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NORTHERN AFFAIRS PROGRAM

CLINTON CREEK
ASBESTOS MINE
ABANDONMENT PLAN

REVIEW REPORT

PREPARED BY

GEO-ENGINEERING (M.S.T.) LTD.

DECEMBER 1986

geo-engineering (M.S.T.) LTD.

REVIEW REPORT

ON

ABANDONMENT PLAN FOR

CLINTON CREEK ASBESTOS MINE

Prepared for:
Northern Affairs Program
Whitehorse, Y.T.

December, 1986

G 052-2

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1.0 INTRODUCTION

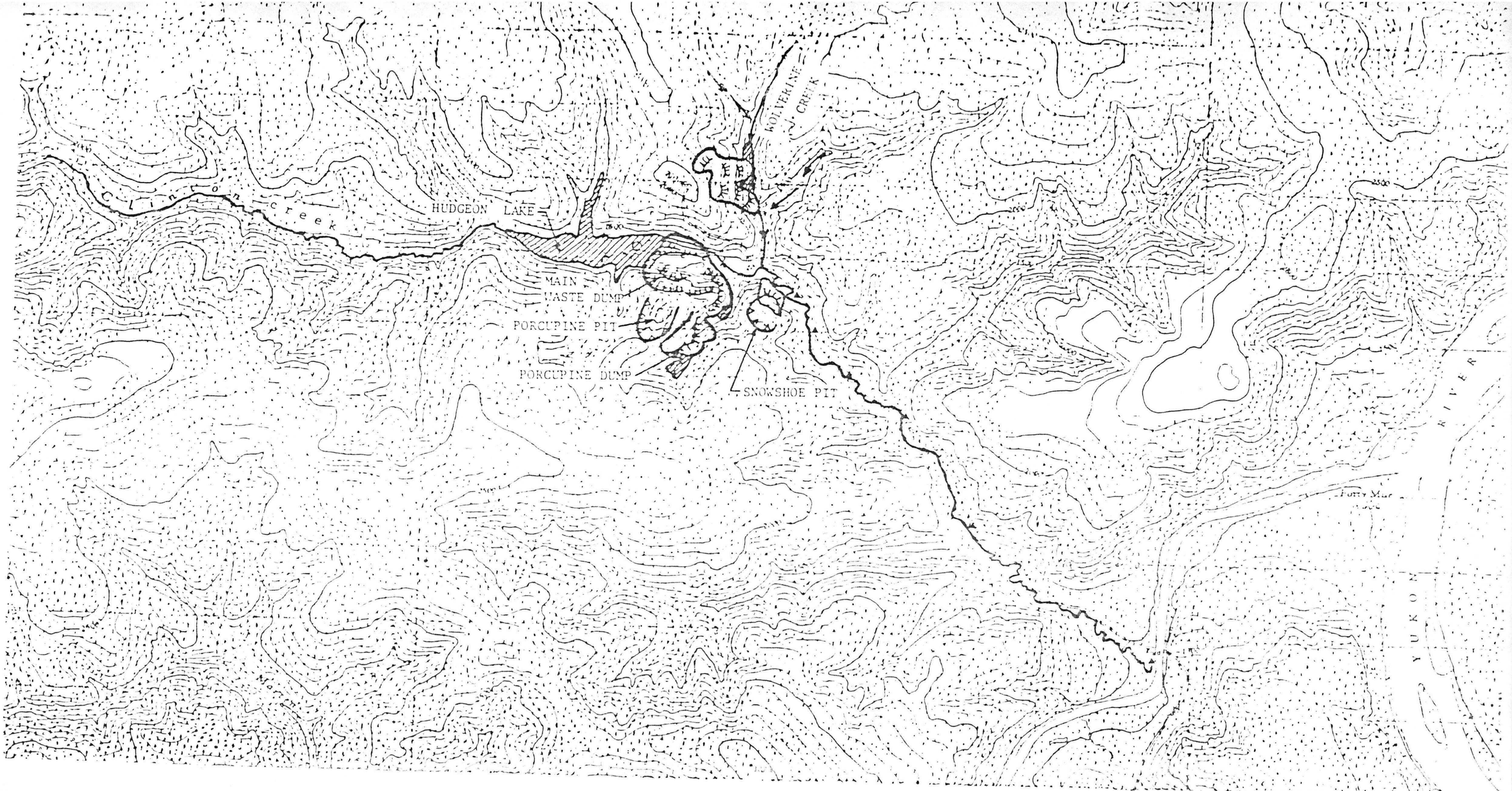
The Clinton Creek mine began its operations in 1968 and was shutdown in 1978. The mine operated under the terms of a water licence dated October 1, 1977, issued in accordance with the Northern Inland Waters Act and Regulations, legislated on February 28, 1972. The licence will expire on September 30, 1987.

Two open pits were excavated south of Clinton Creek. Waste rock from the pits was dumped into the Clinton Creek and Porcupine Creek valleys; tailings from the mill were placed into the Wolverine Creek valley (Figure 1). A majority of waste dumps and the tailings pile became unstable during the early stages of the mine operation and eventually blocked their respective valleys forming lakes. Both waste and tailings embankments have remained unstable despite the mine company efforts to stabilize them and to control erosion of valley blockages.

Cassiar Mining Corporation has been carrying out decommissioning of the mine since 1978. The behavior of both embankments was monitored until 1986 and their impact on the streams (and environment, in general) was studied by geotechnical, hydrological and aquatic specialists. Main studies and reports are listed in the References. While this work contributed to the understanding of the behavior and current impacts of these structures on the streams, it did not yield a final solution to the problem.

In summary, the main aspects relative to the abandonment of the mine site are listed below:

- The mining company, during the early stages of the mine decommissioning process, agreed to rehabilitate the site with the objective to leave the mine area in a stable condition, consistent with the natural surrounding and vegetation or to establish the potential to achieve a vegetative cover consistent with the end land use.



LEGEND:

OPEN PIT

WASTE OR TAILINGS DUMP

LAKE

▲ SEDIMENT TRANSPORT INSPECTION SITE

CLIENT NORTHERN AFFAIRS PROGRAM	CASSIAR ASBESTOS MINE
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SCALE 1:50 000	PROJECT No G 052 2 · FIGURE 1

- Stabilization efforts, undertaken by Cassiar in 1978 and 1979, did not restore equilibrium of the main dump nor the tailings pile. The rates of movement are classified as low to high, respectively.

- Following the failure of stabilization efforts, the mining company commissioned Klohn Leonoff Consulting Engineers to prepare an "Abandonment Plan for Clinton Creek Asbestos Mine." The plan is presented in a report dated September 12, 1986.

- The Plan postulates that both the waste dumps and tailings pile are in suitable condition for abandonment. According to the results of a sediment transport analysis, undertaken by Klohn Leonoff in 1985, the expected ongoing erosion will result in some limited deposition of coarse material downstream of the confluence of Wolverine and Clinton Creeks.

- The applicability of the sediment transport analysis is challenged. Deposition of significant volumes of waste and tailings materials is probable downstream of the Clinton Creek and Wolverine Creek junction.

- Contrary to the opinion expressed by the mining company, it is our view that a cycle of accelerating sloughing and channel blockages (with resulting ponding of water) followed by increased erosion will occur. This process is expected to repeat itself until significant volumes of waste and tailings materials are redeposited downstream.

- It is suggested that the erosion of stream channel blockage could be accompanied by severe flood. Marks of an unusual flood (well above the recent flow levels) were observed downstream from the Clinton Creek and Wolverine Creek confluence. This severe flood flow likely occurred after the 1974 tailings pile failure.

- The submitted Abandonment Plan is criticized because, in our opinion, it does not present a realistic prediction of possible impacts of the proposed abandonment.

- It is suggested that because of previously undertaken irreversible actions, there is no easy solution to this problem. Neither does there exist a simple and economical measure to protect the affected streams and environment.

This report discusses the present mine site conditions and reviews concerns, potential problems and various rehabilitation options insofar as its abandonment is concerned.

2.0 MINE AREA DESCRIPTION

The Clinton Creek mine area is situated approximately 97 km northwest of Dawson City. It occupies a southwesterly-trending ridge at an elevation between 457.5 and 610.0 m a.s.l., some 8 km up Clinton Creek, a tributary to the Forty Mile River. Few hills in the area rise above 900 m a.s.l. Access to the mine is via a 42 km all-weather road from the Sixty Mile Boundary Road.

2.1 MINE AND DUMPS

Asbestos fibre was discovered in the Clinton Creek area in 1956 and the ground was staked in 1957. During the period 1963-1965, the exploration programs were completed and in 1966, work consisting of about one million tons of pre-production stripping and construction of various parts of the mine-mill complex were undertaken. The mill began operation in October 1967 treating ore from the Porcupine Hill orebody. The official opening of the mine took place in April, 1968. The early stage of the mine development is shown on an air photo taken in 1970 (Figure 2).

The ore was extracted from the bedrock in two open pits referred to as the Snowshoe and Porcupine Pits. Due to deterioration and subsequent instability of the Porcupine Pit walls, a significant amount of the reserves were lost. The mineable reserves of the orebodies were exhausted and the mine closed in August, 1978. A total of 13 x 10^6 tons of ore were milled, using a dry hammer mill process, producing approximately 1.1 x 10^6 tons of asbestos fibre.

Tailings, produced by the milling process (and representing reject of milled ore), were end-dumped over the west slope of the Wolverine Creek valley. The tailings consist largely of serpentinized peridotite and short asbestos fibre. The initial failure of the tailings pile (resulting in the valley blockage) occurred in the spring of 1974. The


AIR STRIP
MILL
CLINTON CR. DUMP
DUMP
SNOWSHOE PIT
PORCUPINE PIT
PORCUPINE DUMP

total volume of tailings is estimated in the order of 12 x 10^6 tons, i.e. approximately 7 x 10^6 m^3.

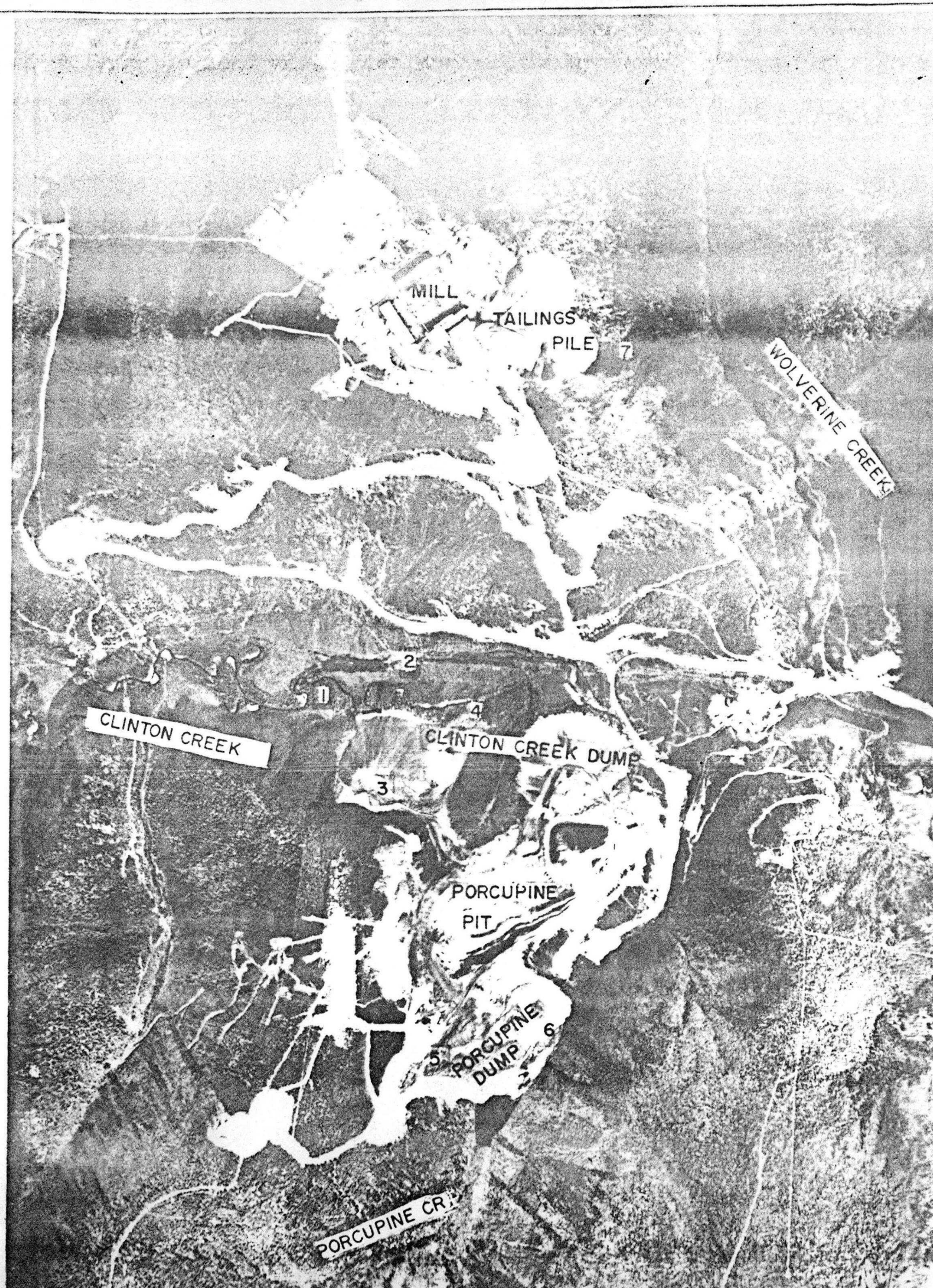
Overburden and waste rock from the Porcupine and Snowshoe Pits were dumped into the Porcupine Creek and Clinton Creek valleys. The waste rock consists mainly of argillite, black phyllite, platy-black limestone, grey argillite, and brown-weathering micaceous quartzite. The dumps became unstable during the early stages of the mine operation and eventually covered the bottoms of both valleys. The blockage of the Clinton Creek valley resulted in ponding of the creek and formation of Hudgeon Lake (Figure 3). The total volume of waste rock is estimated to be in the order of 67 x 10^6 tons or approximately 32 x 10^6 m^3.

