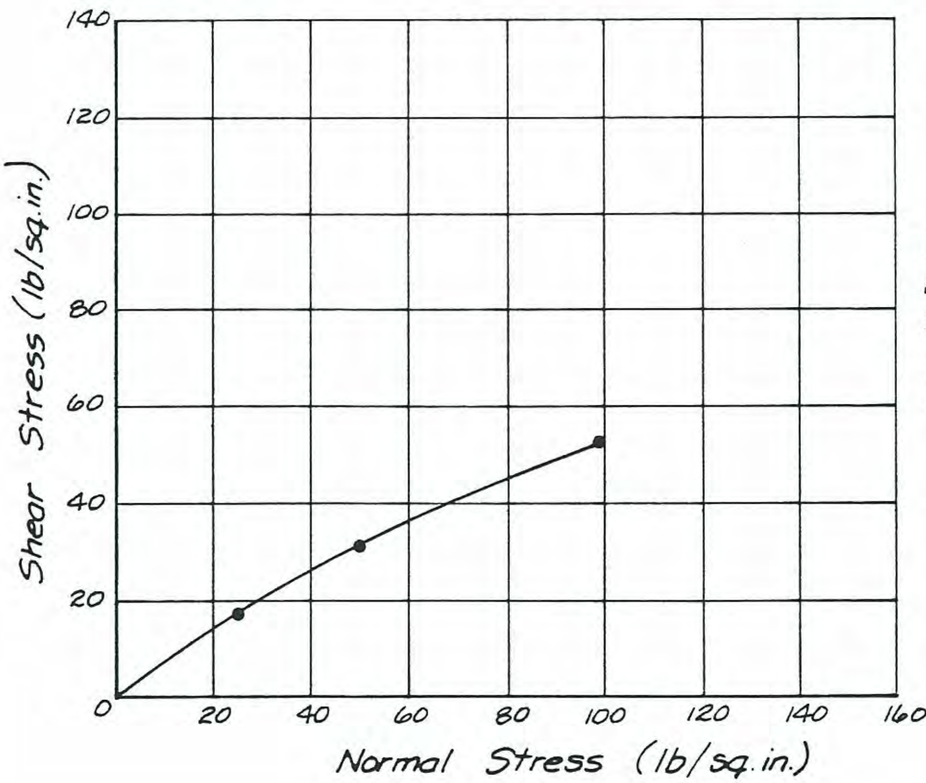
Project No. V77016 Drawn R.D. Reviewed EBF Date June '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 9





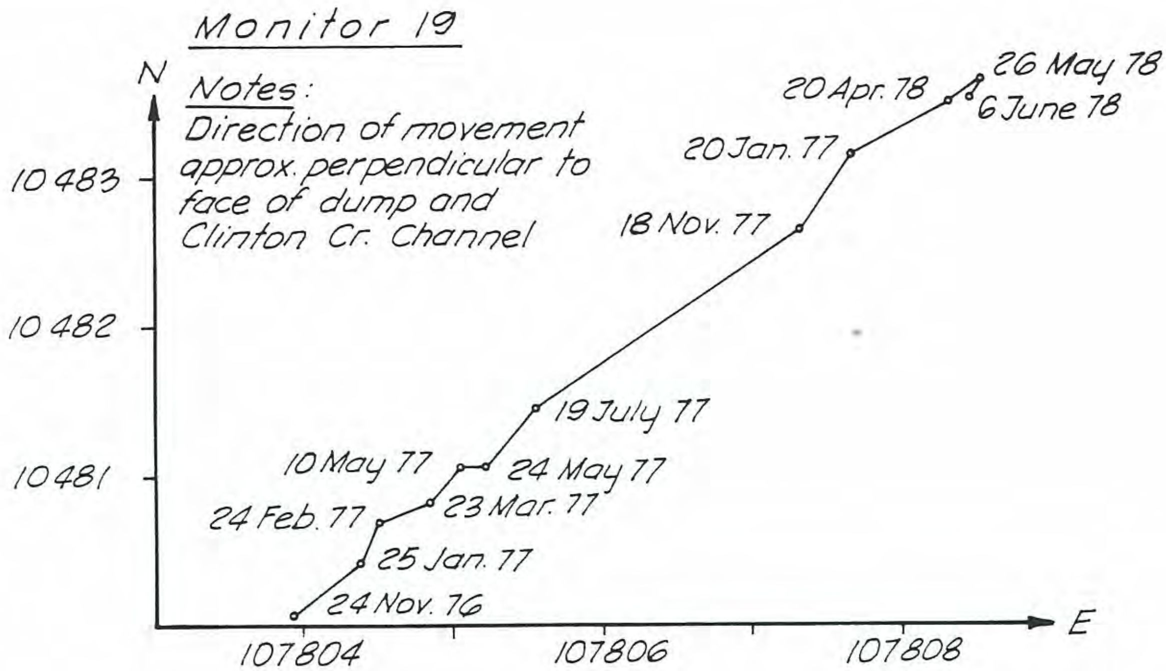


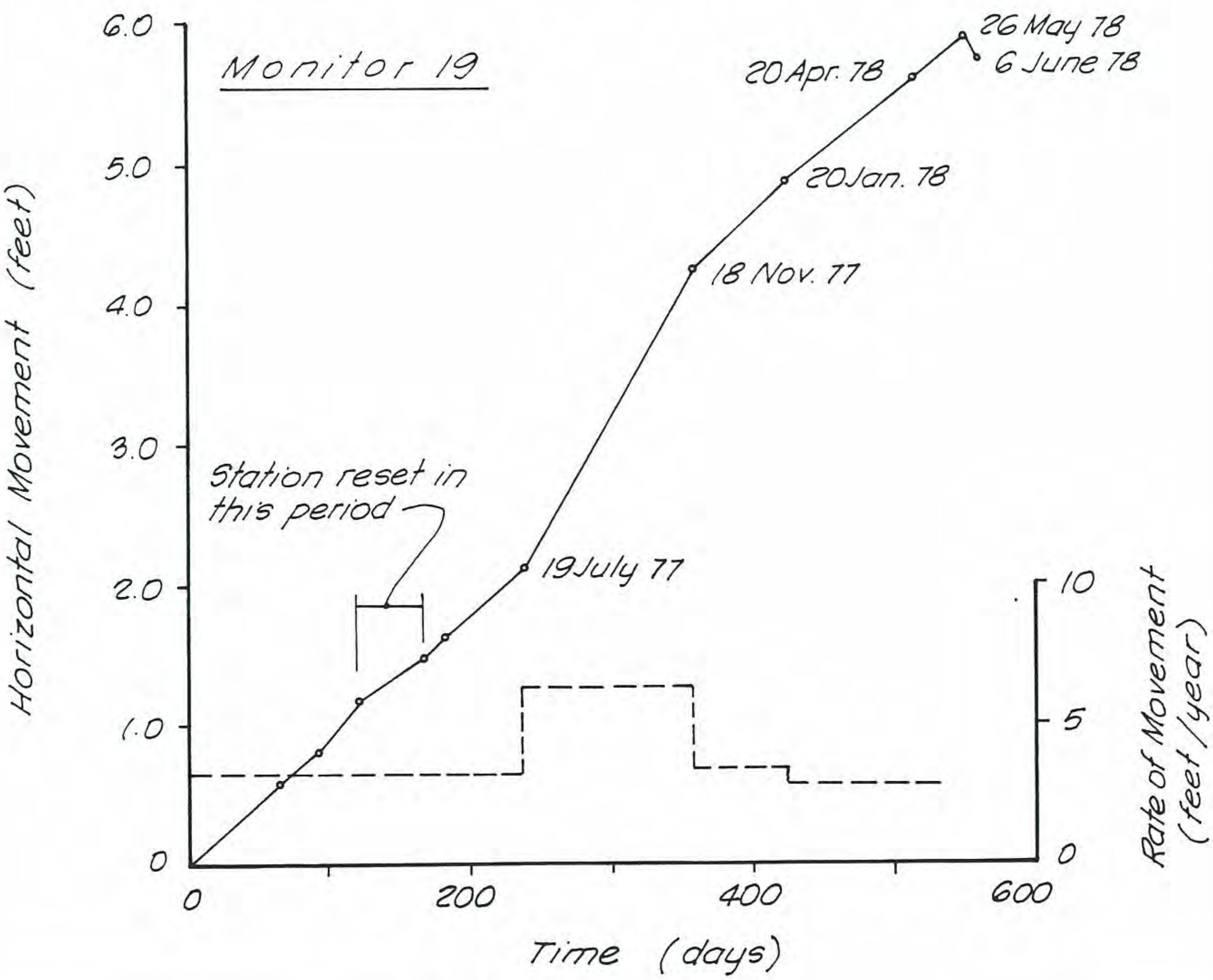
Borehole No. 16(T-8)
Location TAILING PILE
Sample No. 1
Depth 66'-68'
Soil Type FLUVIAL-LACUSTRINE GRAVEL