2.2 GEOLOGIC CONDITIONS

Regionally, the Clinton Creek area is contained within the unglaciated Yukon-Tanana upland, within the continuous permafrost zone. The terrain is underlain by bedrock originally included within the Yukon Group and now, more recently, thought to be from the Yukon Cataclastic Complex (Abbott, 1982). Exposures in the vicinity of the mine site indicate that the geology in the area consists of two relatively complex assemblages of rock types as follows:

a) Sheared Assemblage: Includes sheared or schistose ultramafic, igneous and metamorphosed sedimentary rocks such as serpentinite, diorite, amphibolite and schist. All the rocks exhibit a strong pervasive foliation, except the ore bearing serpentinite.

b) Weakly Deformed Assemblage: Includes comparatively underformed and unmetamorphosed shale, siltstone and sandstone with some local phyllite and phyllonite. These strata are exposed above, below and adjacent to the sheared assemblage. They are thought to be of mid to upper Triassic in age.



NOTES :

BOTH CLINTON CREEK AND PORCUPINE CREEK DUMPS WERE UNSTABLE ALREADY IN 1970
MAIN INSTABILITY FEATURES SHOWN ON AIRPHOTO.

CLINTON CREEK 1- ORIGINAL CHANNEL

2- DIVERSION CHANNEL

CLINTON CREEK WASTE DUMP

3- FISSURES ON TOP OF THE DUMP

4- MAJOR SLIDE AND BULGING TOE

PORCUPINE DUMP

5- FISSURES ON TOP OF THE DUMP

6- VALLEY BLOCKAGE AND BULGING TOE

WOLVERINE CREEK TAILINGS PILE

7- SOUTH LOBE IS BLOCKING LOCAL DRAINAGE COURSE (RAVINE)
FAN AT THE BOTTOM OF THE RAVINE INDICATES PREVIOUS SEDIMENT TRANSPORT

CLIENT NORTHERN AFFAIRS PROGRAM	CASSIAR ASBESTOS MINE
geo-engineering (M.S.T.) LTD.	TITLE MINE AREA IN 1970
SCALE 1:15000 (approx)	PROJECT No. G 05? 2
	FIGURE 2.

The orebody consists of a stockwork of cross-fibre chrysolite asbestos veinlets cutting jade-green serpentine. Asbestos at Clinton Creek could be related to granitic intrusions or shearing and thrusting.

From a structural standpoint, the mine site and surrounding area are criss-crossed with a series of steep faults and thrust faults. The former are near vertical and tend to bound the orebody while the latter are of low angle and by their nature tend to occur along the contact of the two assemblages.

Bedrock exposures are scattered throughout the lower portions of the Clinton and Wolverine Creek valleys. The bedrock is mostly covered with overburden. The soil cover comprises colluvium on the slopes and alluvium in the valley bottoms. Water-laid deposits (usually classified as fluvial-lacustrine) cover the ridge where the concentrator was located. A brief characterization of main overburden materials follows:

a) Alluvium apparently comprises silty and sandy deposits with gravel, topped with organic silts and muskeg. No tests have been undertaken to determine properties of these materials. However, it is likely that the fine-grained deposits are ice-rich and when thawed, saturated and soft.

b) Colluvium is described as a heterogeneous mixture of sands, silts and clays with rock fragments and occasional boulders. The material is of low plasticity (Liquid and Plastic Limits are 27.3 and 18.7 percent, respectively) and its natural moisture content is approximately 9 percent. The shear strength of remolded colluvium (See Appendix A) is indicated to be 23 degrees with zero cohesion.

c) Fluvial-lacustrine deposit comprises silty sands with a variable gravel content (ranging from infrequent pebbles to about 35 percent) which exist in the former mill area, covering the uppermost segments of the hill. These deposits are described as dense and moist when thawed. Segregated ice and seepage was observed in the sheared tailings pile subgrade. Several shear strength tests have been undertaken (Appendix A) giving angles of internal friction ranging from 24 to 32 degrees.

d) Near surface bedrock is, in general, comprised of broken and weathered argillite. This material is similar to colluvium insofar as its competency and general behavior are concerned. Indeed, the properties of fractured ice-rich bedrock could be worse than those of the colluvial mantle. It is of interest to note that an approximately 75 mm thick ice lense was recovered from one test hole excavated in the bedrock in the area adjacent to the tailings pile. Direct shear strength tests conducted on weathered argillite show zero cohesion and an angle of internal friction of 26 and 27 degrees (Appendix A).

There is no detailed information available on the permafrost conditions at the site. The active layer has been reported to be 0.3 to 0.5 m thick, but this appears to be inconsistent with the vegetation in the area.

2.3 TECHNICAL CONSIDERATIONS

Waste material from the mine excavations was dumped on the slopes (ranging in 10 to 35 degrees gradient) adjacent to the open pits. The main waste dump was developed in the Clinton Creek valley and the ancillary dumps are located in the Porcupine Creek valley and adjacent to the Snowshoe Pit also in the Clinton Creek valley. The tailings pile was placed over the west wall (ranging from 16 to 20 degrees) of the Wolverine Creek valley. All waste and the tailings embankments are unstable. These embankments blocked the valleys of Clinton, Porcupine and Wolverine Creeks, thus significantly changing the stream regimes and gradients within the affected valley sectors. Both Wolverine and Clinton Creeks show signs of bank erosion and downcutting in areas where the streams traverse the valley blockages.

Examination of the surface features of these embankments indicates that there are essentially two types of failure involved:

° within the dumped material, apparently governed by the material properties and the geometric configuration;

° within the foundation, influenced by the properties of the foundation materials, the amount of segregated ice and the rate of permafrost degradation.

Two basic types of waste material were produced by the mining process: rock (overburden) waste and tailings. The characteristics and properties of these materials are described below:

a) Overburden Waste comprises sand and silt size particles (ranging in volume between 20 and 80 percent) with gravel-sized rock fragments and infrequent large blocks. The waste comprises predominantly argillite which breaks down very rapidly after it is excavated and exposed to weathering. A sample of this was subjected to a direct shear test and showed a residual friction angle of 23° (Appendix A). The bulk unit weight is estimated to be in the order of 20.6 kN/m^3.

b) Tailings consist of well-graded, crushed serpentine rock containing some asbestos fibre not recovered in the milling process. Particle sizes range from about 25 mm to approximately 10% passing the #200 sieve size. Most of the material is in the sand size range, i.e. 0.1 to 0.5 mm. The bulk unit weight is estimated to be 16.7 kN/m^3. The angle of internal friction of the tailings (Hardy, 1977; Golder, 1978) ranges from over

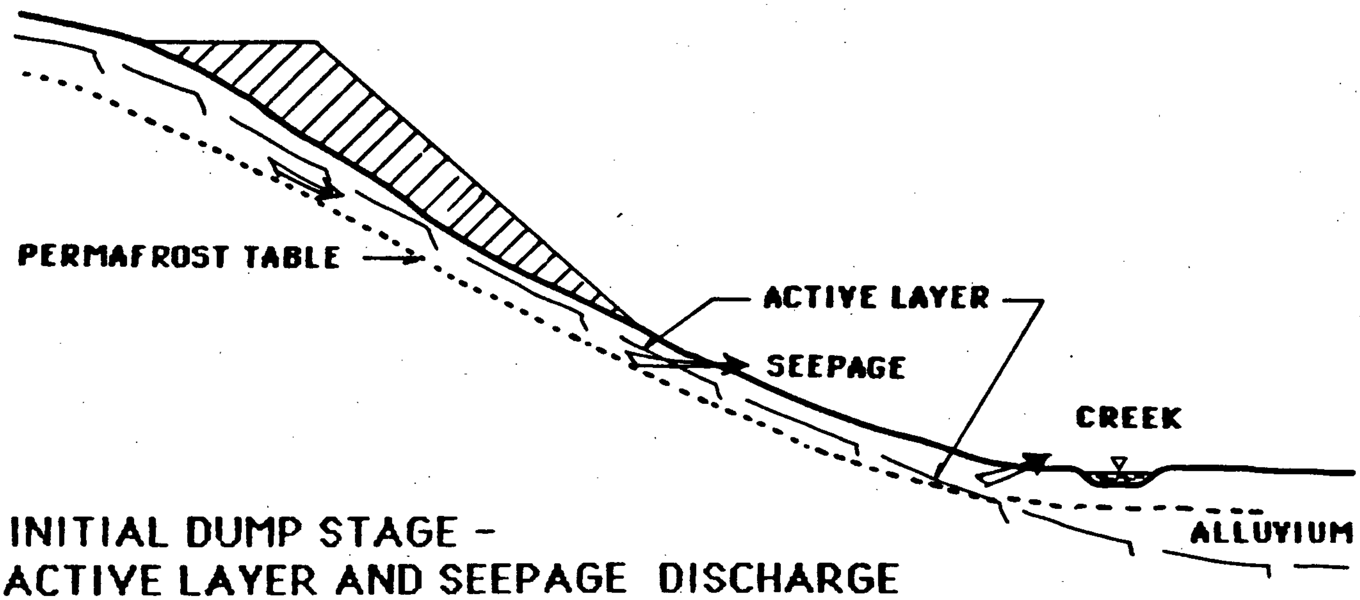
40° at low confining stresses to 30° at higher stresses. The difference between peak and residual strength indicates that a fabric develops on a shearing surface as the shearing progresses. This may be due to a large amount of asbestos fibre present in the tailings sample tested.

It is our opinion that the strength properties of the foundation materials, ice content and rate of thawing govern the overall stability of the embankments. The thaw-consolidation process also likely affects the pore pressure distribution. In addition, the embankment may insulate the subgrade and inhibit discharge of groundwater from the active zone during the warm season (Figure 4).