Project No. V77016 Drawn R.D. Reviewed EBF Date June '78

WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 19

Figure C-1

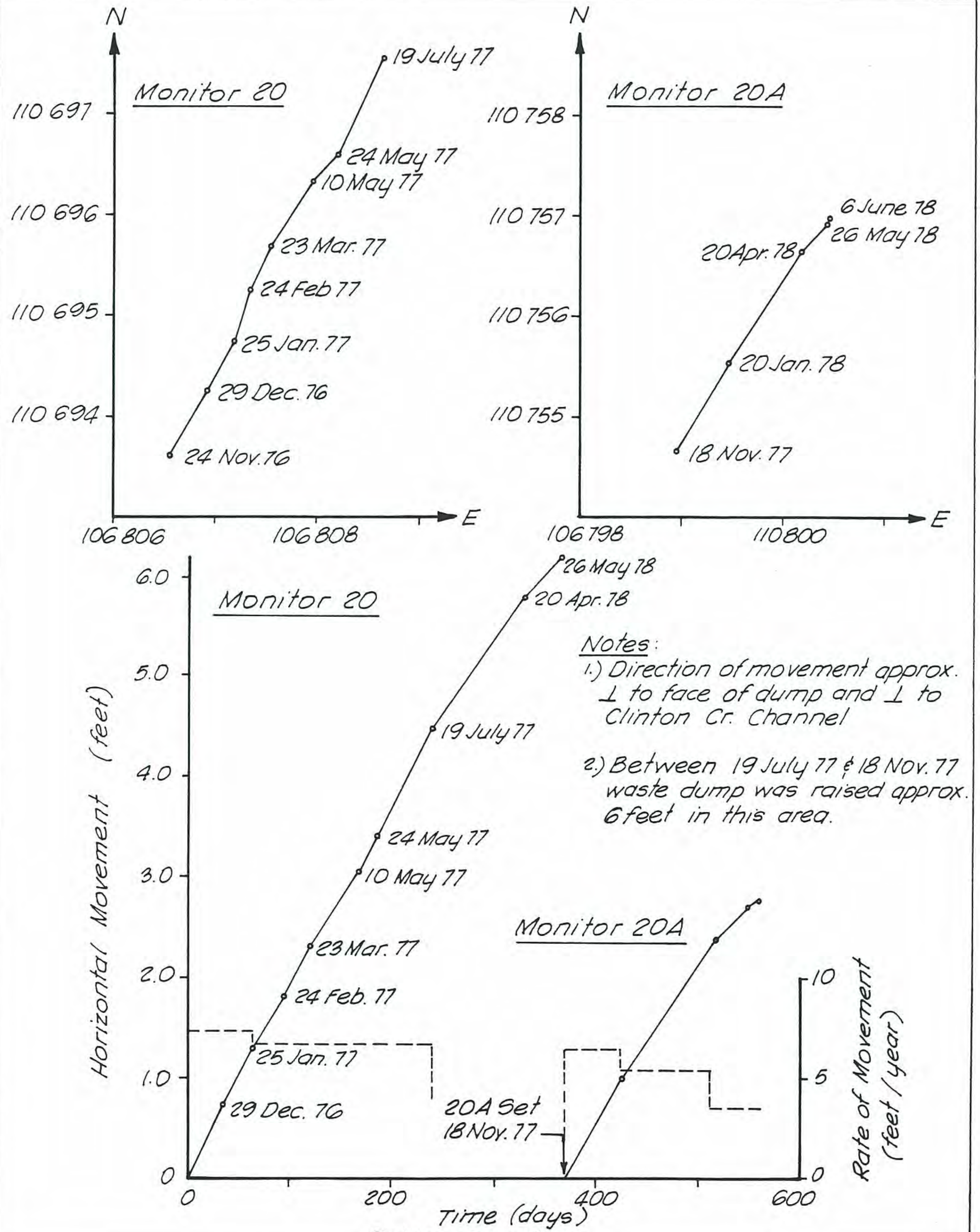




V77016 SH EBF June '78

WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 20

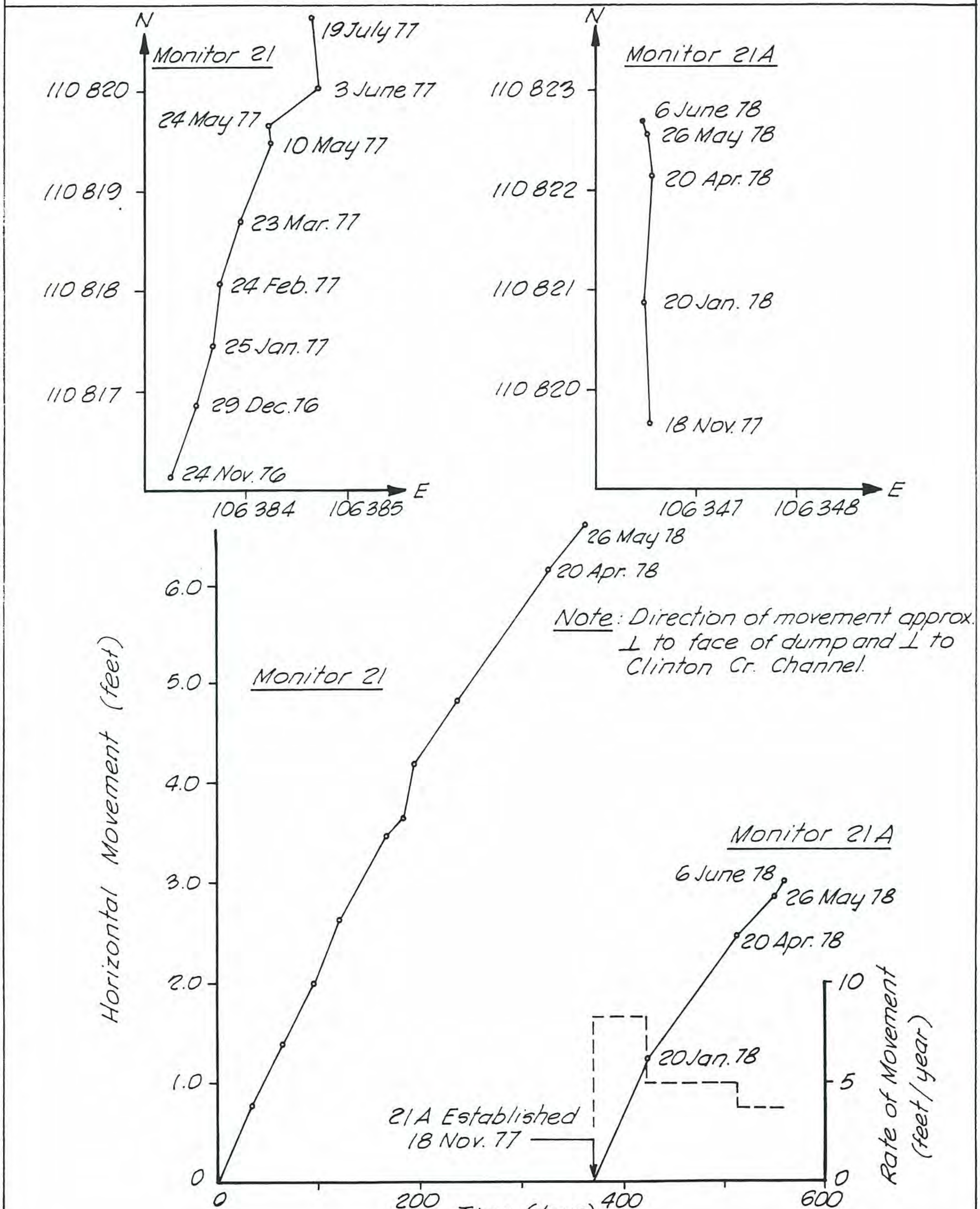
Figure C-2



V77016 SH June '78

WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 21

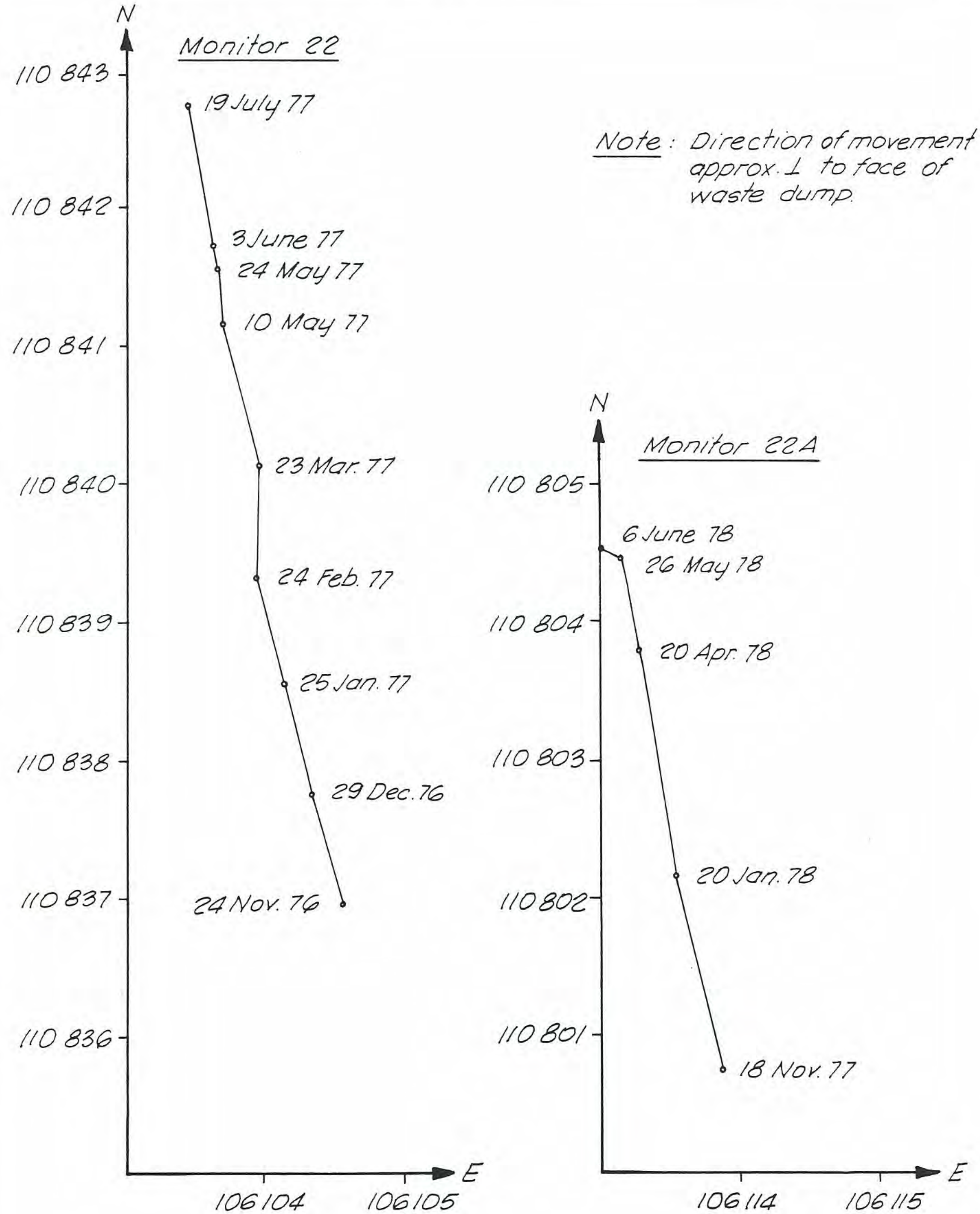
Figure C - 3



V77016 SH E&F June '78

WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 22

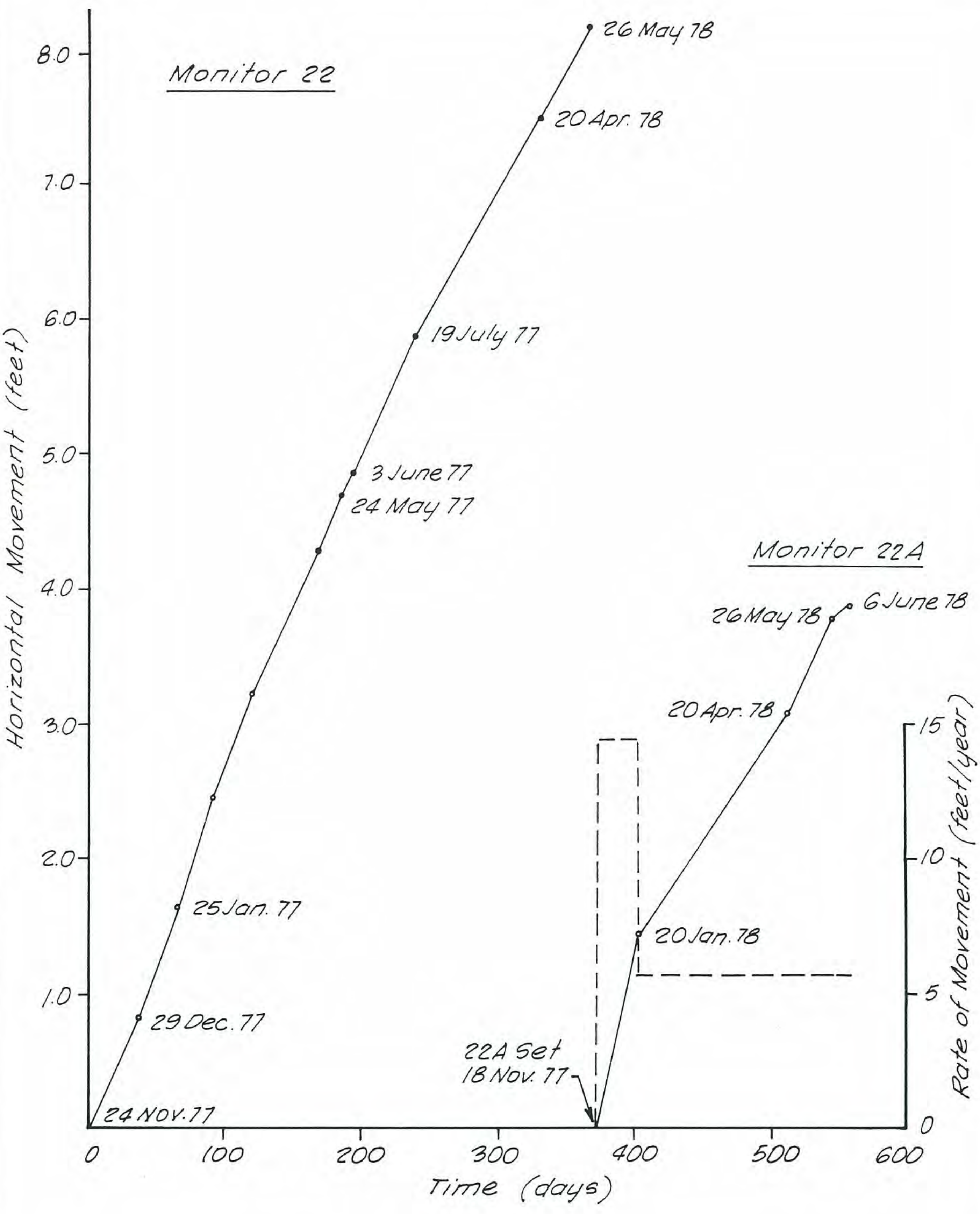
Figure C-4



V77016 SH E&F June '78

WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 22

Figure C - 5

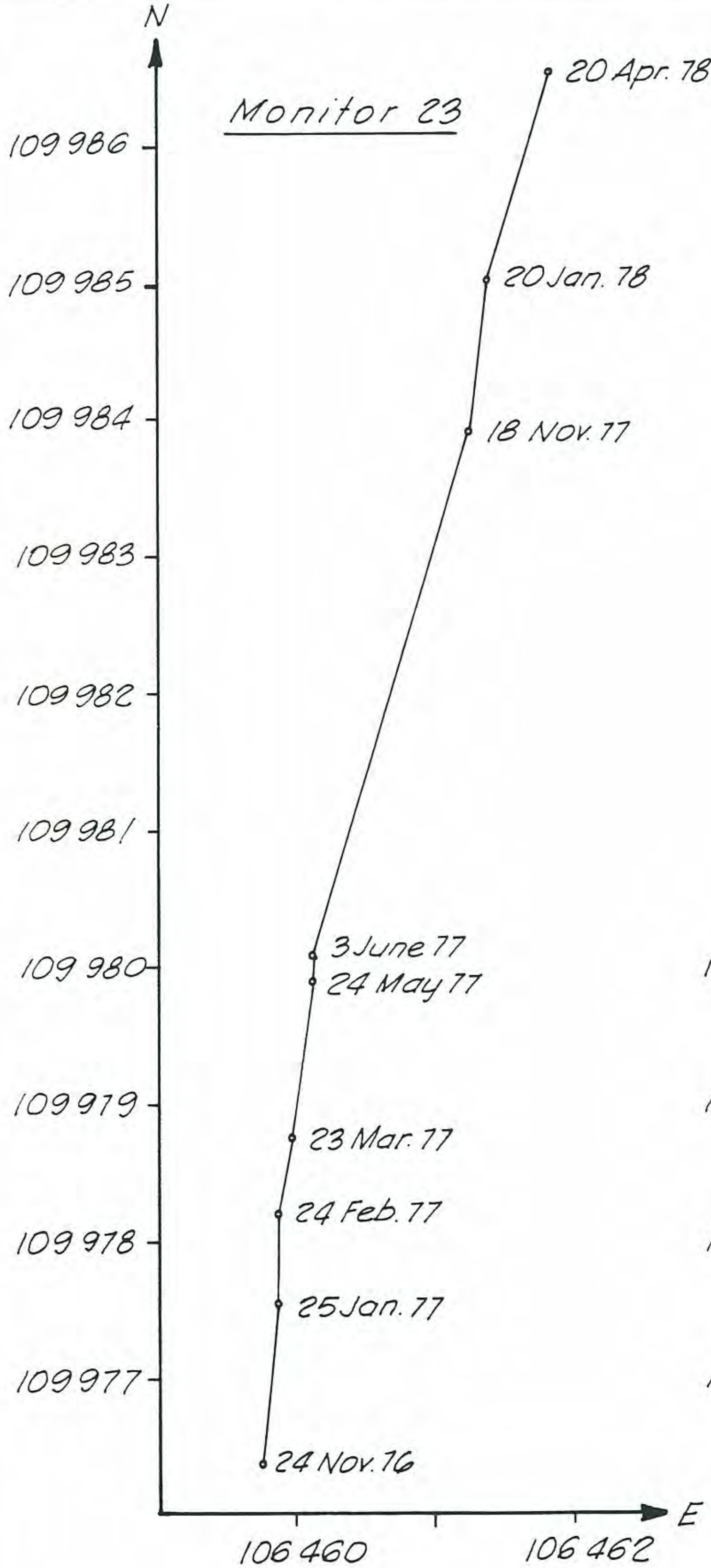


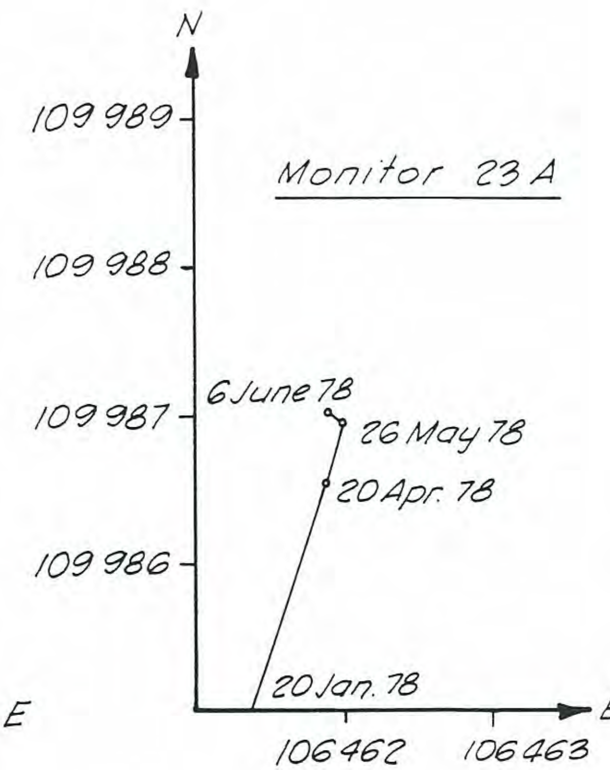
V77016 SH June '78

Golder Associates

WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 23

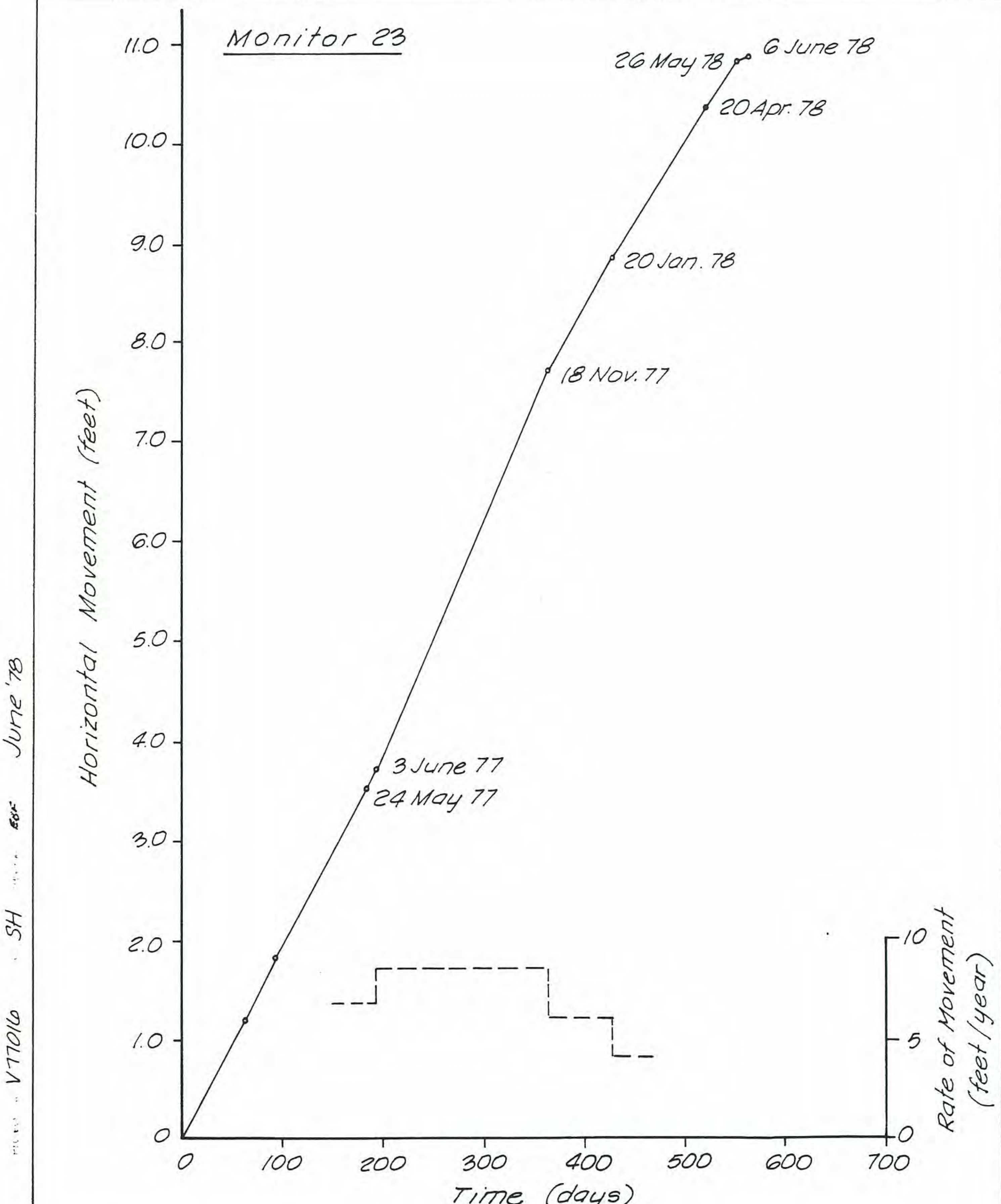
Figure C - 6



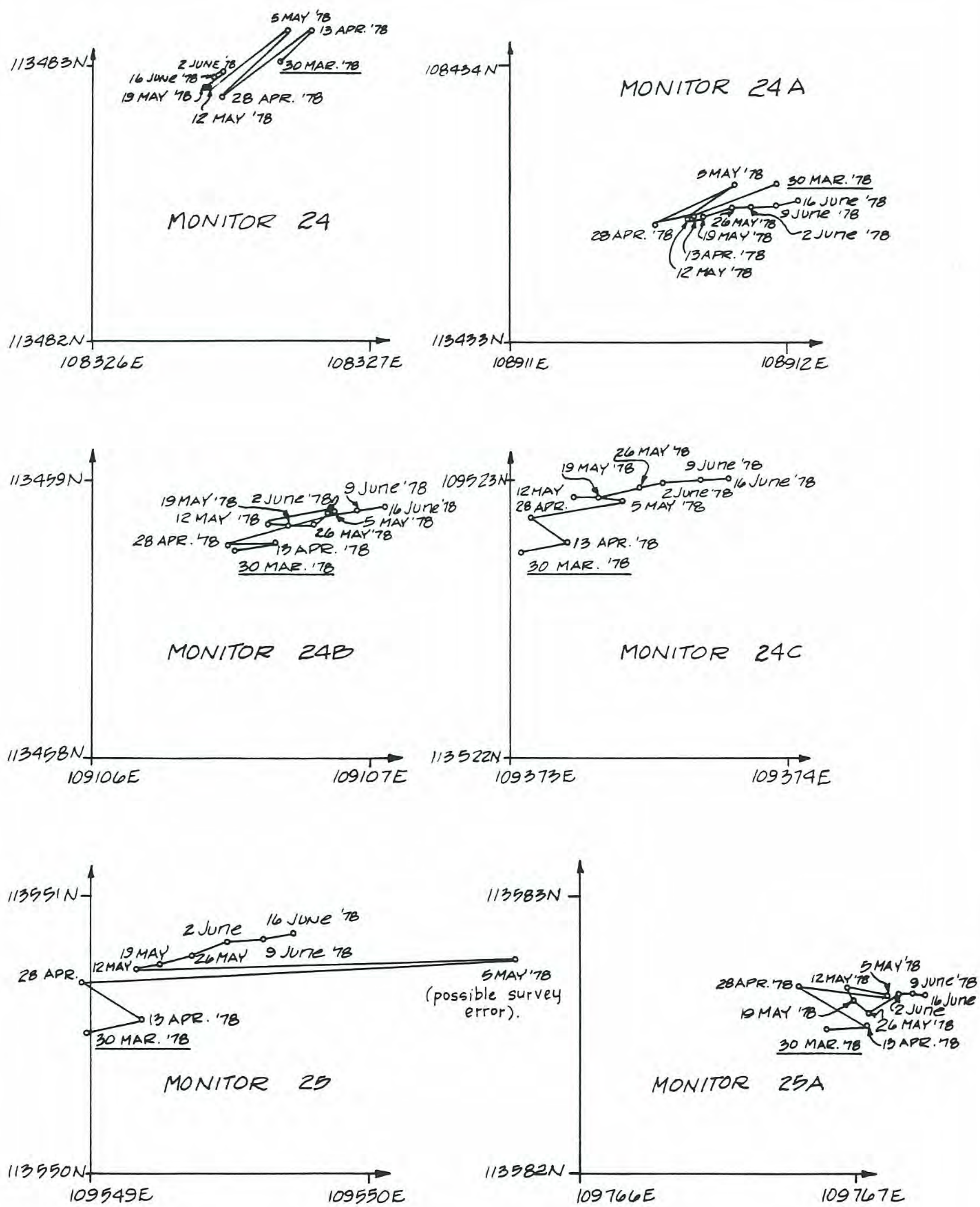


WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 23

Figure C-7



TAILING PILE
HORIZONTAL MOVEMENTS - FAILURE LOBE MONITORS **Figure C - 8**
MARCH 30 TO JUNE 16, 1978

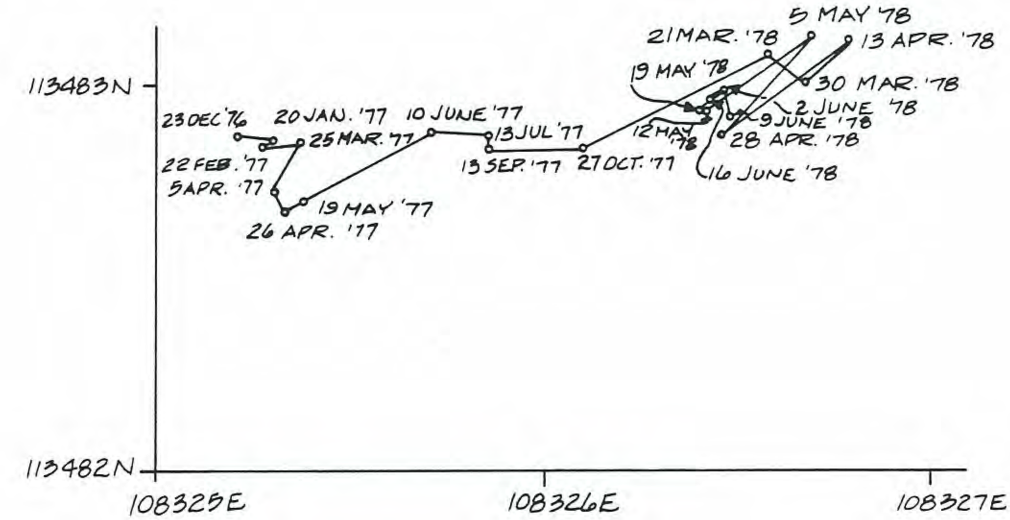


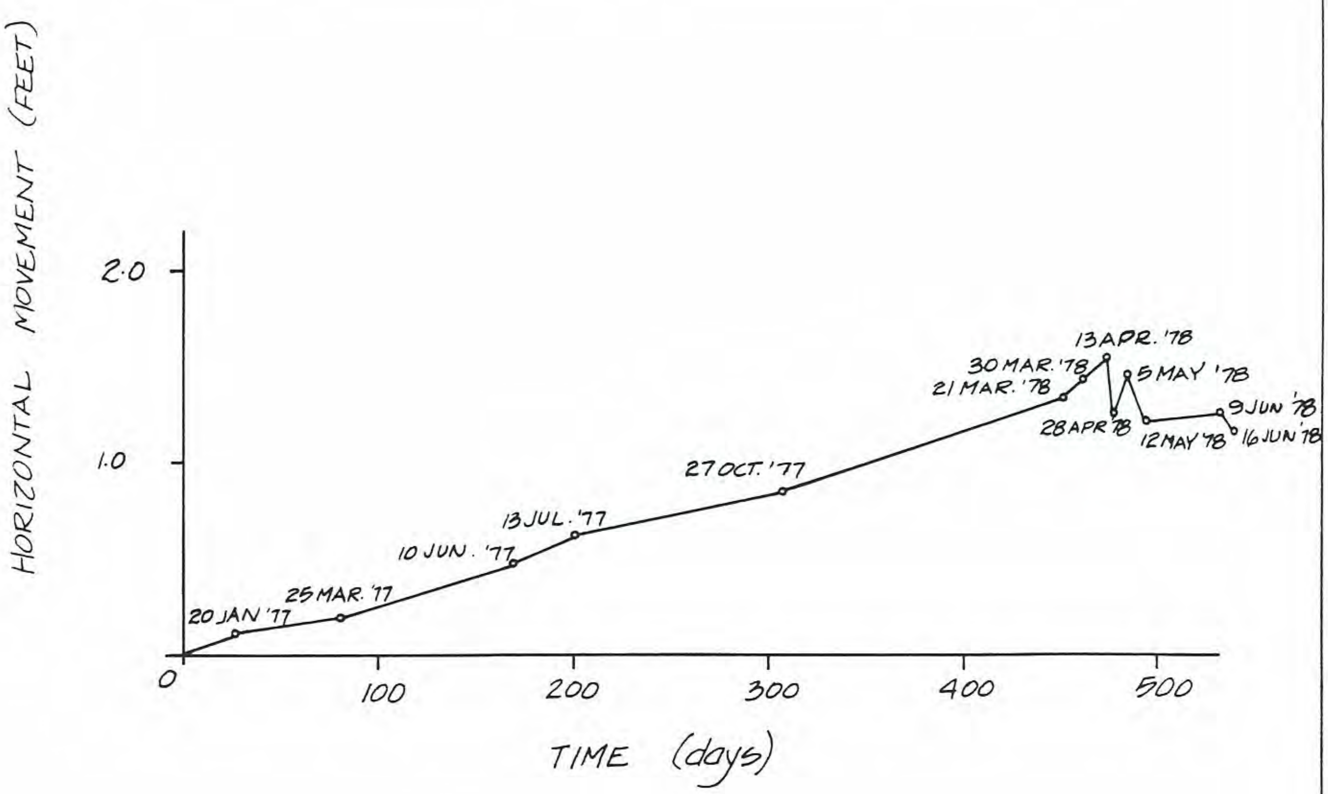
V77016 SMF

TAILING PILE
HORIZONTAL MOVEMENT DATA
MONITOR 24

Figure C-9

MONITOR 24



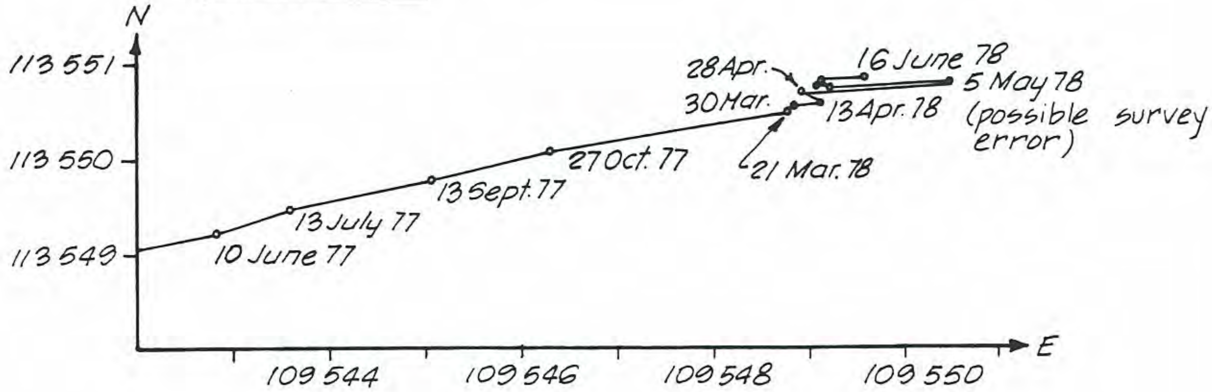


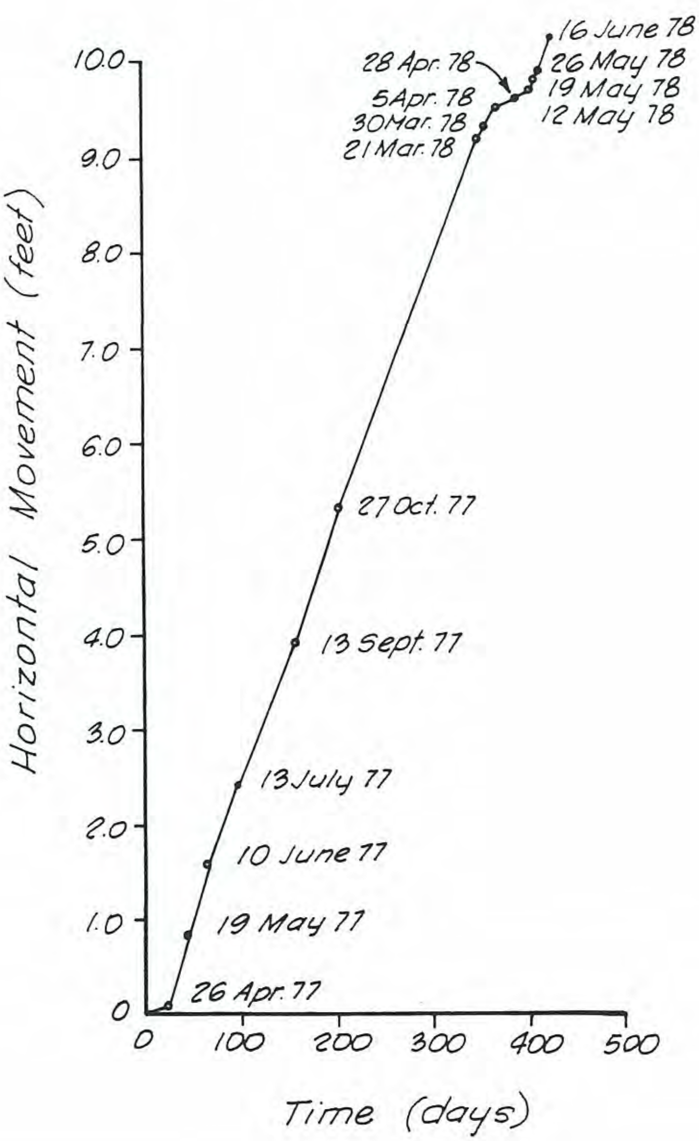
V77016 . SMF

TAILING PILE
HORIZONTAL MOVEMENT DATA
MONITOR 25

Figure C-10

Monitor 25

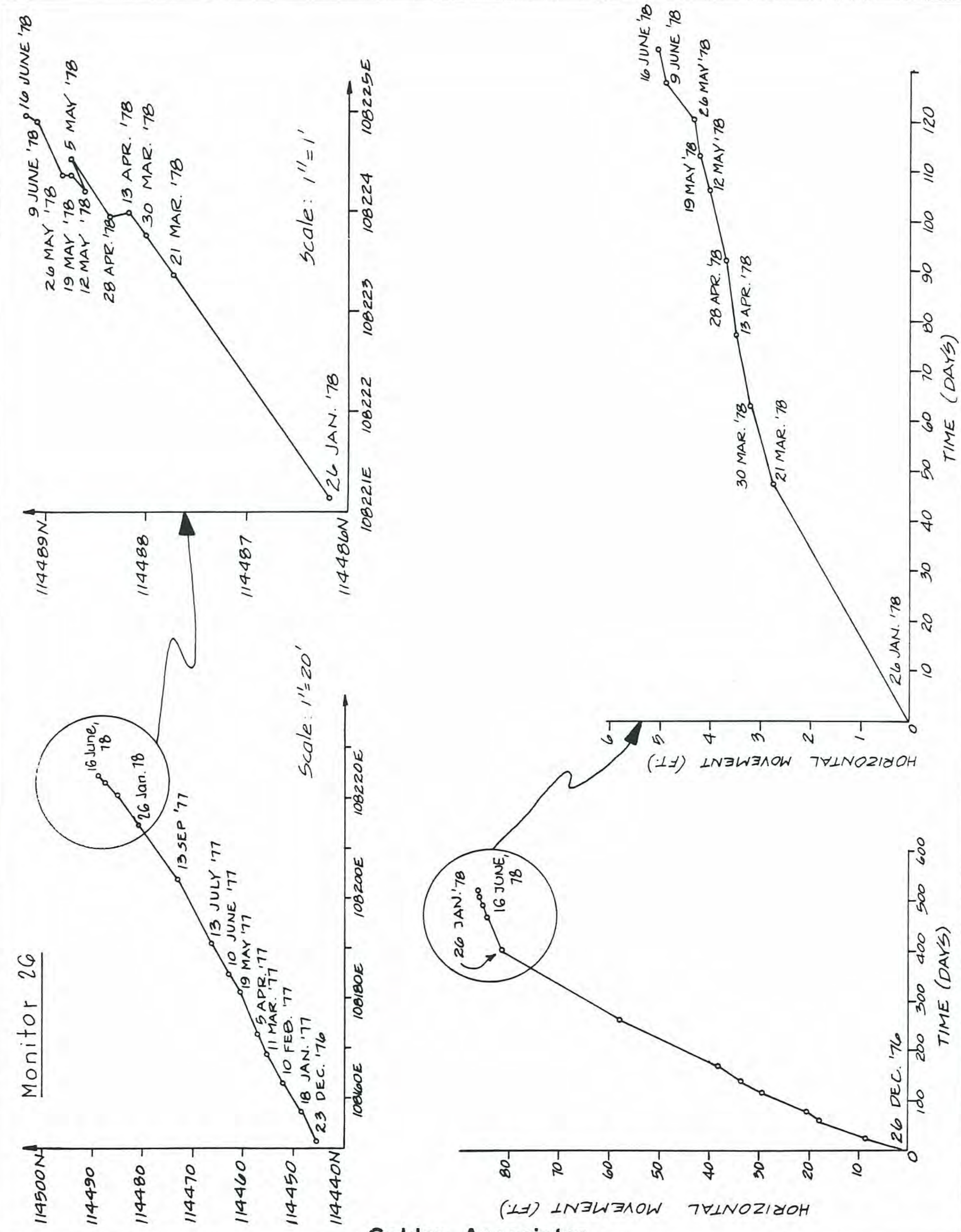




V77016 SH June '78

TAILING PILE
HORIZONTAL MOVEMENT DATA
MONITOR 26

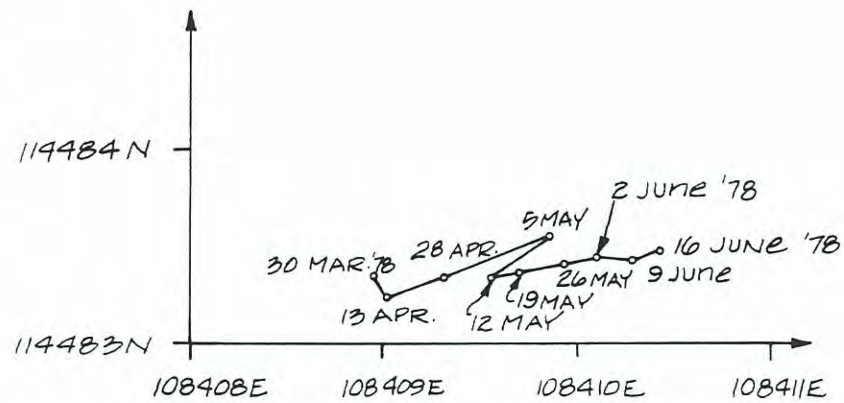
Figure C-11



TAILING PILE
HORIZONTAL MOVEMENT DATA
MONITOR 26A

Figure C - 12

Monitor 26A



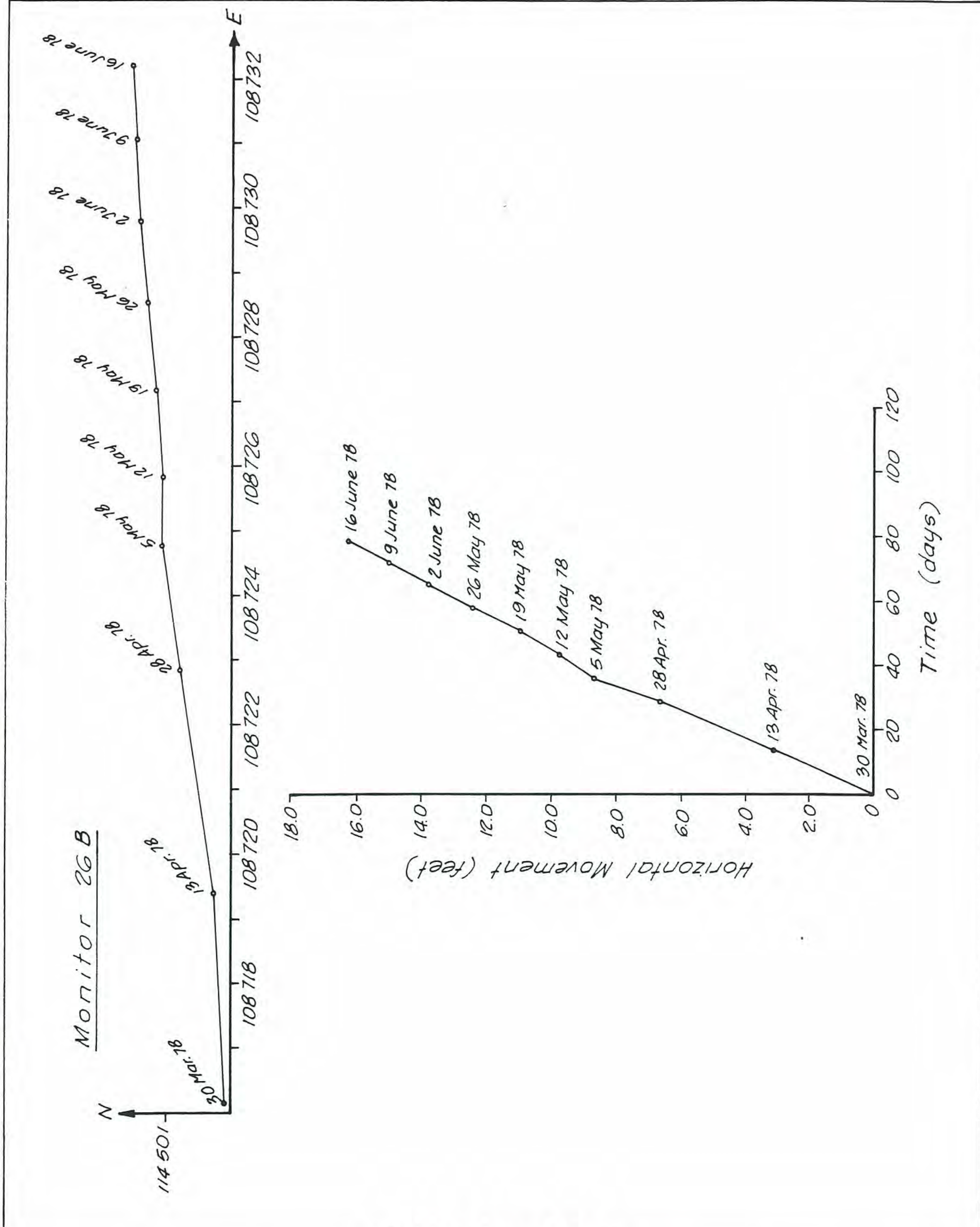
$$\frac{ds}{dt} = 0.014 \text{ ft/day}$$

(av. 5 May to 16 June '78

V77016 · SMF EC: June '78

TAILING PILE
HORIZONTAL MOVEMENT DATA
MONITOR 26B

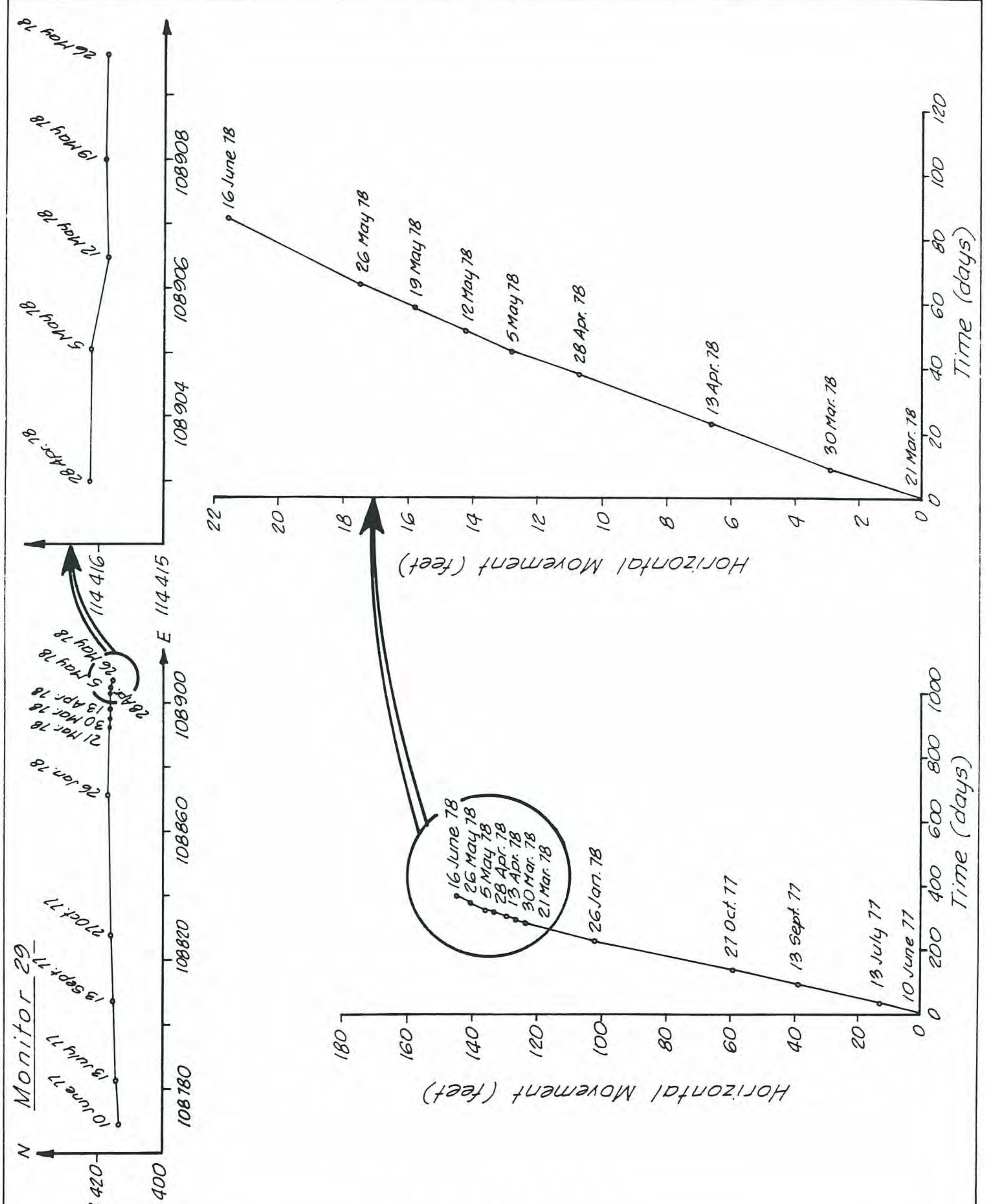
Figure C-13



V77016 SH June '78

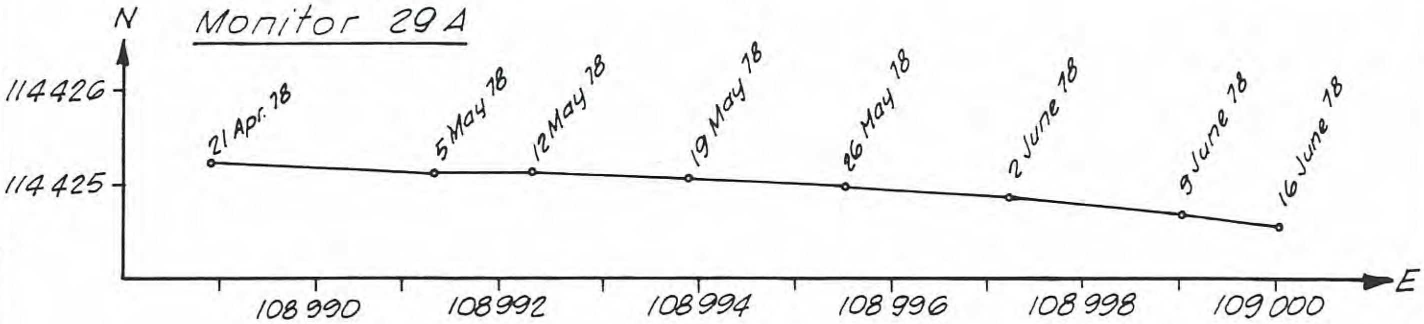
TAILING PILE
HORIZONTAL MOVEMENT DATA
MONITOR 29

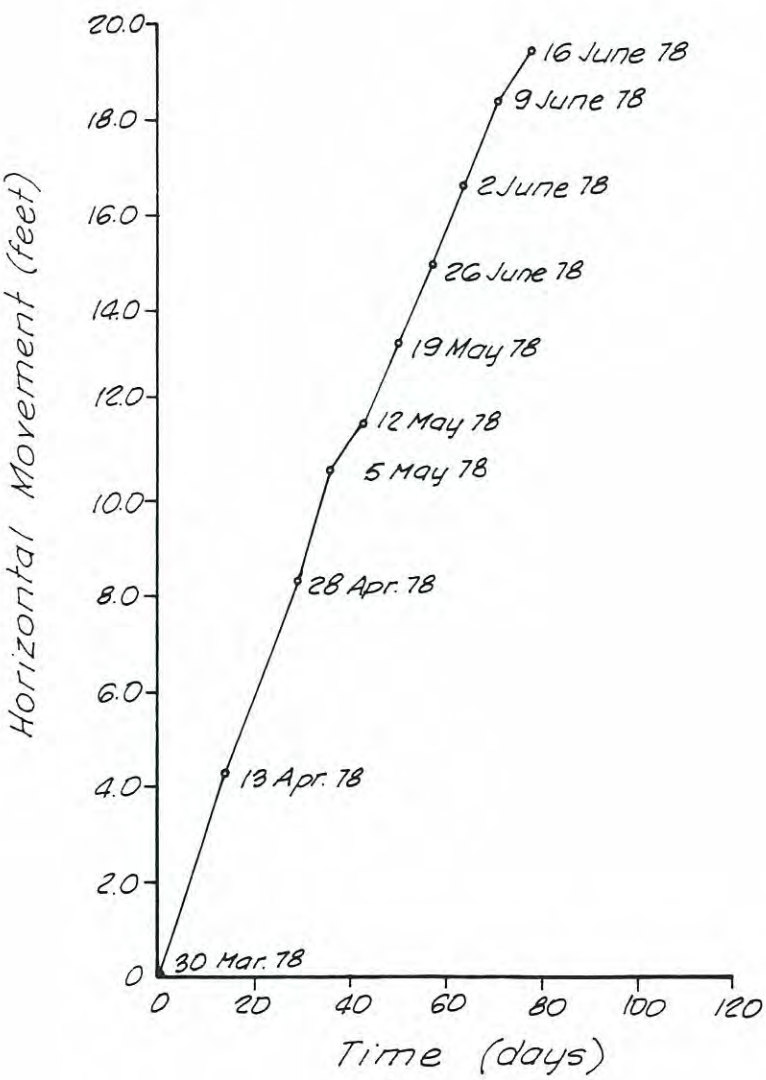
Figure C-14



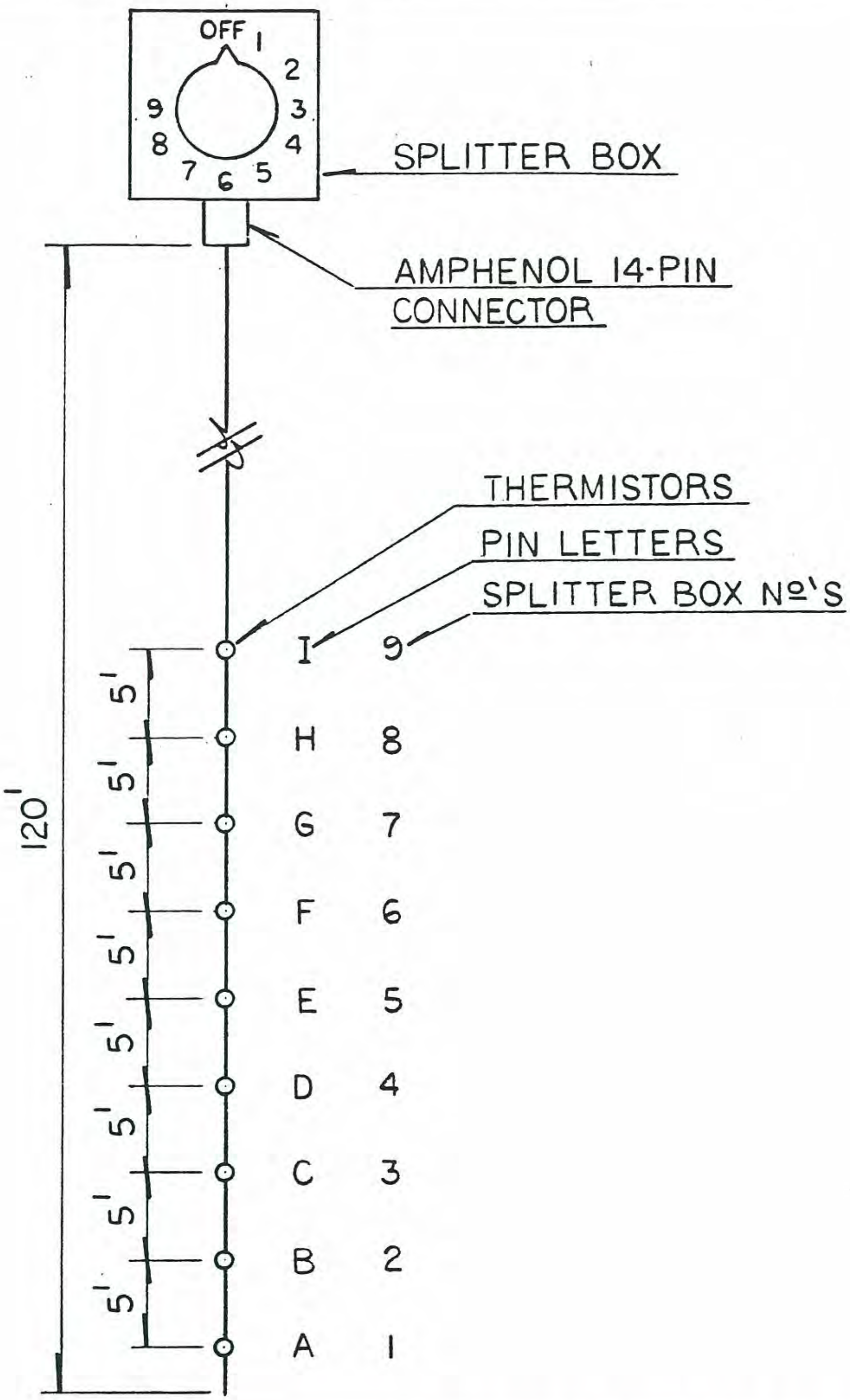
TAILING PILE
HORIZONTAL MOVEMENT DATA
MONITOR 29A

Figure C-15





V77016 SH EBF June '78



REVISIONS		
NO.	REVISED BY	DATE
1		
2		
3		
4		
5		
6		
7		
8		

CANTECH CONTROLS LTD.
CALGARY—ALBERTA

120' THERMISTOR CABLE-ASS'Y.

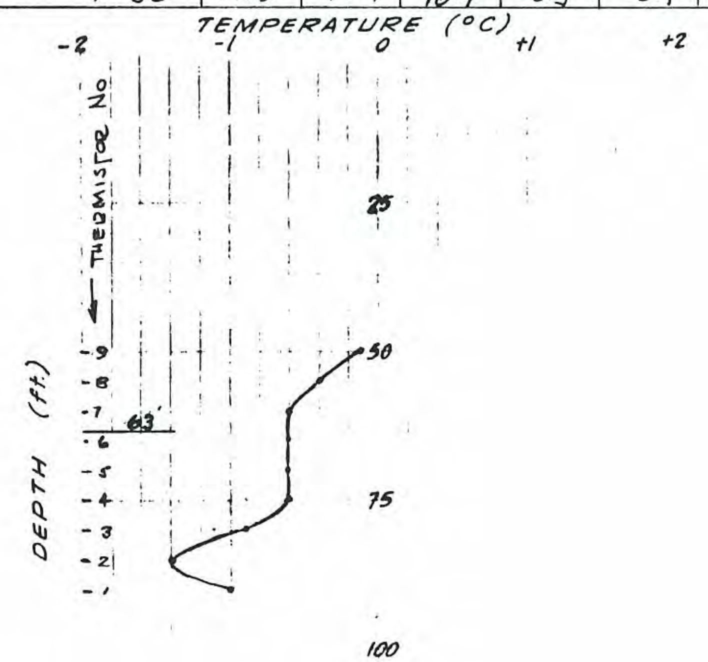
DESIGNED-	DRAWN- NM	SCALE- ✓	DATE- MAR '78
CHKD.-	APPR.-		
PROJECT NO.- 22-60028		DRWG. NO.- A 10172	

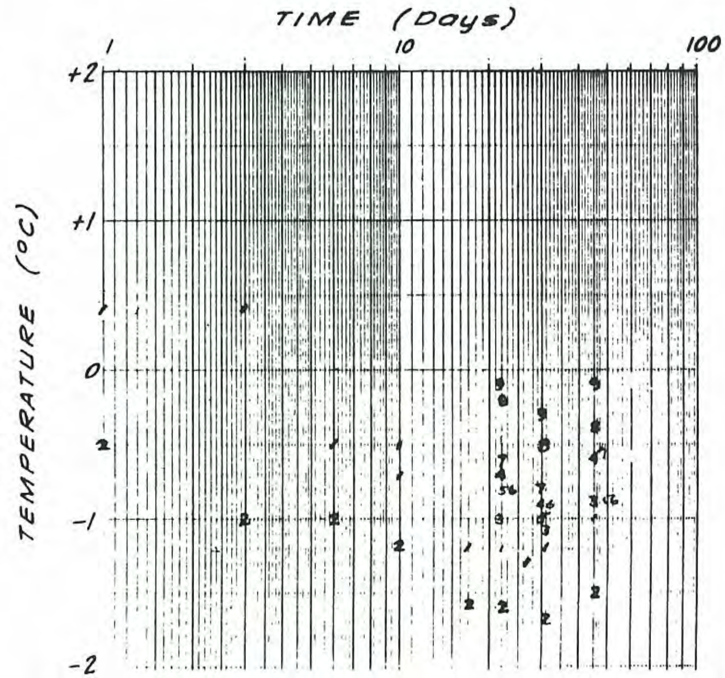
RECORD OF THERMISTOR DATA

THERMISTOR INSTALLATION No. 1
DATE OF INSTALLATION 4 April 78 (94)
LOCATION N 109626.75, E107872.04

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)	4 Apr	5 Apr	7 Apr	10 Apr	14 Apr	21 Apr	1 MAY	5 MAY	15 MAY	19 MAY	2 JUNE	19 June			
			1	3	6	10	17	27	31	41	45	59	76			
9	50	+0.5	+0.5	+0.5	+0.5	+0.3	-0.1	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1			
8	55	+1.5	+0.5	+0.5	+0.5	+0.2	-0.2	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4			
7	60	+0.6	+0.5	+0.3	+0.2	-0.3	-0.6	-0.8	-0.8	-0.6	-0.6	-0.6	-0.6			
6	65	+0.5	0.0	0.0	0.0	-0.4	-0.8	-0.9	-0.9	-0.9	-0.6	-0.6	-0.6			
5	70	+0.3	0.0	0.0	0.0	-0.5	-0.8	-1.0	-1.0	-0.9	-0.6	-0.6	-0.6			
4	75	+0.5	0.0	0.0	0.0	-0.4	-0.7	-0.9	-0.9	-0.6	-0.6	-0.6	-0.6			
3	80	+0.5	0.0	0.0	-0.4	-0.6	-1.0	-1.1	-1.1	-0.9	-0.9	-0.9	-0.9			
2	85	0.0	-0.5	-1.0	-1.0	-1.2	-1.6	-1.7	-1.7	-1.5	-1.5	-1.5	-1.4			
1	90	+1.5	+0.4	+0.4	-0.5	-0.7	-1.2	-1.3	-1.2	-1.0	-1.1	-1.0	-1.0			



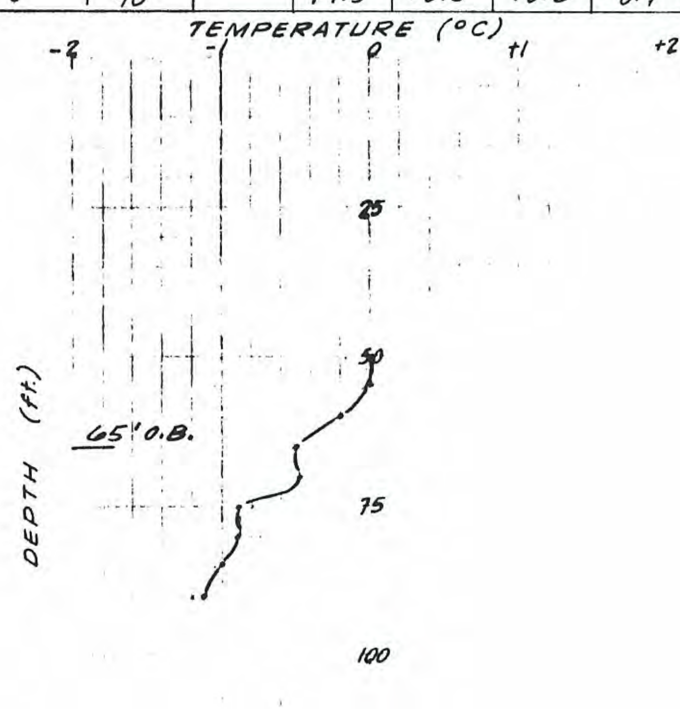


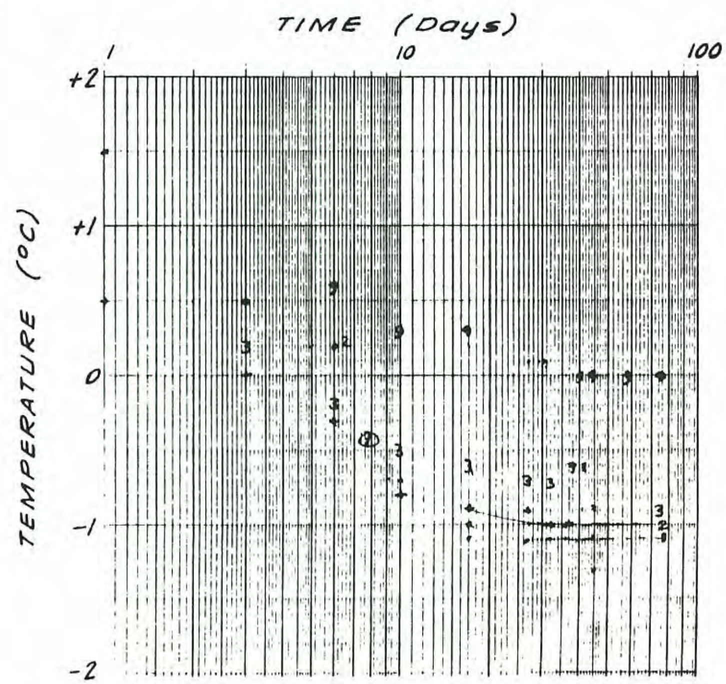
RECORD OF THERMISTOR DATA

THERMISTOR INSTALLATION No. 2
DATE OF INSTALLATION 4 APR 78 (84)
LOCATION N. 109692.92, E.107513.05

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)	4 APR	5 APR	7 APR	10 APR	14 APR	21 APR	1 MAY	6 MAY	12 MAY	15 MAY	19 MAY	2 JUNE	19 June		
			1	3	6	10	17	27	32	38	41	45	59	76		
9	50		+0.5	+0.5	+0.6	+0.3	+0.3	+0.1	+0.1	0.0	0.0	0.0	0.0	0.0		
8	55		+1.0	+0.5	+0.5	+0.3	+0.2	0.0	0.0	0.0	0.0	-0.1	0.0	0.0		
7	60		0.0	+0.4	+0.2	+0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.4	-0.2	-0.2		
6	65		0.0	+0.2	+0.1	-0.1	-0.1	-0.4	-0.4	-0.4	-0.5	-0.5	-0.5	-0.5		
5	70		+1.0	+0.3	+0.1	-0.2	-0.3	-0.4	-0.4	-0.4	-0.4	-0.6	-0.5	-0.5		
4	75		+1.2	+0.4	+0.2	-0.3	-0.5	-0.6	-0.7	-0.6	-0.6	-0.9	-0.9	-0.9		
3	80		+0.5	+0.2	-0.2	-0.5	-0.6	-0.7	-0.7	-0.6	-0.6	-0.9	-0.9	-0.9		
2	85		+0.5	0.0	-0.3	-0.8	-0.9	-0.9	-1.0	-1.0	-1.0	-1.1	-1.0	-1.0		
1	90		+1.5	+0.5	+0.2	-0.7	-1.0	-1.1	-1.1	-1.0	-1.1	-1.3	-1.2	-1.1		

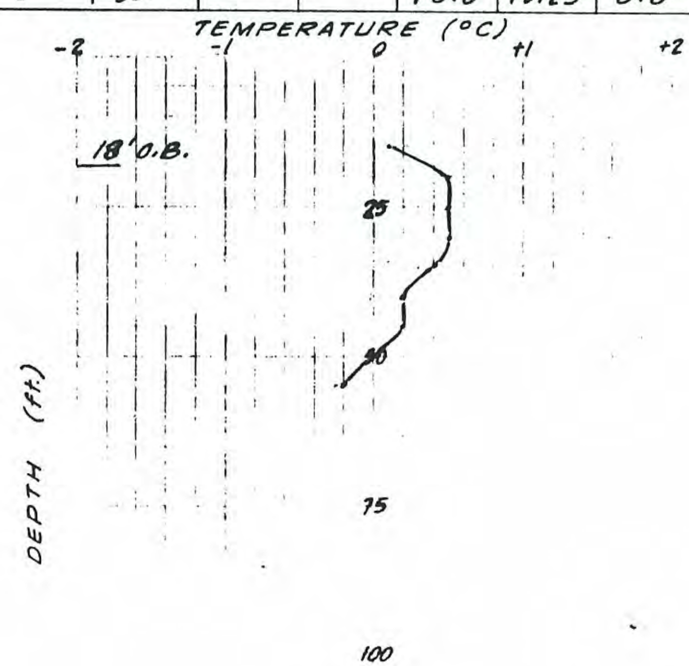


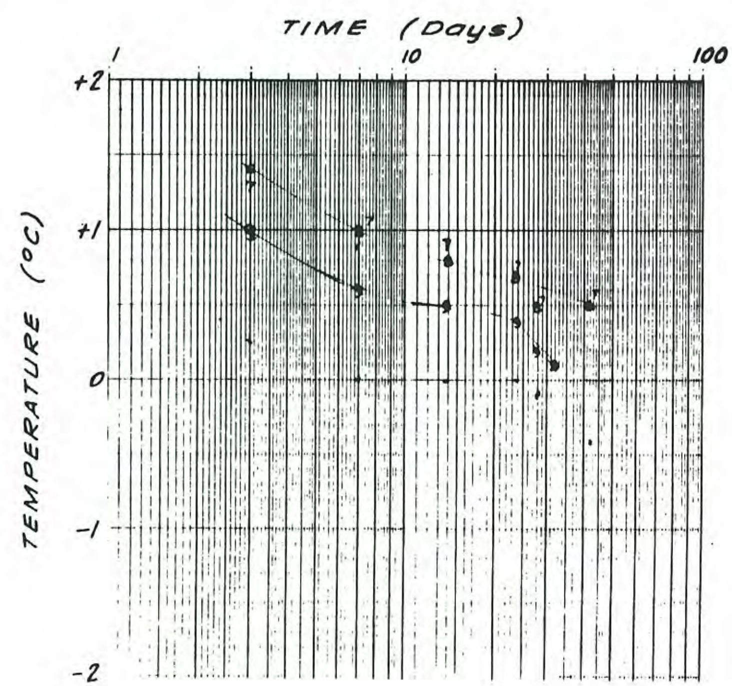


RECORD OF THERMISTOR DATA

THERMISTOR INSTALLATION No. 3
DATE OF INSTALLATION 7APR.78 (97)
LOCATION (ON DUMP) N.109647.94
E.106690.27

Thermistor No.	Depth (ft.)			7APR	10 APR	14APR	21APR	1 MAY	5MAY	19MAY	2JUNE	19June				
					3	7	14	24	28	42	56	73				
9	15			+1.0	+1.0	+0.6	+0.5	+0.4	+0.2	+0.1	+0.1	+0.1				
8	20			+1.5	+1.4	+1.0	+0.8	+0.7	+0.5	+0.5	+0.4	+0.5				
7	25			+3.5	+1.3	+1.0	+0.9	+0.7	+0.5	+0.5	+0.4	+0.5				
6	30			+4.0	+1.4	+1.0	+0.8	+0.7	+0.5	+0.5	+0.5	+0.5				
5	35			+3.5	+1.1	+0.7	+0.6	+0.5	+0.3	+0.3	+0.3	+0.4				
4	40			+4.0	+0.9	+0.5	+0.4	+0.3	+0.2	+0.2	+0.2	+0.2				
3	45			+1.5	+0.5	+0.2	+0.3	+0.2	+0.1	+0.1	+0.1	+0.2				
2	50			+4.0	+0.25	0.0	+0.2	+0.2	0.0	0.0	0.0	0.0				
1	55			+5.0	+0.25	0.0	0.0	0.0	-0.1	-0.4	-0.4	-0.2				



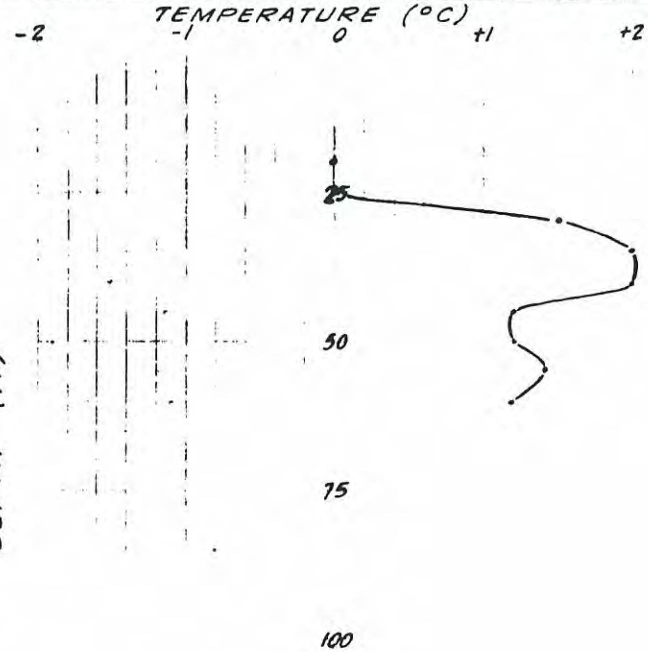


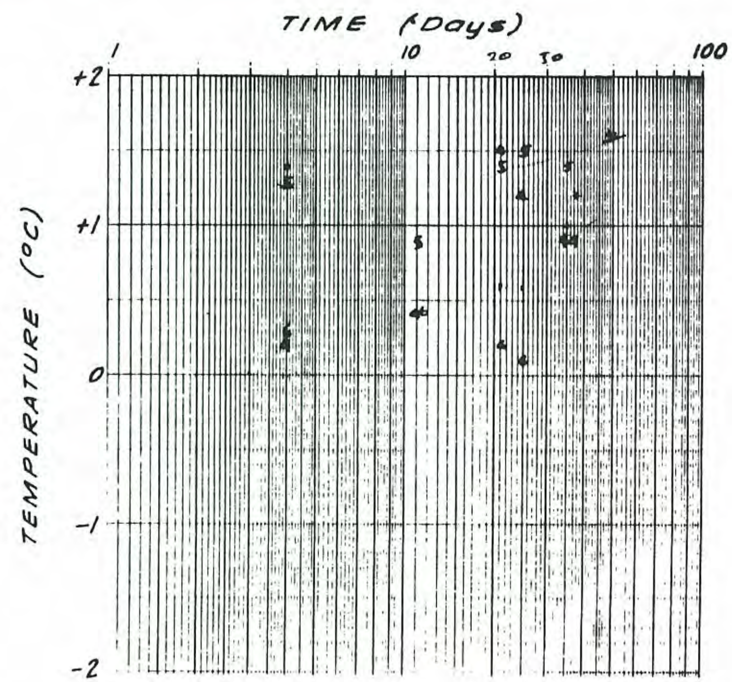
RECORD OF THERMISTOR DATA

THERMISTOR INSTALLATION No. 4
DATE OF INSTALLATION 10 APR. 78
LOCATION N. 110917.76, E. 107487.30

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)				10 APR (IN WATER)	14 APR	21 APR	1 MAY	5 MAY	15 MAY	17 MAY	19 MAY	2 JUNE	19 June		
						4	11	21	25	35	37	39	53	70		
9	20				+2.5	+0.2	+0.2	0.0	0.0	-0.4	-0.4	0.0	-0.1	0.0		
8	25				+2.4	+0.2	+0.2	0.0	-0.1	-0.4	-0.4	-0.1	-0.2	0.0		
7	30				+2.0	+0.2	+0.3	+0.1	0.0	-0.1	-0.1	0.0	0.0	+1.5		
? 6	35				+2.3	+0.3	+0.4	+0.2	+0.1	+2.9	+2.9	+2.2	+1.6	+20		
5	40				+2.0	+1.3	+0.9	+1.4	+1.5	+1.4	+1.4	+1.6	+1.6	+2.0		
4	45				+2.4	+0.2	+0.4	+1.5	+1.2	+0.9	+0.9	+1.2	+0.9	+1.2		
3	50				+2.5	+0.25	+1.7	+0.8	+1.2	+1.5	+1.5	+2.4	+1.2	+1.2		
2	55				+2.3	+1.0	+1.7	+2.0	+1.6	+1.0	+1.0	+1.4	+1.1	+1.4		
1	60				+1.6	+1.4	+0.9	+0.6	+0.6	+1.0	+1.0	+1.2	+0.9	+1.2		





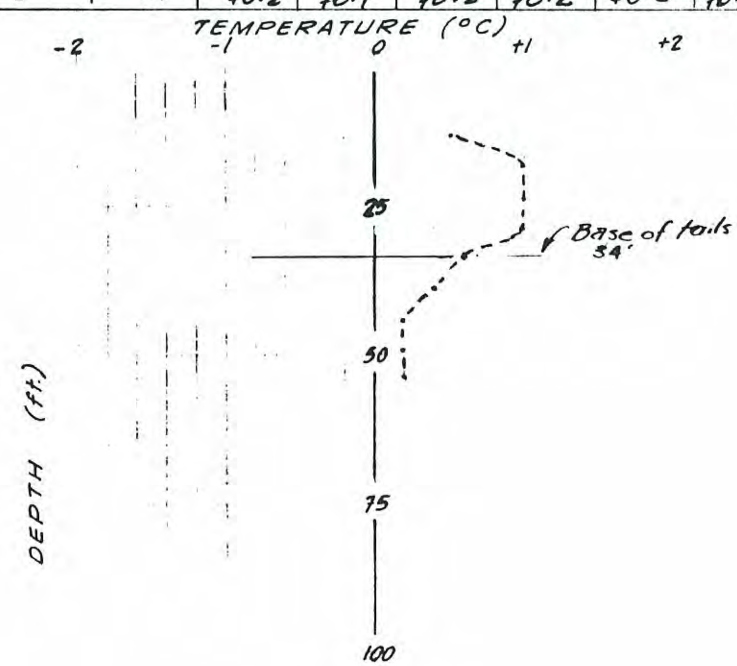
RECORD OF THERMISTOR DATA

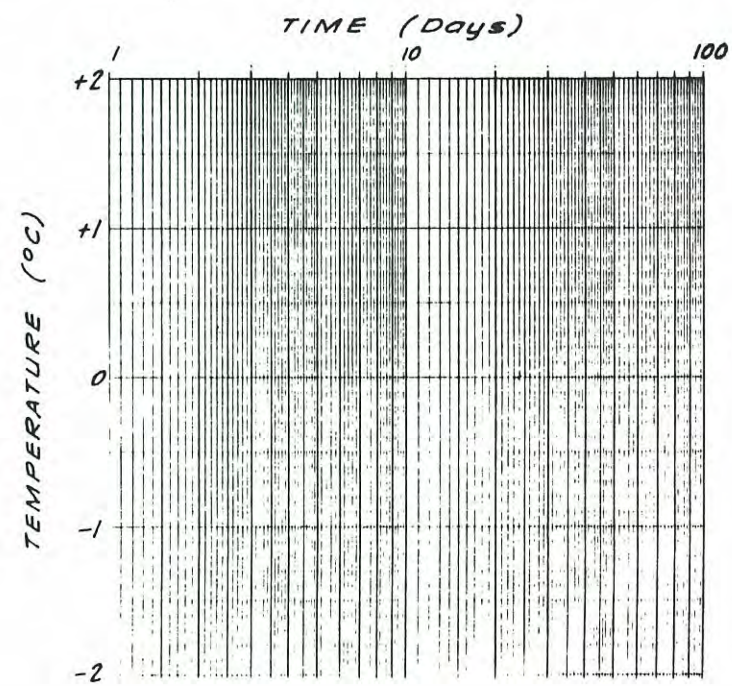
THERMISTOR INSTALLATION No. 5 (PH 12)
DATE OF INSTALLATION 9 MAY 78 (129)
LOCATION (TAILING PILE) N.113521.34, E.107717.23

TAILS IN PLACE 4.5 YRS

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)	11 MAY	17 MAY	19 MAY	26 MAY	5 JUNE	19 June									
		2	8	10	17	27	41									
9	14	+1.1	+0.5	+0.5	+0.5	+0.5	+0.5									
8	19	+1.7	+1.0	+1.1	+1.1	+1.0	+1.0									
7	24	+1.7	+1.1	+1.1	+1.1	+1.0	+1.0									
6	29	+1.5	+1.0	+1.0	+1.0	+1.0	+1.0									
* 5	34	+1.1	+0.6	+0.7	+0.7	+0.6	+0.6									
4	39	+0.6	+0.4	+0.4	+0.4	+0.4	+0.4									
3	44	+0.3	+0.2	+0.2	+0.2	+0.2	+0.2									
2	49	+0.2	+0.1	+0.2	+0.2	+0.2	+0.2									
1	54	+0.2	+0.1	+0.2	+0.2	+0.2	+0.2									

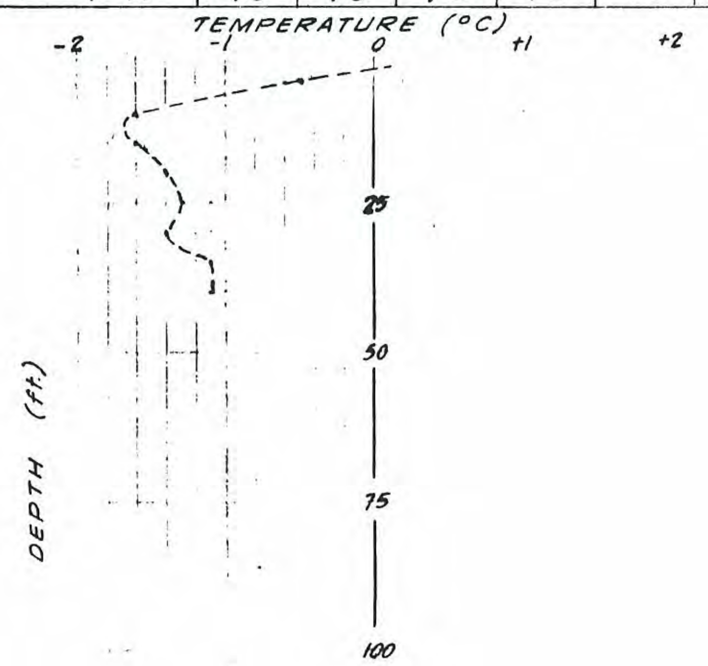


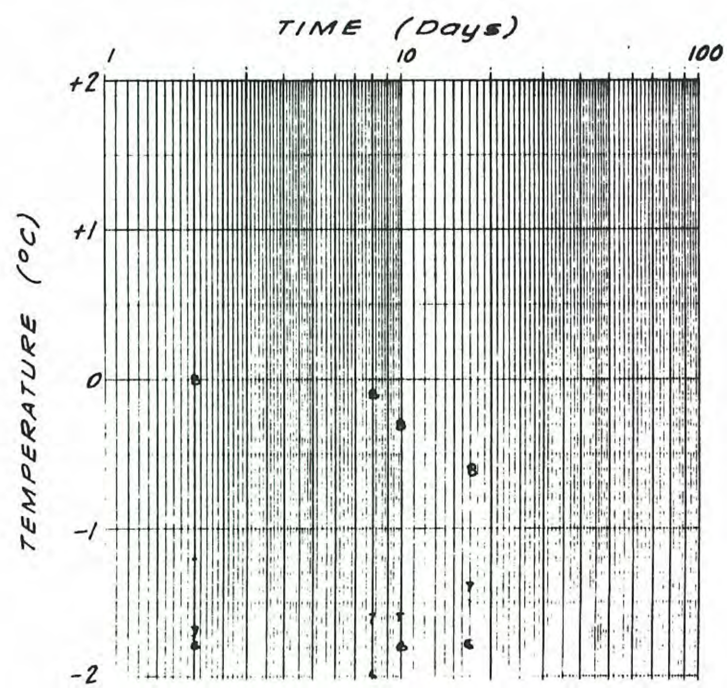


RECORD OF THERMISTOR DATA

THERMISTOR INSTALLATION No. 6 (BH-13)
DATE OF INSTALLATION 9 MAY 78 (129)
LOCATION ~200' NORTH OF TAILING PILE N. 115070.50
IN UNDISTURBED GROUND E. 107162.86

Thermistor No.	Depth (ft.)	Date of Temperature Measurement/Number of Days Subsequent to Installation														
		11 MAY	17 MAY	19 MAY	26 MAY	5 JUNE	19 June									
		2	8	10	17	27	41									
9	0	+1.7	+6.6	+5.4	+7.5	+8.4	+0.1									
8	5	0.0	-0.1	-0.3	-0.6	-0.6	-0.5									
7	10	-1.7	-1.6	-1.6	-1.4	-1.4	+1.6									
6	15	-1.8	-2.0	-1.8	-1.8	-1.6	-1.6									
5	20	-1.2	-1.4	-1.4	-1.4	-1.4	-1.4									
4	25	-1.0	-1.0	-1.1	-1.1	-1.1	-1.3									
3	30	-1.1	-1.1	-1.1	-1.1	-1.1	-1.4									
2	35	-1.1	-1.1	-1.0	-1.0	-1.1	-1.1									
1	40	-1.0	-1.0	-1.0	-1.0	-1.0	-1.1									



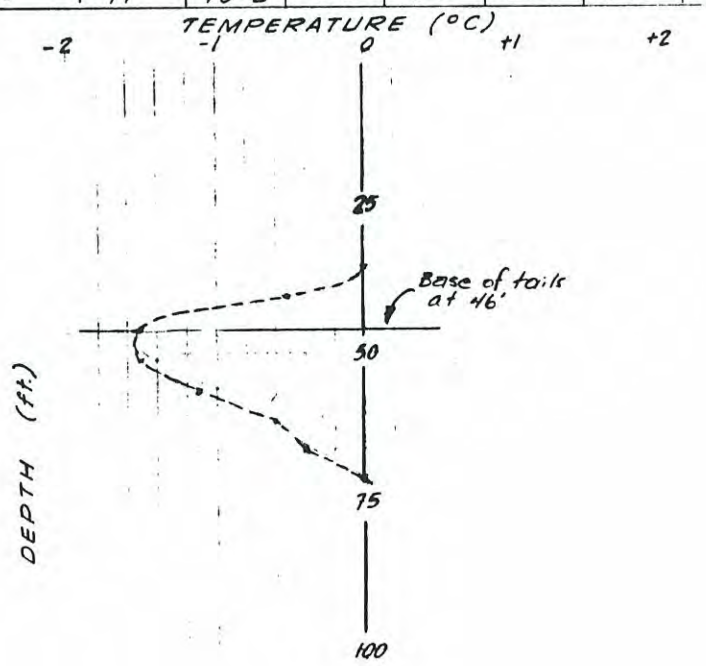


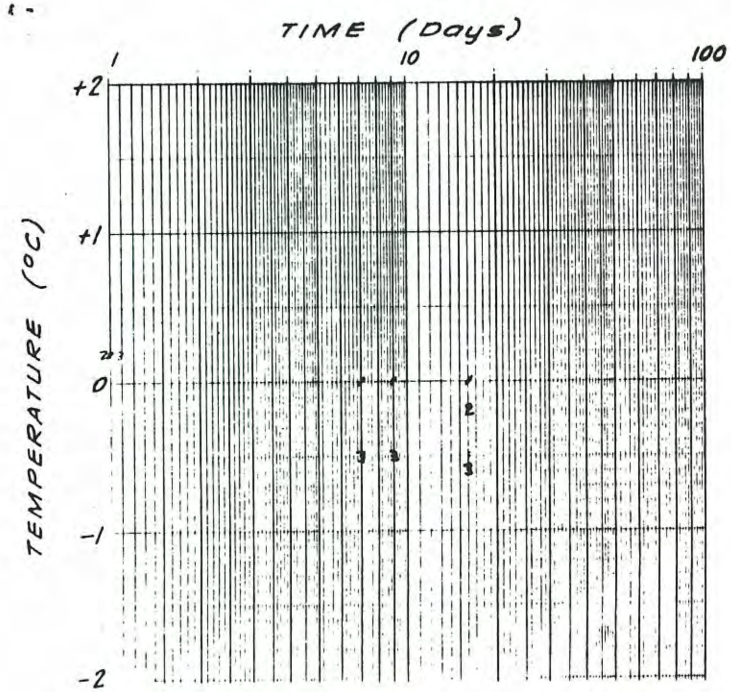
RECORD OF THERMISTOR DATA

THERMISTOR INSTALLATION No. 7 (B.H.14)
DATE OF INSTALLATION 10 MAY ~~70~~ 130
LOCATION (TAILING PILE) N.114965.16, E.108473.94
TAILS IN PLACE 1 to 2 YRS

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)	11MAY	17MAY	19MAY	26MAY	5JUNE	19June									
		1	7	9	16	26	40									
9	31	+2.1	-0.1	0.0	0.0	0.0										
8	36	+2.2	+0.2	+0.1	+0.1	+0.1	0.0									
7	41	+0.3	-0.2	-0.2	-0.4	-0.4	-0.5									
* 6 -	46	+0.2	-1.9	-1.6	-1.5	-1.4	-1.5									
5	51	+0.1	-1.5	-1.5	-1.4	-1.4	-1.5									
4	56	+0.2	-1.0	-1.0	-1.0	-1.0	-1.1									
3	61	+0.2	-0.5	-0.5	-0.6	-0.6	-0.6									
2	66	+0.2	0.0	0.0	-0.2	-0.3	-0.4									
1	71	+0.2	0.0	0.0	0.0	0.0	0.0									



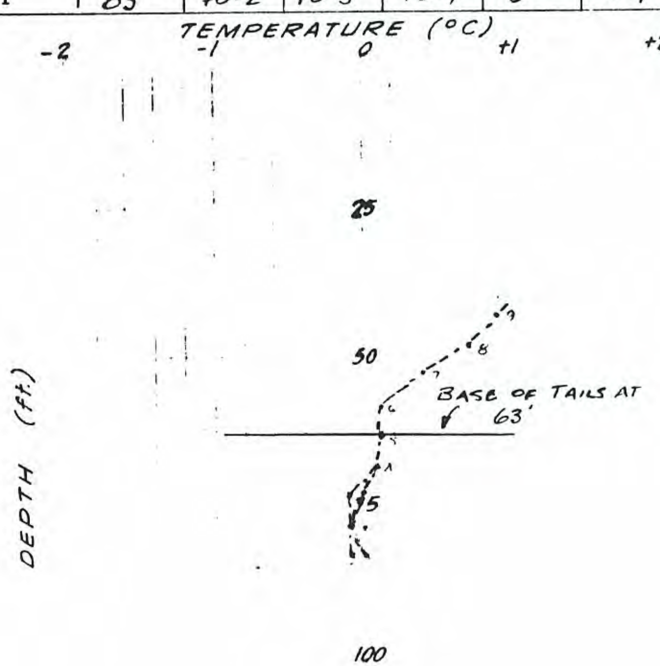


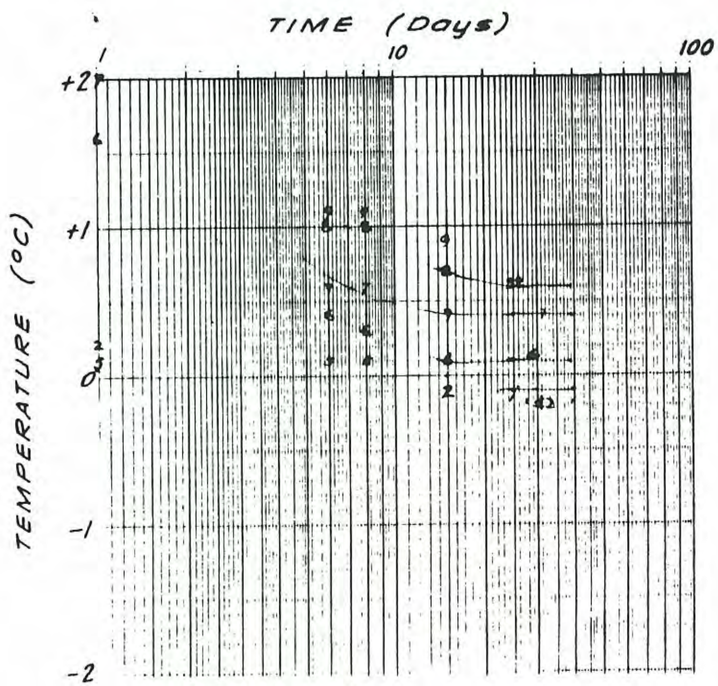
RECORD OF THERMISTOR DATA

THERMISTOR INSTALLATION No. 8 (B.H. 16)
DATE OF INSTALLATION 11 MAY 78 (131)
LOCATION TAILING PILE - 1974 FAILURE LOBE N.113481.47
TAILS IN PLACE ~4 YRS E.108871.16

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)	12 MAY	17 MAY	19 MAY	26 MAY	5 JUNE	19 June
		1	6	8	15	25	39
9	43	+3.0	+1.1	+1.1	+0.9	+0.6	+0.6
8	48	+2.4	+1.0	+1.0	+0.7	+0.6	+0.6
7	53	+2.0	+0.6	+0.6	+0.4	+0.4	+0.4
6	58	+1.6	+0.4	+0.3	+0.1	+0.1	+0.1
* 5	63	+0.1	+0.1	+0.1	+0.1	+0.1	+0.1
4	68	+0.1	+0.1	+0.1	+0.1	+0.1	+0.1
3	73	+0.1	+0.1	+0.1	0.0	-0.1	-0.1
2	78	+0.2	+0.1	+0.1	-0.1	-0.1	-0.1
1	83	+0.2	+0.3	+0.4	0	-0.1	-0.1





APPENDIX E

Horizontal Movements, Crack Patterns & Implied Stresses

As shown on Figure 3, the azimuth of the horizontal movement factors form a general pattern which fans outward from the central region of the dump toward the perimeter. The azimuth of the horizontal movement factors indicate that the primary direction of movement is toward the Clinton channel.

The surface of the Clinton dump is characterized by a series of prominent cracks which are clearly visible on aerial photographs. Characteristically, these cracks are simple tension features which, in general, do not show any evidence of differential vertical displacement from one side of the crack to the other. In some cases, the tension cracks form a zone which extends over a width of several feet. This tension zone gives rise to graben-like features on the surface of the dump. Typically, the tension cracks and graben-like features are aligned roughly perpendicular to the Clinton channel, and approximately parallel to the azimuth of the horizontal movement vectors. The mechanism of development of these prominant cracks is explained in the following paragraphs.

Consider three points, A, B, and C on the surface of the dump. The movement vectors for these three points over an interval of time, Δt, are as illustrated on Figure E-1(b). In the following discussion, the absolute movements of the points are considered to occur relative to the Cartesian coordinates x and y as illustrated in Figure E-1(a). Relating the coordinate system to the Clinton dump, the y-axis represents north.

The movement vectors clearly indicate that the movements are occurring predominantly in the y-direction. For example, at point A, the movement in the y-direction is 9 times greater than the movement in the x-direction. Similarly, at point C the movement in the y-direction is twice as large as the movement in the x-direction.

Although the absolute movements of points A, B, and C are predominently in the y-direction, the movements of the three points relative to one another are predominantly in the x-direction. Figure E-1 (c) shows the movement vectors of points A and C relative to point B. The movement of point A relative to point C is illustrated on Figure E-1(d). By the end of the time interval Δt, points A, B, and C have all moved further apart relative to one another, with the result that stretching has occurred between these points. This stretching could be expected to result in development of tension cracks on the ground surface. The alignment of these tension cracks could be expected to be approximately perpendicular to the relative movement vectors, that is approximately parallel to the azimuth of the vectors of absolute movement.

Figure E-2 shows a 1976 airphoto of the Clinton dump with some of the prominent tension cracks highlighted to facilitate reproduction. A sketch of the Clinton dump drawn to the same scale as the aerial photograph, and showing the crack patterns, together with the azimuth of the horizontal movement vectors that developed during late 1976 and early 1977 is also shown on the figure. The similarity between the azimuth of the horizontal movement vectors and the azimuth of the surface cracks is readily apparent.

Large segments of the surface of the dump are approximately level. Within these areas, the major principal stress planes are approximately horizontal (1).

The presence of the cracks on the surface of the dump indicate that tension strains have occurred at depth below the surface with the result that the horizontal stresses have been reduced to the active state. Thus, the minor principal planes are vertical (or approximately 30), and their azimuths are approximately coincident with the azimuths of the tension cracks, and the minor principal stresses are equal to the active earth pressures. Since the major principal stress is equal to geostatic pressure, and the minor principal stress is equal to the active earth pressure, it follows that the intermediate principal stress must be equal to or greater than the active pressure, and must be equal to or less than geostatic pressure. The pattern of cracking indicates that the intermediate principal stresses are greater than the active pressures.

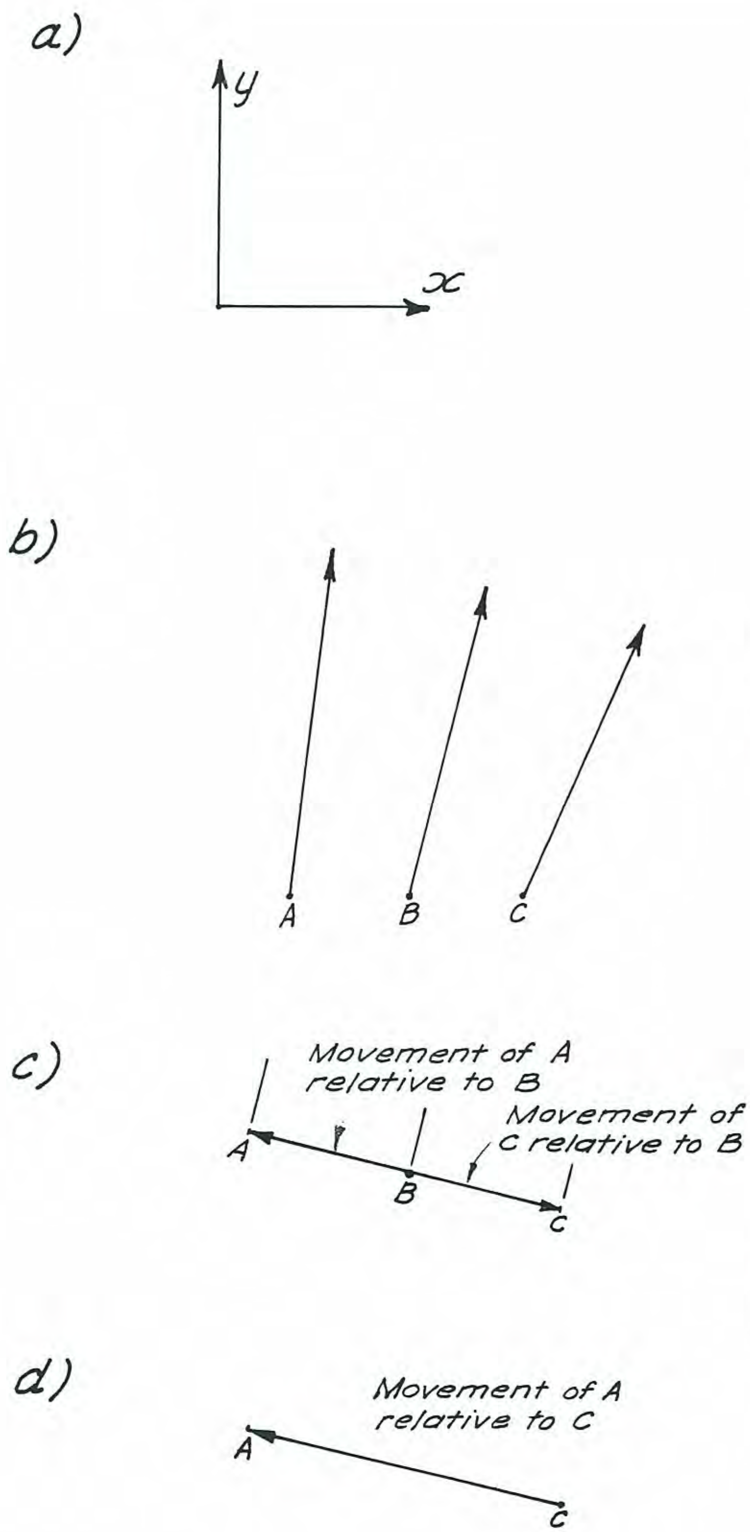
Examination in the field shows evidence of tension cracks extending to the edge of the Clinton channel and aligned in directions perpendicular to the channel. The upward inclination toward the north of the movement vectors for reference points adjacent to the channel are clear evidence that within the northern limit of the dump, the toe of the dump is being displaced upward as a result of base sliding over the toe region of

Within segments of the dump where the slope of the surface deviates significantly from the horizontal, and near the base of the dump which may be subject to the influence of base friction, the attitude of the major principal plane can be expected to deviate from the horizontal, with the result that the attitude of the minor and intermediate principal planes will also deviate from the vertical.

the original north valley wall. Thus, although the toe region of the dump is being displaced upward as a result of earth pressures in a direction approximately perpendicular to the channel, the stresses in a direction parallel to the channel remain at the active earth pressures (see Figure E-3). Thus, at least within the upstream portion of the channel, minor principal planes are approximately vertical, and are aligned approximately perpendicular to the channel. It follows that, within this region, the intermediate principal planes are approximately vertical, are aligned approximately parallel to the channel, and that the intermediate principal stresses are greater than the active earth pressures and are equal to or less than the geostatic pressures.

ABSOLUTE AND RELATIVE MOVEMENTS
CLINTON DUMP

Figure E - I



CARTESIAN COORDINATES IN PLAN -
THE y - AXIS IS APPROXIMATELY NORTH.

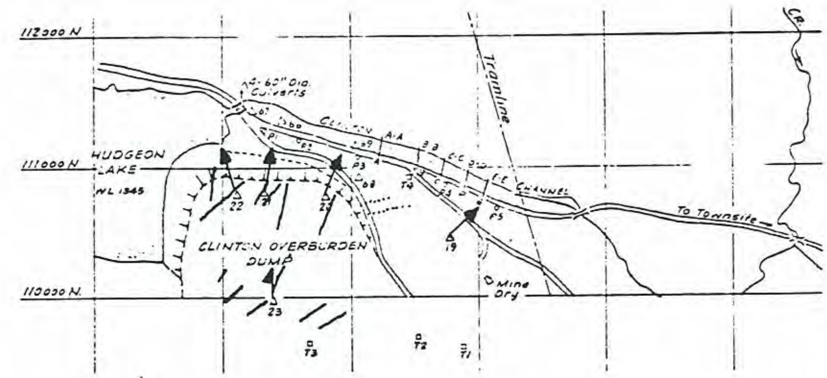
PLAN SHOWING ABSOLUTE HORIZONTAL MOVEMENT VECTORS DURING TIME ΔT RELATIVE TO x and y AXES.

RELATIVE HORIZONTAL MOVEMENTS AT THE END OF TIME INTERVAL ΔT.

Project No V77016 Drawn Ing. Reviewed E&F Date June '78

CRACK PATTERNS AND VECTOR AZIMUTHS
CLINTON DUMP

Figure E - 2

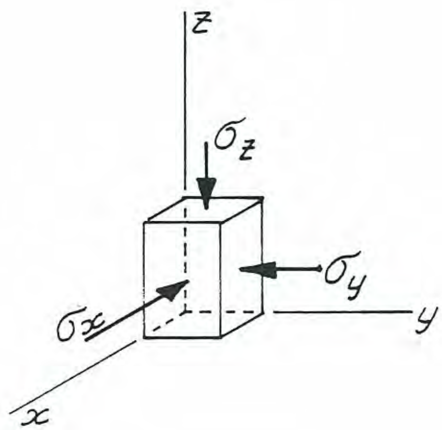


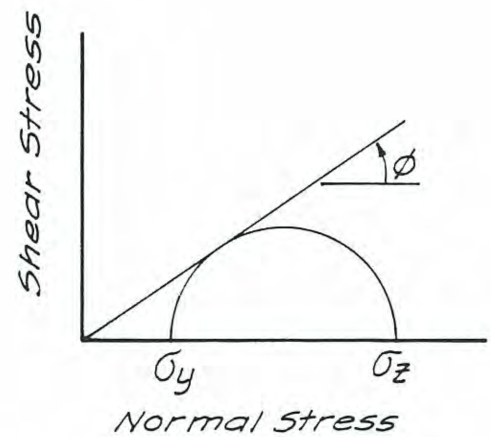
Approx. Scale: 1 in. to 1580 ft.

V77016 Ing EBF June '78

IMPLIED STRESSES
CLINTON DUMP

Figure E-3





The z axis is vertical.

The x axis is horizontal and perpendicular to the channel (or approximately so).

The y axis is perpendicular to the z and x axes. i.e. approximately parallel to the channel.

σ_z = Geostatic pressure = γz where z = depth below surface and γ = effective unit weight of the material.

σ_y = $K_A \sigma_z$ where K_A = active earth pressure coefficient = $\dfrac{1}{\tan^2(45 + \phi/2}$

σ_x = The intermediate principal stress $\sigma_y \leqq \sigma_x \leqq \sigma_z$

V77016 . Ing. E&C June '78

Project No. V77016

RECORD OF BOREHOLE 1 (T-1)

LOCATION (See Figure 2)

BORING DATE April 4, 1978

BOREHOLE TYPE

BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

DATUM

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1386.6' 0.0'	WASTE ROCK -argillite -dry -grey -some asbestos fibres							
1370.6' 16.0'	WASTE ROCK -argillite -dry -brownish grey -very fibrous.							
1364.6' 22.0'	WASTE ROCK -argillite with some serpentine -dry to damp -grey to brown to green -some asbestos fibres							
	Original Ground Surface							
1323.6' 63.0'	ORGANICS- dark brown -moss, leaves etc. -ice chips							
65.0'	ARGILLITE -weathered -moist -grey brown -ice chips							
1306.6' 82.0'	ARGILLITE -weathered -grey (brownish) -wet -ice chips							Thermistor cable installed to 90' (9 units at 5' intervals)
1296.6' 90.0'	End of Hole							

VERTICAL SCALE 1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

RECORD OF BOREHOLE 2 (T-2)

Project No. V77016

LOCATION (See Figure 2)
BOREHOLE TYPE
SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 5, 1978
BOREHOLE DIAMETER 6 in.
DATUM

ELEV. / DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1398.1' / 0.0'	WASTE Rock - argillite - dark grey - damp							
1386.1' / 12.0'	WASTE ROCK - argillite - dark grey - damp		1	D.O				
			2	"				
			3	"				
1333.1' / 65.0'	Original Ground Surface / ORGANICS - dark brown							
66.0'	ARGILLITE - dark grey - weathered - ice chips		4	"				
1308.1' / 90.0'	End of Hole							Thermistor cable installed to 90 ft. (9 units at 5 ft. interval)

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 3

LOCATION (See Figure 2)
BOREHOLE TYPE
SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 6, 1978
BOREHOLE DIAMETER 6 in.
DATUM

SOIL PROFILE								
ELEV. DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION ADDITIONAL LAB. TESTING
0.0'	WASTE ROCK -argillite -dry -dark grey							
8.0'	WASTE ROCK -argillite -damp		1	D.O.				
			2	"				
52.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 4 (T-3)

LOCATION (See Figure 2)

BOREHOLE TYPE

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 7, 1978

BOREHOLE DIAMETER 6 in.

DATUM

SOIL PROFILE ELEV. / DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1559.9' / 0.0'	WASTE ROCK - argillite - dry - grey							
1541.9' / 18.0'	Original Ground Surface ARGILLITE - damp - dark grey - original rock		1	D.O.				Thermistor cable installed to 55ft. (9 units at 5' intervals)
1504.9' / 55.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.O.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 5

LOCATION (See Figure 2)

BOREHOLE TYPE

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 8, 1978

BOREHOLE DIAMETER 6 in.

DATUM

SOIL PROFILE: ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P — W — W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
0.0'	WASTE ROCK - argillite - dry to damp - grey							
80.0'	End of Hole (hole collapsed at 80ft.)							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. K77016

RECORD OF BOREHOLE 6 (T-4)

LOCATION (See Figure 2)

BOREHOLE TYPE

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 10, 1978

BOREHOLE DIAMETER 6 in.

DATUM

SOIL PROFILE: ELEV. DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
0.0'	WASTE ROCK - argillite - dark grey - dry - some asbestos fibre							
25.0'	WASTE ROCK - argillite - dark grey - damp							
50.0'	WASTE ROCK - argillite - wet - free water running into hole at 50.0' - some asbestos fibres - possible original ground surface at approx. 80'							Thermistor cable installed to 60' (9 units at 5' intervals) Borehole collapsed during installation preventing cable from reaching full depth in bore hole
82.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 7 (P-4)

LOCATION (See Figure 2)

BOREHOLE TYPE

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 10, 1978

BOREHOLE DIAMETER 6 in.

DATUM

SOIL PROFILE: ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P — W — W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1304.6'								
	WASTE ROCK -argillite -dry -dark grey -damp at 40'							
1241.6' 63.0'	End of Hole							Piezometer el. 1245.17'

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 8 (P-5)

LOCATION (See Figure 2)

BOREHOLE TYPE

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 10, 1978

BOREHOLE DIAMETER 6 in.

DATUM

SOIL PROFILE									
ELEV. / DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION	ADDITIONAL LAB. TESTING
1271.5' / 0.0'	WASTE ROCK - argillite - dry - dark grey								
1241.5' / 30.0'	ARGILLITE - dark grey - damp. ARGILLITE bedrock-weathered								
1202.5' / 69.0'	End of Hole							Piezometer el. 1202.76'	

VERTICAL SCALE 1 inch to 20 feet

Golder Associates

DRAWN R.D.

CHECKED EBF

Project No. KZZ016

RECORD OF BOREHOLE 9 (P-3)

LOCATION (See Figure 2)

BORING DATE April 11, 1978

BOREHOLE TYPE

BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

DATUM

SOIL PROFILE: ELEV. DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P W W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1364.3'								
	WASTE ROCK - argillite - dry to damp - dark grey - moist at 45.0'							
1301.3' 66.0'	End of Hole							Piezometer el. 1314.19'

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 10 (P-2)

LOCATION (See Figure 2)

BOREHOLE TYPE

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 11, 1978

BOREHOLE DIAMETER 6in.

DATUM

SOIL PROFILE								
ELEV. DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1368.0' 0.0'	WASTE ROCK - argillite - dry to damp - dark grey							
1330.0' 42.0'	End of Hole							Piezometer el. 1329.43'

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.O.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 11 (P-1)

LOCATION (See Figure 2)

BOREHOLE TYPE

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 11, 1978

BOREHOLE DIAMETER 6in.

DATUM

SOIL PROFILE ELEV. DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION ADDITIONAL LAB. TESTING
1363.0' 0.0'	WASTE ROCK - argillite - dry to damp - dark grey							Piezometer el. 1321.95'
1345.0' 38.0'	End of Hole							

VERTICAL SCALE 1 inch to 20 feet

Golder Associates

DRAWN R.D.

CHECKED

Project No. V77016

RECORD OF BOREHOLE 12 (T-5)

LOCATION (See Figure 6) — BORING DATE May 9, 1978

BOREHOLE TYPE — BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN. — DATUM

SOIL PROFILE: ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P, W, W_L) 10 20 30 40	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1945.2'	Surface of Tailing Pile							
0.0'	Tails							
1911.7' / 33.5'	Compact, light brown, sub-rounded, fine to med. GRAVEL with clay, silt and sand - fluvial lacustrine traces of organics at bottom of tails		1				⊙ (approx. 18)	
			2					Thermistor cable installed to 54 ft. (9 units at 5' intervals)
1891.2 / 54.0'	End of Hole							

VERTICAL SCALE 1 inch to 20 feet

Golder Associates

DRAWN R.O.
CHECKED EBF

Project No. 777016

RECORD OF BOREHOLE 13 (T-6)

LOCATION (See Figure 6)

BOREHOLE TYPE

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE May 9, 1978

BOREHOLE DIAMETER 6 in.

DATUM

SOIL PROFILE: ELEV. DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P — W — W_L) 10 20 30 40	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1880.6' 0.0'	Ground Surface in Roadway Cut							
	Frozen, light brown sub-rounded fine to med. GRAVEL with clay, silt & sand fluvial lacustrines		1					
			2				≈41	
			3				≈32	
			4				≈28	
1840.6' 40.0'	End of Hole							Thermistor cable installed to 40 ft. (9 units at 5' intervals)

VERTICAL SCALE 1 inch to 20 feet

Golder Associates

DRAWN R.Q.
CHECKED EBF

RECORD OF BOREHOLE 14 (T-7)

Project No. V77016

LOCATION (See Figure 6) | BORING DATE May 10, 1978
BOREHOLE TYPE | BOREHOLE DIAMETER 6 in.
SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN. | DATUM

SOIL PROFILE: ELEV. / DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P — W — W_L (10, 20, 30, 40)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1741.0 / 0.0'	Surface of Tailing Pile							
	Tails							
1696.0' / 45.0'	-Frozen - ice crystals - light brown - sub-rounded - fine to med. GRAVEL with clay, silt & sand. - fluvial - lacustrine		1 2					Thermistor cable installed to 74ft. (9 units at 5' intervals)
1667.0' / 74.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 15 (ST-8)

LOCATION (See Figure 6)

BORING DATE May 11, 1978

BOREHOLE TYPE

BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

DATUM

ELEV. DEPTH	SOIL PROFILE – DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P — W — W_L) 10 20 30 40	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1607.2'	Ground Surface in Road Cut							
0.0' / 1607	-Frozen - light brown - sub rounded -fine to med. GRAVEL with clay silt & sand - fluvial lacustrines		1				⊙ (approx. 6)	
	-Frozen - black - ARGILLITE weathered bedrock		2				⊙ (approx. 12)	
1567.2 / 40.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

RECORD OF BOREHOLE 16 (T-8)

Project No. 777016

LOCATION (See Figure 6)

BORING DATE May 12, 1978

BOREHOLE TYPE

BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

DATUM

ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P — W — W_L; 10 20 30 40)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1623.8 / 0.0'	Surface of Tailing Pile							
	Tails							
1560.8 / 63.0'	- light brown - sub-rounded - fine to med. GRAVEL with clay silt & sand. fluvial lacustrine		1				⊙ (approx. 13)	Thermistor cable installed to 83.0 ft. (9 units at 5' intervals)
1540.8 / 83.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

RECORD OF BOREHOLE 17 (D.S.-2)

Project No. K77016

LOCATION (See Figure 6) | BORING DATE May 16, 1978

BOREHOLE TYPE | BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN. | DATUM

SOIL PROFILE								
ELEV. DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P — W — W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
0.0'	Frozen dark brown organic silty SAND							
3.0'	Frozen dark brown PEAT							
5.0' / 7.0'	Frozen, light brown, sub-rounded, fine to med. GRAVEL with clay, silt & Sand (fluvial Lacustrine)							
	ARGILLITE - hard, dry unweathered							
19.0'	SERPENTINE, weathered frozen							
21.0'	ARGILLITE BEDROCK soft, weathered, frozen		1					
46.0'	ARGILLITE BEDROCK unweathered, frozen		2					
57.0'	End of Hole							

VERTICAL SCALE 1 inch to 20 feet

Golder Associates

DRAWN

RECORD OF BOREHOLE 18 (D.S-5)

Project No. V77016

LOCATION (See Figure 6)

BORING DATE May 17, 1978

BOREHOLE TYPE

BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

DATUM

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
0.0'	Frozen, dark brown, organic silty, SAND							
8.0'	Frozen, light brown, sub-rounded, fine to med. GRAVEL with clay, silt & sand (fluvial lacustrian)		1					
19.0'	ARGILLITE frozen, weathered (ice lens approx. 3in. thick recovered with sample)		2					
37.0'	ARGILLITE - frozen, becoming harder with depth, unweathered		3, 4					
60.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED E.BF

RECORD OF BOREHOLE 19(D-5·6)

Project No. V77016

LOCATION (See Figure 6) BORING DATE May 18, 1978

BOREHOLE TYPE BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN. DATUM

ELEV. DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
0.0'	Frozen, light brown sub-rounded, fine to medium GRAVEL with clay, silt & sand (alluvial)							
7.0'	Frozen silt with layers of fibrous peat		1					
17.0'	Frozen, light brown sub-rounded, fine to medium GRAVEL with clay, silt and sand (fluvial lacustrine)							
20.0'	ARGILLITE frozen, weathered		2					
32.0'	ARGILLITE - frozen becoming harder with depth, unweathered		3					
60.0'	End of Hole							

VERTICAL SCALE 1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED E.B.F.