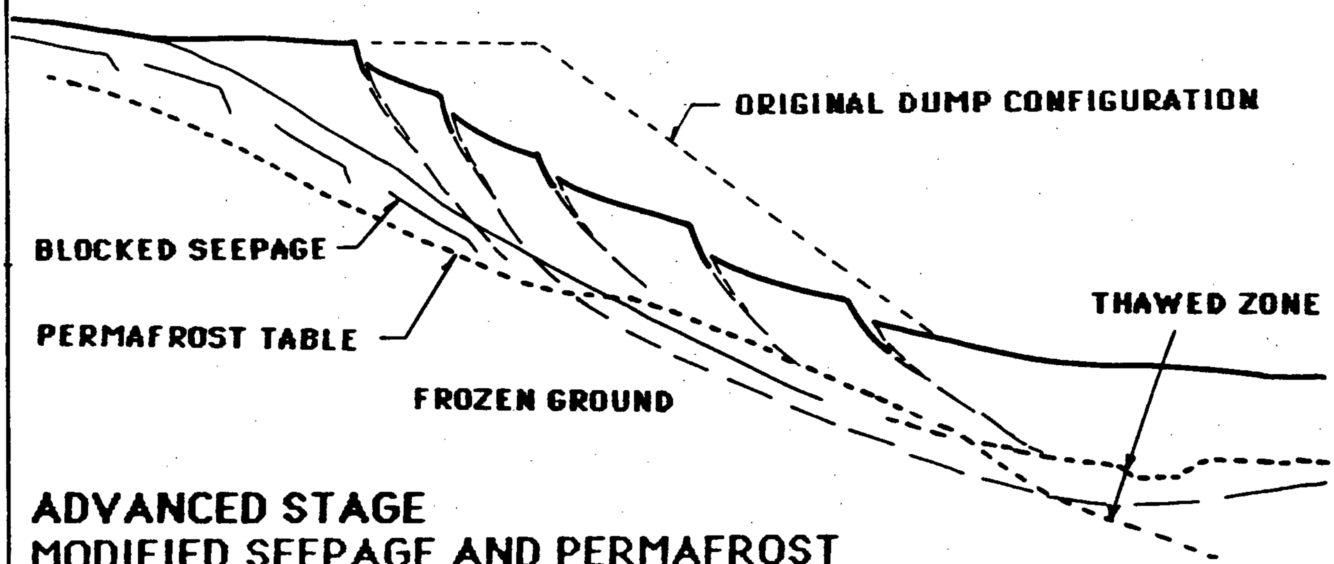
The instabilities were analyzed by Hardy (1977) and Golder (1978) and the stability of the tailings pile was also reviewed by Klohn Leonoff (1985). All these analyses indicate that a build-up of excess pore pressures in the subgrade is likely a contributing factor.

Another factor which should be considered when assessing the long-term stability of these embankments is seismicity. A seismic risk study has been undertaken by W.G. Milne (1978) who recommended that a factor of 0.1 to 0.15 g be applied in the tailings pile analysis. A similar conclusion is presented by Klohn Leonoff (1986) based on Stephens (1973). According to Stevens, a 100 year return period shows an expected acceleration equal to 6% of the acceleration due to gravity (g) at Clinton Creek.

Stability analysis confirms that a Factor of Safety of unity exists for postulated slip surfaces within the foundation if a modest pore pressure exists (r_u in the range of 0.1 to 0.2). When a seismic loading of 0.1 g was applied to the analysis of the tailings pile, a Factor of Safety of below one was obtained for all tested slip planes.



INITIAL DUMP STAGE -
ACTIVE LAYER AND SEEPAGE DISCHARGE



ADVANCED STAGE
MODIFIED SEEPAGE AND PERMAFROST

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CASSIAR ASBESTOS MINE

TITLE
INSTABILITY and FOUDATION THAWING

SCALE AS SHOWN
PROJECT No 6 052-2
FIGURE 4

3.0 RESIDUAL IMPACTS

Major residual aspects of the mining operation are two open pits, various cuts and fills (for exploration and access), Porcupine, Snowshoe and Clinton Creek waste dumps, and the Wolverine Creek tailings pile. All waste and tailings embankments are unstable and the movements range from slow creep to accelerated failures, reaching horizontal displacements in the order of 20 m per year.

3.1 OPEN PITS

The open pits expose bedrock and Porcupine pit contains a lake (Photos 1 and 2). They have a local impact on the groundwater regime and permafrost table. The walls of the pits are unstable and in the long run, they will degrade to a rubble covering bedrock. The slope failures are confined to the pit areas with little or no impact on the surrounding ground.

3.2 CLINTON CREEK WASTE DUMP

The major portion of overburden rock from the Porcupine pit was dumped over the slope which forms the south wall of the Clinton Creek valley. Originally, the valley floor was flat-bottomed with a width of about 240 m and Clinton Creek meandered within the valley bottom (Photo 3). As the toe of the dump reached the valley floor, it began to spread over the low shear strength, presumably ice-rich alluvial soils comprising the valley bottom. As more waste material was placed on the dump, the dump continued to spread until the entire valley bottom was blocked (Photo 4).

It is apparent that the steep hillside (sloping up to some 30°) did not provide any significant support to the waste material dumped from the crest. The weak deposits forming the alluvial floodplain of Clinton Creek were unable to resist the shear stresses imposed from a more than

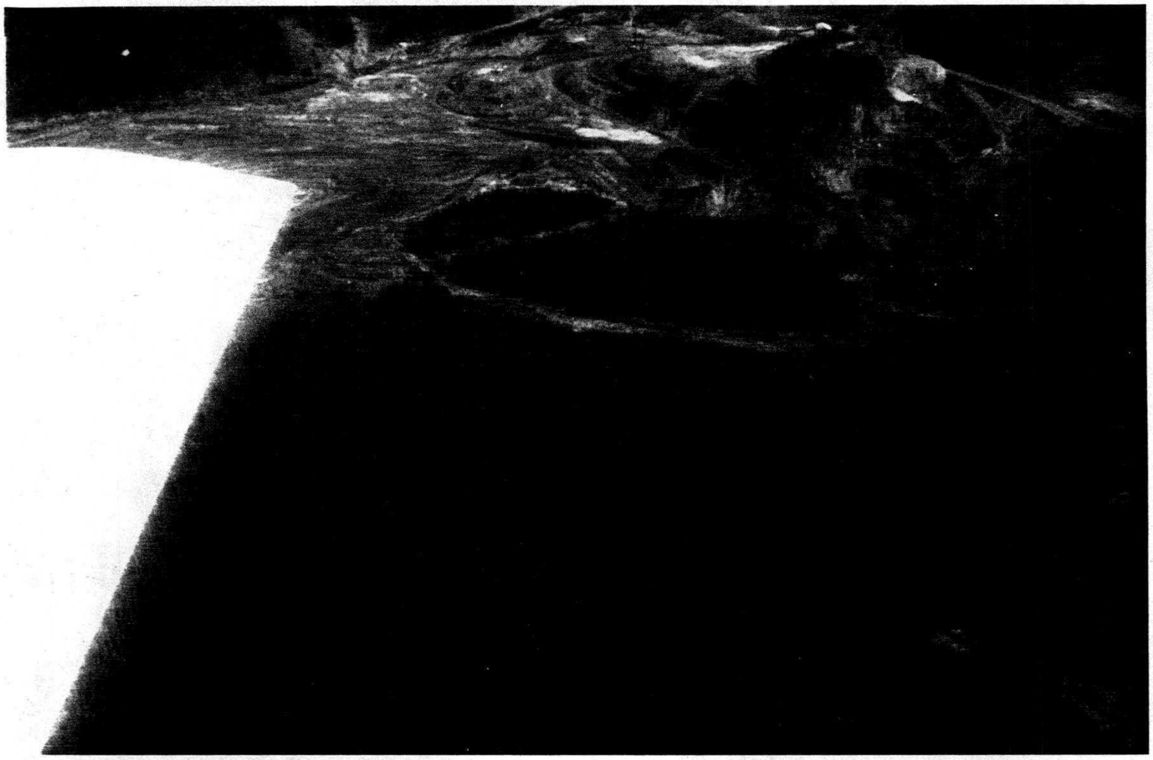


Photo 1: View of Porcupine Pit and a small unstable waste dump, looking east (June, 1983).

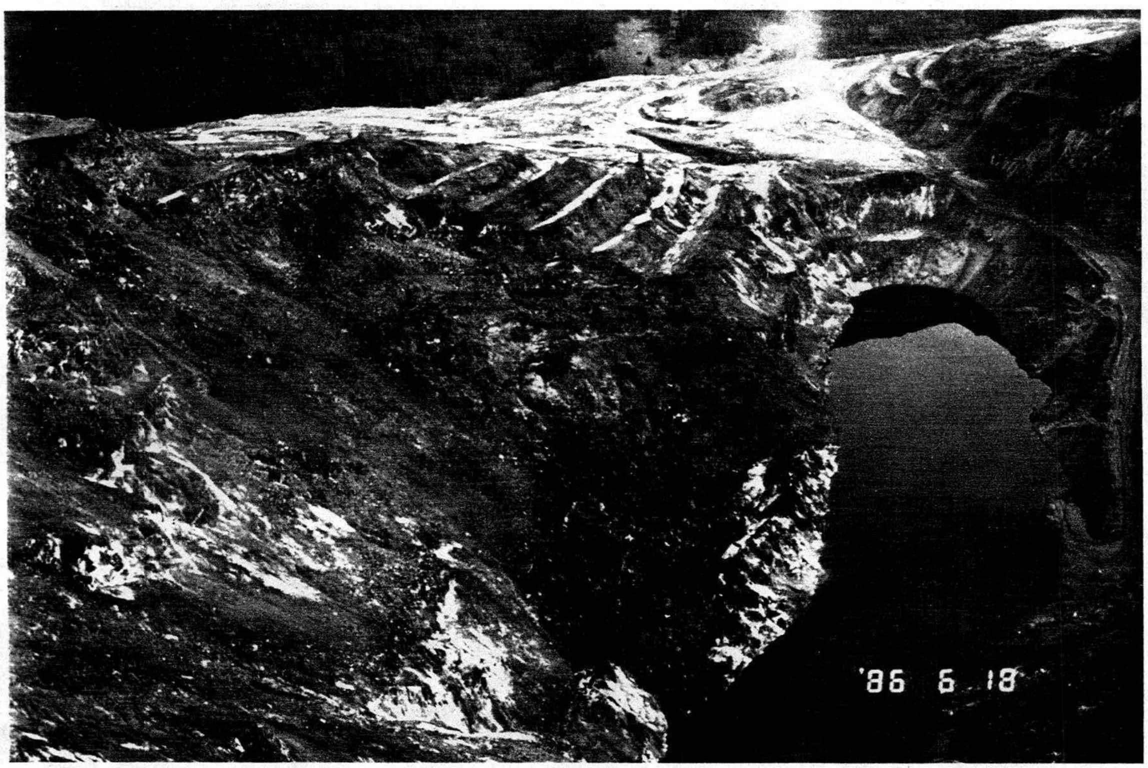


Photo 2: Porcupine Pit looking north. Note unstable west and south walls.

138 m high embankment. This resulted in failure of the foundation materials. It is also possible that if the floodplain material was of low permeability, the embankment loading could have created excess pore water pressures in the foundation material which, in turn, could itself precipitate failure extending through the foundation.

Degradation of the permafrost table in the valley bottom would also be a contributing factor. Water impounded upstream of the failed waste mass could further degrade the permafrost.

The valley blockage formed a lake (Photo 5), now known as Hudgeon Lake. The depth of water in the lake is about 26 m and its surface area is about 180 acres. Outlet from the lake currently passes through four 1.5 m diameter culverts into the Clinton Creek channel which flows across the waste dump, along its north side. The channel has incised a trough bounded by waste material on the south and the valley wall on the north (Photo 6). The channel has an overall gradient across the dump of about 4.5%.

The dump movement has been monitored since 1977 by surveying monuments located on the dump surface and cross-channel reference lines. The horizontal rate of movement (Figure 5) decreased from approximately 1.2 m/year in 1978 to some 0.3 - 0.6 m/year during the 1985 and 1986 monitoring seasons.

The original abandonment concept (1977) considered channel training works and bank as well as bed armouring with the objective to control erosion and maintain the lake. A section of rock weirs was constructed near the lake outfall in 1981 (Photo 7). During the spring runoff in 1982, Clinton Creek escaped the channel formed by the rock-lined section

Photo 3: Clinton Creek and the waste dump, probably in 1970. Note slide on left side of the dump.

Photo 4: Clinton Creek valley and Porcupine Pit in 1986.

and undercut the north valley wall. This rock-lined section was modified and reconstructed in 1984 (Photo 8). The design included backfilling of the eroded channel and placing rip-rap along both banks of the channel. A rip-rap apron at the outlet culverts from Hudgeon Lake was also provided.

The downstream segment of the rock-lined channel shows signs of distress and the initial stages of bypassing the armoured channel. Local bed erosion (retrogressive) is apparent from the longitudinal channel profiles, surveyed in 1983, 1984 and 1986. Downcutting and oversteepening of the channel banks is also apparent.

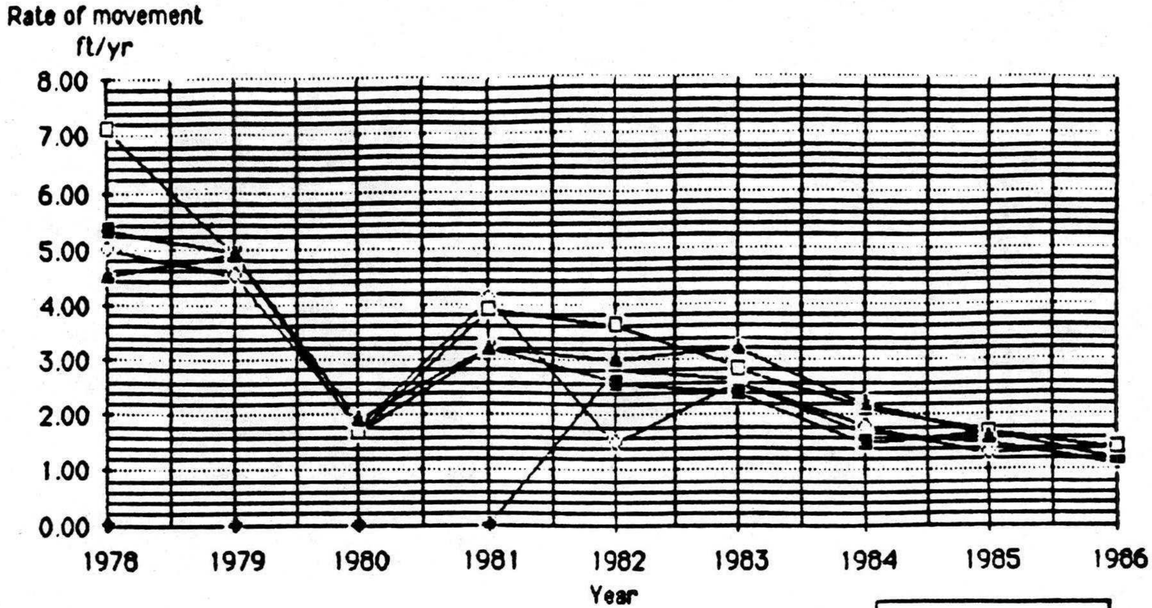
It is not believed that the current state of the Clinton Creek waste dump ensures reasonable stability of the lake, its outlet and immediately adjacent stream channel. While a catastrophic failure of the dump is not expected, a blockage of the channel followed by erosion of slide debris could occur.

This process will eventually lead to failure of the lake outlet control and to localized removal of waste from the channel banks, which, in turn, will cause temporary acceleration of waste dump movement and deposition of eroded materials further downstream. This process could repeat itself several times until an equilibrium condition is achieved.

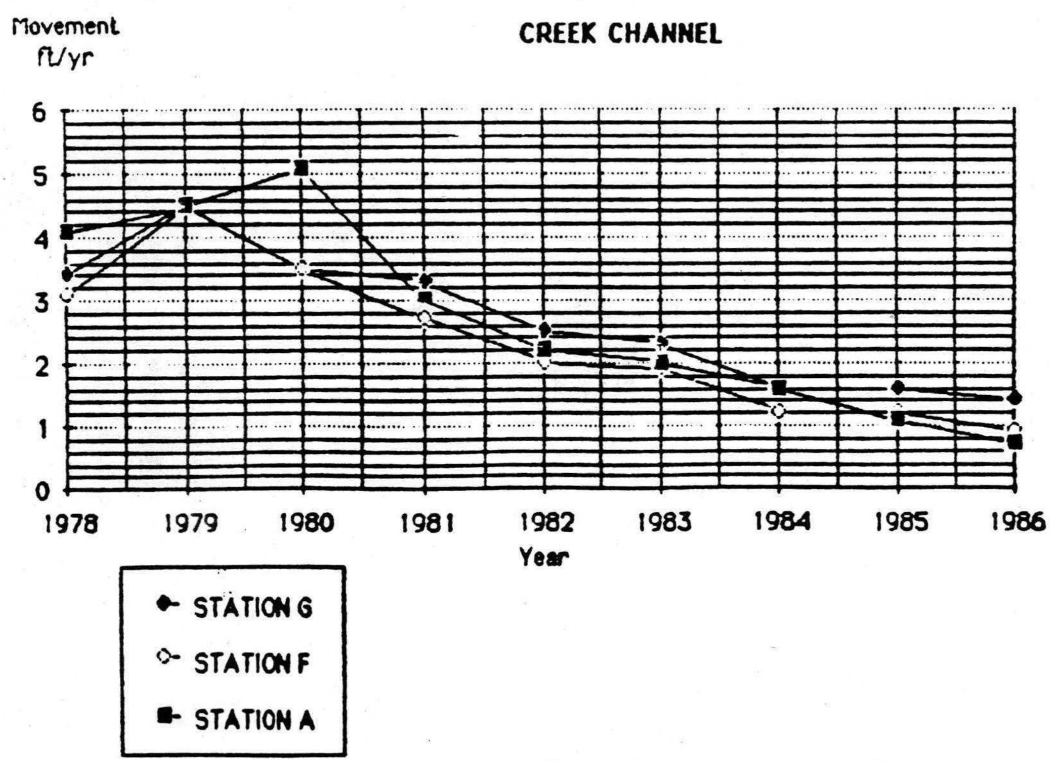
The state of equilibrium will not be achieved until a substantial amount of the current valley blockage is redeposited further downstream. The estimated total volume of waste material is in the range of 32×10^6 m^3. It is conceivable that about one third to one half of this volume will be eventually (during the next several hundred years) eroded away and redeposited downstream.

Photo 5: Hudgeon Lake and the upstream segment of the waste dump.

Photo 6: Clinton Creek channel squeezed between the north valley wall and unstable dump.



Station 81-2 installed in 1981.
1980 survey data are dubious.



CLIENT NORTHERN AFFAIRS PROGRAM	**CASSIAR ASBESTOS MINE**
geo-engineering (M.S.T.) LTD.	TITLE **CLINTON CREEK WASTE DUMP RATES OF MOVEMENT**
	SCALE As shown | PROJECT No. G 052-2 | **FIGURE 5.**

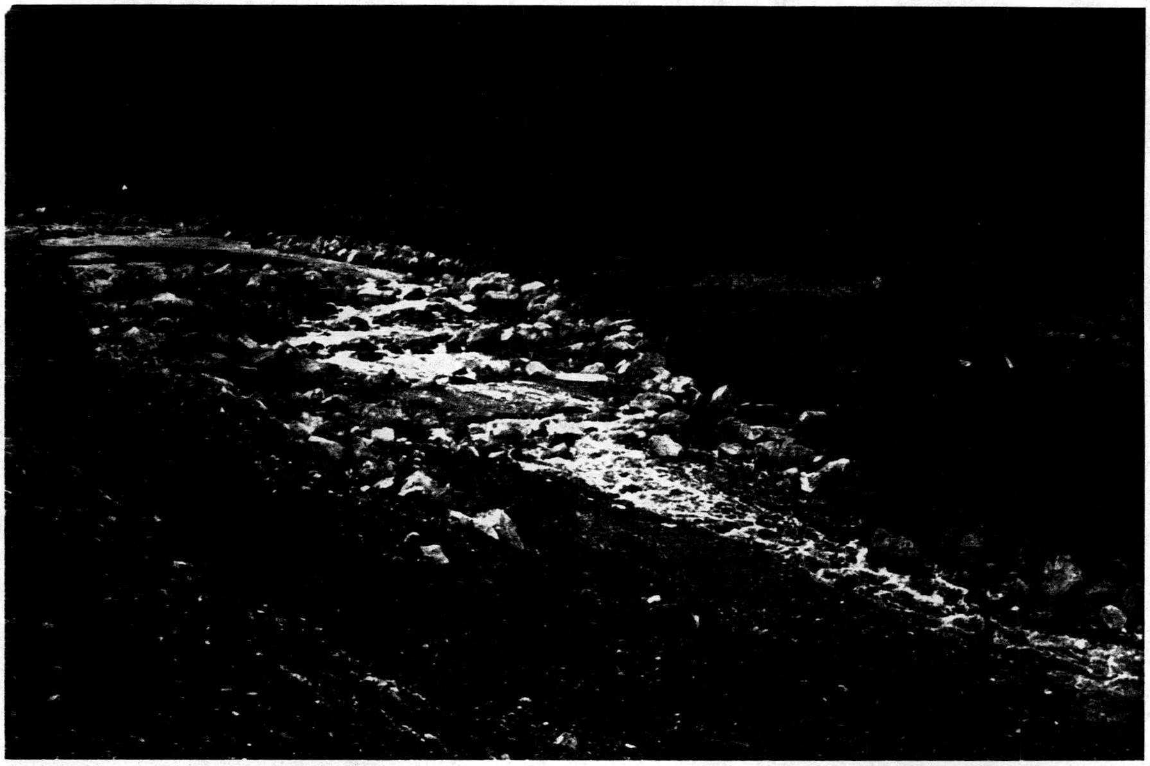


Photo 7: Clinton Creek at the outlet from Hudgeon Lake. Rock weirs constructed in 1981 were bypassed during the spring break-up in 1982.

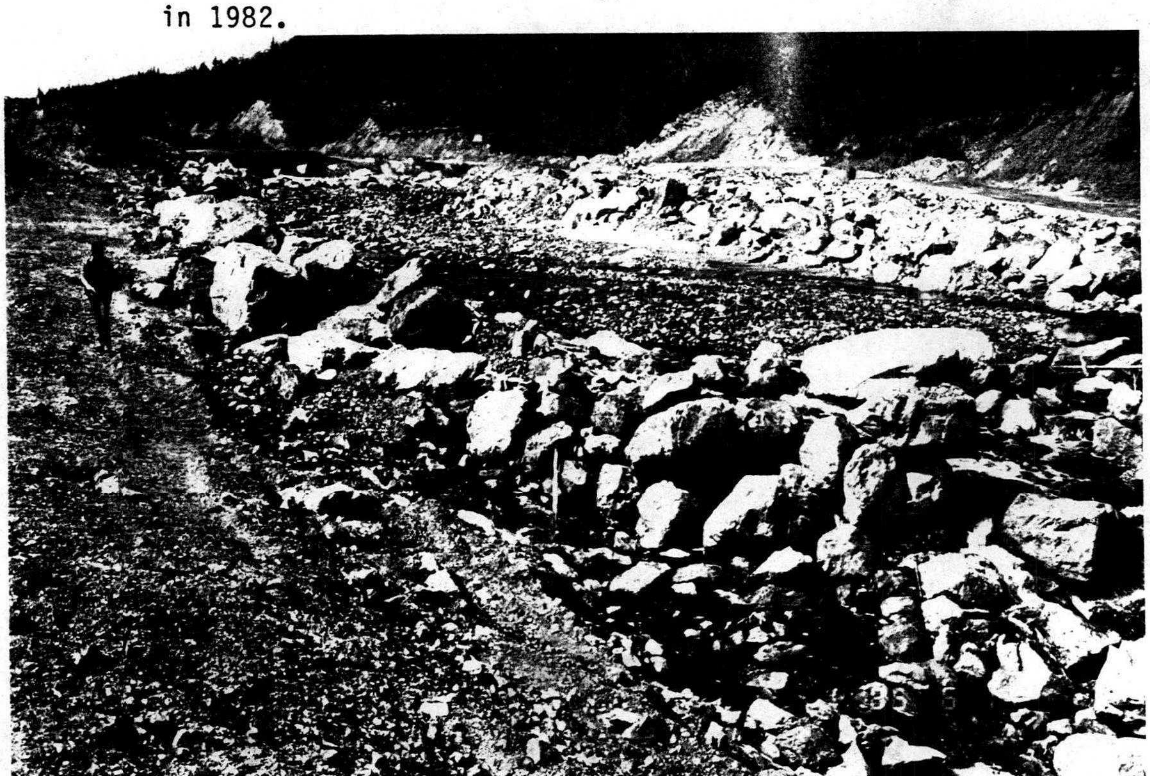


Photo 8: The rock-lined stream section (re-constructed in 1984) shows signs of erosion in 1986.