INDIAN AND NORTHERN AFFAIRS CANADA
ABANDONED CLINTON CREEK
ASBESTOS MINE
CONDITION ASSESSMENT REPORT

APRIL, 2000

PREPARED BY
UMA ENGINEERING LTD.
ENGINEERS AND PLANNERS
1479 BUFFALO PLACE
WINNIPEG, MANITOBA
R3T 1L7

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Our File: 41 01 4440 038 01 02

April 13, 2000

Indian and Northern Affairs Canada
345 - 300 Main Street
Whitehorse, Yukon
Y1A 2B5

Attention: **Mr. Brett Hartshorne**

Dear Sir:

Reference: **Abandoned Clinton Creek Asbestos Mine
Condition Assessment Report**

Enclosed is our report describing the physical and environmental conditions at the abandoned Clinton Creek Asbestos Mine, Yukon Territory. Information presented in this report is based on observations documented in previous studies and information collected during recent investigations undertaken by UMA Engineering Ltd. and Royal Roads University in 1998 and 1999. It is important to recognize, however, that future changes in physical conditions can be expected as a result of ongoing movements of the waste rock dump and tailings piles and subsequent creek channel blockages.

Please contact Mr. Ken Skaftfeld, P.Eng. if you have any questions or require any additional information.

Yours truly,

UMA ENGINEERING LTD.

J. A. Terris
Vice President & Manager
Manitoba & Northwestern Ontario
PB/dh

T. Wingrove, P.Eng.
Director
Earth & Environmental Division

TABLE OF CONTENTS

1.0 INTRODUCTION

UMA Engineering Ltd. was retained Indian and Northern Affairs Canada to assemble a Condition Assessment Report for the abandoned Clinton Creek Asbestos Mine located at Clinton Creek, Yukon Territory. The overall objective of this project was to summarize the current status of the physical and environmental conditions at the Clinton Creek Mine Site based on available information. To achieve this objective, a desktop review of existing information was carried out including observations documented in previous reports and information collected during recent investigations undertaken by UMA and Royal Roads University (RRU) – Applied Research Division in 1998 and 1999 (Appendix A).

2.0 BACKGROUND

The abandoned Clinton Creek Asbestos Mine is located about 100 km north of Dawson City in the Yukon Territory, approximately thirteen kilometres east of the Yukon/Alaska border (Drawing 01). The mine was operated from 1968 to 1978 by the Cassier Mining Corporation. Following mine closure, the mill buildings were disposed of at auction in 1978 (P.Roach, 1998). The mine site is accessible via a gravel road from the former Clinton Creek Town-site along the north side of Clinton Creek near the base of the valley. A gravel airstrip is located to the north of the Mill Site. An overhead hydro transmission line was formerly located along the south edge of the access road between the mine and town-site.

Serpentine ore was extracted from the bedrock from three open pits (Porcupine, Snowshoe and Creek) located on the south side of Clinton Creek (Drawing 02). Ore was transported via a cable tramway to the mill site, which was located on a flat topped ridge on the north side of the Clinton Creek Valley. During the life of the mine approximately 12 million tonnes of serpentine ore was milled to produce one million tonnes of asbestos fibre. Approximately 60 million and 3 million tonnes of overburden and waste rock was deposited over the slopes adjacent to the open pits, within the Clinton Creek and Porcupine Creek valleys respectively. Approximately 10 million tonnes of tailings was placed over the west slope of the Wolverine Creek valley adjacent to the mill site.

Slope failures of the waste rock dump obstructed the Clinton Creek stream channel across the natural valley floor, leading to the formation of a 115 ha reservoir (Hudgeon Lake) immediately upstream (west) of the obstructed channel. The lake has a maximum depth estimated at 27 metres. A new creek channel was subsequently formed along the interface between the waste rock material and natural valley slope, some 25 metres above the original valley bottom. Outflow from Hudgeon Lake originally passed through four 1800 millimetre diameter culverts into an armoured section of the Clinton Creek channel at the mill site access road crossing. Two of the culverts have since been removed and the road crossing has washed out. Waste rock placement and instabilities also blocked natural drainage in Porcupine Creek creating a small un-named upstream reservoir. Failures of the north and south tailings lobes have blocked natural drainage through the Wolverine Creek valley forming a relatively small un-named reservoir.

In the spring of 1997, significant channel erosion occurred as the result of a large flow of water from Hudgeon Lake. The outflow at the toe of the waste rock dump destroyed the timber access road bridge and deposited coarse material eroded from the channel through the waste rock dump. Intermittent failures and erosion of the tailings blocking Wolverine Creek have also occurred. The eroded tailings have subsequently been transported downstream into the receiving creeks.

3.0 GEOLOGICAL SETTING

Clinton Creek is located in the discontinuous permafrost zone of the unglaciated Yukon-Tanana Upland. The asbestos ore bodies were located within westerly trending ridges along the south side of Clinton Creek. The ridges reach elevations of approximately 610 metres above sea level (A.S.L.) and the valley bottom is at about elevation 400 metres A.S.L.

The regional bedrock consists of two complex assemblages from the Yukon Cataclastic Complex. They are the sheared assemblage and the weakly deformed assemblage. The sheared assemblage consists of ultramafic, igneous and metamorphosed rocks, including serpentine, diorite, amphibolite, and schist, of which all but the ore rich serpentine rock exhibit a strong pervasive foliation. The weakly deformed assemblage consists of Triassic-aged shale, siltstone and sandstone with some phyllite and phyllonite strata. The asbestos ore body at Clinton Creek consisted of cross fibre chrysolite asbestos veinlets cutting jade green serpentine, believed to be a result of granitic intrusions or shearing and thrusting.

The Clinton Creek Mine site's structural geology is characterized by a series of steeply dipping normal faults and low angle thrust faults criss-crossing the area. The normal faults are near vertical and tend to bound the ore body. The low angle thrust faults occur near the contact of the two assemblages. The bedrock is mostly covered with overburden, however scattered outcrops are found throughout the lower portions of the Clinton and Wolverine Valleys. The overburden typically consists of silty sandy gravel (colluvium) deposits on the slopes and sand and gravel (alluvium) deposits in the valleys. The mill site ridge consists of fluvial-lacustrine granular deposits.

4.0 DRAINAGE AND HYDROLOGY

The mine site is located along Clinton Creek approximately nine kilometres upstream from Forty Mile River. Two main tributaries, Wolverine and Porcupine Creeks, join with Clinton Creek within the mine site area as shown on Drawing 02. Their respective drainage areas are approximately 28.6 and 4.7 square kilometres. The drainage area of Clinton Creek is approximately 116.6 square kilometres upstream of the confluence with Wolverine Creek, increasing to 203.8 square kilometres at the junction with Forty Mile River. Forty Mile River flows into the Yukon River two kilometres downstream of the Clinton Creek confluence. The Yukon River flows towards the north west and enters Alaska approximately seventy kilometres downstream of the former Clinton Creek Town-site.

5.0 PHYSICAL CONDITIONS

5.1 CLINTON CREEK WASTE ROCK DUMP

The waste rock from the Porcupine Pit placed along the south slope of the Clinton Creek valley is referred to as the Clinton Creek Waste Rock Dump (Drawing 03). The waste rock dump consists of overburden and argillite waste rock consisting of sand, gravel and cobble sizes containing occasional boulder size material. Significant lateral spreading of the rock fill, in particular at the west end of the dump towards Hudgeon Lake, has occurred as a consequence of instabilities associated with the placement of waste rock during the mining operation. Active movement of the waste rock dump has continued since the mine closure as seen in Photo 1(1986).

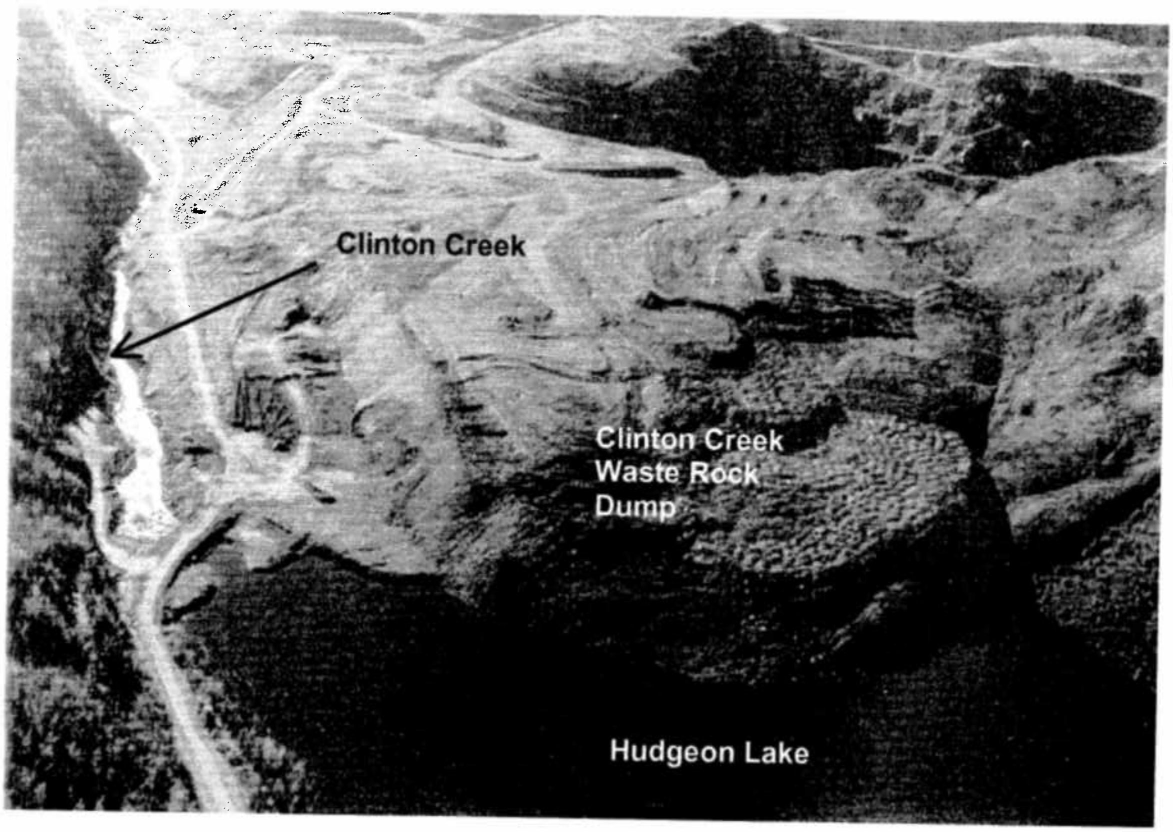


Photo 1
Clinton Creek Waste Rock Dump

The surface of the waste rock dump is hummocky with a series of benches, slump blocks and tension cracks resulting from the on-going displacements (Photo UMA 9-9 and 9-4). Ground vegetation in the areas of the waste rock dump is extremely scarce and plant diversity very low. Ground vegetation species at the waste rock site was similar to that found at the tailings site. Nevertheless, the re-establishment of trees and vegetation in general has been much greater at the waste rock site than on the tailings lobes.

Photo UMA 9-9
Slumping of Waste Rock Dump (1998)

Photo UMA 9-4
Tension Cracks West End of Waste Rock Dump (1998)

During the operation of the mine, ground movement monitoring monuments were installed to monitor the movement of the waste rock dump slope. The survey monuments were surveyed for horizontal and vertical movements annually from 1977 (just prior to the closure of the mine) to 1986. The devices consisted of survey prisms mounted on steel rods which are driven into the waste rock. Most of the monuments are identified with conical sheet metal markers. During the site reconnaissance several of the monuments were observed. Monument locations at the waste rock dump are shown on Drawing 03 and a typical marker (shown on the tailings pile) is shown in Photo UMA 5-12.

Photo UMA 5-12
Typical Ground Movement Monitoring Monument (1998)

Several cross-channel reference lines were also established along Clinton Creek to monitor vertical and horizontal waste rock movements towards and into the creek channel. The cross-channel reference lines consist of steel bars driven into the waste rock along the north edge of the road on the south side of the creek. At each reference line, corresponding survey prisms are mounted on steel rods driven into the north valley slope. Six cross-channel reference lines were re-established during UMA's 1999 site surveys (Drawing 03). Based on surveys completed in July 1999, on-going waste rock movements are evident.

5.2 CLINTON CREEK CHANNEL

The road crossing at the lake outlet has been washed out and only two of the original four-1.8m diameter corrugated metal pipe (CMP) culverts remain, one of which (north) was only partially intact. Outflow from Hudgeon Lake passes through the culverts and between the north culvert and the north bank (Photo UMA 8-9). The inlet of the south culvert is not visible and is blocked by debris, limiting flow. Water depths in the open channel were estimated at 0.5 metres in September 1998 and 0.1 metres in July 1999 (Photo UMA 15-0/1). The north culvert is badly out of round. A CMP section visible in the channel through the waste rock dump a considerable distance downstream is believed to be a missing section of this culvert.

Photo UMA 8-9
Hudgeon Lake Outlet and Access Road Culverts (1998)

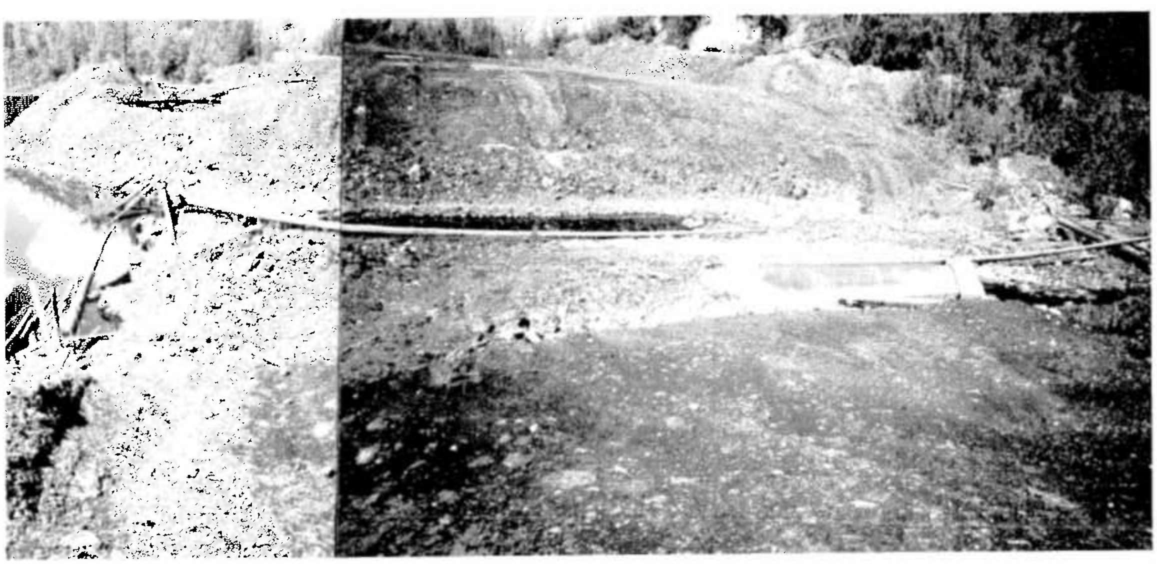


Photo UMA 15-0/1
Hudgeon Lake Outlet and Access Road Culverts (1999)

Previous erosion control works (rip rap armouring) constructed in 1979 were almost completely destroyed in the spring of 1997 (Photo RRU-1).

Photo RRU-1
Clinton Creek Channel Immediately Downstream of Outlet (1998)

Since 1986, down-cutting near the Hudgeon Lake outlet has occurred (Photo UMA 7-24). Up to 2 to 3 metres of incising has occurred immediately downstream of the outlet where the channel bed is bounded to the south by waste rock and to the north by natural colluvial soils overlying bedrock on the valley slope. Two springs discharge from the waste rock just downstream of the lake outlet. Water from both springs is clear with no evidence of fines. Brown slime was growing over the rocks at the downstream spring and the water had a noticeable hydrogen sulphide odour.

Photo UMA 7-24
Channel Down-cutting Immediately Downstream of Hudgeon Lake Outlet

Channel widening and incising is evident throughout the waste rock dump where both waste rock and valley material is being actively eroded (Photo UMA 7-17).

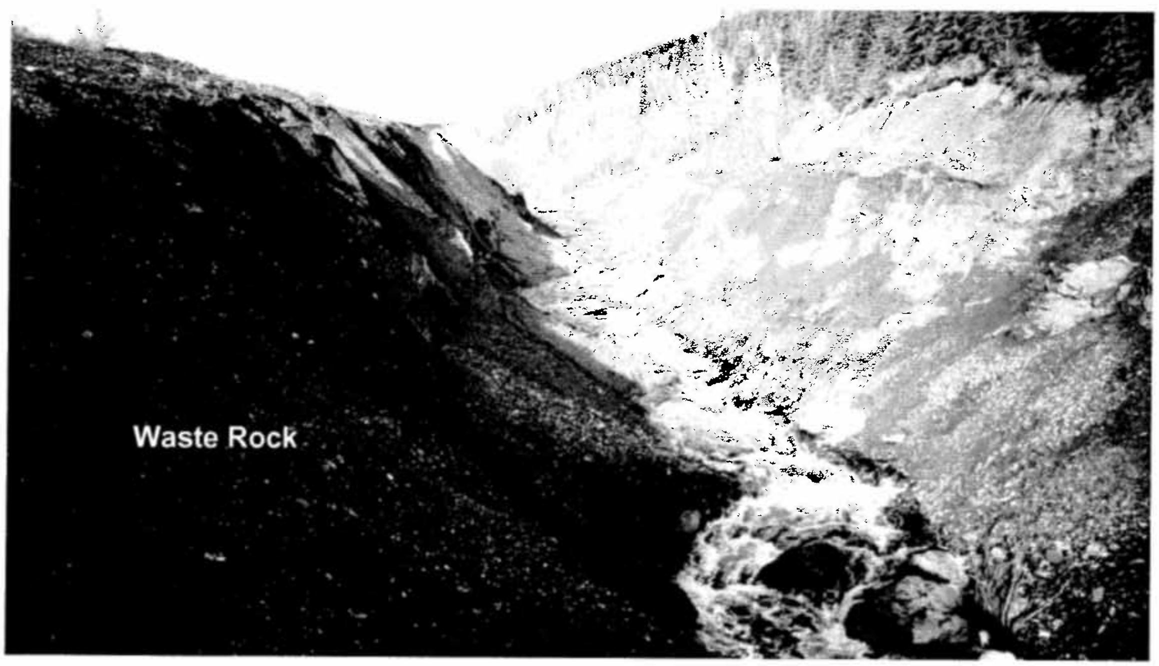


Photo UMA 7-17
Channel Erosion (1998)

Numerous slumps and localized slope failures are occurring on both the waste rock and valley slopes (Photo UMA 7-6) as a result of channel erosion and incising. These localized instabilities have lead to meandering of the stream bed which has impacted the integrity of the access road along the waste rock dump. Tension cracks are visible along the north shoulder of the access road (Photo UMA 7-14) and narrowing of one section of the access road has occurred as a result of a slope failure into the channel (Photos UMA 14-18/19 and UMA 2-8).

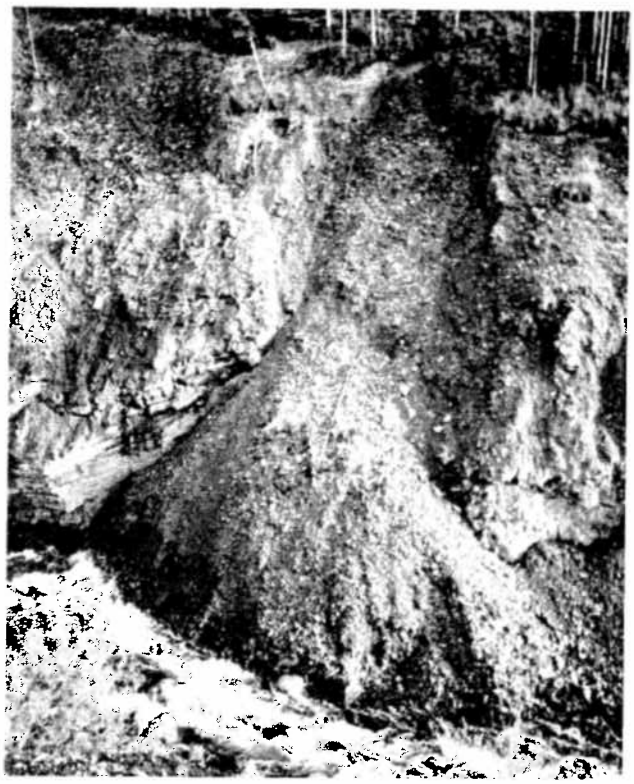


Photo UMA 7-6
Slumping of Valley Slope(1998)

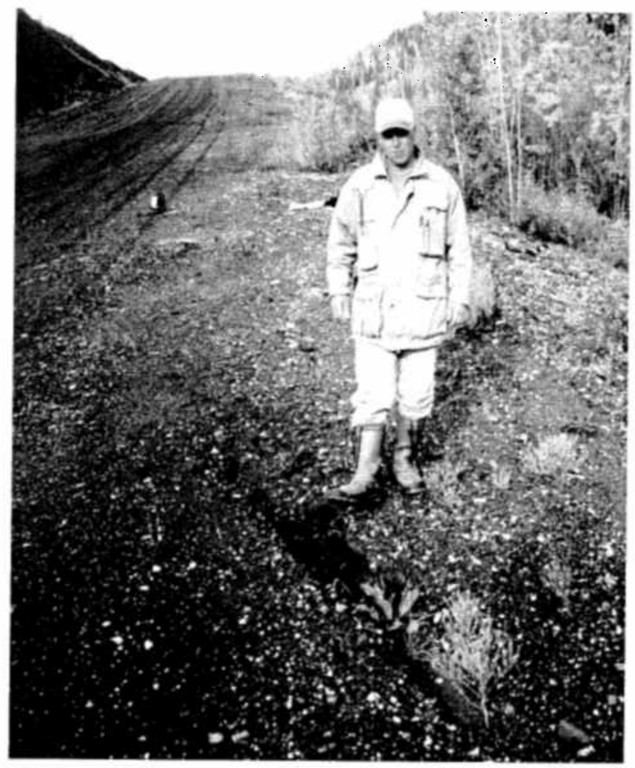
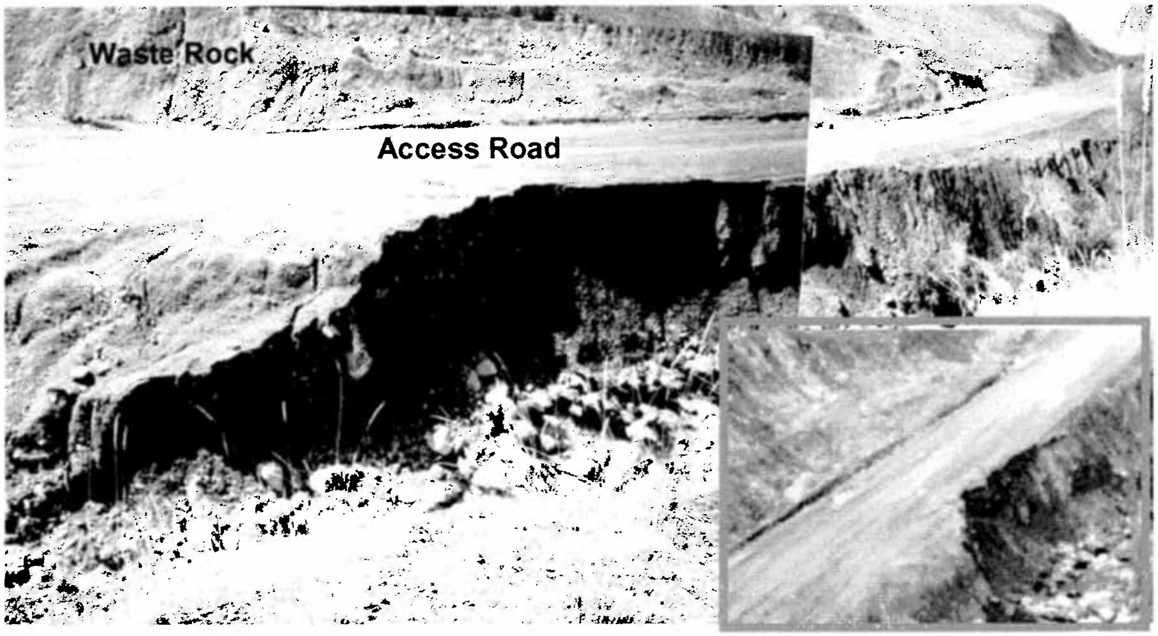


Photo UMA 7-14
Tension Cracks in Waste Rock Along Access Road (1998)



Photos UMA 14-18/19 and UMA 2-8 (Insert)
Slope Failure Along Access Road (1998 &1999)

Downstream portions of the creek channel through the waste rock slope have been cut into the weathered argillite bedrock on the valley slope (Photo UMA 14-15). At these locations, the bedrock consists of a weathered weaker bedrock unit overlying a stronger more competent bedrock unit with horizontal to slightly dipping bedding planes.

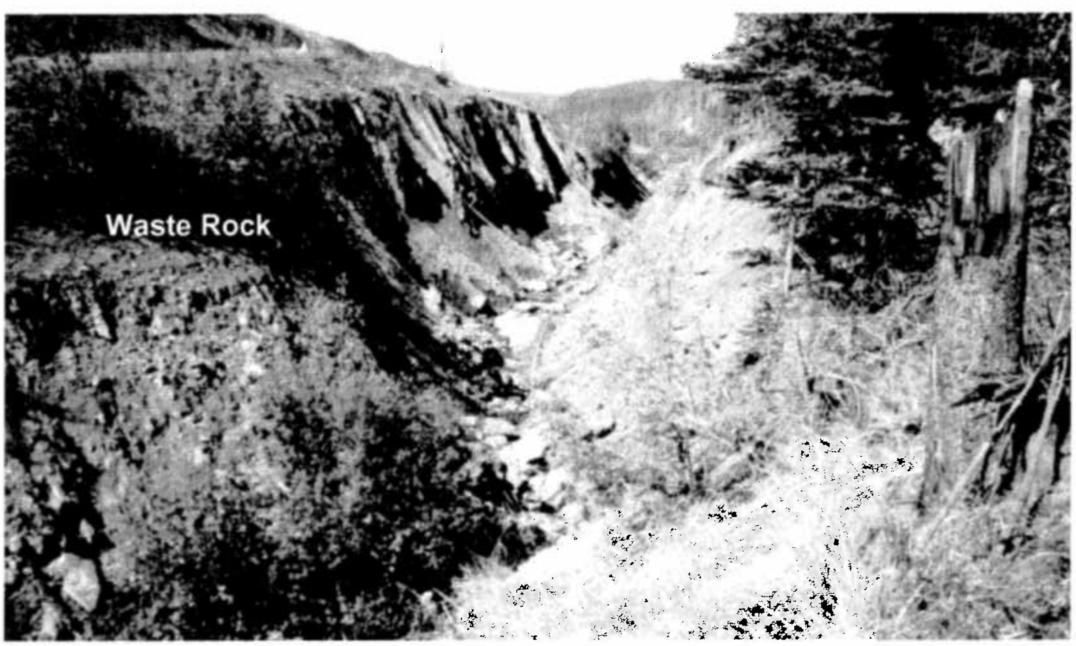


Photo UMA 14-15
View Upstream Along Creek Channel (1998)

The timber access road bridge at the downstream toe of the waste rock dump was washed out in the spring of 1997 (Drawing 03). The creek valley in the area of the bridge was infilled with out-wash material where a new creek channel was incised (Photo UMA 14-20/21/22). The out-wash (flow debris) material consists of gravel and cobbles up to 200 millimetres in diameter. Several channel remnants and evidence of significantly wider historic channel flow are visible. High water marks on trees immediately downstream of the waste rock dump are about 0.6 metres above the ground surface, or about 1.5 to 2 metres higher than the existing creek channel. At locations as far as 200 metres downstream of the bridge, trees and brush have trapped debris.

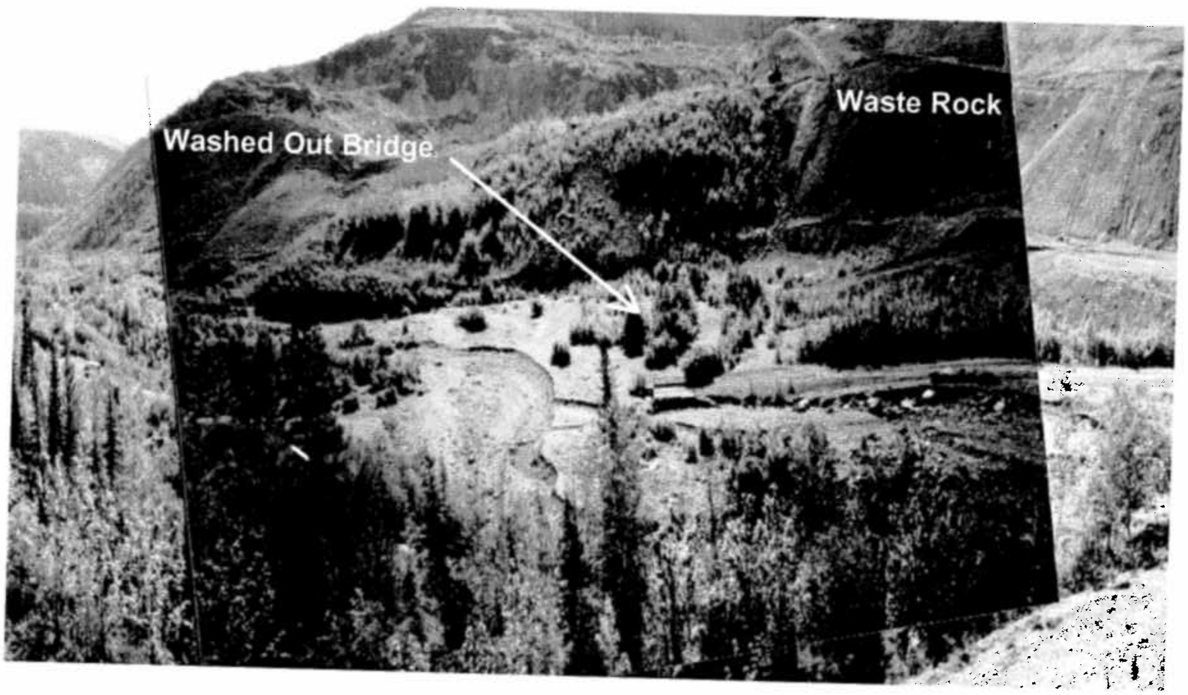


Photo UMA 14-20/21/22
Clinton Creek Channel at Washed Out Bridge Location (1998)

The confluence of Clinton Creek and Wolverine Creek is approximately 500 metres downstream of the washed out bridge. Under normal flow conditions, Wolverine Creek drops approximately two metres into Clinton Creek through a 1600 millimetre diameter steel plate (19 millimetre thick) culvert under the access road. As seen in Photo UMA 2-6, a significant amount of tailings out-wash material has been deposited within the Wolverine Creek channel just upstream of the culverts. Beaver dams several hundred metres downstream of the bridge have flooded a large area near the junction of Wolverine and Clinton Creek.

Photo UMA 2-6
Confluence of Wolverine Creek and Clinton Creek (1998)

The access road culvert is in good condition. The outlet of a second culvert (corrugated metal pipe) located at a lower elevation was submerged in the Clinton Creek stream bed (Photo UMA 15-10 and 15-8). The invert of a third 1200 millimetre diameter culvert, located immediately south of the Wolverine Creek outlet culvert, is set about 1 metre higher.

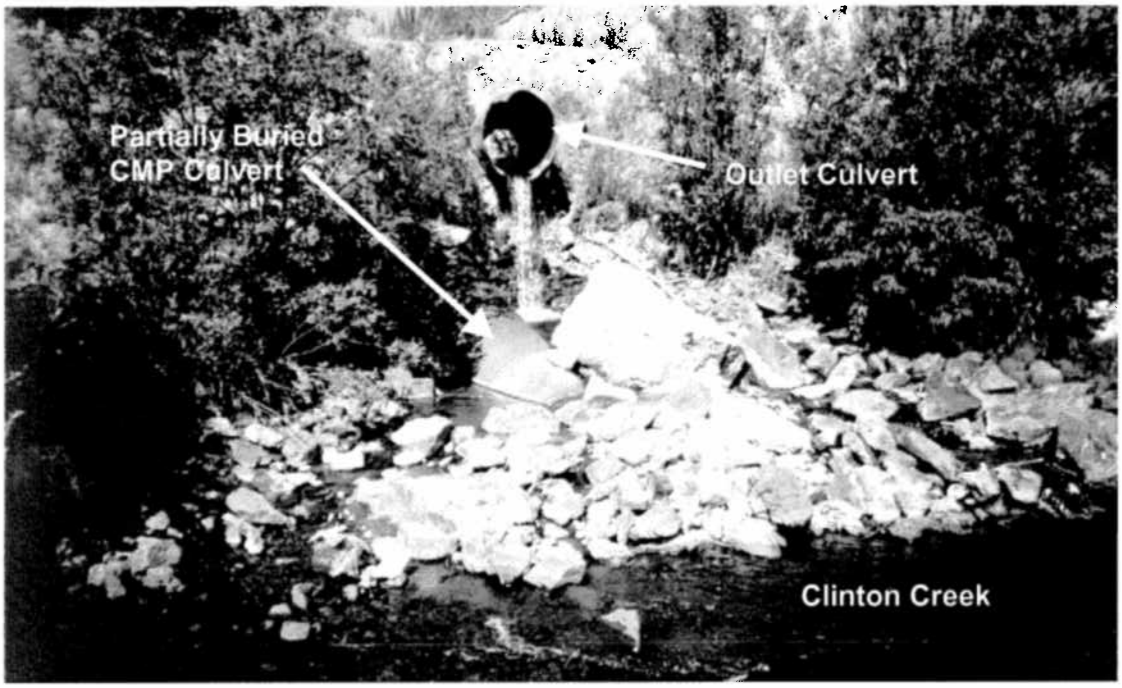


Photo UMA 15-10
Wolverine Outlet Culvert at Clinton Creek (1999)

Photo UMA 15-8
Wolverine Creek Outlet Culvert (1999)

5.3 HUDGEON LAKE

The deepest point of the lake (approximately 27 metres) occurs at the east end near the confluence of Bear Creek. The surface area and volume of Hudgeon Lake are estimated to be approximately 115 ha and 12 million cubic metres respectively. The results of a bathymetric survey carried out by Royal roads University are summarized in Figure 3-1.

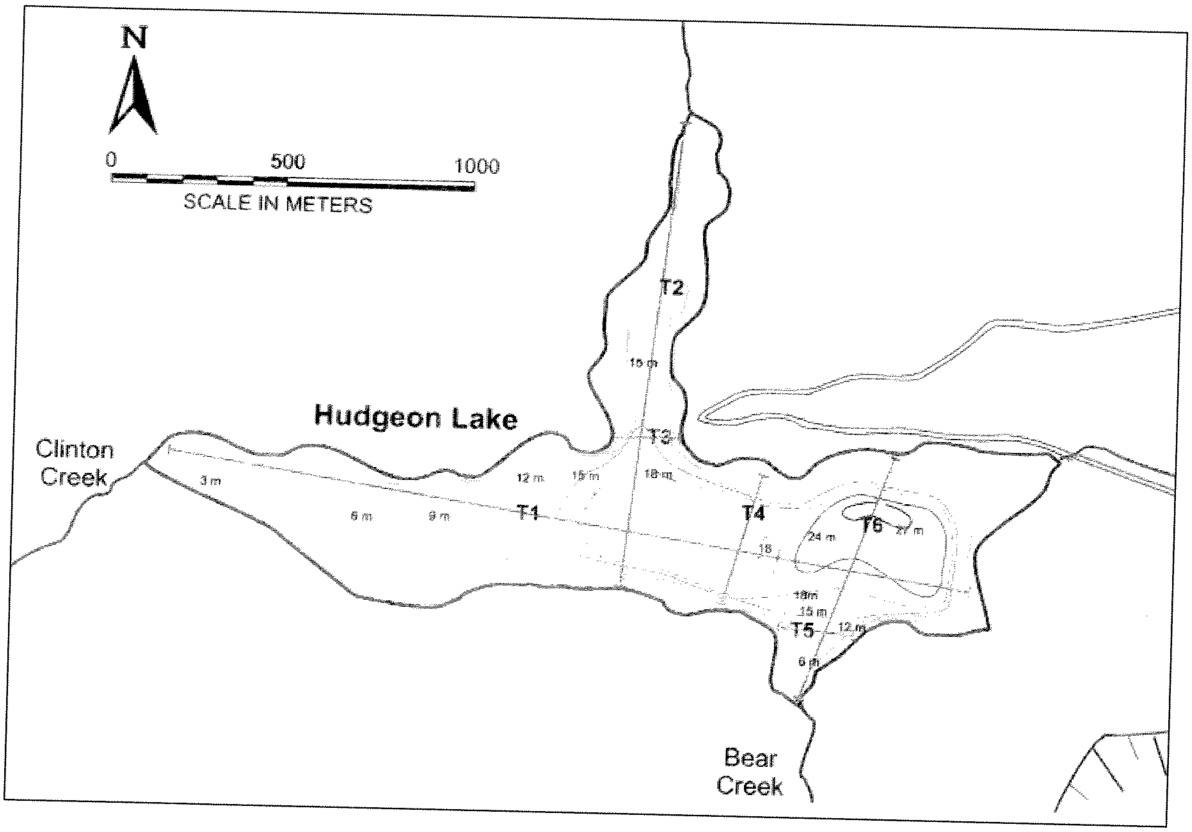


Figure 3-1
Bathymetry of Hudgeon Lake (Royal Roads University, 1998)

5.4 PORCUPINE PIT

Porcupine pit walls are a maximum height of about 200 metres inclined at approximately 45 to 50 degrees (Photo UMA 11-1). Water is currently ponded in the bottom of the pit at approximately elevation 385 metres. Instabilities of the pit walls are evident, in particular along the north and west sides. The instabilities range from ravelling and small wedge failures along the remnants of the pit benches to deep seated movements along the west side where back scarps and tension cracks well back from the edge of the pit wall are visible. Sloughing of the pit walls is clearly evident and debris could be heard falling into the water during the reconnaissance in the area.

Photo UMA 11-1
View East at Porcupine Pit (1998)

The former Crusher Building is situated near the crest between Porcupine Pit and Creek Pit, across the valley from the mill site (Drawing 04, Photo RRU-3 and Photo RRU-4). Large sections of the metal roofing and metal siding are missing and there is scattered debris in the general area. Remnants of what may have been the hydro sub-station are located at the base of the Creek Pit Road.

Photo RRU-3
Crusher Building (1998)

Photo RRU-4
Crusher Building (1998)

Abandoned equipment, including a drag line excavator and a drill rig, are located down slope, north of the Crusher Building (Photo RRU-5 and Photo RRU-6).

Photo RRU-5
Abandoned Equipment (1998)

Photo RRU-6
Excavator (1998)

5.5 PORCUPINE CREEK WASTE ROCK DUMP

Waste rock material placed on the north east side of Porcupine Pit has resulted in blockages of natural drainage along Porcupine Creek (Drawing 04 and Photo UMA 10-2) and the formation of a small unnamed reservoir. The two northeasterly blockages are relatively stable with no signs of active movement. The southwestern section of the waste rock dump has undergone extensive movement, however, resulting in numerous tension cracks and back scarps as shown in Photo UMA 11-0.

Photo UMA 10-2
Porcupine Creek Northern Waste Rock Blockage (1998)

Photo UMA 11-0
Porcupine Creek Waste Rock Failure Backscarp (1998)

An above ground storage tank is visible on the aerial photography on Drawing 04 at the top of the ridge west of Porcupine Pit in an area believed to have formerly housed a fertilizer storage facility.

5.6 PORCUPINE CREEK CHANNEL

Impounded water upstream of the waste rock dump continues to flow either below or through the waste rock or along the east valley slope in subterranean channels. The majority of flow occurs via a drainage channel incised through the slide debris from the unstable southern portion of the waste rock where it enters the waste rock pile (Drawing 04 and Photo UMA 10-9).

Photo UMA 10-9
Inlet into Waste Rock (1998)

Water draining internally through the waste rock discharges through the waste rock about 5 metres above the toe of the north slope, approximately 550 metres to the north of the inlet (Spring A). In September 1998, discharge at Spring A was estimated to be in the order of 10 l/s approximately 5 m above ground surface. Localized slumping of the waste rock is evident at the discharge point as illustrated in Photo UMA 11-3. Water is subsequently conveyed along a drainage channel incised along the south edge of the road where it eventually spills into the Creek Pit.

Photo UMA 11-3
Spring A at Porcupine Creek Waste Rock Dump (1998)

Discharge is also occurring via subterranean flow along the toe of the waste rock and east valley slope where flowing water is visible below the organic mat on the valley slope (Photo UMA 9-24, Drawing 04). Discharge from the subterranean flow system occurs as a spring (Spring B) near the northwest corner of the waste rock dump (Drawing 04). Some fine grained material has been deposited at the discharge point.

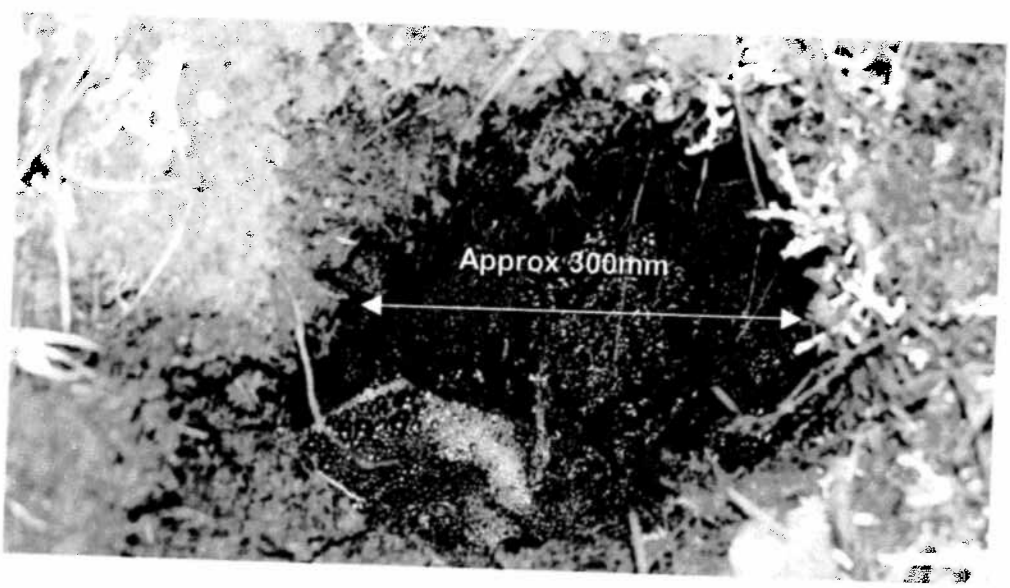


Photo UMA 9-24
Subterranean Flow at SE Edge of Waste Rock (1998)

5.7 TAILINGS PILES

The tailings from the milling process were originally deposited with a stacker conveyor over the valley crest on the west slope of Wolverine Creek (Drawing 05). The mill tailings generally consist of well graded 25 millimetre down crushed serpentine rock with some asbestos fibre not removed during milling. In 1974, a sudden failure of the tailings pile (referred to as the south lobe) lead to a complete blockage of Wolverine Creek. Following the failure of the south lobe, tailings were deposited further north along the west slope of Wolverine Creek. This area is referred to as the north lobe. Gradually, failure of the north lobe lead to another blockage of the creek channel just upstream of the south lobe (Photo UMA 1-3).