3.3 PORCUPINE WASTE DUMP

The waste embankments deposited into the Porcupine Creek valley are also unstable (Photo Nos. 9 and 10). A small reservoir has developed as a result of the blocking of Porcupine Creek, but the water is percolating through the soil. It appears that the rock waste at the bottom of the dump is of low to medium permeability and this would account for the flow of water through the mass. Since the inflow appears to be quite small, it is unlikely that a much larger reservoir could develop.

We do not consider this area to present a significant hazard insofar as a major movement or pollution of the stream is concerned. However, the dump instability will adversely affect the natural revegetation of this area.

3.4 SNOWSHOE WASTE DUMP

This dump, placed across the south valley wall of the Clinton Creek valley, is relatively small. The toe of the dump barely reaches the valley bottom. The face of the dump is bulging out - indicating incipient failure (Photo 11). The toe of the dump acts as a passive wedge against the driving force of the uppermost dump segment.

This dump will eventually fail, partially blocking the valley bottom. The failure will likely impact on the Clinton Creek channel.

3.5 WOLVERINE CREEK TAILINGS PILE

The tailings were placed over the valley slopes dipping at an average angle of about 16 to 17° to the valley bottom. According to Golder (1978), the foundations of the tailings pile consist of a surface organic layer overlying a deposit of silty sandy gravel, followed by weathered argillitic bedrock. The overburden soils and bedrock were frozen prior to the deposition of the tailings and contained segregated ice.

Photo 9: Porcupine Creek waste dump and valley blockage forming a small lake.

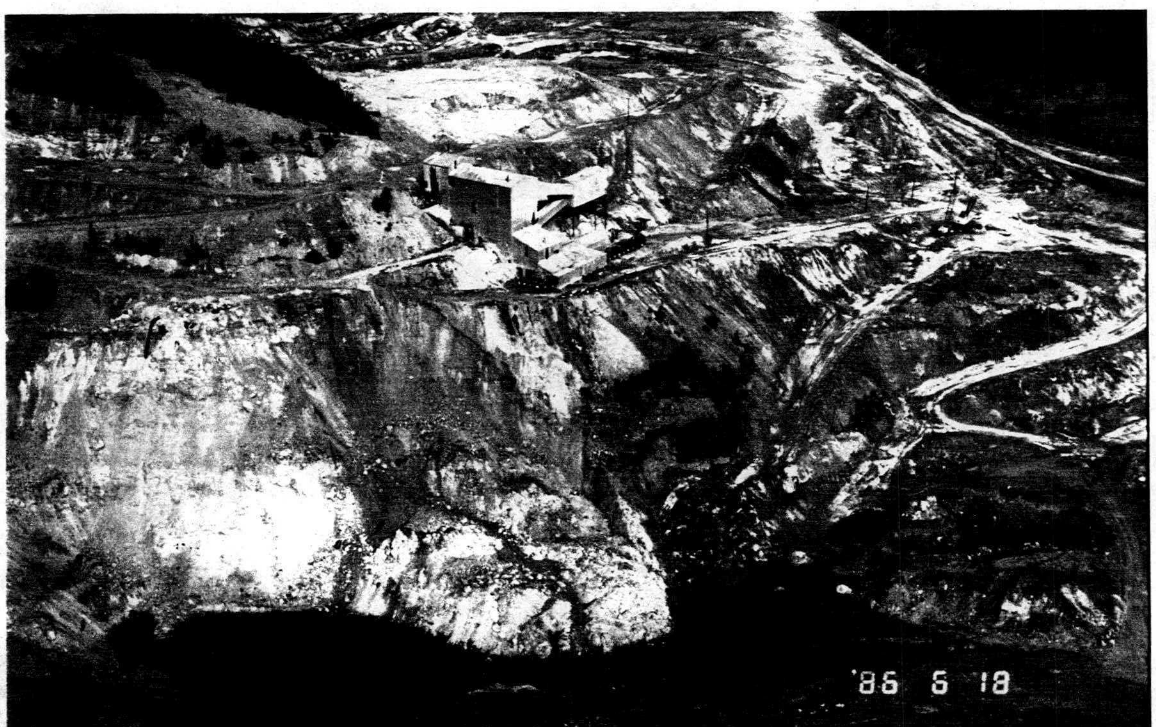


Photo 10: Slump in the vicinity of the crusher partially blocking the Porcupine Creek valley.

The tailings have been stacked in two piles, referred to as the north and south lobes. The south lobe was deposited from startup until 1974, when a failure of the tailings pile occurred and a segment of the pile moved downslope and blocked the valley bottom including the creek. Following the failure, tailings were placed on the north lobe until the mine shutdown in 1978. A rock-lined outfall channel has been constructed to control erosion and convey the creek across the valley blockage (Photo 12).

The rates of movement recorded are greater and more erratic than those of the waste dump (Figure 6). The tailings are moving in a "caterpiller-like" manner. As a lower segment fails, toe support for the section above it is removed and the failure gradually progresses up the slope with the amount of horizontal movement decreasing in the upslope direction. The toe of the dump is rising and gradually increasing the blockage of the valley bottom.

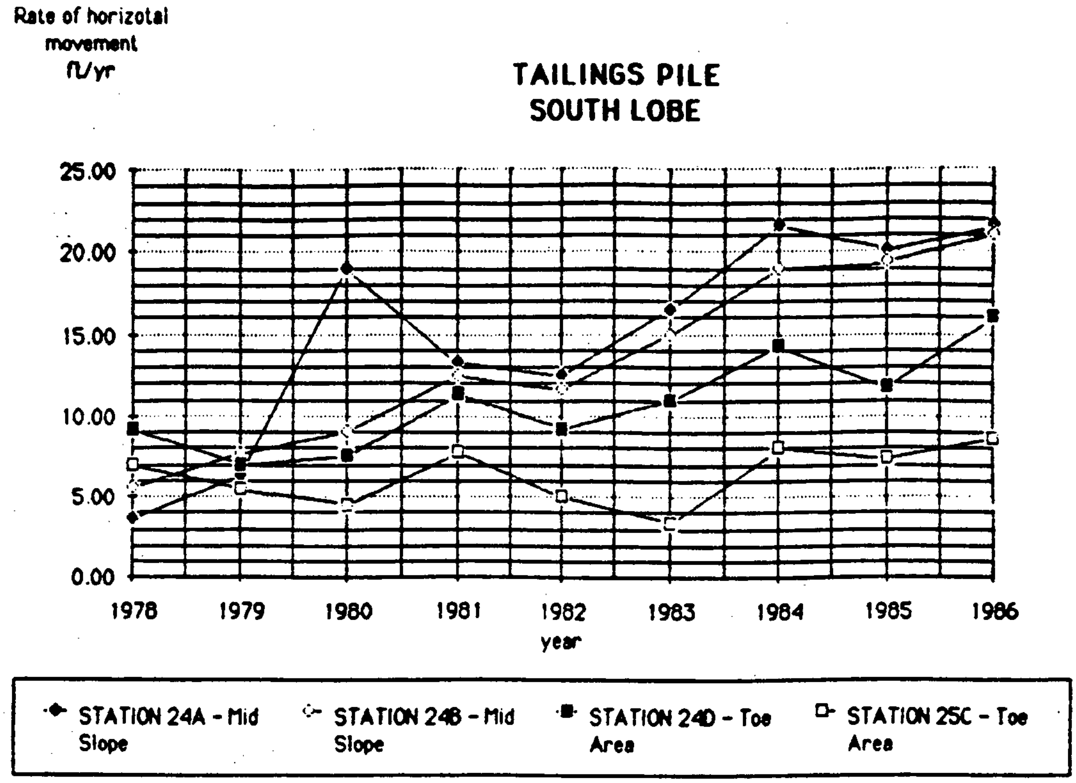
The south tailings pile lobe blocked the existing Wolverine Creek channel in 1986. There was no flow through the rock-lined channel in June, 1986 (Photo 13). The long-term stability of the rock-lined channel is questionable. It is a generally accepted practise that structures of this type require frequent monitoring and maintenance.

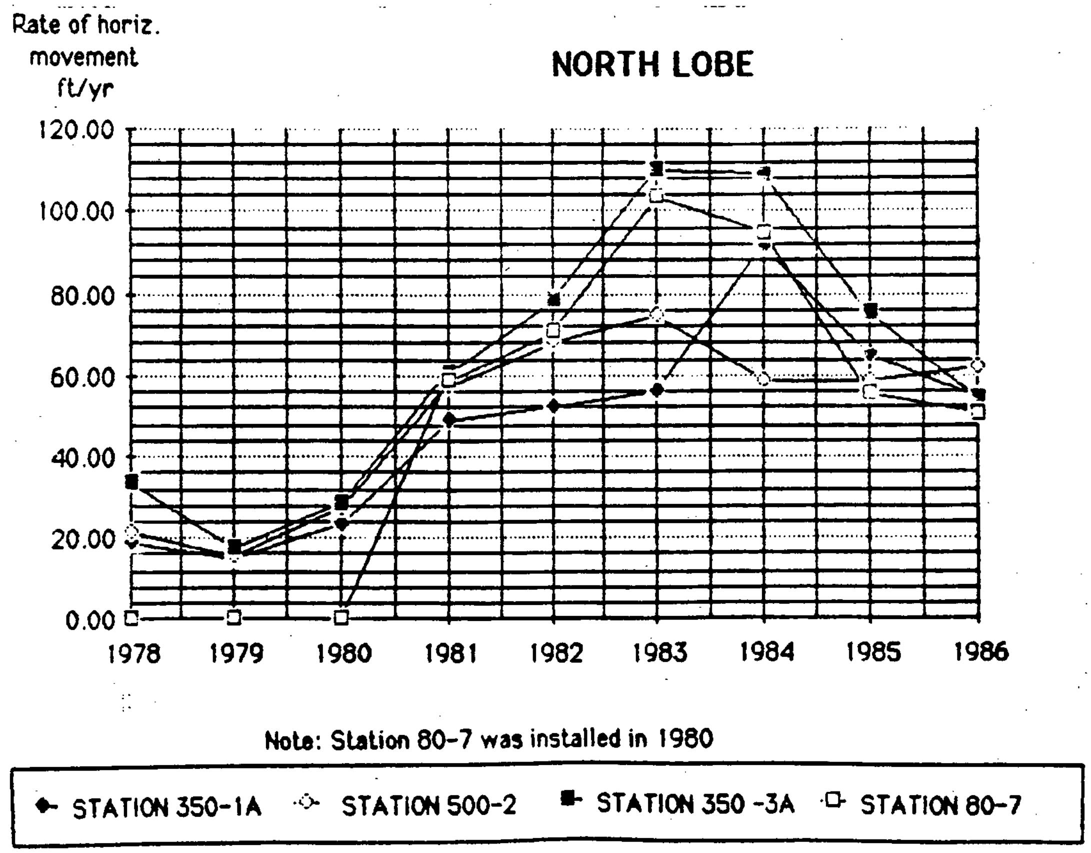
The blockage will be eventually overtopped with consequences similar to events which followed the south lobe failure in 1974. This could occur as early as during or after the 1987 spring breakup. In that case, the tailings pile toe would be eroded progressively down resulting in lowering of the lake level and flooding of the downstream valley section. Transportation as well as deposition of fine to coarse tailings particles throughout the Wolverine Creek and Clinton Creek valleys would accompany the breach of the valley blockage.

Similar development is to be expected in the area of the north lobe. The toe of this lobe reached the valley bottom in 1985 and almost

Photo 11: Snowshoe Pit waste dump deposited over the Clinton Creek valley. The dump is unstable - note the bulging.

Photo 12: View of the Wolverine Creek tailings pile, looking north; June 1982.





CLIENT NORTHERN AFFAIRS PROGRAM	CASSIAR ASBESTOS MINE
geo-engineering (M.S.T.) LTD.	TITLE WOLVERINE CREEK TAILINGS PILE RATES OF MOVEMENT
SCALE As shown	PROJECT No. G 062-2 — FIGURE 6.

blocked the valley in the summer of 1986 (Photo 14). While buttressing against the opposite valley wall will temporarly slow the rate of movement, the bulging toe will dam the valley forming a new lake. At some point in time, the dam will likely be overtopped and breached. Progressive erosion of tailings will be followed by accelerated slope movements.