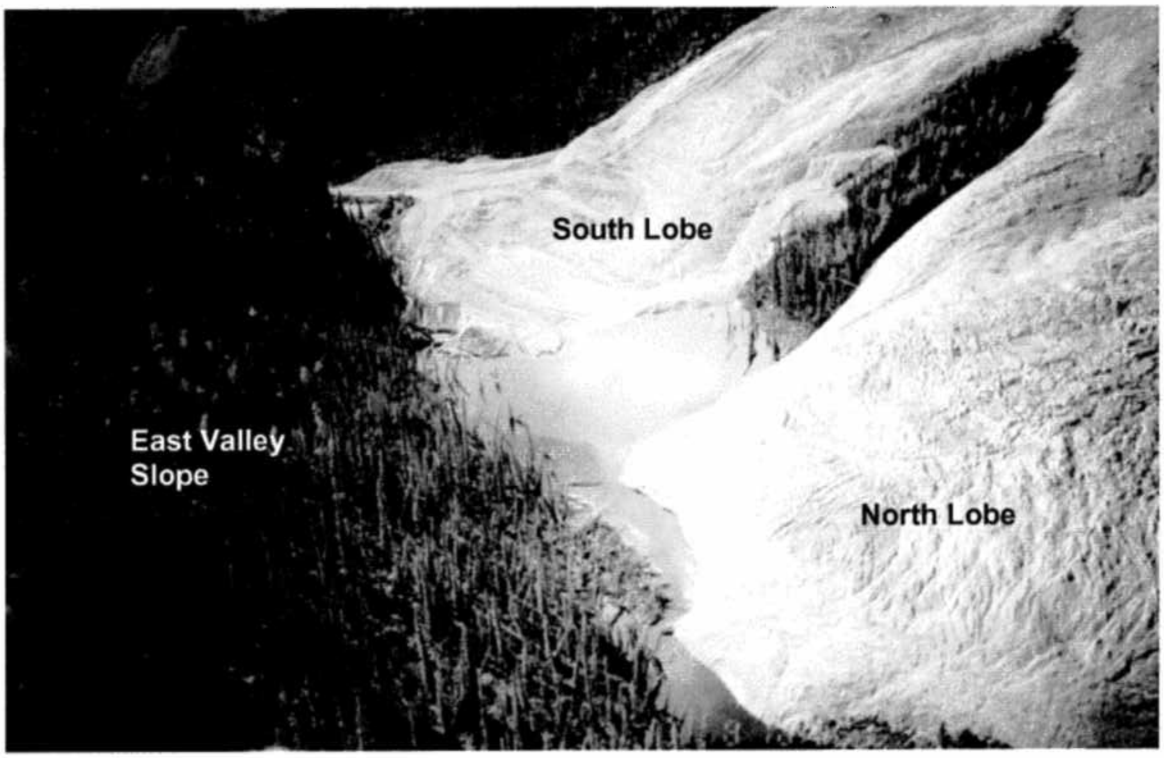


Photo UMA 1-3
North and South Tailing Lobes (1998)

Continued instabilities of the south and north lobes are evident with numerous tension cracks and slump blocks between the crest and toe (Photo UMA 3-6 and 1-6). As a result of the on-going instabilities, the leading edge of the lobes gradually advance into the Wolverine Creek channel where the tailings are eroded and transported downstream (Photo UMA 5-20).

Photo UMA 3-6
View West at Failed Tailings Pile(1998)

Photo UMA 1-6
Tension Cracks and Slumping at Top of Tailings Pile (1998)

Photo UMA 5-20
Erosion at Toe of Advancing Tailings (1998)

In addition to the channel obstruction created by the advancing tailings, heaving of the valley floor directly in the path of the advancing north lobe is evident (Photo RRU-10). A small reservoir is located upstream of the tailings lobes on Wolverine Creek creating by the blockage of the creek channel as shown on Drawing 05.

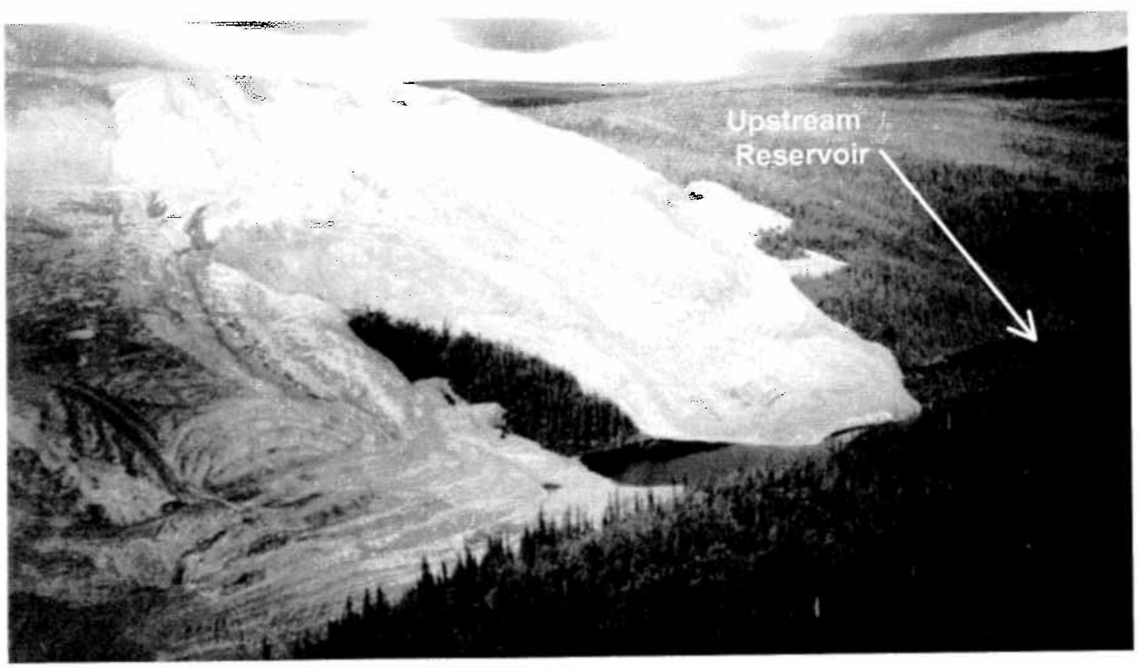


Photo RRU-10
View North West at Tailings Pile (1998)

Several ground movement monitoring monuments with conical sheet metal markers, similar to those found at the waste rock dump site, are located on both the north and south tailings lobes.

5.8 WOLVERINE CREEK CHANNEL

Four beaver dams (numbered 1 to 4) are located between the upstream side of the north lobe and the downstream side of the south lobe as shown on Drawing 05. Beaver dam 1 is located at the north end of the north lobe where the valley floor has heaved. The first beaver dam has raised the water level in the upstream reservoir about 1 metre higher than would occur from the overburden blockage at this location. High water marks on the trees in the upstream reservoir suggest water levels have been about 0.5 metres higher than were observed in September 1998. Surficial slumping of the east valley slope is also occurring opposite from beaver dam 1.

The second beaver dam, located between the upstream side of a small channel island and the toe of the north tailings lobe, does not impound a significant amount of water. The third beaver dam is located at the upstream end of the south lobe as shown in Photo UMA 5-18 and is responsible for raising the water level in the pond between the two tailings lobes by at least one metre. Beaver dam 4 is located immediately downstream of dam 3.

Photo UMA 5-18
Beaver Dam 3, Wolverine Creek (1998)

The four beaver dams have reduced channel velocities and erosion of the channel where the tailings piles meet the toe of the valley slope. Downstream of the beaver dams however, velocities increase significantly as the channel narrows and the gradient steepens. Within this stretch, the channel has down-cut into the underlying weathered argillite bedrock resulting in surficial slumping of the overburden soils (Photo UMA 5-23). A series of rock weirs line the channel immediately downstream of the south lobe. Flow is contained within the channel with no significant erosion or down-cutting observed. Ground vegetation in the areas of the tailings lobes is extremely scarce and plant diversity very low. Mats of chrysotile asbestos were observed in the lower branches of trees at a height corresponding to that of the snow pack.

Photo UMA 5-23
View Upstream Along Wolverine Creek *(1998)*

5.9 MILL SITE

The former Clinton Creek Asbestos Mine mill was located on the crest of the north slope of Clinton Creek west of Wolverine Creek, as shown on Drawing 05 and shown in the background of Photo RRU-7. Physical remnants of the mill include the following:

- concrete foundations and floor slabs of the former service building and former fibre building,
- two conveyor shafts,
- two large above ground diesel storage tanks (ASTs),

- two small structures near the location of the former office building and
- the terminus and intermediate foundation structures for the overhead tram (Photo RRU-8).

Sump pits within the foundation slab of the service building are debris filled with a noticeable hydrocarbon odour. Hydrocarbon staining was visible on the surface of the foundation slab which is extensively cracked. A large volume of fill material (likely tailings) has been deposited on the east side of the former fibre building, south of the former dryer building as shown in Photo RRU-9. Demolition debris is scattered throughout the mill site area.

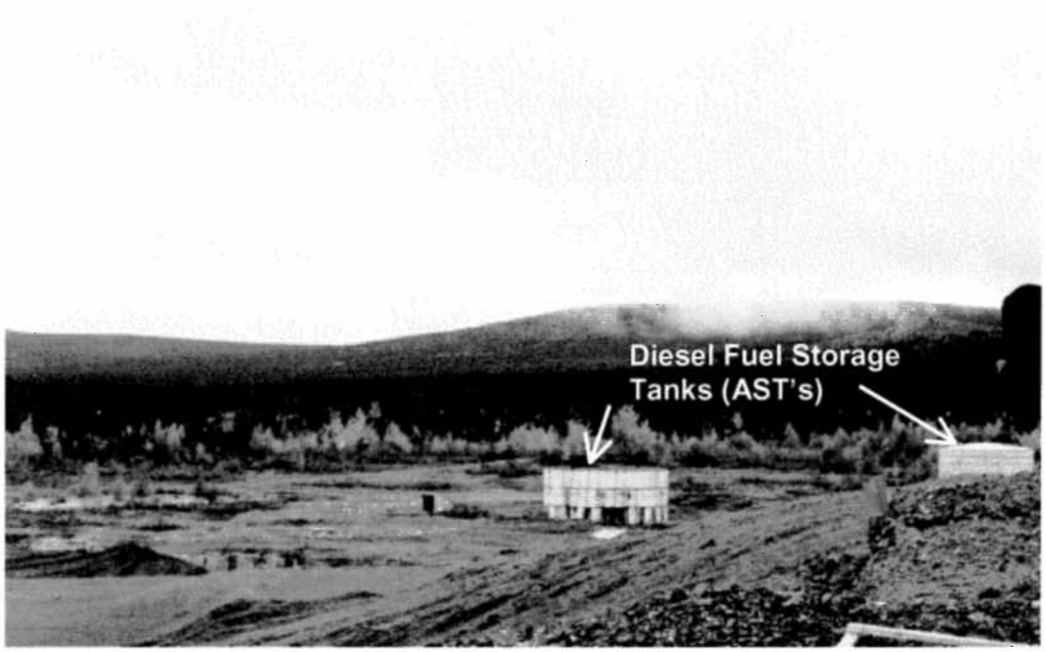


Photo RRU-7
View of Mill Site From Tailings Pile (1998)

The former aerial tramline terminated at a large steel tower on a suspected concrete footing or piles (Photo RRU-8). Seven intermediate towers are located between the terminus and the Crusher Building as seen in Photo RRU-9 and on Drawing 02. The intermediate towers are steel and are also likely founded on concrete footings or piles.

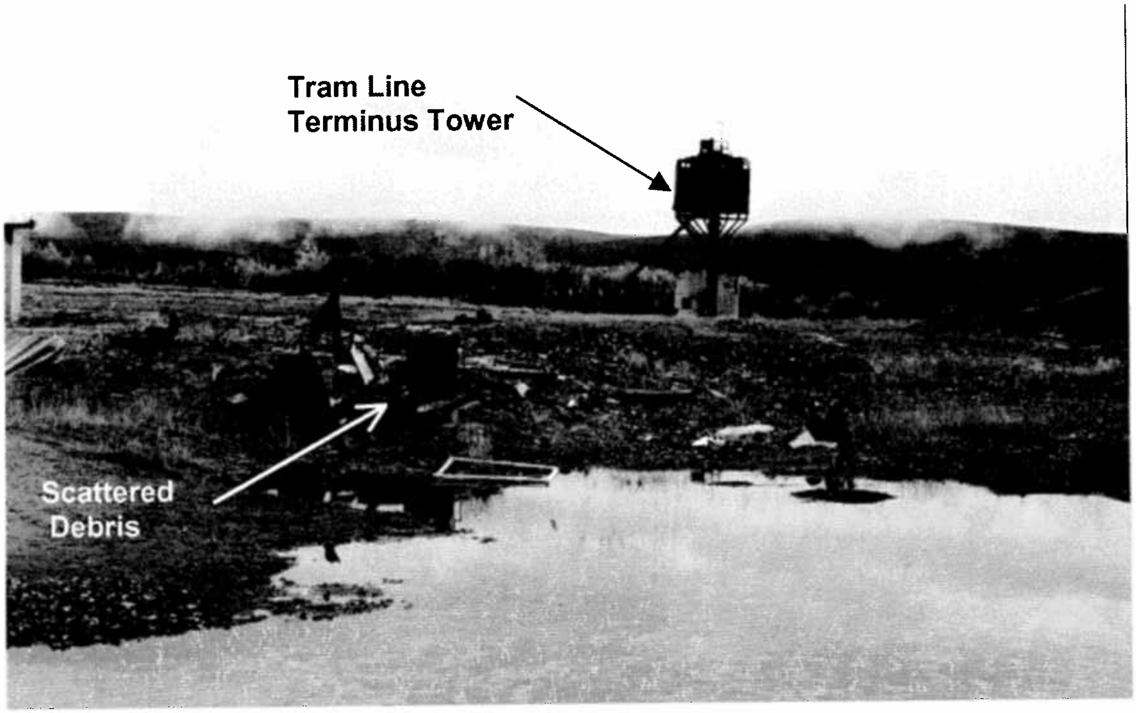


Photo RRU-8
Mill Site Area(1998)

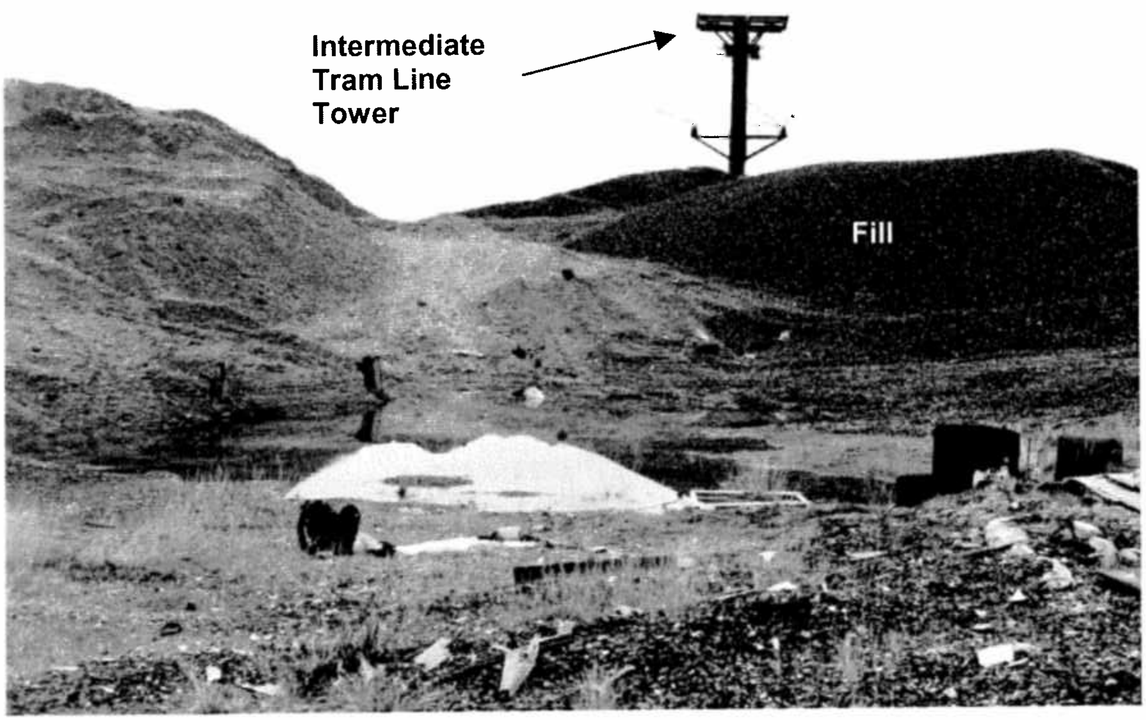


Photo RRU-9
Fill Material Above Fibre Building Foundation (1998)

6.0 GEOCHEMICAL SAMPLING RESULTS

A total of 32 soil samples were collected from the site for Royal Roads University's geochemical assessment of the waste rock and tailings materials. In addition, 27 water and 23 sediment samples were taken from Hudgeon Lake and Wolverine Creek, Forty Mile River and three reference locations. Sampling locations are shown in Figure 4-1 and laboratory analyses of select soil and water samples is provided as Appendix B.

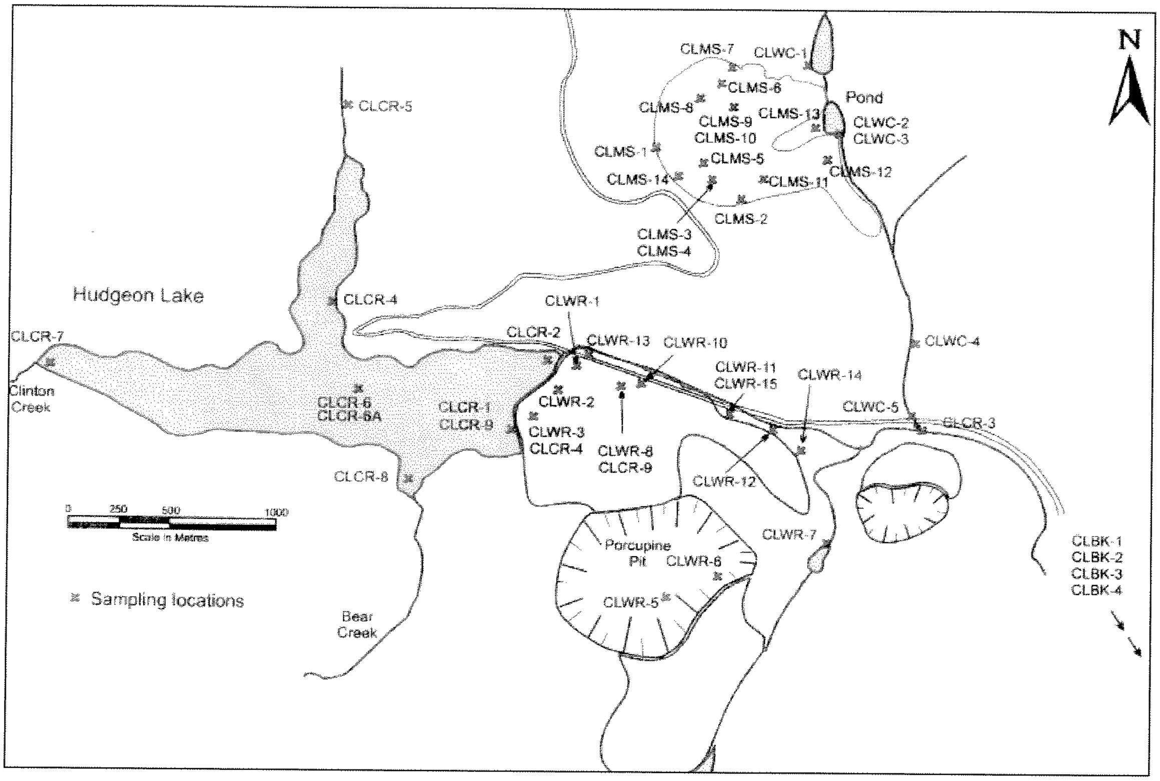


Figure 4-1
Geochemical Sample Location (Royal Roads University, 1998)

The soil, sediment and water samples were analyzed for metals, metalloids and asbestos. Inorganic non-metallic parameters were also determined in the water samples. The soil and water samples constantly demonstrated elevated pH indicating alkaline conditions. Antimony, lead, molybdenum, silver, and tin were generally below the detection limits in soil/sediment samples. Detection limits for these elements, however, were high due to matrix interference caused by elevated chromium and nickel concentrations found in the samples. Concentrations of arsenic, barium, chromium and nickel exceeded the CCME guidelines for residential parkland land use in substrate samples. These elements were not detected in the water samples. Asbestos concentrations in water were elevated. An anoxic condition was noted in a sample collected from the lower depths of Hudgeon Lake.

Thank you for the opportunity to provide continued assistance on this project. Should you have any questions or require additional information, please contact either of the undersigned.

Yours Truly,

UMA ENGINEERING LTD.

Peter R. Bohonos
Project Engineer

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Senior Project Engineer

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APPENDIX A
LIST OF REFERENCES

REFERENCES

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APPENDIX B
GEOCHEMICAL SAMPLING LABORATORY RESULTS

RESULTS OF ANALYSIS - Water File No. J8624

			CLCR-1	CLCR-2	CLCR-3	CLCR-4	CLCR-5
			98 09 13 10:15	98 09 10 11:05	98 09 11 16:30	98 09 10 14:20	98 09 10 16:10
Dissolved Anions							
Alkalinity-Total		$CaCO_3$	-	105	-	-	101
Bromide	Br		-	<0.5	-	-	<0.5
Chloride	Cl		-	<0.5	-	-	<0.5
Fluoride	F		-	0.13	-	-	0.19
Sulphate	SO_4		-	110	-	-	61
Nutrients							
Nitrate Nitrogen		N	-	0.2	-	-	<0.1
Nitrite Nitrogen		N	-	<0.1	-	-	<0.1
Total Metals							
Aluminum	T-Al		0.059	0.067	0.061	0.063	0.066
Antimony	T-Sb		<0.2	<0.2	<0.2	<0.2	<0.2
Arsenic	T-As		<0.2	<0.2	<0.2	<0.2	<0.2
Barium	T-Ba		0.05	0.05	0.05	0.05	0.03
Beryllium	T-Be		<0.005	<0.005	<0.005	<0.005	<0.005
Boron	T-B		<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	T-Cd		<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Calcium	T-Ca		46.8	46.7	48.3	45.4	32.1
Chromium	T-Cr		<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	T-Co		<0.01	<0.01	<0.01	<0.01	<0.01
Copper	T-Cu		0.02	<0.01	<0.01	<0.01	<0.01
Iron	T-Fe		0.23	0.25	0.27	0.24	0.17
Lead	T-Pb		<0.001	<0.001	<0.001	<0.001	<0.001
Magnesium	T-Mg		26.0	27.1	27.7	26.3	21.9
Manganese	T-Mn		0.110	0.118	0.108	0.107	0.010
Mercury	T-Hg		<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum	T-Mo		<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	T-Ni		<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	T-Se		0.0014	<0.001	0.0012	0.0009	<0.001
Silver	T-Ag		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Thallium	T-Tl		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Uranium	T-U		0.00141	0.00151	0.00149	0.00150	0.00159
Zinc	T-Zn		<0.005	<0.005	<0.005	<0.005	<0.005

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

File No. J8624

			CLCR-6	CLCR-6A	CLCR-7	CLCR-9	CLCR-Z6
			98 09 10 17:00	98 09 11 11:00	98 09 10 17:15	98 09 13 10:20	98 09 11 14:05
Dissolved Anions							
Alkalinity-Total		CaCO3	102	337	98	-	120
Bromide	Br		<0.5	<0.5	<0.5	-	<0.5
Chloride	Cl		<0.5	2.2	<0.5	-	0.7
Fluoride	F		0.14	0.26	0.17	-	0.18
Sulphate	SO4		111	307	106	-	148
Nutrients							
Nitrate Nitrogen		N	0.2	<0.1	0.2	-	0.2
Nitrite Nitrogen		N	<0.1	<0.1	<0.1	-	<0.1
Total Metals							
Aluminum	T-Al		0.062	0.08	0.123	0.059	0.220
Antimony	T-Sb		<0.2	<0.2	<0.2	<0.2	<0.2
Arsenic	T-As		<0.2	<0.2	<0.2	<0.2	<0.2
Barium	T-Ba		0.05	0.11	0.05	0.05	0.05
Beryllium	T-Be		<0.005	<0.005	<0.005	<0.005	<0.005
Boron	T-B		<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	T-Cd		<0.0002	<0.0004	<0.0002	<0.0002	<0.0002
Calcium	T-Ca		45.0	122	45.7	44.9	53.5
Chromium	T-Cr		<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	T-Co		<0.01	<0.01	<0.01	<0.01	<0.01
Copper	T-Cu		<0.01	<0.01	<0.01	<0.01	<0.01
Iron	T-Fe		0.24	0.94	0.26	0.21	0.42
Lead	T-Pb		<0.001	<0.002	<0.001	<0.001	<0.001
Magnesium	T-Mg		26.3	67.7	25.8	25.7	35.8
Manganese	T-Mn		0.117	2.70	0.112	0.111	0.149
Mercury	T-Hg		<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum	T-Mo		<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	T-Ni		<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	T-Se		<0.001	<0.002	0.0011	0.0013	0.0011
Silver	T-Ag		<0.0001	<0.0002	<0.0001	<0.0001	<0.0001
Thallium	T-Tl		<0.0001	<0.0002	<0.0001	<0.0001	<0.0001
Uranium	T-U		0.00148	0.00231	0.00145	0.00141	0.00142
Zinc	T-Zn		<0.005	<0.005	<0.005	<0.005	<0.005

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

1988 Triumph Street, Vancouver, B.C., Canada V5L 1K5

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FAX: (604) 253-6700 TEL: (604) 253-4188

CHEMICAL ANALYSIS REPORT

Date: October 1, 1998

ASL File No. J8625

Report On: Yukon Sediment Analysis

Report To: **Royal Roads University**
Applied Research Division
2005 Sooke Road
Victoria, BC
V9B 5Y2

Attention: **Dr. Matthew Dodd**, Professor

Received: September 16, 1998

ASL ANALYTICAL SERVICE LABORATORIES LTD.
per:

Frederick Chen, B.Sc. - Manager, Special Projects
Brent A. Makelki, B.Sc. - Supervisor, Client Services

REMARKS

File No. J8625

Please note that the detection limits for several metals parameters have been increased due to matrix interferences caused by elevated chromium and nickel concentrations found in the samples.

RESULTS OF ANALYSIS - Sediment/Soil

File No. J8625

		CLMS-1S	CLMS-2S	CLMS-3S	CLMS-5S	CLMS-9S
		98 09 12 10:45	98 09 12 11:30	98 09 12 12:10	98 09 12 12:35	98 09 12 16:00
Physical Tests						
Moisture	%	43.4	27.0	9.8	15.5	15.4
pH		8.86	9.08	8.59	7.93	8.43
Total Metals						
Antimony	T-Sb	<100	<100	<100	<40	<80
Arsenic	T-As	74	14	3.2	160	265
Barium	T-Ba	981	207	279	502	228
Beryllium	T-Be	<3	<3	<3	<1	<2
Cadmium	T-Cd	<0.1	<0.1	<0.1	2.0	<0.1
Chromium	T-Cr	1410	1380	1650	771	928
Cobalt	T-Co	103	81	87	60	76
Copper	T-Cu	7	<5	<5	30	<4
Lead	T-Pb	<300	<300	<300	<100	<200
Mercury	T-Hg	0.109	0.018	0.018	0.172	0.409
Molybdenum	T-Mo	<20	<20	<20	<8	<20
Nickel	T-Ni	2210	2030	2140	1150	1740
Selenium	T-Se	<0.1	<0.1	<0.1	3.5	<0.1
Silver	T-Ag	<10	<10	<10	<4	<8
Tin	T-Sn	<50	<50	<50	<20	<40
Vanadium	T-V	26	21	11	34	<8
Zinc	T-Zn	30	13	14	133	6

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per dry kilogram except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Sediment/Soil

File No. J8625

		CLMS-10S	CLMS-11S	CLMS-12S	CLMS-13S	CLWC-1S
		98 09 12 16:05	98 09 12 16:50	98 09 12 17:20	98 09 12 18:30	98 09 12 16:05
Physical Tests						
Moisture	%	13.3	7.7	10.6	9.5	45.5
pH		8.52	9.55	8.56	7.02	6.46
Total Metals						
Antimony	T-Sb	<60	<40	<100	<20	<20
Arsenic	T-As	321	2.4	2.4	7	11
Barium	T-Ba	588	5	346	270	223
Beryllium	T-Be	<2	<1	<3	0.8	<0.5
Cadmium	T-Cd	<0.1	<0.1	<0.1	0.4	0.6
Chromium	T-Cr	1430	1530	1470	36	62
Cobalt	T-Co	99	65	111	19	11
Copper	T-Cu	3	<2	<5	42	26
Lead	T-Pb	<200	<100	<300	<50	<50
Mercury	T-Hg	0.444	<0.005	0.034	0.057	0.080
Molybdenum	T-Mo	<20	<8	<20	<4	5
Nickel	T-Ni	2200	1640	2300	54	70
Selenium	T-Se	<0.1	<0.1	0.1	1.1	1.6
Silver	T-Ag	<6	<4	<10	<2	<2
Tin	T-Sn	<30	<20	<50	<10	<10
Vanadium	T-V	19	8	20	43	30
Zinc	T-Zn	12	9	14	122	97

Remarks regarding the analyses appear at the beginning of this report.
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< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Sediment/Soil

File No. J8625

		CLWC-2S	CLWC-3S	CLMS-14	CLWR-3S	CLWR-4S
		98 09 12 19:15	98 09 12 19:20	98 09 10 10:40	98 09 13 12:00	98 09 13 12:05
Physical Tests						
Moisture	%	29.2	27.2	-	8.1	7.8
pH		8.53	8.37	-	7.92	8.03
Total Metals						
Antimony	T-Sb	<100	<100	-	<20	<20
Arsenic	T-As	11	9	-	13	14
Barium	T-Ba	41	49	-	84	103
Beryllium	T-Be	<3	<3	-	0.5	0.7
Cadmium	T-Cd	<0.1	<0.1	-	2.3	2.5
Chromium	T-Cr	1580	1670	-	19	22
Cobalt	T-Co	88	89	-	15	15
Copper	T-Cu	<5	5	-	58	62
Lead	T-Pb	<300	<300	-	<50	<50
Mercury	T-Hg	0.011	0.016	-	0.299	0.343
Molybdenum	T-Mo	<20	<20	-	14	16
Nickel	T-Ni	1920	1860	-	65	64
Selenium	T-Se	0.1	0.2	-	8	8
Silver	T-Ag	<10	<10	-	<2	<2
Tin	T-Sn	<50	<50	-	<10	<10
Vanadium	T-V	14	21	-	30	36
Zinc	T-Zn	19	25	-	248	238
Polychlorinated Biphenyls						
Total Polychlorinated Biphenyls		-	-	<0.05	-	-

Remarks regarding the analyses appear at the beginning of this report.
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< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Sediment/Soil

File No. J8625

		CLWR-5S	CLWR-6S	CLWR-7S	CLWR-10S	CLWR-11S
		98 09 13 13:50	98 09 13 14:25	98 09 13 15:20	98 09 13 16:00	98 09 13 16:25
Physical Tests						
Moisture	%	18.7	17.6	29.7	6.6	16.5
pH		8.44	7.86	8.42	8.38	8.01
Total Metals						
Antimony	T-Sb	<80	<100	<100	<80	<20
Arsenic	T-As	28	13	17	15	18
Barium	T-Ba	65	397	1060	10	296
Beryllium	T-Be	<2	<3	<3	<2	0.8
Cadmium	T-Cd	0.2	<0.1	0.5	<0.1	1.6
Chromium	T-Cr	1110	1810	625	1180	486
Cobalt	T-Co	55	105	46	76	49
Copper	T-Cu	25	10	21	14	48
Lead	T-Pb	<200	<300	<300	<200	<50
Mercury	T-Hg	0.046	0.142	0.167	0.197	0.297
Molybdenum	T-Mo	<20	<20	<20	<20	12
Nickel	T-Ni	1230	852	867	1710	834
Selenium	T-Se	0.3	0.1	1.2	<0.1	4.4
Silver	T-Ag	<8	<10	<10	<8	<2
Tin	T-Sn	<40	<50	<50	<40	<10
Vanadium	T-V	23	66	47	<8	38
Zinc	T-Zn	29	27	71	8	143

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per dry kilogram except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Sediment/Soil

File No. J8625

		CLWR-5S	CLWR-6S	CLWR-7S	CLWR-10S	CLWR-11S
		98 09 13 13:50	98 09 13 14:25	98 09 13 15:20	98 09 13 16:00	98 09 13 16:25
Physical Tests						
Moisture	%	18.7	17.6	29.7	6.6	16.5
pH		8.44	7.86	8.42	8.38	8.01
Total Metals						
Antimony	T-Sb	<80	<100	<100	<80	<20
Arsenic	T-As	28	13	17	15	18
Barium	T-Ba	65	397	1060	10	296
Beryllium	T-Be	<2	<3	<3	<2	0.8
Cadmium	T-Cd	0.2	<0.1	0.5	<0.1	1.6
Chromium	T-Cr	1110	1810	625	1180	486
Cobalt	T-Co	55	105	46	76	49
Copper	T-Cu	25	10	21	14	48
Lead	T-Pb	<200	<300	<300	<200	<50
Mercury	T-Hg	0.046	0.142	0.167	0.197	0.297
Molybdenum	T-Mo	<20	<20	<20	<20	12
Nickel	T-Ni	1230	852	867	1710	834
Selenium	T-Se	0.3	0.1	1.2	<0.1	4.4
Silver	T-Ag	<8	<10	<10	<8	<2
Tin	T-Sn	<40	<50	<50	<40	<10
Vanadium	T-V	23	66	47	<8	38
Zinc	T-Zn	29	27	71	8	143

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per dry kilogram except where noted.
< = Less than the detection limit indicated.

Westmont, NJ	Piscataway, NJ	Carle Place, NY	Smyrna, GA	Melbourne, FL	Ann Arbor, MI	San Mateo, CA
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EMSL

Thursday, October 1, 1998

Royal Roads University
2005 Sooke Road
Victoria, BC V9B 5Y2

Project: Canada
Attention: Matt Dodd
Ref Number: CA986778
Date Sampled 9-10-98 - 9-12-98

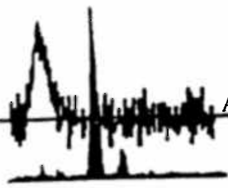
Asbestos Analysis in Water by Transmission Electron Microscopy (TEM) Performed by Method EPA/600/R-94/134 - (100.2)
"Determination of Asbestos Structures Over 10μm In Length in Drinking Water"; by Brackett, Clark & Millette

SAMPLE ID	#ASBESTOS STRUCTURES		#NON-ASBESTOS FIBROUS STRUCTURES	TYPE(S) OF ASBESTOS	CONCENTRATION OF ASBESTOS STRUCTURES (MILLIONS/LITER)		95% Confidence Limits (Lower-Upper) (MILLIONS/LITERS)		DETECTION LIMIT (MFL)
	>10μm	≤10μm			>10μm	Total	>10 μm	Total	
CLCR-Z3B	0	4	0	Chysotile	<1.07	4.29	0.02-5.98	1.17-10.99	1.07
CLCR-Z8	0	1	1	Chysotile	<1.07	1.07	0.02-5.98	0.02-5.98	1.07
CLCR-2 wc	0	22	0	Chysotile	<1.07	22.62	0.02-5.98	14.8-35.76	1.07
CLCR-3 wc	0	9	0	Chysotile	<1.07	9.66	0.02-5.98	4.43-18.34	1.07
CLCR-5	0	8	1	Chysotile	<1.07	8.59	0.02-5.98	3.71-16.92	1.07
CLCR-7	0	5	0	Chysotile	<1.07	5.36	0.02-5.98	1.74-12.51	1.07
CLCR-8	0	0	2	Chysotile	<1.07	<1.07	0.02-5.98	0.02-5.98	1.07
CLCR-Z6	14	128	5	Chysotile	15.03	152.45	8.2-25.22	119.9-191.52	1.07
CLCR-6	0	10	9	Chysotile	<1.07	10.73	0.02-5.98	5.15-19.74	1.07
CLCR-2	2	103	1	Chysotile	2.15	112.73	0.03-7.75	89.13-143.06	1.07
CLCR-6A	1	12	2	Chysotile	1.07	13.96	0.02-5.98	7.43-23.87	1.07
EMSL Blank	0	0	0	None Detected	<0.18	<0.18	0-0.68	0-0.68	0.18

***Samples that contain high levels of particulate which require the laboratory to filter a dilution less than the minimum recommended method volume of 50 ml, will necessarily have higher detection limits. Refer to EPA/600/R-94/134 Method 100.2, Sections 11.10 and 13.6.**

Analyst

Approved Signatory



ACCREDITATIONS: NVLAP #101048-03 and CA STATE ELAP #1620

North West Environmental
Project Number: 1012
Royal Roads University - Bulk Sample Results

15/10/98

NO.	DATE	SAMPLE INFORMATION	DESCRIPTION	ASBESTOS		OTHER	ANALYST
1	07/10/98	CLMS-13 Sediment	1 sediment (100%)	None Detected		cellulose(3%), nf(97%)	RC
2	07/10/98	CLWC-1 Sediment	1 sediment (100%)	None Detected		cellulose(25%), nf(75%)	RC
3	07/10/98	CLWC-2 Sediment	1 sediment (100%)	Chrysotile	10%	nf(90%)	RC
4	07/10/98	CLWC-3 sediment	1 Sediment (100%)	Chrysotile	3-5%	cellulose(2%), nf(93%)	RC
5	07/10/98	CLWR-3 sediment	1 Sediment (100%)	Chrysotile	1-2%	cellulose(2%), nf(97%)	RC
6	07/10/98	CLWR-4 sediment	1 Sediment (100%)	Chrysotile	< 1%	cellulose(1%), nf(99%)	RC

NF = Non-Fibrous material; SS = Small Sample size
PLEASE NOTE: Due to space limitations, these sample(s) will be disposed of after 3 months, unless we are instructed otherwise by our client.

North West Environmental
Project Number: 1012
Royal Roads University - Bulk Sample Results

NO.	DATE	SAMPLE INFORMATION	DESCRIPTION	ASBESTOS		OTHER	ANALYST
7	07/10/98	CLWR-1 sediment	1 Sediment (100%)	Chrysotile	3-5%	cellulose(1%), nf(95%)	RC
8	07/10/98	CLWR-11 sediment	1 Sediment (100%)	Chrysotile	7%	cellulose(1%), nf(92%)	RC
9	07/10/98	CLWR-15 sediment	1 Sediment (100%)	Chrysotile	6%	cellulose(1%), nf(93%)	RC
10	07/10/98	CLBK-1 sediment	1 Sediment (100%)	Chrysotile	3-5%	cellulose(2%), nf(95%)	RC
11	08/10/98	CLCR-27 Sediement	1 sediment (100%)	None Detected		cellulose(4%), nf(96%)	RC
12	08/10/98	CLCR-28 Sediment	1 sediment (100%)	None Detected		cellulose(10%), nf(90%)	RC

NF = Non-Fibrous material; SS = Small Sample size
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North West Environmental
Project Number: 1012
Royal Roads University - Bulk Sample Results

15/10/98

NO.	DATE	SAMPLE INFORMATION	DESCRIPTION	ASBESTOS		OTHER	ANALYS
13	08/10/98	CLCR-29 Sediment	1 sediment (100%)	None Detected		cellulose(2%), nf(98%)	RC
14	08/10/98	CLMS-1 Sediment	1 sediment (100%)	Chrysotile	35%	nf(65%)	RC
15	08/10/98	CLMS-2 Sediment	1 sediment (100%)	Chrysotile	40%	nf(60%)	RC
16	09/10/98	CLMS-3 Sediment	1 sediment (100%)	Chrysotile	15%	nf(85%)	RC
17	09/10/98	CLMS-4 Sediment	1 sediment (100%)	Chrysotile	15%	nf(85%)	RC
18	09/10/98	CLMS-6 Sediment	1 sediment (100%)	Chrysotile	10%	cellulose(2%), nf(88%)	RC

NF = Non-Fibrous material; SS = Small Sample size
PLEASE NOTE: Due to space limitations, these sample(s) will be disposed of after 3 months, unless we are instructed otherwise by our client.

NO.	DATE	SAMPLE INFORMATION	DESCRIPTION	ASBESTOS		OTHER	ANALYST
19	09/10/98	CLMS-9 Sediment	1 sediment (100%)	Chrysotile	40%	nf(60%)	RC
20	09/10/98	CLMS-10 Sediment	1 sediment (100%)	Chrysotile		nf(70%)	RC
21	09/10/98	CLCR-2 Sediment	1 sediment (100%)	Chrysotile	3-5%	cellulose(1%), nf(94%)	RC
22	09/10/98	CLCR-3 Sediment	1 sediment (100%)	Chrysotile	3-5%	nf(97%)	RC
23	09/10/98	CLCR-4 Sediment	1 sediment (100%)	Chrysotile	1-2%	cellulose(1%), nf(98%)	RC
24	09/10/98	CLCR-5 Sediment	1 sediment (100%)	Chrysotile	1-2%	cellulose(3%), nf(96%)	RC

NF = Non-Fibrous material; SS = Small Sample size
PLEASE NOTE: Due to space limitations, these sample(s) will be disposed of after 3 months, unless we are instructed otherwise by our client.

NO.	DATE	SAMPLE INFORMATION	DESCRIPTION	ASBESTOS	OTHER	ANALYS
25	09/10/98	CLCR-7 Sediment	1 sediment (100%)	None Detected	cellulose(1%), nf(99%)	RC
26	09/10/98	CLCR-23 Sediment	1 sediment (100%)	None Detected	cellulose(1%), nf(99%)	RC
27	09/10/98	CLCR-23B Sediment	1 sediment (100%)	None Detected	cellulose(1%), nf(99%)	RC
28	09/10/98	CLCR-24 Sediment	1 sediment (100%)	Chrysotile 1-2%	nf(98%)	RC
29	09/10/98	CLCR-25 Sediment	1 sediment (100%)	Chrysotile < 1%	nf(99%)	RC
30	09/10/98	CLCR-26 Sediment	1 sediment (100%)	Chrysotile < 1%	nf(99%)	RC

NF = Non-Fibrous material; SS = Small Sample size
PLEASE NOTE: Due to space limitations, these sample(s) will be disposed of after 3 months, unless we are instructed otherwise by our client.

RESULTS OF ANALYSIS - Water

File No. J8624

			CLCR-Z3B	CLCR-Z8	CLMS-1	CLWC-1	CLWC-2
			98 09 11 15:45	98 09 11 07:45	98 09 12 10:45	98 09 12 18:05	98 09 12 19:00
Dissolved Anions							
Alkalinity-Total		CaCO3	-	-	-	87	88
Bromide	Br		-	-	-	<0.5	<0.5
Chloride	Cl		-	-	-	0.6	0.6
Fluoride	F		-	-	-	0.14	0.14
Sulphate	SO4		-	-	-	124	128
Nutrients							
Nitrate Nitrogen		N	-	-	-	<0.1	<0.1
Nitrite Nitrogen		N	-	-	-	<0.1	<0.1
Total Metals							
Aluminum	T-Al		0.98	0.28	0.006	0.246	0.193
Antimony	T-Sb		<0.2	<0.2	<0.2	<0.2	<0.2
Arsenic	T-As		<0.2	<0.2	<0.2	<0.2	<0.2
Barium	T-Ba		0.08	0.04	0.04	0.05	0.05
Beryllium	T-Be		<0.005	<0.005	<0.005	<0.005	<0.005
Boron	T-B		<0.1	<0.1	0.6	<0.1	<0.1
Cadmium	T-Cd		<0.0002	<0.0002	<0.0004	<0.0002	<0.0002
Calcium	T-Ca		41.8	21.4	6.69	45.2	41.7
Chromium	T-Cr		<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	T-Co		<0.01	<0.01	<0.01	<0.01	<0.01
Copper	T-Cu		<0.01	<0.01	<0.01	<0.01	<0.01
Iron	T-Fe		0.66	0.36	<0.03	0.39	0.34
Lead	T-Pb		<0.001	<0.001	<0.002	<0.001	<0.001
Magnesium	T-Mg		14.8	6.6	150	29.0	28.3
Manganese	T-Mn		0.040	0.017	<0.005	0.091	0.070
Mercury	T-Hg		<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum	T-Mo		<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	T-Ni		<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	T-Se		0.0023	<0.001	0.0024	<0.001	<0.001
Silver	T-Ag		<0.0001	<0.0001	<0.0002	<0.0001	<0.0001
Thallium	T-Tl		<0.0001	<0.0001	<0.0002	<0.0001	<0.0001
Uranium	T-U		0.00078	0.00059	<0.00002	0.00184	0.00176
Zinc	T-Zn		<0.005	<0.005	<0.005	<0.005	<0.005

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

File No. J8624

			CLWC-3	CLWR-13	CLWR-7
			98 09 12 19:05	98 09 13 17:00	98 09 13 15:15
Dissolved Anions					
Alkalinity-Total		CaCO3	86	-	223
Bromide	Br		<0.5	-	<0.5
Chloride	Cl		0.6	-	0.7
Fluoride	F		0.14	-	0.30
Sulphate	SO4		127	-	900
Nutrients					
Nitrate Nitrogen		N	<0.1	-	0.5
Nitrite Nitrogen		N	<0.1	-	<0.1
Total Metals					
Aluminum	T-Al		-	0.010	0.006
Antimony	T-Sb		-	<0.2	<0.2
Arsenic	T-As		-	<0.2	<0.2
Barium	T-Ba		-	0.06	0.02
Beryllium	T-Be		-	<0.005	<0.005
Boron	T-B		-	<0.1	<0.1
Cadmium	T-Cd		-	<0.001	<0.001
Calcium	T-Ca		-	141	270
Chromium	T-Cr		-	<0.01	<0.01
Cobalt	T-Co		-	<0.01	<0.01
Copper	T-Cu		-	<0.01	<0.01
Iron	T-Fe		-	1.21	<0.03
Lead	T-Pb		-	<0.005	<0.005
Magnesium	T-Mg		-	130	123
Manganese	T-Mn		-	1.18	<0.005
Mercury	T-Hg		-	<0.00005	<0.00005
Molybdenum	T-Mo		-	<0.03	<0.03
Nickel	T-Ni		-	<0.05	<0.05
Selenium	T-Se		-	<0.005	0.0081
Silver	T-Ag		-	<0.0005	<0.0005
Thallium	T-Tl		-	<0.0005	<0.0005
Uranium	T-U		-	0.00040	0.00467
Zinc	T-Zn		-	<0.005	<0.005

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

File No. J8624

		CLCR-1	CLCR-2	CLCR-9	CLCR-Z6
		98 09 13 10:15	98 09 10 11:05	98 09 13 10:20	98 09 11 14:05
Dissolved Metals					
Aluminum	D-Al	0.103	0.050	0.092	0.048
Antimony	D-Sb	<0.2	<0.2	<0.2	<0.2
Arsenic	D-As	<0.2	<0.2	<0.2	<0.2
Barium	D-Ba	0.05	0.05	0.05	0.05
Beryllium	D-Be	<0.005	<0.005	<0.005	<0.005
Boron	D-B	<0.1	<0.1	<0.1	<0.1
Cadmium	D-Cd	<0.0002	<0.0002	<0.0002	<0.0002
Calcium	D-Ca	45.2	47.8	46.1	53.2
Chromium	D-Cr	<0.01	<0.01	<0.01	<0.01
Cobalt	D-Co	<0.01	<0.01	<0.01	<0.01
Copper	D-Cu	<0.01	<0.01	<0.01	<0.01
Iron	D-Fe	0.25	0.23	0.22	0.23
Lead	D-Pb	<0.001	<0.001	<0.001	<0.001
Magnesium	D-Mg	26.2	27.7	26.4	35.7
Manganese	D-Mn	0.110	0.130	0.111	0.130
Mercury	D-Hg	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum	D-Mo	<0.03	<0.03	<0.03	<0.03
Nickel	D-Ni	<0.05	<0.05	<0.05	<0.05
Selenium	D-Se	0.0012	<0.001	0.0011	0.0010
Silver	D-Ag	<0.0001	<0.0001	<0.0001	<0.0001
Thallium	D-Tl	<0.0001	<0.0001	<0.0001	<0.0001
Uranium	D-U	0.00147	0.00156	0.00147	0.00142
Zinc	D-Zn	<0.005	<0.005	<0.005	<0.005

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

T: 0.00%

MOISTURE - DENSITY RELATION TEST

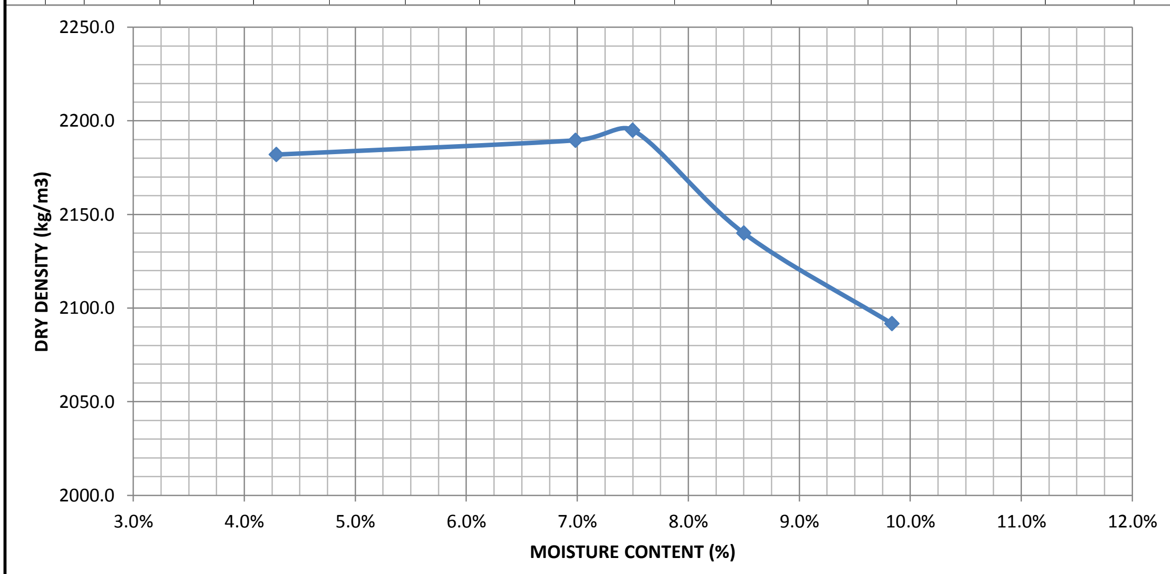
M-41

PROJECT NO:	YT15070	CONTRACT NO:	--	TEST NO:	1
DATE SAMPLED:	Aug-13-15	SAMPLE NO:	1	CONTRACTOR:	Sidhu Trucking
DATE TESTED:	Aug-19-15	SAMPLE SOURCE:	Slope	Consultant:	CAP Engineering

COMPACTION STANDARD:	☐ ASTM D698	☑ ASTM D1557	METHOD:	C	
RAMMER TYPE:	☑ MANUAL	☐ AUTO		VISUAL SOIL CLASSIFICATION:	Waste Material
PREPARATION:	☑ MOIST	☐ DRY		AS RECEIVED MOISTURE CONTENT:	7.00%

DENSITY	A	VOLUME OF MOLD (cm^3)	2124.0	2124.0	2124.0	2124.0	2124.0
	B	WEIGHT OF WET SAMPLE + MOLD (g)	11461.5	11601.5	11638.1	11559.8	11507.6
	C	WEIGHT OF MOLD (g)	6628.2	6626.0	6626.2	6628.0	6627.9
	D	WEIGHT OF WET SAMPLE (g)	4833.3	4975.5	5011.9	4931.8	4879.7
	E	WET DENSITY (kg/m^3)	2275.56	2342.514	2359.65	2321.94	2297.41
	F	DRY DENSITY (kg/m^3)	2182.0	2189.6	2195.0	2140.0	2091.7
MOISTURE CONTENT	G	MOISTURE ADDED / RUN NUMBER (g)	4%	Insitu	~7.5%	~9%	~10%
	H	CONTAINER NUMBER	1	2	3	5	4
	I	WEIGHT OF WET SAMPLE + TARE (g)	1070	1364.9	933.8	0	880
	J	WEIGHT OF DRY SAMPLE + TARE (g)	1026	1275.8	870	0	801.2
	K	TARE OF CONTAINER (g)	0	0	0	0	0
	L	WEIGHT OF WATER (g)	44.0	89.1	63.8	0.0	78.8
	M	WEIGHT OF DRY SOIL (g)	1026.0	1275.8	870.0	0.0	801.2
	N	MOISTURE CONTENT (%)	4.3%	7.0%	7.5%	8.5%	9.8%

% RETAINED:					
4.75mm SIEVE:	12.6%				
9.5mm SIEVE:	27.1%	OPTIMUM MOISTURE CONTENT (%)	7.5%	*CORRECTED OPTIMUM M/C (%)	8.3%
19.0mm SIEVE:	63.4%	MAXIMUM DRY DENSITY (kg/m^3)	2195.0	*CORRECTED DRY DENSITY (kg/m^3)	2259.3
				*OVERSIZE ROCK CORRECTION PER ASTM D4718	



HAS AN IDENTICAL SAMPLE BEEN SENT TO A TESTING LABORATORY?			YES		
IF YES, LAB NAME:	MT.Sima	BAG NO.	1	DATE:	Aug-19-15
REMARKS:					
TESTED BY:	Jessica Pottier	CONTRACTOR PROJECT MANAGER:			
REVIEWED BY:		DATE:			

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATE

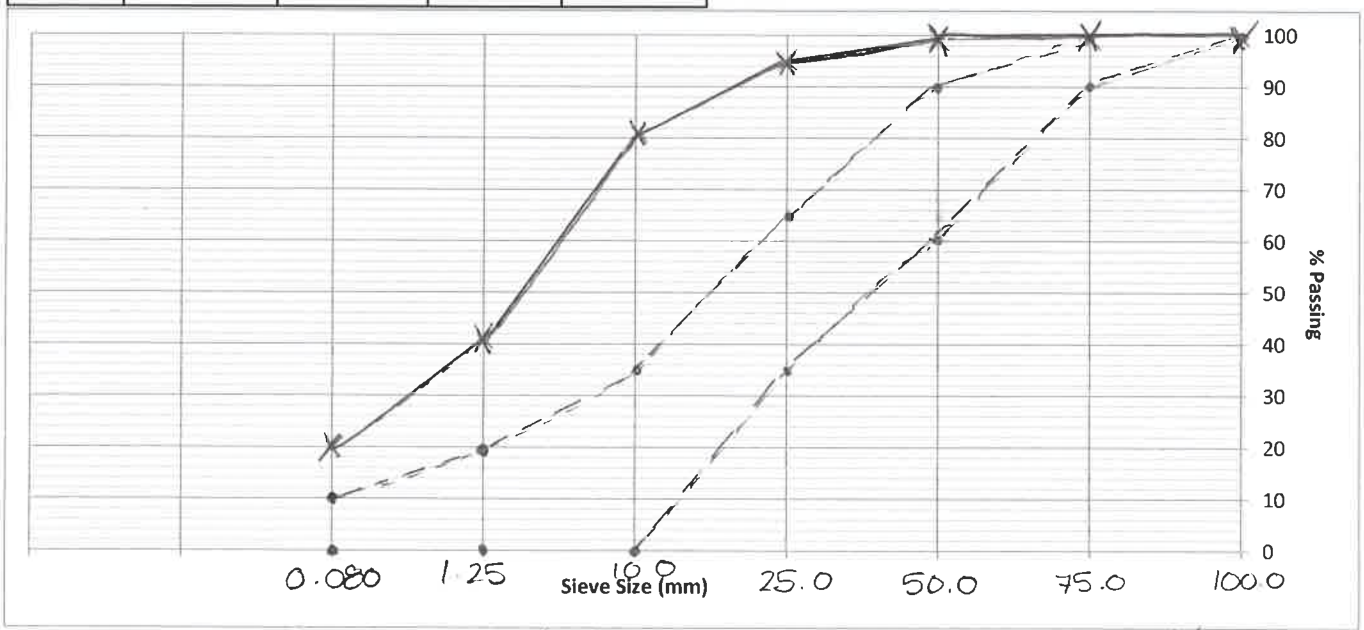
PROJECT NUMBER: VT 15070
DATE SAMPLED: 13-Aug-15
DATE TESTED: 18-Aug-15
TECHNICIAN: J. Pottier

LOCATION: Clinton Creek
MATERIAL TYPE: Waste Rock
SAMPLE No.: 4/4
SAMPLE TIME: —

I	J	K	L	M
Sieve No.	Cumulative Mass (g)	Percent Retained (%) (100-L)	Percent Passing (%) (D-J)/D	Granular Specification
100.0	0	0	100	- 100
75.0	0	0	100	90 - 100
50.0	0	0	100	60 - 90
25.0	220.0	5.0	95.0	35 - 65
10.0	854.8	19.4	80.6	0 - 35
1.25	2468.1	56.1	43.9	0 - 20
0.080	3516.7	80	20.0	0 - 10
PAN	3620.4			-
				-
				-
				-
				-
				-

A	Mass Wet Aggregate and Tare (g):		4657.2
B	Mass Dry Aggregate and Tare	(A/1+F)	4397.7
C	Mass Tare (g):		0
D	Mass Dry Aggregate Before Wash (g):		4397.7
E	Mass Moisture (g):	(A-B)	259.5
F	Moisture Content (%):	(E/D)*100	5.9%
G	Mass Dry Aggregate Afer Wash (g):		3621.0
H	Fineness Modulus*		—

*Fineness Modulus = (Total % of sample retained on a series of sieves/100)



COMMENTS: One oversized Rock weighed 2647.1 g. Would not pass through the 100.0 mm sieve.

REVIEWED BY & DATE:

ASTM C136

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATE

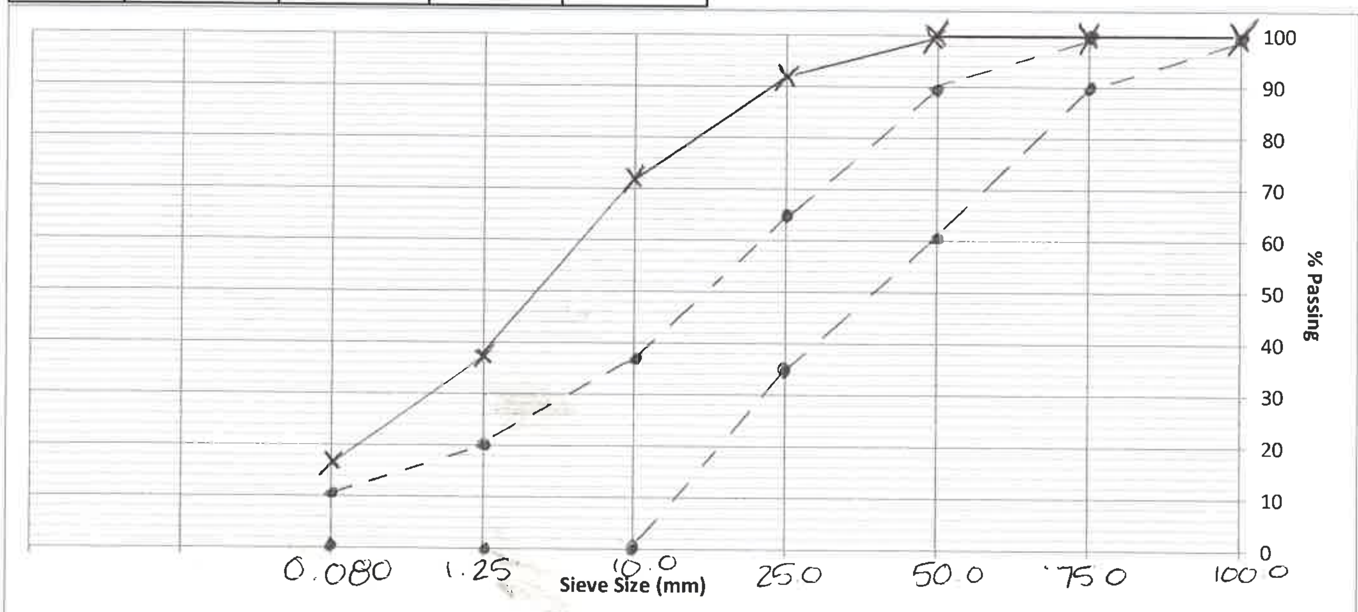
PROJECT NUMBER: YT15070
DATE SAMPLED: Aug-13-15
DATE TESTED: Aug 20-15
TECHNICIAN: J. Pottier

LOCATION: Clinton Creek
MATERIAL TYPE: Waste Rock
SAMPLE No.: 1/4
SAMPLE TIME: —

I	J	K	L	M
Sieve No.	Cumulative Mass (g)	Percent Retained (%) (100-L)	Percent Passing (%) (D-J)/D	Granular Specification
100.0	0	0	100	- 100
75.0	0	0	100	90 - 100
50.0	0	0	100	60 - 90
25.0	323.3	7.6	92.4	35 - 65
10.0	1179.9	27.8	72.2	0 - 35
1.25	2637.9	62.2	37.8	0 - 20
0.080	3510.8	82.8	17.2	0 - 10
PAN	3540.9	—	—	-
				-
				-
				-
				-

A	Mass Wet Aggregate and Tare (g):		4583.9
B	Mass Dry Aggregate and Tare	(A/1+F)	4239.7
C	Mass Tare (g):		0
D	Mass Dry Aggregate Before Wash (g):		4239.7
E	Mass Moisture (g):	(A-B)	344.2
F	Moisture Content (%):	(E/D)*100	8.1%
G	Mass Dry Aggregate Afer Wash (g):		3540.9
H	Fineness Modulus*		—

*Fineness Modulus = (Total % of sample retained on a series of sieves/100)



COMMENTS: One Over sized Rock, 152.4 mm at widest point, not included in sample, would not pass 100 mm Sieve.

REVIEWED BY & DATE:

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Whitehorse, YT
Y1A 2C6 Canada

Date: September 22, 2015

Dear Ms. Perron

CLINTON CREEK LAB TEST RESULTS, REV. 0

1. Introduction

Lab testing has been completed on samples recovered during the May 31, 2015 site visit. Acid rock drainage and metal leaching (ARD/ML) testing was carried out at the Maxxam Analytics (Maxxam) laboratory in Burnaby, British Columbia (BC). General Geotechnical characteristics testing was carried out at the Tetra Tech EBA (TT) laboratory in Whitehorse, Yukon (YT). A summary of the completed tests is provided in Table A.

Table A Lab Testing Summary

Test Type	Testing Standard	No. of Tests Conducted
Modified Acid Base Accounting (ABA) Package (paste pH, total sulphur [by Leco])	ASTM D3987	6
Carbonate Carbon (CO_2 HCl method)	ASTM D4373	6
Ultratrace Metals on Solids by Aqua Regia Digestion (Group 1F-MS)	QOP Hg FIMS	6
Sulphur speciation (sulphate sulphur, sulphide sulphur, insoluble sulphur [by difference])	ASTM D5504, D5623	6
Shake Flask Extraction	MEND	2
Grain Size Analysis (sieve/hydrometer)	ASTM D422	2
Atterberg Limits	ASTM D4318	2
Modified Proctor Analysis	ASTM D1557	2

2. Soil Testing

Soil samples were recovered by Advisian at two locations: at a natural sand hill face along the Clinton Creek access road, termed herein "Sand Hill Pit", and at a quarried rock face (i.e. rock pile) immediately outside the Clinton Creek access gate, termed herein "Entrance Pit". Samples from Sand Hill Pit were taken from the sand pit located 27 km from the turn off from the Top of the World Highway on May 31, 2015. Recovered samples comprised coarse grained soils comprised mostly of sand and gravel of relatively uniform grain size distribution at both locations. Fines content ranged from 6% to 11% suggesting non-plastic material. Therefore, Atterberg Limit testing could not be completed. Modified Proctor analysis indicated corrected densities of 2,210 kg/m³ and 2,475 kg/m³ with corresponding optimum moisture contents of 8.2% and 5.2% for Sand Hill Pit and Entrance Pit, respectively. Soil test results are summarized in Table B and detailed test results are provided in Appendix A.

Table B Soils Test Results Summary

Location	Soil Classification	Gravel	Sand	Fines	Corrected Proctor Density	Corrected Optimum Moisture	In Situ Moisture	Plasticity Index
Sand Hill Pit	Sand and gravel, some silt	37%	52%	11%	2,210 kg/m³	8.2%	7.4%	non-plastic
Entrance Pit	Gravel, sandy, and trace silt	63%	31%	6%	2,475 kg/m³	5.2%	1.5%	non-plastic

3. Acid Rock Drainage (ARD) Testing

3.1 Introduction

To assess the potential of the waste pile and Entrance Pit material to generate ARD/ML, an ARD/ML screening level program was conducted.

3.2 Sampling and Laboratory Testing

A total of six samples (three waste rock and three Entrance Pit rock) were collected by Advisian personnel during the site visit, and sent to Maxxam in Burnaby, BC for testing. Samples were collected from different locations of the waste rock pile and Entrance Pit site to capture potential spatial variability within the piles.

The ARD/ML program comprised:

- ABA including fizz test, paste pH, inorganic carbon (CO2), sulphur speciation (total sulphur, sulphide sulphur [measured], sulphate sulphur, and insoluble sulphate sulphur, by difference) and the Modified-Sobek Neutralization Potential (MS-NP).
- Ultratrace metal analysis using aqua-regia, followed by ion coupled plasma mass spectrometry (ICP-MS).
- MEND Shake Flask Extraction test.

3.3 Laboratory Analytical Results

3.3.1 Quality Assurance (QA)

A quality assurance (QA) framework was followed to assess the accuracy of laboratory analytical results. QA included the following:

- Relative percent difference (RPD): duplicate samples were included in the analyses and their RPD calculated. Results show that RPD values within acceptable range (±20%) indicate good reproducibility.
- Sulphur species balance: all samples had total sulphur higher than sulphate sulphur and sulphide sulphur.
- Standards: standards used in the analyses were reported with the analytical results, and are within the expected values.

3.3.2 Acid Base Accounting (ABA)

ABA was used to evaluate the balance between acid potential (AP) and neutralization potential (NP) of samples. The ratio of NP to AP is used as a tool for the classification of geological materials according to their ARD potential ("Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials" by MEND 2009).

ABA sampling is strictly static testing, meaning it provides information on the samples only as they occur at the time of analysis. Results provide the present drainage pH of the sample (paste pH). They also allow initial classification of the samples with respect to the potential for future acidic drainage (MEND 2009). Static testing does not provide any information on rates of acid generation or neutralization under site-specific conditions. Thus, where sulphide minerals are present in rock samples, ABA testing cannot be used alone to make definitive conclusions about the potential for long-term acid generation.

Results of the ABA are reported in Table C and laboratory results are provided in Appendix B.

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Table C Acid Base Accounting Results

Sample ID	Description	Paste pH (units)	CO_2 (weight per cent [wt.%])	$CaCO_3$ Equivalent (kg $CaCO_3$/T)	Total Sulphur (wt.%)	Sulphate Sulphur (wt.%)	Sulphide Sulphur (wt.%)	Non-Extractable Sulphur (by difference) (wt.%)	Acid Generation Potential (kg $CaCO_3$/T)	MS-NP (kg $CaCO_3$/T)	T-NPR	S-NPR	Fizz Rating	ARD Classification
CCENTPILES01	Meta- Sandstone	9.2	14.86	337.70	0.18	**0.01**	0.11	0.07	5.63	266	47.3	78.3	Moderate	Non-PAG
CCENTPILES02	Meta- Sandstone	9.3	14.13	321.10	0.24	**0.01**	0.15	0.09	7.50	265	35.3	56.4	Moderate	Non-PAG
CCENTPILES03	Meta- Sandstone	9.2	15.07	342.50	0.15	**0.01**	0.09	0.06	4.69	280	59.7	100.0	Moderate	Non-PAG
CCWR01	Serpentinized Utramafic	9.5	1.12	25.50	0.15	0.05	0.01	0.09	4.69	155	33.1	516.0	None	Non-PAG
CCWR02	Graphitic Argillite	8.5	8.94	203.20	0.16	0.04	0.04	0.08	5.00	136	27.2	104.8	Strong	Non-PAG
CCWR03	Mudstone/Siltstone	8.7	4.37	99.30	0.57	0.21	0.18	0.18	17.81	104	5.8	18.6	Moderate	Non-PAG

CCENTPILE = Clinton Creek Entrance Pit

CCWR = Clinton Creek Waste Rock

GREY values are detection limit.

T-NPR = Neutralization potential ratio calculated assuming total sulphur as source of acidity.

S-NPR = Neutralization potential ratio calculated assuming the sum of sulphide sulphur and non-extractable sulphur as source of acidity.

Paste pH

Paste pH indicates the present drainage pH of each sample. The present pH provides an indication of ongoing sulphide oxidation or previous weathering processes. Paste pH values lower than 6.0 are considered signs of the release of acidity, while pH values greater than 6.0 indicate sulphide oxidation associated with neutralization or negligible sulphide oxidation.

The paste pH of the waste rock samples ranges from 8.5 to 9.5 with a median of 8.7, while the paste pH of the Entrance Pit samples ranges from 9.2 to 9.3 with a median of 9.2. These neutral to slightly alkaline paste pH values indicate that, at the present time, all samples tested have sufficient NP to buffer acidity produced from sulphide oxidation.

Sulphur Species and Acid Potential (AP)

Determining the types of sulphur species in the samples and their concentration is an important aspect of the ARD/ML assessment. Sulphide minerals are particularly important because they determine the potential for ARD/ML.

Total sulphur content of the waste rock samples varies from 0.15 weight per cent (wt.%) to 0.57 wt.% with a median value of 0.16 wt.%, while total sulphur content of the Entrance Pit samples varies from 0.15 wt.% to 0.24 wt.% with a median of 0.18 wt.%. These values indicate low sulphur content with the exception of one waste rock sample (CCWR03).

Sulphate sulphur content of all the samples is extremely low with the exception of one sample (CCWR03). The sulphide sulphur content is also very low and range from 0.09 wt.% to 0.15. wt.% (median of 0.11 wt.%) in the Entrance Pit and from 0.01 wt.% to 0.18 wt.% (median 0.04 wt.%) in the waste pile.

Figure A is a plot of total sulphur versus sulphide sulphur and illustrates that sulphide sulphur is a major source of sulphur in the Entrance Pit samples while the waste rock samples contain an additional unidentified source of sulphur. This unidentified sulphur could be derived from low solubility or insoluble acidic sulphur species, elemental sulphur, alunite, or organically bound sulphur (MEND 2009), and further tests are usually needed to determine its origin. Because total sulphur is used in the estimation of AP (below), no additional test is needed.

The samples do comprise an undetermined source of sulphur and limited information is available with respect to their sulphide mineralogy. Thus, the AP was estimated conservatively using total sulphur. The calculated AP is very low and varies from 4.7 kg $CaCO_3$/t to 7.5 kg $CaCO_3$/t (median of 5.6 kg $CaCO_3$/t) in the Entrance Pit samples and from 4.7 kg $CaCO_3$/t to 17.8 kg $CaCO_3$/t (median of 5.0 kg $CaCO_3$/t) in the waste rock samples.

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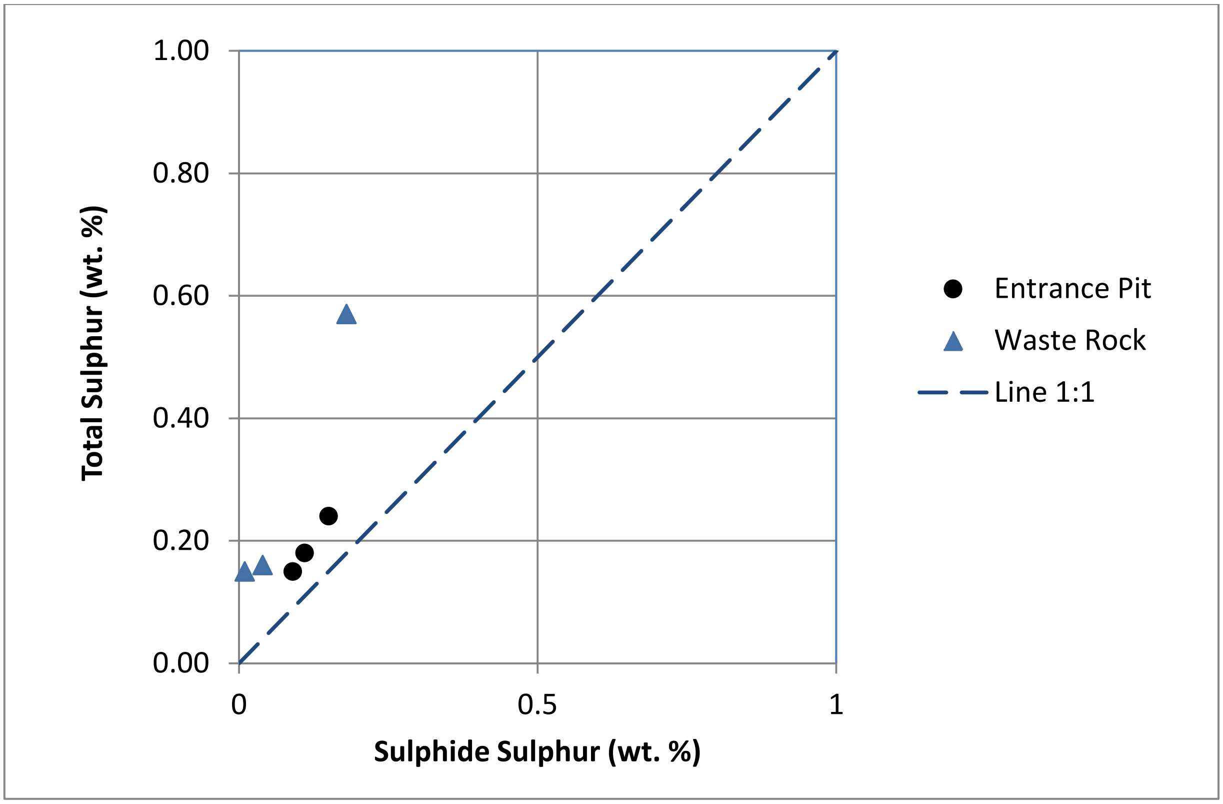

Figure A Total Sulphur versus Sulphide Sulphur

Carbonate Species and Neutralization Potential

Carbonate minerals such as calcite are the most effective in neutralizing acidity generated from sulphide oxidation. Fast dissolving carbonate minerals like calcite, aragonite, and dolomite and the most reactive non-carbonates like anorthite are particularly important for neutralization. There are carbonate minerals, including iron and manganese carbonates that do not contribute to neutralizing potential.

The carbonate carbon measured during the ABA test as CO2 indicates readily available NP derived mainly from carbonates minerals. The CO2 content was used to estimate the carbonate NP.

The CO2 of the Entrance Pit samples ranges from 14.1 wt.% to 15.1 wt.% (median 14.9%) indicating potentially high carbonate NP (Table C). The waste rock samples contain lower NP as indicated by CO2 content ranging from 1.1 wt.% to 8.9 wt.% (median 4.4 wt.%). This NP is theoretically sufficient to buffer the acidity generated from these waste rock samples.

The NP of the samples was estimated using the MS-NP method to approximate the bulk NP of the samples. The MS-NP includes NP from fast reactive carbonates and most-reactive silicates. The MS-NP of the Entrance Pit samples ranges from 266 kg CaCO3/t to 280 kg CaCO3/t, while the MS-NP of waste rock sample ranges from 104 kg CaCO3/t to 155 kg CaCO3/t. These are significant NP, especially in low sulphide sulphur environment.

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Figure B is a plot of carbonate NP versus MS-NP and illustrates that iron and manganese carbonate, considered net neutral in terms of neutralization capacity, contribute some NP to the carbonate NP in four of the six samples (samples above the 1:1 relationship line). Also, one waste rock sample shows significant NP from alumino-silicates (sample below the 1:1 relationship line).

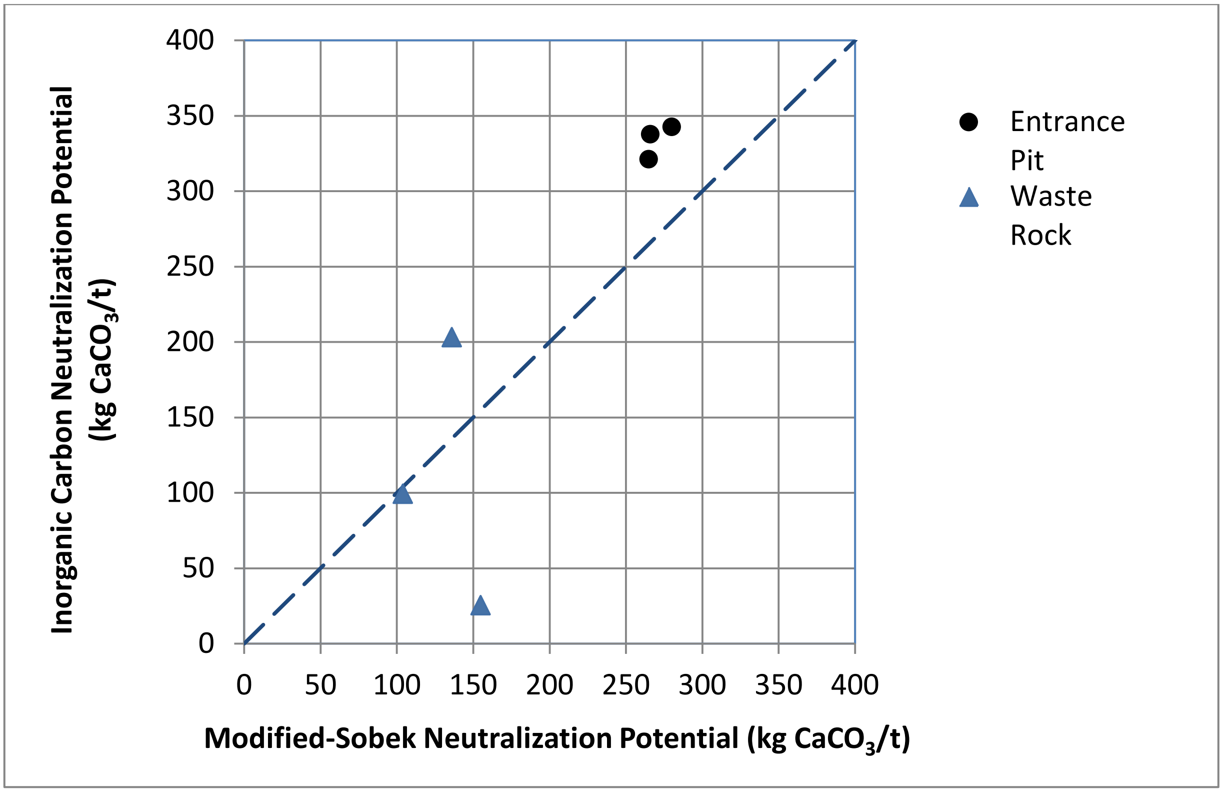

Figure B Carbonate NP versus Modified-Sobek NP

Acid Rock Drainage (ARD) Classification

The neutralization potential ratio (NPR) assesses the balance between acid generation and neutralization capacities of the sample, and is used worldwide as screening criteria for the classification of geological materials based on their ARD potential (MEND 2009). The NPR of the samples was calculated using the MS-NP and the AP calculated from the total sulphur, and was called T-NPR.

The non-site-specific criteria developed in British Columbia and used worldwide are shown in Table D (MEND 2009) and were used to classify the rock samples based on their ARD potential. The calculated NPR in Table C (T NPT) shows that all samples have a T-NPR much higher than 2, which indicates that they are all classified as non-potentially acid generating (non-PAG). The result is shown graphically in Figure C.

Table D ARD Potential Screening Criteria based on NPR

Classification	Potential for ARD	Initial Screening Criteria	Comments
Potentially Acid Generating (PAG) or Acid Generating (AG)	Likely	NPR < 1	Likely ARD generating unless sulphide materials are non-reactive.
Uncertain	Uncertain	1 ≤ NPR ≤ 2	Possibly ARD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides. Requires further static and/or kinetic testing.
Non-Potentially Acid Generating (Non-PAG)	Low	NPR > 2	Non-potentially ARD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP.

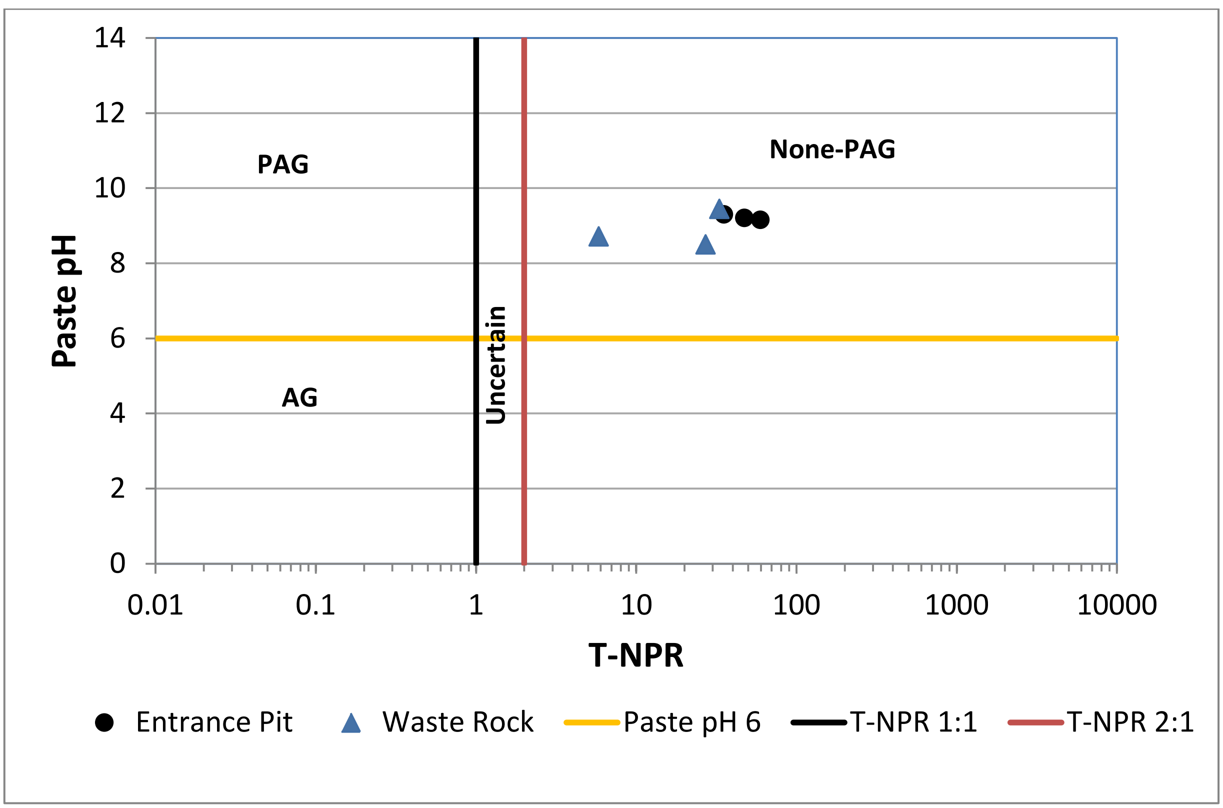

Figure C Paste pH versus T-NPR

3.3.3 Solid-Phase Metal Analysis and Metal Leaching (ML)

Acid generation from sulphide oxidation increases the weathering of rock forming minerals releasing their elemental constituents (e.g. metals, metalloids) into the environment; however, several metals and metalloids can still be released at high concentration under non-acidic conditions. This is the case of arsenic, molybdenum, selenium, antimony and zinc, for example.