Again, this event may re-occur several times until equilibrium between the erosion rate and the tailings pile movement is achieved. It is possible that more than one half of the pile volume, which comprises about 10 to 12 x 10^6 tonnes (about 7 x 10^6 m^3) of tailings, will eventually (considering the geological time scale) be displaced.

3.6 IMPACT ON DOWNSTREAM SECTORS OF CREEKS

It is expected that a significant impact on streams draining the mine area will occur if the natural erosion process is allowed to influence the valley blockages. This is suggested on the basis of a review of the impacts of the 1974 tailings pile failure on the downstream sectors of Wolverine and Clinton Creeks, undertaken during the 1986 annual inspection.

The Wolverine Creek valley bottom up to its confluence with Clinton Creek has been covered with tailings and the creek is currently downcutting through the sediment.

Extensive deposits (up to 50 cm thick) of asbestos fibres and sand-sized tailings are encountered in the area located 0.5 km downstream from the creeks' confluence. The fibres on trees are approximately 2 to 3 m above the creek channel, indicating an unprecedented flood. Changes in the channel occurred about 0.6 km downstream from the creek's junction.

The asbestos fibres were observed approximately 4.2 m above the normal level of the creek, at a location approximately 3 km downstream from the

Wolverine Creek - Clinton Creek junction. Further downstream, including the area of the Clinton Creek - Forty Mile River junction, sporadic fibres exist on trees outside of the creek channel. Serpentine and argillite fragments exist in the alluvial fan at the creek's confluence with 40 Mile River. However, the sources of these fragments are uncertain.

- Two major slides occurred sometime in the geologic history about 20 km southwest of Bragg Creek, Alberta. Terraces concordant with the height of the debris in the more northerly slide indicate the debris dammed the Elbow River. The river now flows northwestwards through a steep sided canyon cut in very coarse slide debris (Cruden, 1976).

- Jonas Creek Slide (crossed by the Banff-Jasper Highway) flowed across the Sunwapta River and formed a shallow, temporary lake. The slide comprises quartzite blocks, probably of the Gog Group. The river re-opened its channel and now flows through a stretch of rapids (Cruden, 1976).

- Mount Kitchener Slide, located about 6 km north of the Columbia Icefield and comprising massive limestones and dolomites, temporarily blocked and dammed the Sunwapta River. The river now flows through a steep-walled canyon of slide debris over 50 m deep (Cruden, 1976).

- A large slope failure forming a temporary lake occurred on April 25, 1974 in the Mantaro River Valley in Peru. The slide debris comprised sandstone blocks and the volume of slide was estimated in the order of 10^9 m^3. After 44 days, the debris dam was overtopped and in two days, washed away (Kojan and Hutchinson, 1974).

On the other hand, there are lakes which were formed by a slide and some of them retain water quite well.

- In the Carpathians, a large rockfall occurred east of Georgheni in Rumania in 1818. The limestone blocks dammed the valley creating a lake (Lacul Rosu) which still exists (Q. Zaruba, 1976).

- In the Rockies, slides formed lakes (such as Moraine Lake, Maligne Lake, etc.) which remain in place.

While the geomorphological characteristics of slides forming lakes described in the previous paragraphs may not be entirely typical for the conditions existing in the Clinton Creek and Wolverine Creek valleys, they are believed to be of assistance when predicting the likelihood of future behavior of valley blockages in these areas. The significant aspects are summarized below:

- Lake barriers formed by slides, and which were not eroded away, appear to be located on grounds which have sufficient permeability to convey inflows, i.e. the barriers are not overtopped.

- The most common type of destabilizing effect is that caused by rivers or streams eroding slide slopes or valley blockages.

- The erosion of man-made slopes by streams is a major cause of land instability.

Our review of case histories indicates that unless the site conditions allow for permanent drainage, the majority of slide-formed valley blockages were breached. Some landslides were breached during a very short period of time while others were eroded away after many years.

5.0 ABANDONMENT PLAN

Since the time the mining operations were discontinued (in 1978), Cassiar Mining Corporation has been decommissioning the facility with the objective of abandoning the mine area. The company has undertaken the following work:

- Removal of structures from the Clinton Creek town site.
- Removal of main segments of the concentrator.
- Removal of most of the mining equipment and facilities, except the primary crusher.
- Hydroseeding of the town site, waste dumps and tailings pile.
- Grading of selected portions of waste dumps and tailings pile.
- Installation of erosion control measures in affected sections of the Clinton and Wolverine Creeks.

5.1 PROPOSED ACTIONS

In the submitted Abandonment Plan, the mining company summarizes their opinion regarding the site conditions and proposes to undertake the following actions:

> "The Clinton Creek waste dump and tailings piles are considered to be in suitable condition for final abandonment. The performance of both the waste dump and tailings piles has been as expected over recent years. The waste dump channel repairs completed in 1984 have performed satisfactorily, while the ongoing processes of dump movement, slight downcutting and channel armouring are continuing on downstream sections of the channel.
>
> The south tailings lobe continues to move at a moderate rate and movements of the north lobe appear

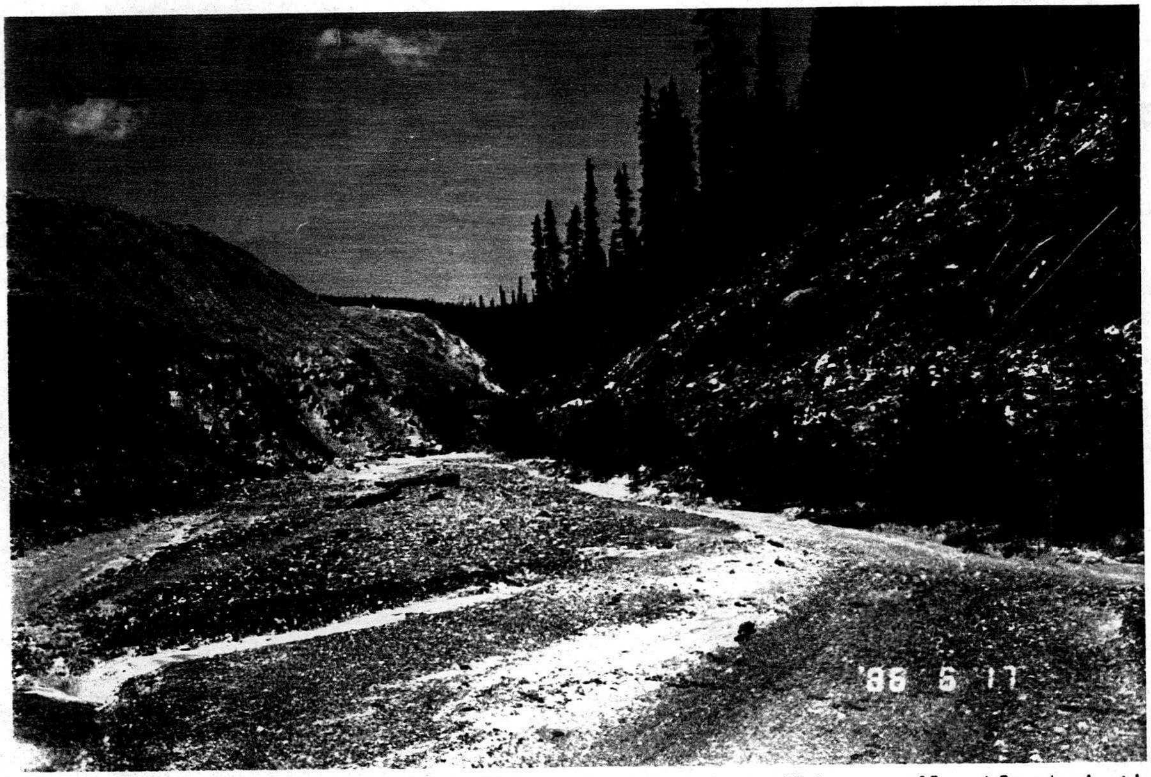


Photo 13: South lobe of the Wolverine Creek tailings pile blocked the outfall channel in June, 1986.

Photo 14: North lobe of the tailings pile reached the valley bottom and almost blocked the valley in June, 1986.

to be slowing down. The toe of the north lobe has reached a relatively flat configuration such that occurrence of a large, rapid failure would not be anticipated.

There do not appear to be any reasonable stabilizing measures possible prior to final abandonment, with the exception that the culverts should be removed from the waste dump channel inlet prior to abandonment. Removal is recommended in order to prevent problems resulting from possible future plugging of the culverts.

The expected ongoing erosion following abandonment of the site will result in some limited deposition of coarse material in Clinton Creek downstream of the confluence with Wolverine Creek. The lower reaches of Clinton Creek are expected to be essentialy unaffected."

Insofar as the environmental impacts are concerned, the report goes on to state:

"Sediment generated from ongoing erosion of the waste dumps and tailings piles is expected to have small impact on Clinton Creek. The coarse fraction (gravel sizes and above) are expected to settle in Clinton Creek in the low gradient reach extending about 2 km downstream of the confluence of Wolverine Creek. The fine fraction of sediments is expected to be carried through Clinton Creek into the Forty Mile and Yukon Rivers, where the small quantities will have negligible impact."

5.2 MAIN CONCERNS

The "Abandonment Plan" put forward by Cassiar Mining Corporation and outlined in the September 12, 1986 Klohn Leonoff report identifies concerns associated with the instability and erosion of the waste and tailings embankments. However, the Plan relies on a future reduction of movement of the waste pile and stabilization of the lake outfall channel. It predicts that the Clinton Creek channel will be armoured (through the natural process of eroding the banks) and eventually stabilized. The Plan also postulates that the tailings will reach a more stable configuration in the valley bottom and implies that only a limited transport capacity of Wolverine Creek will minimize the impact on its downstream sector.

It is apparent, from the monitoring of the embankments, that the rates of movement vary with time and during certain periods, have a decreasing tendency. On the other hand, accelerated movement has been also recorded, namely on the tailings pile. Consequently, a break through of the dammed up water either from Hudgeon Lake or the Wolverine Creek impoundment may occur. While the blockages of the Clinton Creek channel would likely be relatively small (and subsequent erosion moderate) relatively large volume of water could be released from Hudgeon Lake. More significant failures could occur on the tailings pile, however, the storage capacity of a lake in the Wolverine Creek valley is smaller than that of Hudgeon Lake. Our review of the 1974 failure of the tailings pile showed that significant flooding was associated with the breach of the valley blockage. It is therefore suggested that a significant flood flow may occur in either case.

We are concerned that short of removal of significant volumes of waste materials and tailings, the state of equilibrium cannot be achieved. While it is difficult to extrapolate our experience of less than 10 years for a period of some 200 or 1000 years, it is apparent that the rates of movement will not converge to zero within the forseeable future.

We believe that predictions made in the Abandonment Plan represent a possible evolutionary scenario and could be classified as optimistic. A possibly more realistic scenario involving breach of tailings blockage in the Wolverine Creek, gradual or periodical discharges from either of the lakes is not considered in the Plan.

We are concerned that a probable range of impacts, associated with smaller or larger break throughs of valley blockages, has not been reviewed. Possible hazards associated with such events are not discussed nor evaluated.

The Plan does not present any contingency measures or actions which may have to be undertaken if a "worse case" scenario occurs.

It is our opinion that the sediment transport model referenced in the report may have seriously over-estimated the sediment transport capacities. A thorough review of this analysis is required.

The "Abandonment Plan" avoids evaluation of the residual impacts of the open pits and exploration and access trails. The instabilities of the Porcupine and Snowshoe Dumps are not assessed. The fact that tailings cannot be revegetated is avoided.

It is our opinion that the Plan undervalues the ongoing process of natural conditions inbalanced as a result of the mining. If the Plan is accepted, the long-term liability for the dynamic process of erosion, permafrost degradation, frost actions, sediment transport, and deposition would rest with the government and public at large.

5.3 REVIEW OF ALTERNATIVE ACTIONS

There has been a significant change in the approach of the mining company towards the abandonment of the suspended mining operation during the past couple of years. Until about 1983, the mining company anticipated that the dumps will achieve (either through regrading or in combination with natural processes) a state of equilibrium which would permit reclamation of the lands. Insofar as the tailings pile is concerned, it was expected that the pile will become stable thus allowing the construction of a permanent creek channel.