Several tests including solid-phase metal analyses are used to assess the metal content (reservoir) of the rock which can be interpreted as a sign of potential ML. Solid-phase metal analyses measure metal concentrations in a sample in order to identify whether the concentration of a given metal is higher or lower than a selected screening value ("Draft guidelines and recommended methods for the prediction of metal leaching and acid rock drainage at mine sites in British Columbia" by W.A. Price 1997). A sample with an elemental concentration higher than the screening value is considered enriched in that element. This indicates an abundance of the element in the rock and may (or may not) be sign of potential for ML, because site-specific conditions ultimately determine the weathering rate and the release and mobility of the element. The screening value generally used can be three, five, or ten times the composition (also known as abundance) of the average composition of the continental crust or a rock type similar to the rock sampled.

For screening purposes for the Clinton Creek waste and Entrance Pit samples, metal concentrations of the samples were compared to the five times the average composition of the continental crust. The results of the solid-phase metal analyses and screening process are reported in Table E and Table F, respectively.

Table F shows that several metals including arsenic, antimony, selenium, mercury, nickel, and magnesium exceed the screening value in one or more samples. This indicates an elevated abundance of arsenic, mercury, nickel, magnesium, and antimony in the Entrance Pit samples and the abundance of nickel, selenium, antimony, chromium, magnesium, and bismuth in the waste rock. These elevated metal contents could result in metal leaching depending on site conditions, especially in the case of arsenic, antimony, and selenium, because these metals and metalloids can reach elevated concentration in solution under non-acidic conditions; however, detailed tests are required to simulate and assess whether weathering process would result in leachates with metal concentration above those permissible under applicable guidelines. The exceedance of magnesium is expected because of the nature of the rock hosting the mineralization at Clinton Creek.

Please note that the average abundance used for screening is a global average value, thus a comparison with a rock similar to those sampled, if known in detail, may provide different results.

Table E Ultratrace Metals Test Results

Sample ID	Mo (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ag (ppm)	Ni (ppm)	Co (ppm)	Mn (ppm)	Fe (%)	As (ppm)	U (ppm)	Au (ppm)	Th (ppm)	Sr (ppm)	Cd (ppm)	Sb (ppm)	Bi (ppm)
Detection Limit	**0.01**	**0.01**	**0.01**	**0.1**	**2.0**	**0.1**	**0.1**	**1.0**	**0.01**	**0.1**	**0.1**	**0.2**	**0.1**	**0.5**	**0.010**	**0.020**	**0.02**
CCENTPILES01	0.27	9.61	0.90	7.8	25	1150	44.5	755	3.54	25.2	0.1	2.0	0.1	199	0.04	6.50	0.02
CCENTPILES02	0.18	5.18	0.80	6.2	20	1430	58.1	679	3.88	29.8	0.1	3.5	0.1	179	0.03	7.62	0.02
CCENTPILES03	0.19	15.8	0.91	10.0	28	1230	56.8	864	4.44	31.4	0.1	0.6	0.1	202	0.03	7.73	0.02
CCWR01	1.24	10.9	3.41	25.8	49	1790	77.5	464	3.42	2.3	0.3	0.2	1.3	30.3	0.20	1.29	0.04
CCWR02	2.53	25.3	5.54	33.2	104	822	43.1	483	3.00	9.0	0.6	0.2	1.7	132	0.33	4.56	0.08
CCWR03	5.38	17.6	6.62	59.4	89	1180	38.4	427	3.08	6.3	0.8	0.2	3.1	88.3	0.40	0.81	0.13

Sample ID	V (ppm)	Ca (%)	P (%)	La (ppm)	Cr (ppm)	Mg (%)	Ba (ppm)	Ti (%)	B (ppm)	Al (%)	Na (%)	K (%)	W (ppm)	Sc (ppm)	Tl (ppm)	Hg (ppm)	Se (ppm)	Te (ppm)	Ga (ppm)	S (%)
Detection Limit	**2.0**	**0.01**	**0.001**	**0.5**	**0.5**	**0.01**	**0.5**	**0.001**	**20**	**0.01**	**0.001**	**0.010**	**0.1**	**0.1**	**0.0**	**5.0**	**0.1**	**0.02**	**0.1**	**0.02**
CCENTPILES01	26	2.84	0.002	0.5	398	15.3	316	0.001	20	0.08	0.008	0.02	0.5	7.8	0.26	1650	0.2	0.05	0.8	0.15
CCENTPILES02	23	2.33	0.001	0.5	482	16.4	380	0.002	20	0.05	0.009	0.02	0.7	6.4	0.33	2300	0.2	0.02	0.6	0.23
CCENTPILES03	49	2.92	0.001	0.5	433	15.8	417	0.002	20	0.10	0.008	0.02	0.8	9.8	0.31	2240	0.3	0.02	0.6	0.15
CCWR01	18	0.56	0.012	3.9	1500	20.5	36.1	0.004	178	0.40	0.003	0.04	0.4	8.1	0.03	32	0.9	0.02	1.0	0.12
CCWR02	16	2.34	0.026	5.2	331	10.4	336	0.001	20	0.14	0.006	0.03	0.2	7.1	0.11	513	0.6	0.02	0.4	0.15
CCWR03	20	1.59	0.023	6.8	796	11.4	75.3	0.002	79	0.33	0.005	0.04	0.3	5.7	0.06	95	1.2	0.02	0.7	0.54

GREY value indicates detection limit.

Table F Elemental Exceedances

Sample ID	Description	Arsenic (ppm)	Bismuth (ppm)	Chromium (ppm)	Mercury (ppm)	Magnesium (%)	Nickel (ppm)	Sulphur (%)	Antimony (ppm)	Selenium (ppm)
CCENTPILES01	Meta- Sandstone	**25.2**	0.02	398	**1.650**	**15.30**	**1,150**	0.15	**6.50**	0.2
CCENTPILES02	Meta- Sandstone	**29.8**	0.02	482	**2.300**	**16.40**	**1,430**	0.23	**7.62**	0.2
CCENTPILES03	Meta- Sandstone	**31.4**	0.02	433	**2.240**	**15.80**	**1,230**	0.15	**7.73**	**0.3**
CCWR01	Serpentinized Utramafic	2.3	0.04	**1,500**	0.032	**20.50**	**1,790**	0.12	**1.29**	**0.9**
CCWR02	Graphitic Argillite	9.0	**0.08**	331	**0.513**	10.40	**822**	0.15	**4.56**	**0.6**
CCWR03	Mudstone/Siltstone	6.3	**0.13**	**796**	0.095	11.40	**1,180**	**0.54**	0.81	**1.2**
Five Times Continental Crustal Abundance Value	---	9	0.0425	510	0.425	11.65	420	0.175	1.0	0.25

BOLD value indicates exceedance of the screening value (five times average abundance of continental crust).

CCENTPILE = Clinton Creek Entrance Pit

CCWR = Clinton Creek Waste Rock

3.3.4 Shake Flask Extraction Test (SFE)

The SFE test is used to identify the readily soluble constituents contained within a rock sample under vigorous short term conditions. Soluble constituents may include elements as surface coatings and soluble minerals. During the test, a crushed sample is placed in a flask at a 3:1 deionized water to solid ratio by weight and gently agitated for 24 hours. The greater volume of water ensures that the solubility limits do not inhibit dissolution of minerals and gentle agitation keeps the sample particles continuously exposed to the extraction fluid. After 24 hours, the sample is left to settle and the supernatant is filtered and analyzed by ICP-MS. For screening purposes, the concentrations are often compared to applicable water quality guidelines. The results of the SFE are shown in Table G.

Overall, the concentrations of chemical elements and metals in both leachates are low. The following are also important observations:

- pH is circum-neutral to slightly alkaline.
- The acidity released is below the detection limit in agreement with the low sulphide sulphur values and indicates low sulphide-oxidation rates.
- there is presently sufficient alkalinity to neutralise the acidity released from these samples.
- Sulphate content of sample CCWR03 is high, in agreement with the high sulphate content from the ABA.
- The electric conductivity of the waste rock leachate is high (1066 µS/cm) reflecting its high ions content.

The SFE data indicate that sulphide oxidation rates and associated metal release have been low in the samples. Neutralizing minerals in the samples have been able to buffer the acidity produced, in agreement with the ABA results that show NPR values >> 2.

As a screening tool, the results of the SFE were compared to the Metal Mining Effluent Regulations Schedule 4 Maximum Authorized Concentration in a Grab Sample (MMER Schedule 4). Table G shows no exceedance of the MMER.

SFE results were additionally screened against the Canadian Council of Ministers of the Environment Water Quality guideline for the Protection of Aquatic Life (CCME). Exceedances of CCME guidelines included pH, arsenic and chromium in CCENTPILES02 and chromium and selenium in CCWR03. The metals exceeding the CCME guidelines (arsenic, selenium, chromium) are metals that can have enhanced mobility under neutral and alkaline conditions, depending on their chemical forms. Because the conditions of the SFE test (large surface area of the sample resulting from crushing increasing the solubility of minerals, shaking of the sample for 24hrs) are likely to be different than site conditions (e.g. oxido-reduction conditions, particle surface area, pH, hydrogeology/hydrology, litho-geochemistry, geology) comparison against CCME aquatic life guidelines serves only to identify elements of potential concern. Exceedances of CCME guidelines in the SFE leachate do not definitively signify exceedances under field conditions, and, likewise, meeting the guidelines cannot be considered a measure of compliance. More accurate estimation of long-term metal leaching potential requires kinetic testing.

Advisian
WorleyParsons Group

Table G Results of the Shale Flask Extraction Test

Parameters/Metals	Units	Detection Limits	Sample ID		MMER Schedule 4 Column 4: Maximum Authorized Concentration in a Grab Sample (mg/L)	Canadian Environmental Quality Guidelines for the Protection of Aquatic Life (mg/L)	
			CCENTPILES02	CCWR03		Chronic	Acute
pH	pH Units	N/A	9.48	8.57	6-9.5	6.5-9.0	---
EC	uS/cm	0.5	107.9	1066.0	---	---	---
ORP	mV		80.0	100	---	---	---
SO_4	mg/L	0.5	4.6	522	---	---	---
Acidity to pH4.5	mg/L	0.5	<0.5	<0.5	---	---	---
Acidity to pH8.3	mg/L	0.5	<0.5	<0.5	---	---	---
Total Alkalinity	mg/L	0.5	47.0	14	---	---	---
Bicarbonate	mg/L	0.5	58.0	17	---	---	---
Carbonate	mg/L	0.5	<0.5	<0.5	---	---	---
Hydroxide	mg/L	0.5	<0.5	<0.5	---	---	---
Fluoride	mg/L	0.01	0.1	0	---	---	---
Dissolved Chloride	mg/L	0.5	<0.5	1	---	---	---
Hardness CaCO3	mg/L	0.50	50.7	551	---	---	---
Dissolved Aluminum (Al)	mg/L	0.00050	0.0209	0.00813	---	0.1*	---
Dissolved Antimony (Sb)	mg/L	0.000020	0.00523	0.000365	---	---	---
Dissolved Arsenic (As)	mg/L	0.000020	0.00665	0.000161	1.0	0.005	---
Dissolved Barium (Ba)	mg/L	0.000020	0.356	0.0374	---	---	---
Dissolved Beryllium (Be)	mg/L	0.000010	<0.000010	<0.000010	---	---	---
Dissolved Bismuth (Bi)	mg/L	0.0000050	<0.0000050	<0.0000050	---	---	---
Dissolved Boron (B)	mg/L	0.050	<0.050	0.379	---	1.5	29
Dissolved Cesium (Cs)	mg/L	0.000050	0.00587	0.00392	---	---	---
Dissolved Cadmium (Cd)	mg/L	0.0000050	<0.0000050	<0.0000050	---	0.00009	0.001
Dissolved Calcium (Ca)	mg/L	0.050	4.46	166	---	---	---
Dissolved Chromium (Cr)	mg/L	0.00010	0.0300	0.00209	---	0.001***	---
Dissolved Cobalt (Co)	mg/L	0.0000050	0.0000238	0.0000466	---	---	---
Dissolved Copper (Cu)	mg/L	0.000050	0.000130	<0.000050	6.0	0.002-0.004**	---
Dissolved Lanthanum (La)	mg/L	0.000050	<0.000050	<0.000050	---	---	---
Dissolved Iron (Fe)	mg/L	0.0010	0.0022	0.0022	---	0.3	---
Dissolved Lead (Pb)	mg/L	0.0000050	<0.0000050	0.0000058	0.4	0.001-0.007**	---
Dissolved Lithium (Li)	mg/L	0.00050	0.00284	0.00908	---	---	---

Parameters/Metals	Units	Detection Limits	Sample ID		MMER Schedule 4 Column 4: Maximum Authorized Concentration in a Grab Sample (mg/L)	Canadian Environmental Quality Guidelines for the Protection of Aquatic Life (mg/L)	
			CCENTPILES02	CCWR03		Chronic	Acute
Dissolved Magnesium (Mg)	mg/L	0.050	9.60	32.7	---	---	---
Dissolved Manganese (Mn)	mg/L	0.000050	0.000058	0.00127	---	---	---
Dissolved Phosphorus (P)	mg/L	0.0020	0.0030	0.0035	---	---	---
Dissolved Molybdenum (Mo)	mg/L	0.000050	0.000231	0.00862	---	0.073	---
Dissolved Nickel (Ni)	mg/L	0.000020	0.00154	0.00615	1.0	0.025-0.15**	---
Dissolved Potassium (K)	mg/L	0.050	1.65	3.66	---	---	---
Dissolved Rubidium (Rb)	mg/L	0.000050	0.00849	0.0103	---	---	---
Dissolved Selenium (Se)	mg/L	0.000040	0.000474	0.00676	---	0.001	---
Dissolved Silicon (Si)	mg/L	0.10	1.73	1.37	---	---	---
Dissolved Silver (Ag)	mg/L	0.0000050	<0.0000050	<0.0000050	---	0.0001	---
Dissolved Sodium (Na)	mg/L	0.050	0.305	0.465	---	---	---
Dissolved Strontium (Sr)	mg/L	0.000050	0.0751	0.485	---	---	---
Dissolved Sulphur (S)	mg/L	10	<10	176	---	---	---
Dissolved Tellurium (Te)	mg/L	0.000020	<0.000020	0.000110	---	---	---
Dissolved Thallium (Tl)	mg/L	0.0000020	0.000150	0.000118	---	0.0008	---
Dissolved Thorium (Th)	mg/L	0.0000050	<0.0000050	<0.0000050	---	---	---
Dissolved Tin (Sn)	mg/L	0.00020	<0.00020	<0.00020	---	---	---
Dissolved Titanium (Ti)	mg/L	0.00050	<0.00050	<0.00050	---	---	---
Dissolved Tungsten (W)	mg/L	0.000010	0.000658	0.000523	---	---	---
Dissolved Uranium (U)	mg/L	0.0000020	0.0000266	0.000104	---	0.015	0.033
Dissolved Vanadium (V)	mg/L	0.00020	0.00124	0.00030	---	---	---
Dissolved Zinc (Zn)	mg/L	0.00010	0.00023	<0.00010	1.0	0.03	---
Dissolved Zirconium (Zr)	mg/L	0.00010	<0.00010	<0.00010	---	---	---
Dissolved Mercury (Hg)	mg/L	0.000050	<0.000050	<0.000050	---	0.000026	---

Notes:

*pH dependent

**Hardness dependent

***Guideline for chromium (VI)

Highlighted values are exceedance of the chronic CCME water quality guidelines for the protection of aquatic life

CCME: Canadian Council of Ministers of the Environment

MMER: Metal Mining Effluent Regulations

Concentrations of metals in the guidelines are total concentrations for most case

3.4 Conclusion

All samples tested have NP that far exceeded the AP and thus, on the basis of the available data, the potential of the waste pile and Entrance Pit rock to generate ARD has been classified as very low.

Total elemental analysis of the rocks indicated that the concentrations of several metals were enriched with respect to the reference levels used for comparative purposes (5*abundance in continental crust). In the leaching test (SFE test), no parameters exceeded MMER maximum authorized concentrations in a grab sample. On the basis of this criteria (i.e. meeting MMER guidelines), the proposed use of waste rock material and Entrance Pit material for construction of DS4 is acceptable.

Comparison of the SFE results against CCME guidelines for the protection of aquatic life did indicate exceedances for 3 metals: arsenic, selenium, and chromium. These metals were also identified as having enriched concentrations with respect to 5*crustal abundance (in one or more of the samples tested). Depending on site geochemical conditions, these elements can all be present as species/in chemical forms that are mobile under circumneutral conditions. The potential for long-term leaching of metals under neutral conditions cannot be estimated by the current work; further kinetic testing would provide a more robust estimation of metal leaching potential.

Given the current presence of large volumes of waste rock in the former Clinton Creek valley, screening of downstream water samples for potential concentrated elevations of these metals should be considered. However, considering the ratio between the current volume of waste rock in the valley, versus the volume proposed to be used during construction, no significant change to downstream water quality is anticipated.

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Appendix A

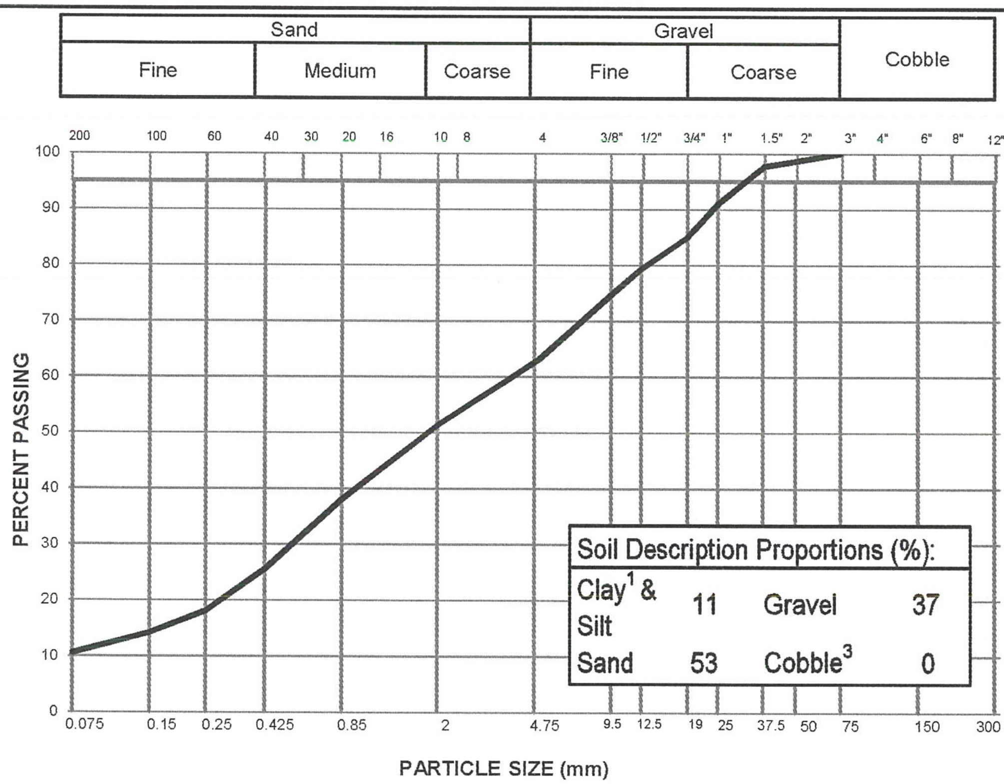
Tetra Tech EBA Lab Test Results

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Clinton Creek	Sample No.:	SA01
Project No.:	W14103619-01	Material Type:	
Site:	Clinton Creek Road	Sample Loc.:	Sand Hill Pit
Client:	WorleyParsons	Sample Depth:	Surface
Client Rep.:	Margret McBride	Sampling Method:	Grab
Date Tested:	June 4, 2015 By: AMT	Date sampled:	May 31, 2015
Soil Description[2]:	SAND and GRAVEL - some silt	Sampled By:	Client
		USC Classification:	Cu: #N/A
Moisture Content:	7.4%		Cc: #N/A

Particle Size (mm)	Percent Passing
300	
200	
150	
100	
75	100
50	
38	98
25	91
19	85
12.5	79
10	76
5	63
2	51
0.85	38
0.425	26
0.25	18
0.15	14
0.075	10.6



Soil Description Proportions (%):			
Clay[1] & Silt	11	Gravel	37
Sand	53	Cobble[3]	0

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

[3] If cobbles are present, sampling procedure may not meet ASTM C702 & D75

Specification: ______________________

Remarks: ______________________

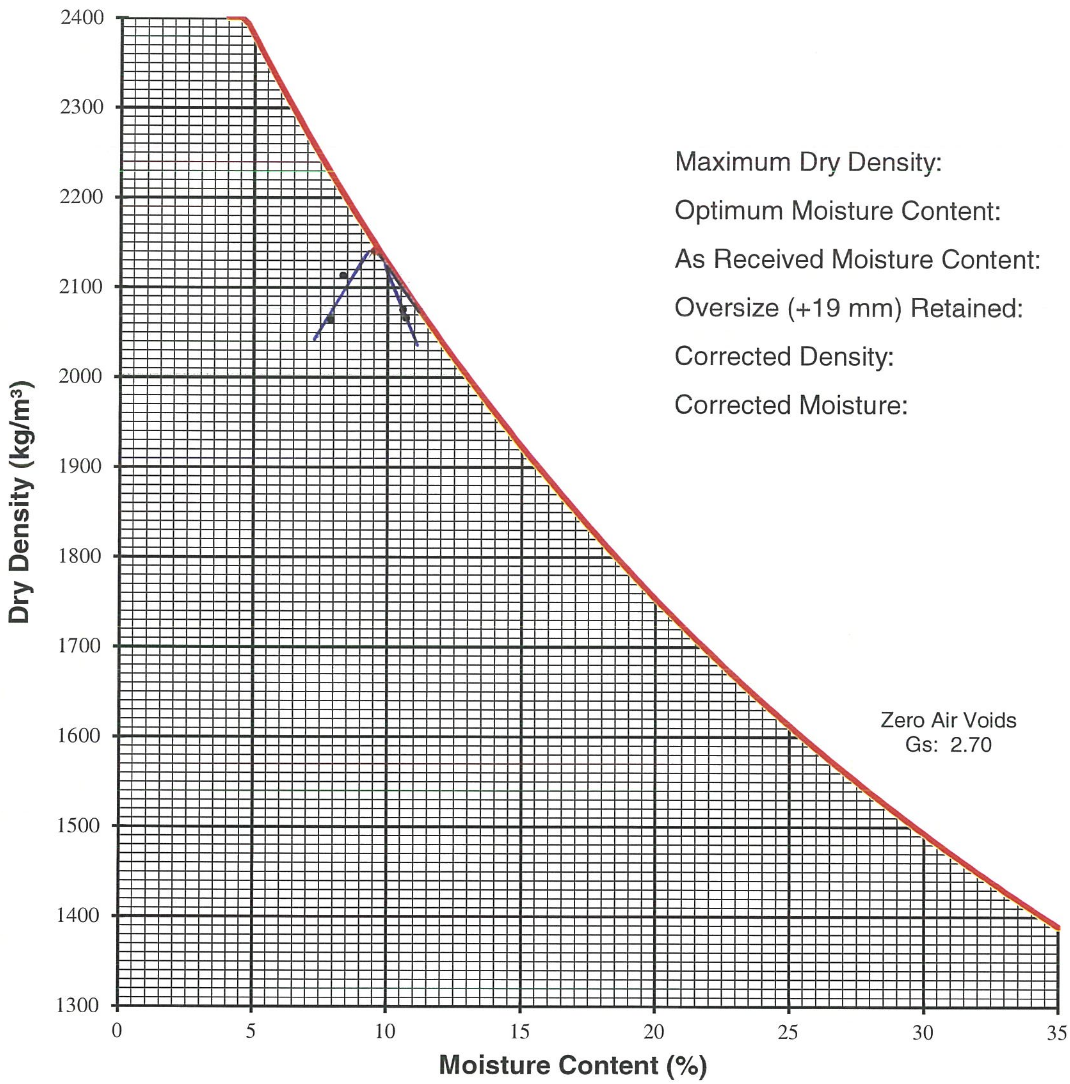
Reviewed By: ______________________ P.Eng.

TETRA TECH

MOISTURE-DENSITY RELATIONSHIP (Proctor) REPORT

ASTM D1557 Modified

Project:	Clinton Creek, Dawson City	Sample No.:	SA01
Client:	WorleyParsons	Sampled By:	MCP
Attention:	Margaret McBride	Sample Date:	06/02/2015
Project No.:	W14103619-01	Test Date:	June 5, 2015
Description:	SAND and GRAVEL - some silt	Preparation:	Oven Dry
Source:	Sand Hill Pit	Compaction:	Manual



Maximum Dry Density:	**2140**	kg/m³
Optimum Moisture Content:	**9.5**	%
As Received Moisture Content:		%
Oversize (+19 mm) Retained:	**15**	%
Corrected Density:	**2210**	%
Corrected Moisture:	**8.2**	%

Remarks:

Reviewed By: C.E.T.

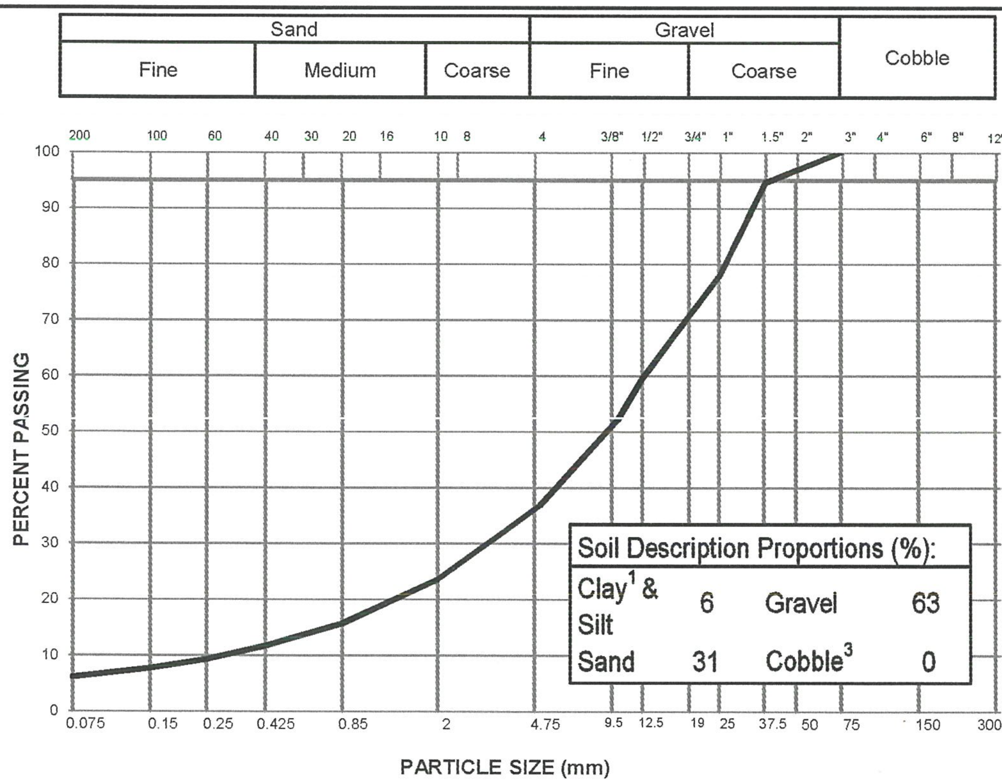
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Clinton Creek	Sample No.:	SA02
Project No.:	W14103619-01	Material Type:	
Site:	Clinton Creek Road	Sample Loc.:	Entrance Pit
Client:	WorleyParsons	Sample Depth:	
Client Rep.:	Margret McBride	Sampling Method:	Grab
Date Tested:	June 3, 2015 By: AMT	Date sampled:	May 31, 2015
Soil Description[2]:	GRAVEL - sandy, trace silt	Sampled By:	Client
		USC Classification:	Cu: 42.3
Moisture Content:	1.5%		Cc: 3.1

Particle Size (mm)	Percent Passing
300	
200	
150	
100	
75	100
50	
38	95
25	78
19	71
12.5	60
10	52
5	37
2	24
0.85	16
0.425	12
0.25	9
0.15	8
0.075	6.1



Soil Description Proportions (%):			
Clay[1] & Silt	6	Gravel	63
Sand	31	Cobble[3]	0

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

[3] If cobbles are present, sampling procedure may not meet ASTM C702 & D75

Specification: ______________________

Remarks: ______________________

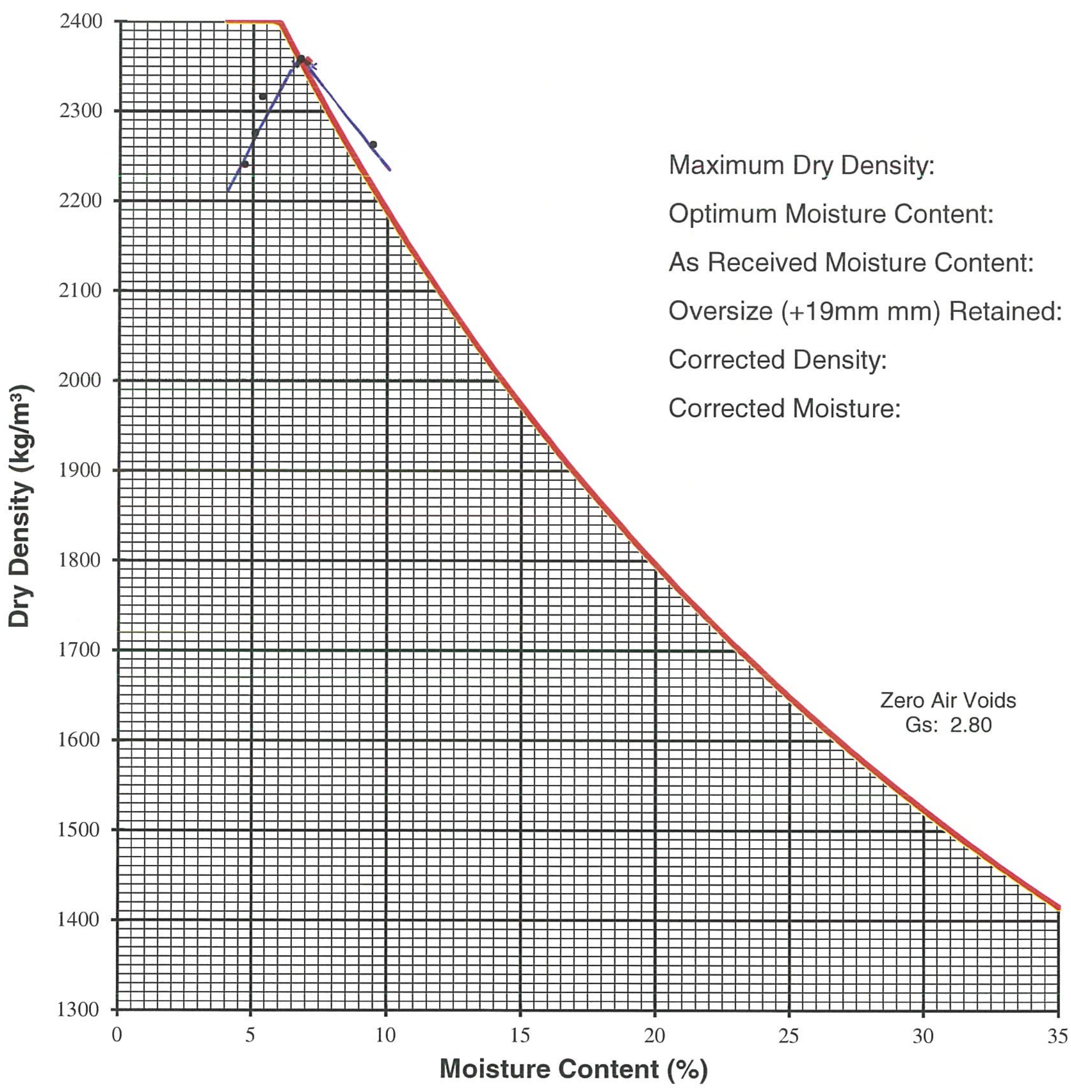
Reviewed By: ______________________ P.Eng.

TETRA TECH

MOISTURE-DENSITY RELATIONSHIP (Proctor) REPORT

ASTM D1557 Modified

Project:	Clinton Creek, Dawson City	Sample No.:	SA02
Client:	WorleyParsons	Sampled By:	RMD
Attention:	Margaret McBride	Sample Date:	June 2, 2015
Project No.:	W14103619-01	Test Date:	June 5, 2015
Description:	GRAVEL - sandy, trace silt	Preparation:	Oven Dry
Source:	Entrance Pit	Compaction:	Manual



Maximum Dry Density:	**2355**	kg/m³
Optimum Moisture Content:	**7.0**	%
As Received Moisture Content:		%
Oversize (+19mm mm) Retained:	**30**	%
Corrected Density:	**2475**	%
Corrected Moisture:	**5.2**	%

Remarks:

Reviewed By: ________________ C.E.T.

TETRA TECH

Appendix B

Maxxam Analytics Lab Test Results

Table 1: ABA Test Results for CLINTON CREEK Project

Maxxam

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Maxxam Sample No	Sample ID	Paste pH	CO2	CaCO3 Equiv.	Total S	HCl Extractable Sulphur	HNO3 Extractable Sulphur	Non Extractable Sulphur (by diff.)	Acid Generation Potential	Mod. ABA Neutralization Potential	Fizz Rating	Net Neutralization Potential	Neutralization Potential Ratio
	Units	**pH Units**	**wt%**	**Kg CaCO3/T**	**wt%**	**wt%**	**wt%**	**wt%**	**Kg CaCO3/T**	**Kg CaCO3/T**	**N/A**	**Kg CaCO3/T**	**N/A**
MJ1359	CCENTPILES01	9.21	14.86	337.7	0.18	<0.01	0.11	0.07	3.4	266	MODERATE	263	78.3
MJ1360	CCENTPILES02	9.30	14.13	321.1	0.24	<0.01	0.15	0.09	4.7	265	MODERATE	260	56.4
MJ1361	CCENTPILES03	9.16	15.07	342.5	0.15	<0.01	0.09	0.06	2.8	280	MODERATE	277	100.0
MJ1362	CCWR01	9.45	1.12	25.5	0.15	0.05	0.01	0.09	0.3	155	NONE	155	516.0
MJ1363	CCWR02	8.50	8.94	203.2	0.16	0.04	0.04	0.08	1.3	136	STRONG	135	104.8
MJ1364	CCWR03	8.71	4.37	99.3	0.57	0.21	0.18	0.18	5.6	104	MODERATE	98.4	18.6
Detection Limits		*N/A*	*0.02*	*0.5*	*0.02*	*0.01*	*0.01*	*0.02*	*0.3*	*0.1*	*N/A*	*0.1*	*0.1*
Maxxam SOP #		*Y0SOP-00*	*LECO*	*BBY WI-00033*	*Acme*	*BBY0SOP-00010*	*BBY0SOP-00010*	*BBY WI-00033*	*BBY WI-00033*	*BBY0SOP-00020*	*BBY0SOP-00*	*BBY WI-00033*	*BBY WI-00033*

Notes:

Lawrence, R.W. 1991. Acid Rock Drainage Prediction Manual

References:

Acid Generation Potential = HNO3 Extractable Sulphide Sulphur*31.25

CaCO3 Equivalency = Carbonate Carbon (CO2)*(100/44)*10

Carbonate carbon (CO2; HCl direct method) by Leco done at Acme Labs.

Fizz Rating - Reference method used is based on NP method.

Non Extractable Sulphur = (Total Sulphur)-(HCl Extractable Sulphate Sulphur)-(HNO3 Extractable Sulphide Sulphur)

Net Neutralization Potential = (Modified ABA Neutralization Potential)-(Acid Generation Potential (HNO3 Extr))

Mod. ABA Neutralization Potential - MEND Acid Rock Drainage Prediction Manual, MEND Project 1.16.1b (pages 6.2-11 to 17), March 1991.

Neutralization Potential Ratio = (Neutralization Potential)/(Acid Generation Potential)

Paste pH - Field and Laboratory Methods Applicable to Overburdens and Minesoils, (EPA 600 / 2-78-054, March 1978).

HCl Extractable Sulphur is based on a modified version of ASTM Method D 2492-02

HCl Extractable Sulphur and HNO3 Extractable Sulphur is based on a modified version of ASTM Method D 2492-02

Total sulphur, total carbon & carbonate carbon (CO2; HCl direct method) by Leco done at Acme Labs.

Table 2: ABA QAQC Test Results for CLINTON CREEK Project

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Duplicate QC

Maxxam Sample No	**Sample ID**	Paste pH Reported	**Paste pH Dup**	CO2 Reported	**CO2 Dup**	Total S Reported	**Total S Dup**	HCl Extractable Sulphur Reported	**HCl Extractable Sulphur**	HNO3 Extractable Sulphur Reported	**HNO3 Extractable Sulphur Dup**	Mod. ABA Neutralization Potential Reported	**Mod. ABA Neutralization Potential Reported Dup**	Fizz Rating Reported	**Fizz Rating Dup**
	Units	pH Units	pH Units	wt%	wt%	wt%	wt%	wt%	wt%	wt%	wt%	Kg CaCO3/T	Kg CaCO3/T	N/A	N/A
MJ1359 Dup	CCENTPILES01	9.21	9.25					<0.01	<0.01	0.11	0.11	266	266	MODERATE	MODERATE
MJ1362 Dup	CCWR01											155	156	NONE	NONE
MJ1363 Dup	CCWR02			8.94	8.84										
MJ1364 Dup	CCWR03					0.57	0.63								

Reference Material QC

	Paste pH	CO2	Total S	HCl Extractable Sulphur	HNO3 Extractable Sulphur	Mod. ABA Neutralization Potential Reported
Units	pH Units	wt%	wt%	wt%	wt%	Kg CaCO3/T
Reference Material						
ARD-Paste pH 8.29 (7929564) (8.29 pH Units)	8.23					
KZK-1ModS Slight (7929565) (58.9 Kg CaCO3/T)						56.5
ARD Spike C02 (7930329) (1.55 wt%)		1.39				
ARD REF MAT GS311-1 (7930330) (2.32 wt%)			0.18			
ARD Spike C02 (7930329) (1.55 wt%)		1.35				
ARD SPIKE GS910-4 CS (7930330) (8.27 wt%)			0.24			
RS10 STD (0.06 % S)				0.05		
ARD Ref Mat DBOHC (0.27 wt%)				0.27		
ARD Ref Mat S-S (0.36 wt%)					0.36	
ARD Ref Mat DBOHN (0.26 wt%)					0.25	

Blank QC

	CO2	Total S	HCl Extractable Sulphur	HNO3 Extractable Sulphur
Method Blank			<0.01	<0.01
Method Blank	<0.02			
Method Blank		<0.02		

Table 3: Ultratrace Metals Test Results for CLINTON CREEK Project

Maxxam Sample No	Sample ID	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Au	Th	Sr	Cd	Sb	Bi	V
	Units	ppm	ppm	ppm	ppm	ppb	ppm	ppm	ppm	%	ppm	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm
MJ1359	CCENTPILES01	0.27	9.61	0.90	7.8	25	1150	44.5	755	3.54	25.2	<0.1	2.0	<0.1	199	0.04	6.50	<0.02	26
MJ1360	CCENTPILES02	0.18	5.18	0.80	6.2	20	1430	58.1	679	3.88	29.8	<0.1	3.5	<0.1	179	0.03	7.62	<0.02	23
MJ1361	CCENTPILES03	0.19	15.8	0.91	10.0	28	1230	56.8	864	4.44	31.4	<0.1	0.6	<0.1	202	0.03	7.73	<0.02	49
MJ1362	CCWR01	1.24	10.9	3.41	25.8	49	1790	77.5	464	3.42	2.3	0.3	<0.2	1.3	30.3	0.20	1.29	0.04	18
MJ1363	CCWR02	2.53	25.3	5.54	33.2	104	822	43.1	483	3.00	9.0	0.6	0.2	1.7	132	0.33	4.56	0.08	16
MJ1364	CCWR03	5.38	17.6	6.62	59.4	89	1180	38.4	427	3.08	6.3	0.8	<0.2	3.1	88.3	0.40	0.81	0.13	20
QAQC																			
Duplicates																			
MJ1364 Dup	CCWR03	5.20	15.9	7.18	53.8	104	1200	40.3	457	3.18	7.8	0.8	<0.2	3.2	90.4	0.25	0.95	0.15	21
Blanks																			
Method Blank										<0.01									
Method Blank						<2							<0.2						
Method Blank		<0.01	<0.01	0.01	<0.1		<0.1	<0.1	<1		<0.1	<0.05		<0.1	<0.5	<0.01	<0.02	<0.002	<2
Reference Material																			
REF OREAS45EA (%) (7930331)										22.62									
True Values REF OREAS45EA										**23.51**									
Percent Difference (7930331)										-3.8									
Reference Material																			
REF OREAS45EA PPB (7930332)						330							53.1						
True Values REF OREAS45EA PPB						**260**							**53**						
Percent Difference (7930332)						26.9							0.2						
Reference Material																			
REF OREAS45EA PPM (7930333)		1.48	719.16	14.53	31		405.1	51	417		9.7	1.8		10.2	4.0	0.05	0.28	0.27	321
True Values REF OREAS45EA PPM		**1.39**	**709**	**14.3**	**28.9**		**381**	**52**	**400**		**9.1**	**1.73**		**10.7**	**3.5**	**0.02**	**0.2**	**0.26**	**303**
Percent Difference (7930333)		6.5	1.4	1.6	7.3		6.3	-1.9	4.3		6.6	4.0		-4.7	14.3	150.0	40.0	3.8	5.9
Reference Material																			
DS10 % (7930331)										2.91									
True Values DS10 %										**2.719**									
Percent Difference (7930331)										7.0									
Reference Material																			
DS10 ppb (7930332)						1998							62.4						
True Values DS10 ppb						**2020**							**91.9**						
Percent Difference (7930332)						-1.1							-32.1						
Reference Material																			
DS10 ppm (7930333)		14.39	161.65	156.99	376.6		75.2	13.5	909		46.3	2.7		7.3	70.9	2.52	7.31	13.09	45
True Values DS10 ppm		**14.69**	**154.61**	**150.55**	**370**		**74.6**	**12.9**	**875**		**43.7**	**2.59**		**7.5**	**67.1**	**2.49**	**8.23**	**11.65**	**43**
Percent Difference (7930333)		-2.0	4.6	4.3	1.8		0.8	4.7	3.9		5.9	4.2		-2.7	5.7	1.2	-11.2	12.4	4.7
Detection Limits		0.01	0.01	0.01	0.1	2	0.1	0.1	1	0.01	0.1	0.05	0.2	0.1	0.5	0.01	0.02	0.002	2
Maxxam SOP #		*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*

Maxxam Sample No	Sample ID	Ca	P	La	Cr	Mg	Ba	Ti	B	Al	Na	K	W	Sc	Tl	Hg	Se	Te	Ga	S
	Units	%	%	ppm	ppm	%	ppm	%	ppm	%	%	%	ppm	ppm	ppm	ppb	ppm	ppm	ppm	%
MJ1359	CCENTPILES01	2.84	0.002	<0.5	398	15.3	316	0.001	<20	0.08	0.008	0.02	0.5	7.8	0.26	1650	0.2	0.05	0.8	0.15
MJ1360	CCENTPILES02	2.33	<0.001	<0.5	482	16.4	380	0.002	<20	0.05	0.009	0.02	0.7	6.4	0.33	2300	0.2	<0.02	0.6	0.23
MJ1361	CCENTPILES03	2.92	0.001	<0.5	433	15.8	417	0.002	<20	0.10	0.008	0.02	0.8	9.8	0.31	2240	0.3	<0.02	0.6	0.15
MJ1362	CCWR01	0.56	0.012	3.9	1500	20.5	36.1	0.004	178	0.40	0.003	0.04	0.4	8.1	0.03	32	0.9	0.02	1.0	0.12
MJ1363	CCWR02	2.34	0.026	5.2	331	10.4	336	0.001	<20	0.14	0.006	0.03	0.2	7.1	0.11	513	0.6	<0.02	0.4	0.15
MJ1364	CCWR03	1.59	0.023	6.8	796	11.4	75.3	0.002	79	0.33	0.005	0.04	0.3	5.7	0.06	95	1.2	<0.02	0.7	0.54
QAQC																				
Duplicates																				
MJ1364 Dup	CCWR03	1.63	0.022	6.9	819	11.8	78.3	0.002	91	0.34	0.006	0.04	0.3	5.9	0.07	114	1.6	<0.02	0.7	0.57
Blanks																				
Method Blank		<0.01	<0.001			<0.01		<0.001		<0.01	<0.001	<0.01								<0.02
Method Blank																<5				
Method Blank				<0.5	<0.5		<0.5		<20				<0.05	<0.1	<0.02		<0.1	<0.02	<0.1	
Reference Material																				
REF OREAS45EA (%) (7930331)		0.04	0.03			0.09		0.099		3.14	0.02	0.06								0.04
True Values REF OREAS45EA		**0.036**	**0.029**			**0.095**		**0.106**		**3.32**	**0.02**	**0.053**								**0.036**
Percent Difference (7930331)		11.1	3.4			-5.3		-6.6		-5.4	0.0	13.2								11.1
Reference Material																				
REF OREAS45EA PPB (7930332)																<5				
True Values REF OREAS45EA PPB																**10**				
Percent Difference (7930332)																				
Reference Material																				
REF OREAS45EA PPM (7930333)				6.7	838.6		151.4		<20				<0.05	77.4	0.06		0.8	0.08	12.2	
True Values REF OREAS45EA PPM				**6.57**	**849**		**148**							**78**	**0.072**		**0.63**	**0.07**	**11.7**	
Percent Difference (7930333)				2.0	-1.2		2.3							-0.8	-16.7		27.0	14.3	4.3	
Reference Material																				
DS10 % (7930331)		1.11	0.083			0.81		0.083		1.06	0.068	0.35								0.31
True Values DS10 %		**1.09**	**0.079**			**0.81**		**0.077**		**1.06**	**0.066**	**0.35**								**0.3**
Percent Difference (7930331)		1.8	5.1			0.0		7.8		0.0	3.0	0.0								3.3
Reference Material																				
DS10 ppb (7930332)																285				
True Values DS10 ppb																**300**				
Percent Difference (7930332)																-5.0				
Reference Material																				
DS10 ppm (7930333)				17.7	58		445.8		<20				3.3	3.2	5.51		2.3	4.89	4.5	
True Values DS10 ppm				**17.5**	**54.6**		**359**						**3.32**	**2.8**	**5.1**		**2.3**	**5.01**	**4.3**	
Percent Difference (7930333)				1.1	6.2		24.2						-0.6	14.3	8.0		0.0	-2.4	4.7	
Detection Limits		0.01	0.001	0.5	0.5	0.01	0.5	0.001	20	0.01	0.001	0.01	0.05	0.1	0.02	5	0.1	0.02	0.1	0.02
Maxxam SOP #		*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*	*1F-MS*

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Table 3B: MEND SFE Test Results for project CLINTON CREEK

Maxxam Sample No	Sample ID	Sample Weight	Volume Used	pH	EC	ORP	SO4	Acidity to pH4.5	Acidity to pH8.3	Total Alkalinity	Bicarbonate	Carbonate	Hydroxide	Fluoride	Dissolved Chloride	Hardness CaCO3	Dissolved Aluminum (Al)
	Units	**g**	**ml**	**pH Units**	**uS/cm**	**mV**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
MJ1360	CCENTPILES02	250	750	9.48	107.9	80.0	4.6	<0.5	<0.5	47	58	<0.5	<0.5	0.07	<0.5	50.7	0.0209
MJ1364	CCWR03	250	750	8.57	1066.0	100	522	<0.5	<0.5	14	17	<0.5	<0.5	0.05	0.6	551	0.00813
QAQC																	
Duplicates																	
MU4850	CCENTPILES02 SPLIT DUP	250	750	9.53	108.4	80.0	3.9	<0.5	<0.5	52	64	<0.5	<0.5	0.07	<0.5	54.5	0.0191
MJ1360 Dup	CCENTPILES02 LEACHATE DUP							<0.5	<0.5	45	55	<0.5	<0.5	0.07			
Blanks																	
Method Blank		0	750	5.87	0.6	205	1.5	<0.5	<0.5	0.7	0.8	<0.5	<0.5	<0.01	<0.5	<0.50	<0.00050
Method Blank																	<0.00050
Method Blank																	<0.00050
Method Blank								<0.5	<0.5								
Method Blank										0.6	0.7	<0.5	<0.5				
Method Blank														0.01			
Method Blank															<0.5		
Method Blank							<0.5										
Reference Material																	
CRC ICPMS H2O (7990532) % Recovery																	105.88190
True Values CRC ICPMS H2O																	**100**
Detection Limits				N/A	0.5											0.50	0.00050
Reference Material																	
Acidity 8.3 W-Van (7990711) % Recovery									102.1								
True Values Acidity 8.3 W-Van									**100**								
Reference Material																	
Alkalinity W Soln' B (7991657) % Recovery										94.96							
True Values Alkalinity W Soln' B										**47.6**							
Reference Material																	
Fluoride water (7991864) % Recovery														96.0			
True Values Fluoride water														**0.5**			
Reference Material																	
Chloride W K-Van (7992265) % Recovery															102.03		
True Values Chloride W K-Van															**20**		
Reference Material																	
Sulphate W K-Van (7992270) % Recovery							98.92										
True Values Sulphate W K-Van							**20**										
Detection Limits				N/A	0.5		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.01	0.5	0.50	0.00050
Maxxam SOP #		BBY0SOP-000	Y0SOP-000	Y0SOP-000	BBY0SOP-00006	Y0SOP-00	Y6SOP-000	BBY6SOP-00037	Y6SOP-000	BBY6SOP-00026	BBY6SOP-00026	BBY6SOP-0002	BBY6SOP-00026	BBY6SOP-00048	BBY6SOP-00011	BBY WI-00033	BY7SOP-0000

References:
Hardness = (Calcium*2.497) + (Magnesium*4.118)
Standard Methods for the Examination of Water and Wastewater, 22nd Edition, 2012, Oxidation-Reduction Potential measurement in Clean Water, 2580 B

Dissolved Antimony (Sb)	Dissolved Arsenic (As)	Dissolved Barium (Ba)	Dissolved Beryllium (Be)	Dissolved Bismuth (Bi)	Dissolved Boron (B)	Dissolved Cesium (Cs)	Dissolved Cadmium (Cd)	Dissolved Calcium (Ca)	Dissolved Chromium (Cr)	Dissolved Cobalt (Co)	Dissolved Copper (Cu)	Dissolved Lanthanum (La)	Dissolved Iron (Fe)	Dissolved Lead (Pb)	Dissolved Lithium (Li)	Dissolved Magnesium (Mg)	Dissolved Manganese (Mn)	Dissolved Phosphorus (P)	Dissolved Molybdenum (Mo)	Dissolved Nickel (Ni)	Dissolved Potassium (K)	Dissolved Rubidium (Rb)
mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
0.00523	0.00665	0.356	<0.000010	<0.0000050	<0.050	0.00587	<0.0000050	4.46	0.0300	0.0000238	0.000130	<0.000050	0.0022	<0.0000050	0.00284	9.60	0.000058	0.0030	0.000231	0.00154	1.65	0.00849
0.000365	0.000161	0.0374	<0.000010	<0.0000050	0.379	0.00392	<0.0000050	166	0.00209	0.0000466	<0.000050	<0.000050	0.0022	0.0000058	0.00908	32.7	0.00127	0.0035	0.00862	0.00615	3.66	0.0103
0.00558	0.00664	0.370	<0.000010	<0.0000050	<0.050	0.00520	<0.0000050	4.75	0.0304	0.0000329	0.000187	<0.000050	0.0090	<0.0000050	0.00310	10.3	0.000099	0.0055	0.000243	0.00152	1.86	0.00905
<0.000020	0.000026	<0.000020	<0.000010	<0.0000050	<0.050	<0.000050	<0.0000050	<0.050	<0.00010	<0.0000050	<0.000050	<0.000050	<0.0010	<0.0000050	<0.00050	<0.050	<0.000050	0.0040	<0.000050	<0.000020	<0.050	<0.000050
<0.000020	0.000023	<0.000020	<0.000010	<0.0000050	<0.050	<0.000050	<0.0000050	<0.050	<0.00010	<0.0000050	<0.000050	<0.000050	<0.0010	<0.0000050	<0.00050	<0.050	<0.000050	0.0021	<0.000050	<0.000020	<0.050	<0.000050
<0.000020	<0.000020	<0.000020	<0.000010	<0.0000050	<0.050	<0.000050	<0.0000050	<0.050	<0.00010	<0.0000050	<0.000050	<0.000050	<0.0010	<0.0000050	<0.00050	<0.050	<0.000050	<0.0020	<0.000050	<0.000020	<0.050	<0.000050
100.58000	101.49500	105.25500	97.20300	103.24000		103.28000	101.75900		103.06400	103.63300	104.39900	103.92000	105.70390	101.66100	97.59500		101.66600		100.45000	103.60200		
1	**10**	**10**	**10**	**1**		**1**	**10**		**10**	**10**	**10**	**1**	**100**	**10**	**10**		**10**		**1**	**10**		
0.000020	0.000020	0.000020	0.000010	0.0000050	0.050	0.000050	0.0000050	0.050	0.00010	0.0000050	0.000050	0.000050	0.0010	0.0000050	0.00050	0.050	0.000050	0.0020	0.000050	0.000020	0.050	0.000050
0.000020	0.000020	0.000020	0.000010	0.0000050	0.050	0.000050	0.0000050	0.050	0.00010	0.0000050	0.000050	0.000050	0.0010	0.0000050	0.00050	0.050	0.000050	0.0020	0.000050	0.000020	0.050	0.000050
BY7SOP-000	BY7SOP-000	BY7SOP-000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-000	BY7SOP-00003	BY7SOP-0000	BY7SOP-00002	BY7SOP-00002	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000

Dissolved Selenium (Se)	Dissolved Silicon (Si)	Dissolved Silver (Ag)	Dissolved Sodium (Na)	Dissolved Strontium (Sr)	Dissolved Sulphur (S)	Dissolved Tellurium (Te)	Dissolved Thallium (Tl)	Dissolved Thorium (Th)	Dissolved Tin (Sn)	Dissolved Titanium (Ti)	Dissolved Tungsten (W)	Dissolved Uranium (U)	Dissolved Vanadium (V)	Dissolved Zinc (Zn)	Dissolved Zirconium (Zr)	Dissolved Mercury (Hg)	Anion Sum	Cation Sum	Balance %
mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**N/A**	**N/A**	**N/A**
0.000474	1.73	<0.0000050	0.305	0.0751	<10	<0.000020	0.000150	<0.0000050	<0.00020	<0.00050	0.000658	0.0000266	0.00124	0.00023	<0.00010	<0.000050	1.04	1.07	-1.20
0.00676	1.37	<0.0000050	0.465	0.485	176	0.000110	0.000118	<0.0000050	<0.00020	<0.00050	0.000523	0.000104	0.00030	<0.00010	<0.00010	<0.000050	11.2	11.1	0.200
0.000553	1.81	<0.0000050	0.325	0.0779	<10	0.000027	0.000176	<0.0000050	<0.00020	<0.00050	0.000721	0.0000230	0.00148	0.00021	<0.00010	<0.000050	1.13	1.15	-1.10
<0.000040	<0.10	0.0000070	<0.050	<0.000050	<10	<0.000020	<0.0000020	<0.0000050	<0.00020	<0.00050	<0.000010	<0.0000020	<0.00020	<0.00010	<0.00010	<0.000050	0.0440	0.000	100
<0.000040	<0.10	<0.0000050	<0.050	<0.000050	<10	<0.000020	<0.0000020	<0.0000050	<0.00020	<0.00050	<0.000010	<0.0000020	<0.00020	<0.00010	<0.00010	<0.000050			
<0.000040	<0.10	<0.0000050	<0.050	<0.000050	<10	<0.000020	<0.0000020	<0.0000050	<0.00020	<0.00050	<0.000010	<0.0000020	<0.00020	<0.00010	<0.00010	<0.000050			
97.95800		89.23000		97.04700		106.21000	102.15000		98.28000	101.42400		104.71100	102.41900	104.62600		108.43000			
10		**1**		**10**		**1**	**1**		**1**	**10**		**10**	**10**	**10**		**1**			
0.000040	0.10	0.0000050	0.050	0.000050	10	0.000020	0.0000020	0.0000050	0.00020	0.00050	0.000010	0.0000020	0.00020	0.00010	0.00010	0.000050			
0.000040	0.10	0.0000050	0.050	0.000050	10	0.000020	0.0000020	0.0000050	0.00020	0.00050	0.000010	0.0000020	0.00020	0.00010	0.00010	0.000050			
BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-000	BY7SOP-000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BY7SOP-0000	BBY7SOP-00002	BBY WI-00033	BBY WI-00033	BBY WI-00033

Table 4: Sample List for CLINTON CREEK Project

Maxxam Sample ID	Client Sample ID	Sample Form	Dry Weight Received (kg)
MJ1359	CCENTPILES01	Rock	7.920
MJ1360	CCENTPILES02	Rock	6.819
MJ1361	CCENTPILES03	Rock	8.200
MJ1362	CCWR01	Rock	7.707
MJ1363	CCWR02	Rock	6.391
MJ1364	CCWR03	Rock	5.975

Total Weight	43.01
Total Samples Recei	6

Table 5: Sample Summary for CLINTON CREEK Project

Date Samples Rec'd by Maxxam:	6 sample were rec'd on 2-Jun-2015.
Sample Prep Conducted by Maxxam:	YES
Date of Analysis:	June 2015

Client:	WORLEYPARSONS CANADA SERVICES
Client Project Name:	CLINTON CREEK
Client Project No:	
ARD Project #:	
Maxxam Job No:	B545827
Contact Person:	ACCOUNTS PAYABLE
E-mail Address:	CAN.TradeAP@WorleyParsons.com

Data Validated by:	Ashley Leow
Position:	Burnaby ARD Laboratory Supervisor

Sample Storage

Sample rejects (and selected test residues where applicable) have been archived
Standard archive protocol is archiving for samples for 3 months after testing is complete.
If archiving is required past 3 months a fee will be required.

APPENDIX C

Results of Golder Associates

Laboratory Analysis

For reference purposes, the sample numbers and locations of the grain size distribution analysis results (which correspond to the respective LA Abrasion samples), are as follows;

Sample No.1 - Granite – Top-of-the-World Highway (#9) km 63 LHS
Sample No.2 - Schist – Top-of-the-World Highway (#9) km 46 RHS
Sample No. 3 - Quartzite – Clinton Creek Mine Site No.1 - 'Entrance Pit'

RESISTANCE TO DEGRADATION OF LARGE-SIZE COARSE AGGREGATE BY ABRASION & IMPACT IN THE LOS ANGELES MACHINE
ASTM C 535

November 2, 2015
Project number: 1403695/3000

CHILKOOT GEOLOGICAL ENGINEERS LTD.
5B Bennett Road
Whitehorse, YT
Y1A 5Z4

ATTENTION: Mr. Tares Dhara, P.Eng.

PROJECT: Borrow Source Assessment – Clinton Creek Area, Yukon - 2015

Sample:	**SA #1 – Granite**
Source:	**Top of the World Highway (#9) – km 63 LHS Quarry**

Date sampled: September 10 & 12, 2015 **Sampled by:** Client
Date tested: October 30, 2015 **Tested by:** IC

Grading	**1**
Number of Revolutions	1000
Loss After 1000 Revolutions (%)	**14.7**

Reported by: I. Chung

Reviewed by: ______________________
L. Hu, M.Sc.E., P.Eng.

Notice: The test data given herein pertain to the sample provided, and may not be applicable to material from other production zones/periods. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

RESISTANCE TO DEGRADATION OF LARGE-SIZE COARSE AGGREGATE BY ABRASION & IMPACT IN THE LOS ANGELES MACHINE

ASTM C 535

November 2, 2015
Project number: 1403695/3000

CHILKOOT GEOLOGICAL ENGINEERS LTD.
5B Bennett Road
Whitehorse, YT
Y1A 5Z4

ATTENTION: Mr. Tares Dhara, P.Eng.

PROJECT: Borrow Source Assessment – Clinton Creek Area, Yukon - 2015

Sample:	**SA #2 – Schist**
Source:	**Top of the World Highway (#9) – km 46 RHS Quarry**

Date sampled: September 10 & 12, 2015 **Sampled by:** Client
Date tested: October 30, 2015 **Tested by:** IC

Grading	**1**
Number of Revolutions	1000
Loss After 1000 Revolutions (%)	**18.2**

Reported by: I. Chung

Reviewed by: Liz
L. Hu, M.Sc.E., P.Eng.

RESISTANCE TO DEGRADATION OF LARGE-SIZE COARSE AGGREGATE BY ABRASION & IMPACT IN THE LOS ANGELES MACHINE

ASTM C 535

November 2, 2015
Project number: 1403695/3000

CHILKOOT GEOLOGICAL ENGINEERS LTD.
5B Bennett Road
Whitehorse, YT
Y1A 5Z4

ATTENTION: Mr. Tares Dhara, P.Eng.

PROJECT: Borrow Source Assessment – Clinton Creek Area, Yukon - 2015

Sample:	**SA #3 – Quartzite**
Source:	**Clinton Creek Mine Site – Entrance Pit**

Date sampled: September 10 & 12, 2015 **Sampled by:** Client
Date tested: October 30, 2015 **Tested by:** IC

Grading	**1**
Number of Revolutions	1000
Loss After 1000 Revolutions (%)	**22.6**

Reported by: I. Chung

Reviewed by: Liyn
L. Hu, M.Sc.E., P.Eng.

Notice: The test data given herein pertain to the sample provided, and may not be applicable to material from other production zones/periods. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

DETERMINATION OF TOTAL OR WATER-SOLUBLE SULPHATE ION CONTENT OF SOIL

CSA A23.2-3B

November 4, 2015
Project Number: 1403965-3000

CHILKOOT GEOLOGICAL ENGINEERS LTD.
5B Bennett Road
Whitehorse, YT
Y1A 5Z4

Attention: Mr. Tares Dhara, P.Eng.

PROJECT: Borrow Source Assessment, Clinton Creek Area, Yukon

Date received: September 24, 2015 **Sampled by:** Client
Date tested: November 3, 2015 **Tested by:** SJ

Sample ID	Source	Total Sulphate Ion Content %	Water-Soluble Sulphate Ion Content %
Sa #1, Granite	Highway #9 (km 63), LHS Quarry	0.03	Not Applicable *
SA #2, Schist	Highway #9 (km 46), RHS Quarry	0.05	Not Applicable *
Sa #3, Quartzite	Clinton Creek Mine Site, Entrance Pit	0.01	Not Applicable *

Note:
1. * Per Clause 9.1.4, the water-soluble sulphate ion content need not be tested when the total sulphate ion content is less than 0.20%
2. Detection limit for the test is 0.005%

Reported by: S. John, AScT

Reviewed by: ______________________
L. Hu, M. Sc. E., P.Eng.

Notice: The test data given herein pertain to the samples provided. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

SPECIFIC GRAVITY AND ABSORPTION OF ROCK FOR EROSION CONTROL

ASTM D 6473

October 28, 2015
Project number: 1403695/3000

CHILKOOT GEOLOGICAL ENGINEERS LTD.
5B Bennett Road
Whitehorse, YT
Y1A 5Z4

ATTENTION: Mr. Tares Dhara, P.Eng.

PROJECT: Borrow Source Assessment – Clinton Creek Area, Yukon - 2015

Sample:	**SA #1 – Granite**
Source:	**Top of the World Highway (#9) – km 63 LHS Quarry**

Date sampled: September 10 & 12, 2015 **Sampled by:** Client
Date tested: October 23, 2015 **Tested by:** IC

Trial No.	Mass (g)	Relative Density (Dry Basis)	Relative Density (SSD Basis)	Apparent Relative Density	Absorption (%)
1	1600.3	2.686	2.699	2.721	0.48
2	3004.3	2.689	2.698	2.714	0.34
3	1941.4	2.692	2.701	2.717	0.34
4	1372.6	2.695	2.705	2.724	0.39
5	1193.6	2.691	2.702	2.721	0.41
AVERAGE		**2.691**	**2.701**	**2.719**	**0.39**

Reported by: I. Chung

Reviewed by:

L. Hu, M.Sc.E., P.Eng.

SPECIFIC GRAVITY AND ABSORPTION OF ROCK FOR EROSION CONTROL

ASTM D 6473

October 28, 2015
Project number: 1403695/3000

CHILKOOT GEOLOGICAL ENGINEERS LTD.
5B Bennett Road
Whitehorse, YT
Y1A 5Z4

ATTENTION: Mr. Tares Dhara, P.Eng.

PROJECT: Borrow Source Assessment – Clinton Creek Area, Yukon - 2015

Sample:	**SA #2 – Schist**
Source:	**Top of the World Highway (#9) – km 46 RHS Quarry**

Date sampled: September 10 & 12, 2015 **Sampled by:** Client
Date tested: October 23, 2015 **Tested by:** IC

Trial No.	Mass (g)	Relative Density (Dry Basis)	Relative Density (SSD Basis)	Apparent Relative Density	Absorption (%)
1	511.3	2.644	2.652	2.665	0.29
2	555.3	2.603	2.612	2.626	0.33
3	402.0	2.607	2.617	2.633	0.37
4	355.8	2.622	2.630	2.643	0.31
5	518.1	2.642	2.650	2.663	0.29
6	457.5	2.640	2.646	2.656	0.22
7	430.9	2.621	2.629	2.642	0.30
8	1177.4	2.626	2.635	2.650	0.35
9	1556.1	2.611	2.621	2.637	0.37
10	603.8	2.632	2.640	2.653	0.30
AVERAGE		**2.625**	**2.633**	**2.647**	**0.31**

Reported by: I. Chung

Reviewed by: ______________________
L. Hu, M.Sc.E., P.Eng.

Notice: The test data given herein pertain to the sample provided, and may not be applicable to material from other production zones/periods. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

GOLDER ASSOCIATES LTD., 300 - 3811 North Fraser Way, Burnaby, BC, Canada V5J 5J2 Tel: 604-412-6899 Fax: 604-412-6816

SPECIFIC GRAVITY AND ABSORPTION OF ROCK FOR EROSION CONTROL

ASTM D 6473

October 28, 2015
Project number: 1403695/3000

CHILKOOT GEOLOGICAL ENGINEERS LTD.
5B Bennett Road
Whitehorse, YT
Y1A 5Z4

ATTENTION: Mr. Tares Dhara, P.Eng.

PROJECT: Borrow Source Assessment – Clinton Creek Area, Yukon - 2015

Sample:	**SA #3 – Quartzite**
Source:	**Clinton Creek Mine Site – Entrance Pit**

Date sampled: September 10 & 12, 2015 **Sampled by:** Client
Date tested: October 23, 2015 **Tested by:** IC

Trial No.	Mass (g)	Relative Density (Dry Basis)	Relative Density (SSD Basis)	Apparent Relative Density	Absorption (%)
1	1429.7	2.820	2.851	2.911	1.11
2	2671.3	2.854	2.871	2.902	0.57
3	4404.7	2.792	2.822	2.878	1.07
4	1964.9	2.821	2.848	2.900	0.98
5	1891.2	2.838	2.861	2.905	0.81
AVERAGE		**2.825**	**2.851**	**2.899**	**0.91**

Reported by: I. Chung

Reviewed by: ______________________
L. Hu, M.Sc.E., P.Eng.

Notice: The test data given herein pertain to the sample provided, and may not be applicable to material from other production zones/periods. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

SPECIFIC GRAVITY AND ABSORPTION OF ROCK FOR EROSION CONTROL

ASTM D 6473

October 28, 2015
Project number: 1403695/3000

CHILKOOT GEOLOGICAL ENGINEERS LTD.
5B Bennett Road
Whitehorse, YT
Y1A 5Z4

ATTENTION: Mr. Tares Dhara, P.Eng.

PROJECT: Borrow Source Assessment – Clinton Creek Area, Yukon - 2015

Sample:	**SA #4 – Serpentine**
Source:	**Clinton Creek Mine Site – Entrance Pit**

Date sampled: September 10 & 12, 2015 **Sampled by:** Client
Date tested: October 23, 2015 **Tested by:** IC

Trial No.	Mass (g)	Relative Density (Dry Basis)	Relative Density (SSD Basis)	Apparent Relative Density	Absorption (%)
1	1902.5	2.502	2.538	2.594	1.41
2	2675.5	2.511	2.543	2.595	1.28
3	1105.2	2.528	2.582	2.673	2.14
4	2425.3	2.538	2.584	2.660	1.81
5	893.0	2.499	2.547	2.626	1.94
AVERAGE		**2.516**	**2.559**	**2.630**	**1.72**

Reported by: I. Chung

Reviewed by: Lin

L. Hu, M.Sc.E., P.Eng.

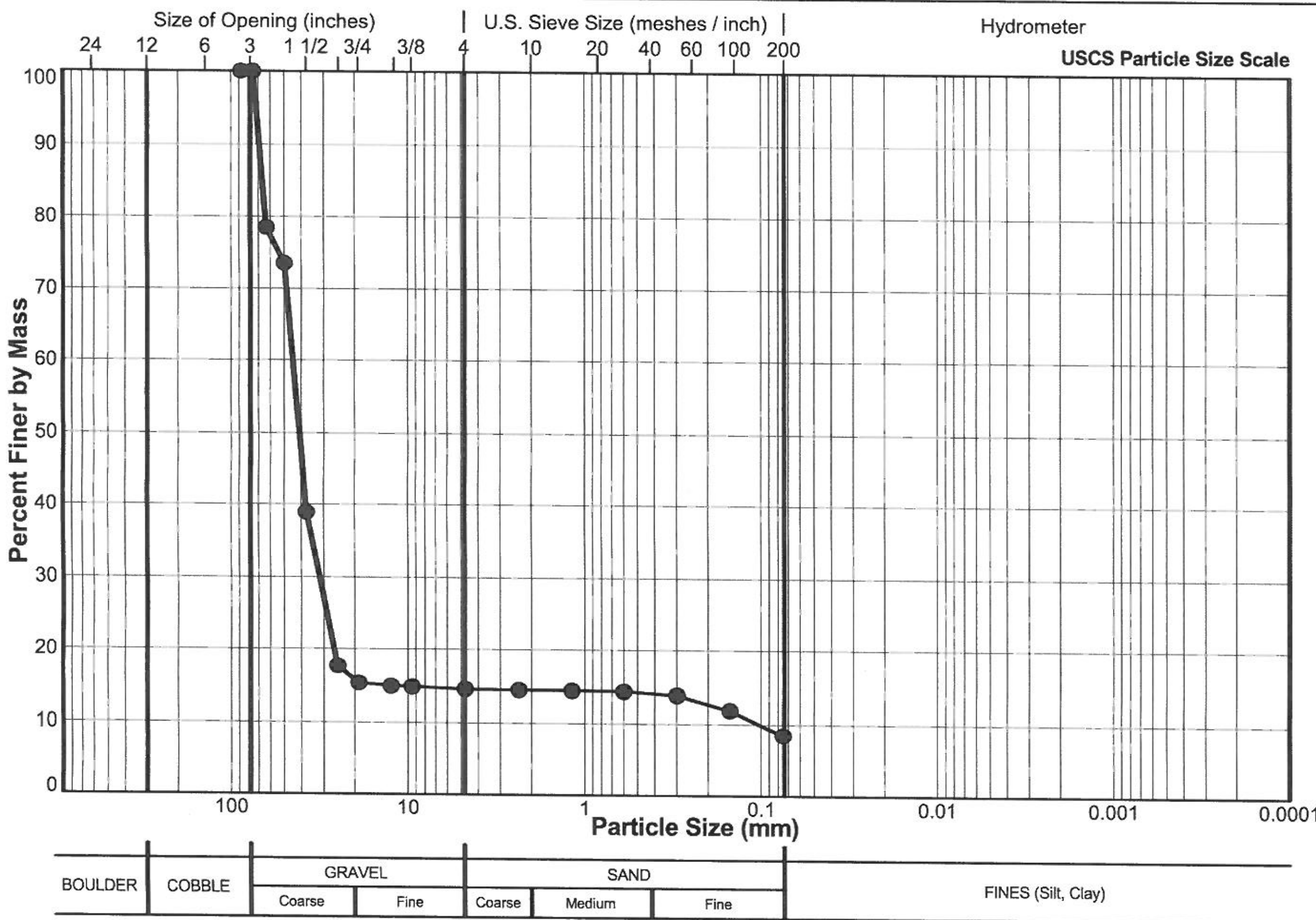
Notice: The test data given herein pertain to the sample provided, and may not be applicable to material from other production zones/periods. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM C136

Client:	Chilkoot Geological Engineers Ltd.
Project:	Borrow Source Assessment
Location:	Clinton Creek Area, Yukon
Project No.:	1403965 **Phase:** 3000

Sample Location:	Borrow Clinton Creek
Sample No.:	Granite
Depth (m):	N/A
Lab Schedule No.:	437



Legend

Sieve Size (USS)	Sieve Size (mm)	Particle Size (mm)	Percent Passing
3.5"	87.5		100.0
3"	75		100.0
2 1/2"	63		78.5
2"	50		73.5
1 1/2"	37.5		38.9
1"	25		17.6
3/4"	19		15.2
1/2"	12.5		14.8
3/8"	9.5		14.8
#4 US MESH	4.75		14.5
#8 US MESH	2.36		14.4
#16 US MESH	1.18		14.3
#30 US MESH	0.6		14.2
#50 US MESH	0.3		13.8
#100 US MESH	0.15		11.8
#200 US MESH	0.075		8.5

IC/RZ	**11/3/2015**	**LH**	**11/4/2015**
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID:1105 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) lhu 11/4/15

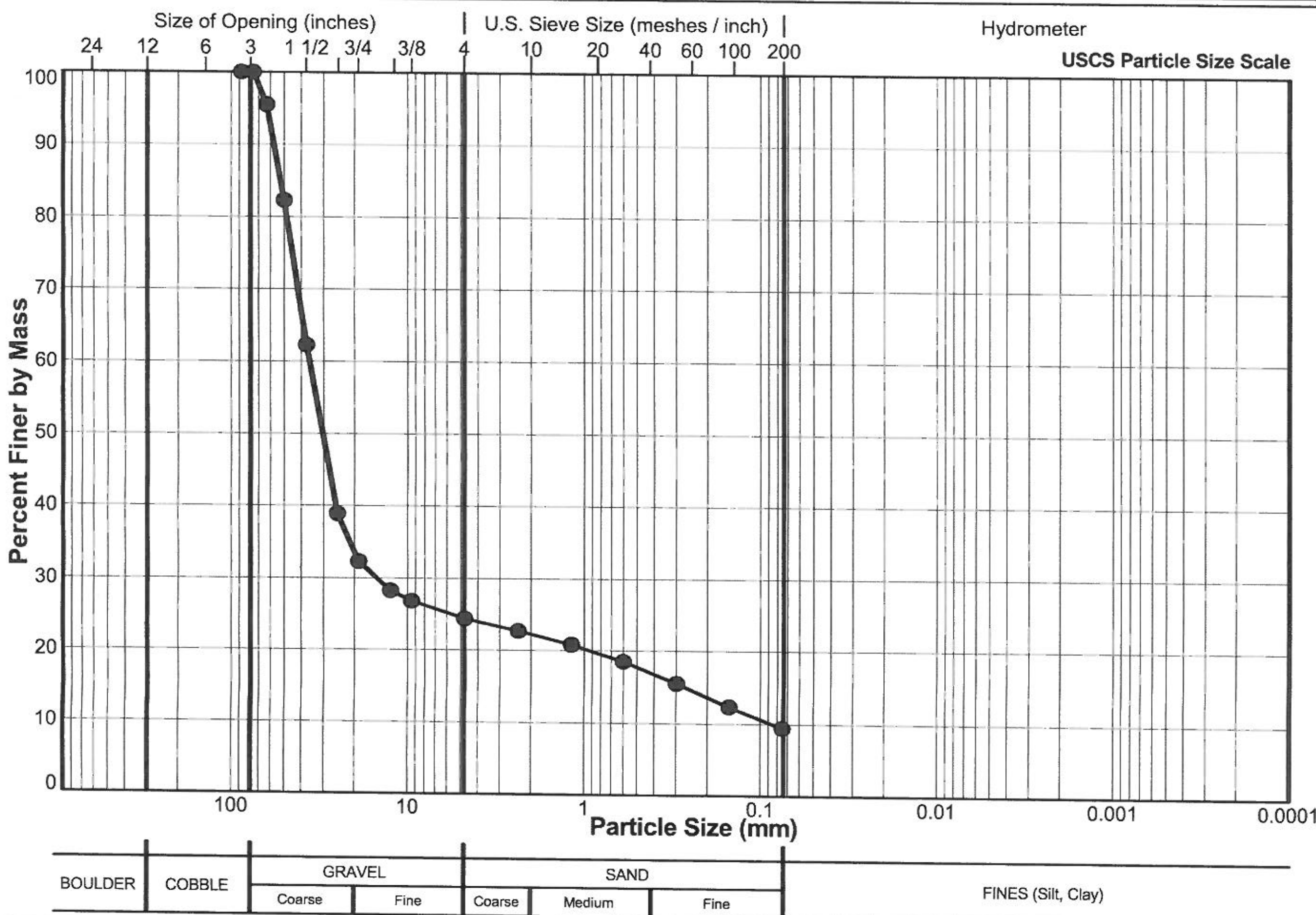
Golder Associates Ltd.
300-3811 North Fraser Way Burnaby, British Columbia Canada V5J 5J2
Tel: (604) 412 6899 Fax: (604) 412 6816 www.golder.com

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Client:	Chilkoot Geological Engineers Ltd.
Project:	Borrow Source Assessment
Location:	Clinton Creek Area, Yukon
Project No.:	1403965 **Phase:** 3000

Reference(s)
ASTM C136

Sample Location:	Borrow Clinton Creek
Sample No.:	Quartzite
Depth (m):	N/A
Lab Schedule No.:	437



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
3.5"	87.5		100.0
3"	75		100.0
2 1/2"	63		95.5
2"	50		82.3
1 1/2"	37.5		62.3
1"	25		38.9
3/4"	19		32.3
1/2"	12.5		28.3
3/8"	9.5		26.8
#4 US MESH	4.75		24.3
#8 US MESH	2.36		22.7
#16 US MESH	1.18		20.8
#30 US MESH	0.6		18.5
#50 US MESH	0.3		15.5
#100 US MESH	0.15		12.3
#200 US MESH	0.075		9.4

IC/RZ	**11/3/2015**	**LH**	**11/4/2015**
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID:1105 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) thu 11/4/15

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Tel: (604) 412 6899 Fax: (604) 412 6816 www.golder.com

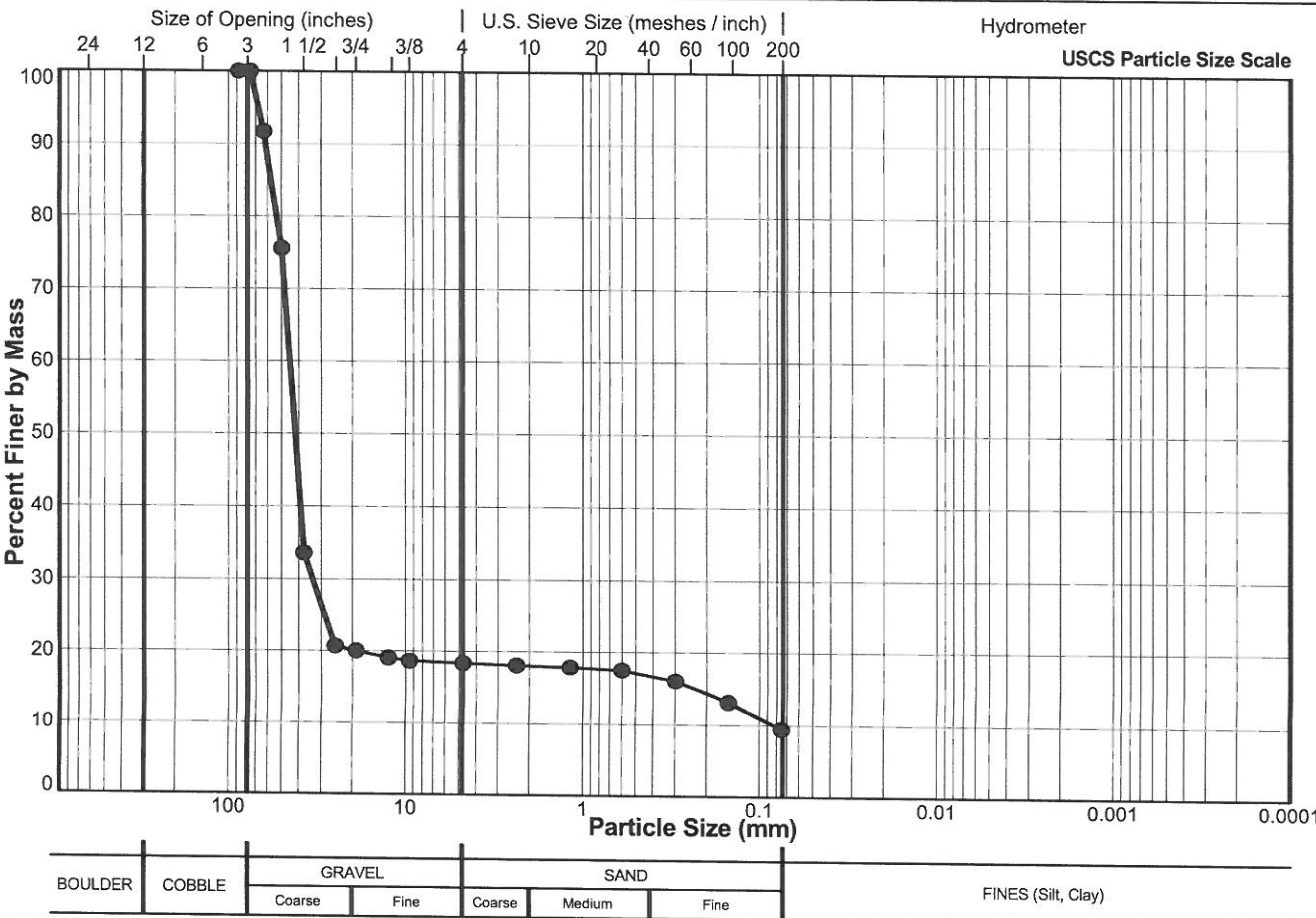
Golder Associates

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM C136

Client:	Chilkoot Geological Engineers Ltd.
Project:	Borrow Source Assessment
Location:	Clinton Creek Area, Yukon
Project No.:	1403965 **Phase:** 3000

Sample Location:	Borrow Clinton Creek
Sample No.:	Schist
Depth (m):	N/A
Lab Schedule No.:	437



Legend

Sieve Size (USS)	Sieve Size (mm)	Particle Size (mm)	Percent Passing
3.5"	87.5		100.0
3"	75		100.0
2 1/2"	63		91.7
2"	50		75.6
1 1/2"	37.5		33.6
1"	25		20.7
3/4"	19		20.0
1/2"	12.5		19.1
3/8"	9.5		18.7
#4 US MESH	4.75		18.4
#8 US MESH	2.36		18.1
#16 US MESH	1.18		17.9
#30 US MESH	0.6		17.5
#50 US MESH	0.3		16.0
#100 US MESH	0.15		13.1
#200 US MESH	0.075		9.4

	RZ	11/3/2015	LH	11/4/2015
	Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID:1105 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) lhu 11/4/15

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300-3811 North Fraser Way Burnaby, British Columbia Canada V5J 5J2
Tel: (604) 412 6899 Fax: (604) 412 6816 www.golder.com