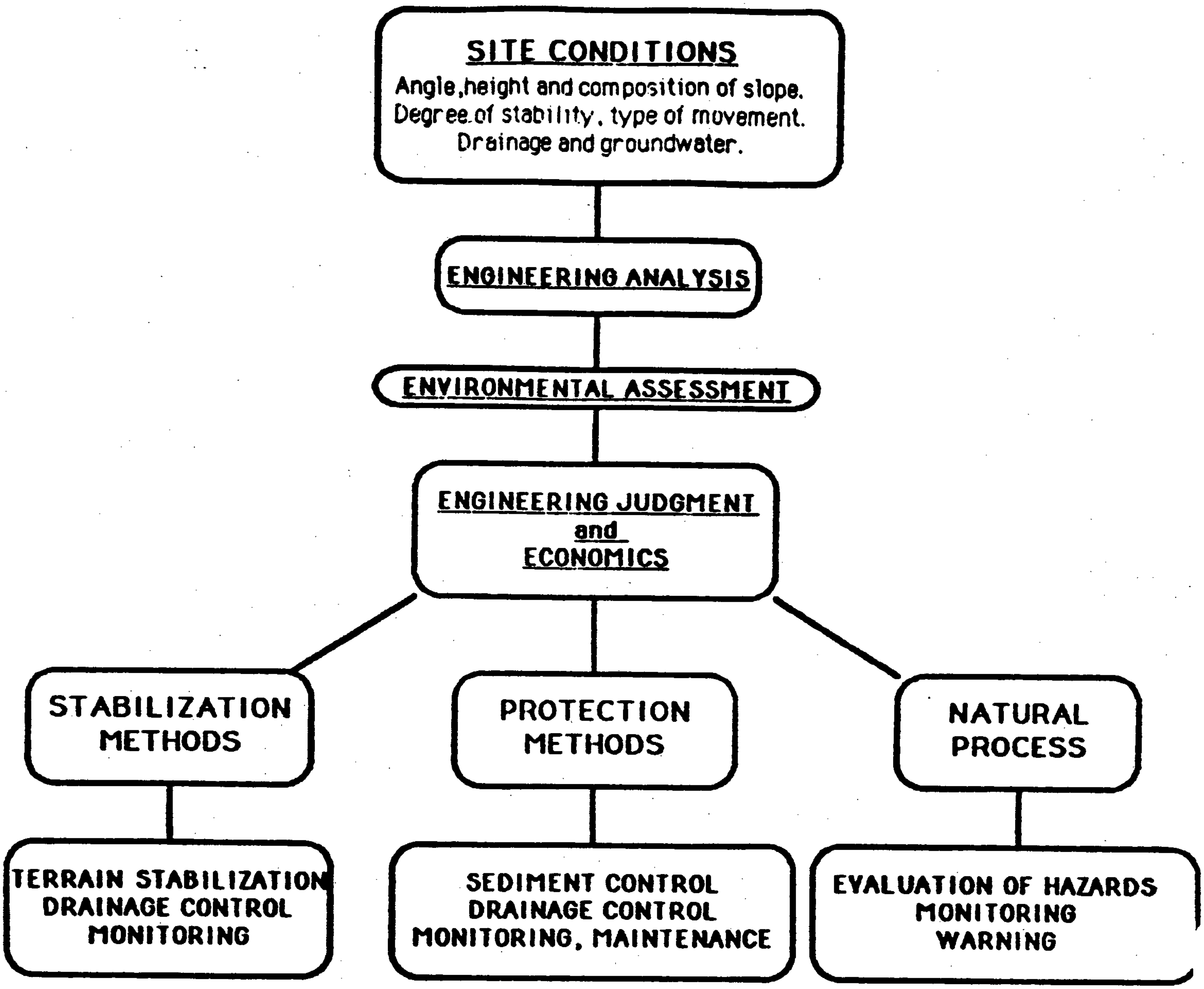
It has been recognized lately that natural processes affecting the stability of these embankments are of a magnitude which is difficult to control, both from the technical as well as economical standpoint.

During the previous stages, several rehabilitation measures were considered with the objective to stabilize the embankments and protect the streams below the mine area. The analysis, selection procedures and options are outlined schematically on Figure 7.

The order of choice could be based on the following considerations:

- Stabilization methods will reduce the impacts on the environment and enhance the reclamation. They are generally complex and expensive. However, if they result in minimum maintenance and give a positive long-term solution, they should be seriously considered.

- Protection methods should receive attention next as offering a positive solution to a problem, often at reasonable cost, but requiring continuing maintenance.



CLIENT

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CASSIAR ASBESTOS MINE

TITLE FLOW CHART OF POSSIBLE REHABILITATION MEASURES

SCALE

PROJECT No 6 052-2

FIGURE 7.

- Warning methods will always be needed if the natural process at some locations could impose significant hazards to the environment or the public. Warning methods involve no reduction (and conversely sometimes an increase) in maintenance costs, and have no effect on the source of danger.

Various strategies were considered by Golder Associates in 1978 and the mining company undertook regrading of selected dump sectors and erosion control measures of critical stream sections.

The options were reviewed again in 1984 by Hardy Associates and the most recent review is contained in the Klohn Leonoff report. They are also summarized in the following two sections.

5.3.1 Clinton Creek Waste Dump

The ongoing movement of the waste dump is squeezing the stream channel along the north side of the dump. The erosion of the toe of the dump is maintaining the dump mobility. Remedial works (erosion control measures at the channel inlet) have been undertaken in an attempt to stabilize Clinton Creek across the dump.

The stabilization measures considered for the dump were evaluated, on a conceptual basis, and are summarized in Table 1. The concepts are also outlined on Figure 8. It is obvious that the stabilization of the dump could only be achieved if the dump toe is buttressed against the opposite valley wall and the flow is safely conveyed across the dump. The estimated costs of such a stabilization, in 1986 dollars, could exceed $1 million. In addition, maintenance of the diversion channel will likely be required for a certain period of time.

The obvious alternative is to allow the movement of the waste dump towards the Clinton Creek channel and accept the consequences of

TABLE 1

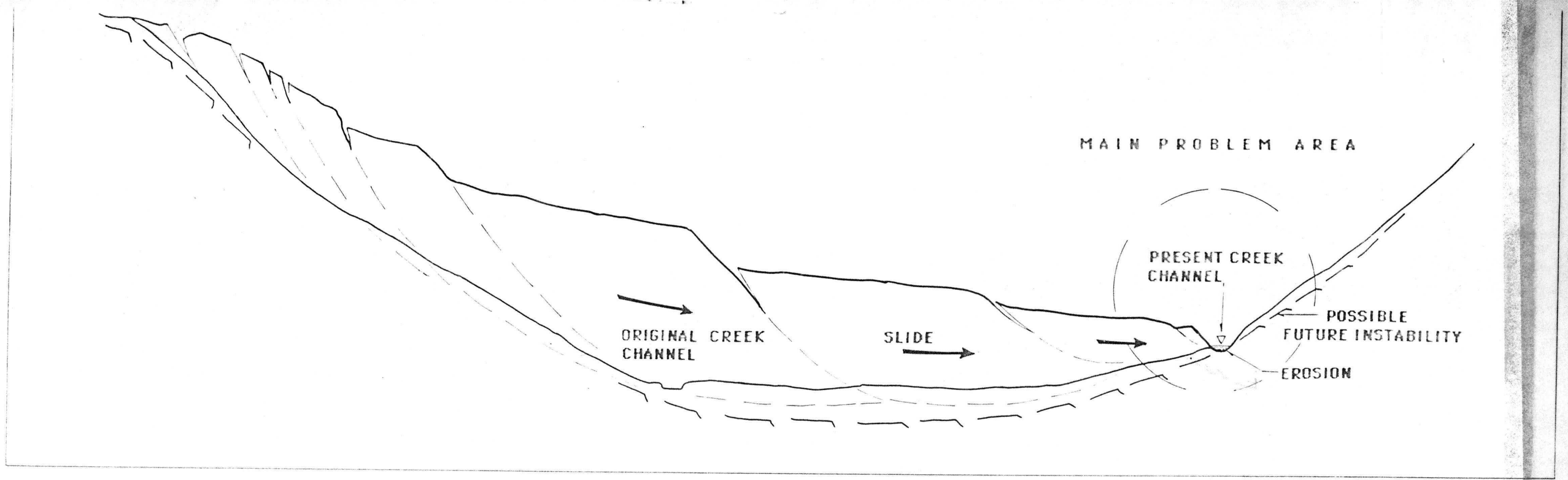
Clinton Creek Waste Dump

MAIN EVENTS:

1968 - Start of mining operations
1970 - Initial dump failure
1978 - Mine shutdown
1980 - Installation of rock-lined outfall channel (weir and apron)
1981 - Rock weir reconstruction
1982 - Rock weir failure
1984 - Rehabilitation of rock-lined channel section

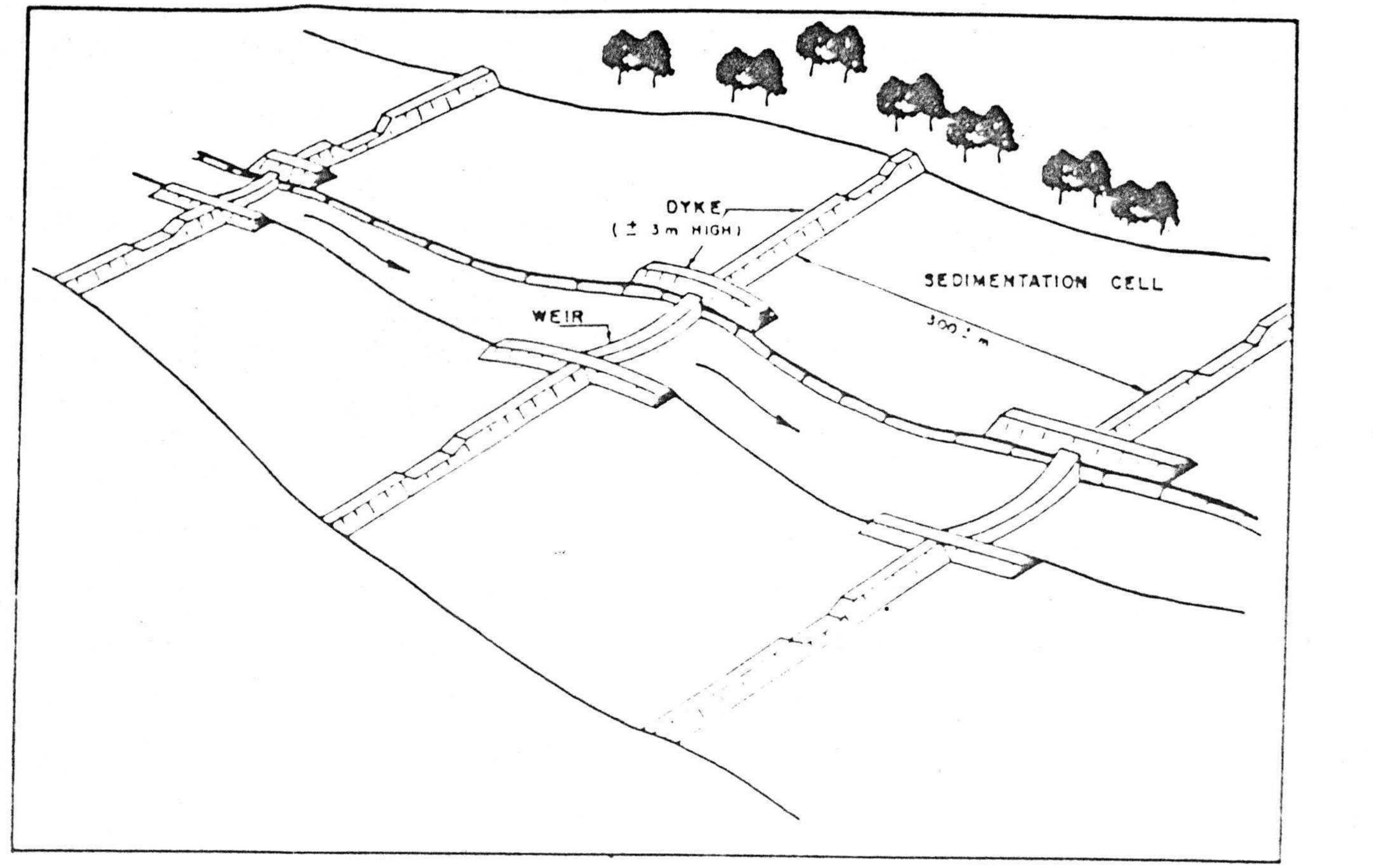
ABANDONMENT OPTIONS

ALTERNATIVE:	COST:	IMPACTS:	BENEFITS:	HAZARDS:
Natural Process Development	?	Destruction of lake outfall. Retrogressive erosion. Deposition of eroded materials downstream.	Restoration of natural equilibrium.	Floods and mudflows Potential loss of life.
Coarse rock drain	>$5 mil	Limited life expectancy because of lack of durable rocks	Stabilization of dumps.	Potential clogging because of lack of durable rocks.
Culvert and valley fill	$1.0 mil	Life expectancy 40 years, possible retrogressive erosion in the long term.	Acceleration of natural stabilization process.	Potential clogging of culvert.
Valley fill, spillway and armoured channel	$0.5 mil to $1.3 mil	Uncertain long-term performance of channel.	Protection of downstream valley sector. Stabilization of dumps.	Erosion of channel.
Sedimentation ponds below Clinton Creek and Wolverine Creek junction.	<$0.5 mil	Erosion of the dump.	Protection of area downstream from the pond. One structure for the entire mine area.	Floods and loss of life.

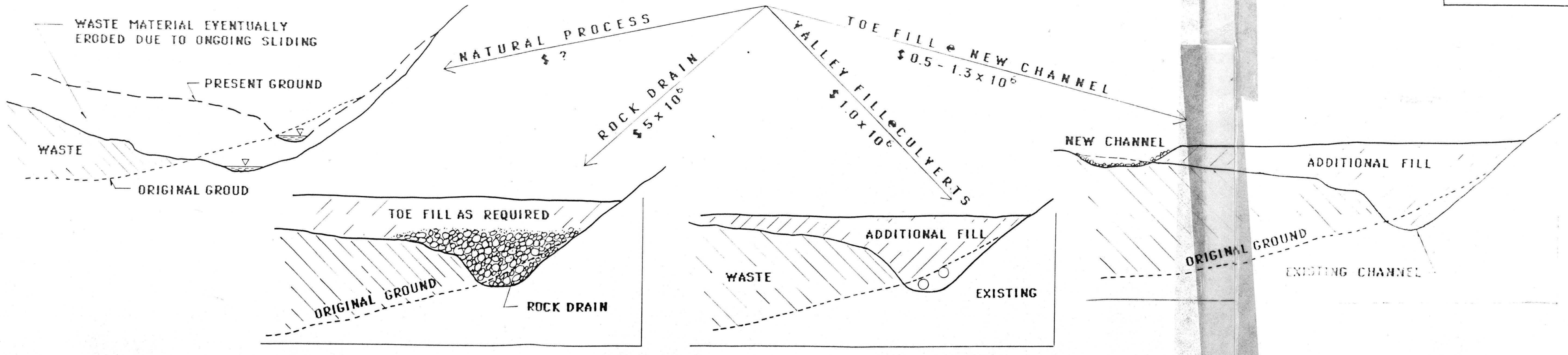


PASSIVE SEDIMENT TRANSPORT CONTROL

(SEDIMENTATION CELLS @ WEIRS LOCATED DOWNSTREAM OF THE DUMP)



POSSIBLE SOLUTIONS



CLIENT NORTHERN AFFAIRS PROGRAM	CASSIAR ASSBESTOS MINE
geo-engineering (M.S.T.) LTD.	TITLE CLINTON CREEK WASTE DUMP CONCEPTUAL STABILIZATION MEASURES
	SCALE AS SHOWN — PROJECT No G 052-2 — FIGURE 8

erosion, transport and re-deposition of eroded waste material. This is the approach recommended by Klohn Leonoff and rationalized as follows:

> "Even if waste dump movement continues at about its current 0.5 m (1.5 ft) per year, the volume of material which could encroach upon Clinton Creek over the 700 m (2,300 ft) deep length is less than 3,000 yd^3 per year. This volume of material, even if it is all eroded, will not create an adverse environmental impact on downstream watercourses."

It is argued that the above estimate of transported sediment disregards events such as channel blockages due to local slumps and flood situations. It is our opinion that slumps significantly exceeding the above volumes will periodically occur. Such slumps could be associated with floods greatly exceeding usual flow events.

The proposed approach ignores the need for an ongoing monitoring and warning system.

5.3.2 Wolverine Creek Tailings Pile

Field observations and monitoring confirm that both main segments of the pile (i.e. south lobe which reached the valley bottom in 1974 and north slope which began to block the valley in 1986) are experiencing horizontal displacement of up to about 20 m/year. Movements of the south lobe have been increasing over recent years. The greatest acceleration occurred in 1986 when the toe almost blocked the existing outfall channel.

Movements of the north lobe are apparently of the same order of magnitude as during previous years. Some decrease in the rate of movement will occur due to the support provided to the toe of the north lobe since it reached the valley bottom. The pile surface is highly distorted. Headscarp positions show that the movement is in the direction of the original slope fall lines, i.e. not only into the Wolverine Creek valley, but also in the northerly and westerly directions. It is of interest to note that sliding occurs also towards the mill site, located on relatively flat ground.

It would be quite difficult to stabilize this embankment. However, several options were evaluated during the past years and the results are summarized on Table 2 and illustrated on Figure 9.

It is apparent that stabilization of the pile could be achieved if the stream is diverted and the lobes are allowed to buttress against the valley wall. However, some ongoing lateral spreading of the lobes cannot be avoided. In addition, the stream diversion would require maintenance.

5.4 PROBABLE IMPACTS OF PROPOSED ABANDONMENT

It appears that the costs of stabilizing the main waste dump and tailings pile are in the order of magnitude which precludes their implementation. Stabilization of the tailings pile would be technically difficult as well. Consequently, the decision should be made whether the area downstream from the mine could be condemned and left exposed to devastation by mudflows, floods and transported sediments, or, at least, partially protected.

It is our opinion that if natural processes are allowed to take place, the combination of the sliding, erosion and depositional features will gradually modify the existing valley gradient across the blockages formed by the embankments. The resulting slope will likely be greater than the original slope of the valley bottom but less than the current gradient across the valley blockage.

TABLE 2

Wolverine Creek Tailings Pile

MAIN EVENTS:

1968 - Start of mining operations
1974 - Failure of the south lobe and formation of a lake
1974 - Start of dumping into north lobe
1978 - Mine shutdown
1978 and 1979 - Unsuccessful attempt to stabilize the pile
1978 - Installation of rock-lined outfall channel (spillway)
1981 - Accelerated movement of north lobe
1985 - North lobe encroaching into the valley bottom

ABANDONMENT OPTIONS

ALTERNATIVE:	COST:	IMPACTS:	BENEFITS:	HAZARDS:
Natural Process Development	?	Destruction of rock-lined channel. Retrogressive erosion. Deposition of eroded materials downstream.	Restoration of natural equilibrium.	Floods and mudflows Potential loss of life.
Coarse rock drain	>$5 mil	Life expectancy limited because of lack of durable rock.	Stabilization of dumps.	Potential clogging of drain.
Tunnel diversion	>$2.5 mil	Life expectancy 100 years.	Natural and undisturbed stabization of piles.	Tunnel and intake structure deterioration, blockage.
Culvert and valley fill	$1.0 mil	Life expectancy 40 years. Potential clogging and induced retrogressive erosion.	Acceleration of natural stabilization process.	Potential obstruction of culvert causing erosion.
Relocation of tailings	$15 mil	New waste dump area	Removal of unstable materials.	
Retaining dam and stabilization berm at south lobe	$0.5 mil	Uncertain long-term performance.	Protection of downstream valley.	Potential overtopping of dam. Loss of life.
Sedimentation ponds downstream from Clinton Creek and Wolverine Creek confluence	<$0.5 mil	Destruction of selected valley segment.	Protection of area downstream from the pond.	Floods and loss of life.

It is anticipated that the waste and tailings embankments will experience the following changes:

- <u>Clinton Creek Waste Dump</u>

  Continuing retrogressive and lateral erosion will gradually lower the crest of the valley blockage and lower the lake level. Some of the events may be more extensive, causing temporary blockages of the outlet channel. This, in turn, will temporarily increase the lake elevation and accelerate erosion. The outflow from the lake could change its pattern and erode a new gully, thus increasing the rate of sliding.

  The state of equilibrium will not be achieved until a significant portion of the current valley blockage is redeposited further downstream.

- <u>Wolverine Creek Tailings Pile</u>

  The blockage formed by the tailings will be eventually overtopped, forming a new outfall channel likely outside of the present rock-lined spillway. The tailings would be eroded progressively down resulting in lowering of the lake level and flooding of the downstream valley section. Transportation as well as deposition of large quantities of fine to coarse tailings particles throughout the Wolverine Creek and Clinton Creek valleys is to be expected. Again, this event may re-occur several times until equilibrium between the erosion rate and the tailings pile movement is achieved.

  The sediment supply rate would depend on the rate of encroachment by the tailings slope confining the right bank of the channel. A repeating cycle of encroachment, toe erosion, localized slope failure and transport of slumped material downstream could be expected. Periodic channel blockages could occur due to local slumping. These would be accompanied by ponding, overtopping and rapid downcutting of the slump material. The delivery of sediment downstream would be consistent with the capacity of the high gradient channel to erode and transport the tailings.

As the rate of tailings encroachment decreases with time, further degradation and lateral migration could be expected. Because the tailings do not contain significant quantities of coarse fragments, bed paving would not substantially slow the erosional processes. Ultimately, the channel could degrade to near its original profile, but the valley would be narrower and contain several levels of terraces comprised of tailings material.

The downstream effects of the above described dynamic processes have been studied by Klohn Leonoff (1975). In their report, Klohn Leonoff analyzes the hydrologic characteristics and sediment transport capacities of Wolverine Creek, Clinton Creek and Forty Mile River into which Clinton Creek discharges. The report presents estimates of the annual sediment transporting capacity of each system. Results of this study have subsequently been used to form conclusions about how sediment that is eroded from the two embankments will be transported through and/or deposited within the downstream drainage systems.

Our review of the limited information contained in the Klohn Leonoff report leads to a concern that the sediment transport model used in the study may have seriously over-estimated sediment transport capacities. On Wolverine Creek, the estimated annual transport capacity is 2.0×10^6 m^3. Yet the annual flow volume is 7.9×10^6 m^3 (based on a reported average annual discharge of 0.25 m^3/s). This implies an average total sediment load concentration of 25 percent. On Forty Mile River (estimated annual sediment capacity - 790×10^6 m^3; annual flow volume - 2870 x 10^6 m^3, the average total sediment load concentration would be 28 percent. There would appear to be a need for a thorough review of this analysis and its results.

6.0 CONCLUSIONS AND RECOMMENDATIONS

It is our opinion that the submitted "Abandonment Plan for Clinton Creek Asbestos Mine" does not consider, in a sufficient detail, the possible range of events and terrain modifications which may be caused by unstable ground conditions and modified stream gradients. It also underestimates, in our view, the potential impacts of impounded water.

Should natural processes be allowed to take place, significant changes, influencing configuration of the open pits and embankments are to be expected. The associated erosion and sedimentation may have, in the long run, a profound impact on the creeks and environment of the valleys downstream from the mine facilities. This will likely include aggradation of the floodplain in certain segments of the Clinton Creek valley.

If the Plan is accepted in its present form, the long-term liability for the ongoing dynamic processes of erosion, permafrost degradation, frost actions, and sediment transport from the unstable embankments will be vested with the government and public at large.

At the same time, it is too late to prepare a normal abandonment plan since decisions have been made (and implemented) which are technically and economically difficult to reverse. Some of them were made, in our opinion, in contravention of prudent engineering standards, routinely adopted by the mining industry during the seventies.

On the other hand, official regulations as well as public perception of what is the current level of acceptance insofar as the impact of mining activities is different from that of 1978, when the mine was shut down.

Consequently, there should be, in our opinion, both mine company participation as well as public participation insofar as the long-term responsibility for the abandoned mine site is concerned.

It is believed that the submitted "Abandonment Plan" is deficient in the evaluation of the possible impacts of abandoned mine facilities as well as in the outlining of appropriate future actions.

The following recommendations are presented to the Yukon Water Board:

a) That the abandonment plan put forward by Cassiar Mining Corporation and outlined in the September 12, 1986 Klohn Leonoff report be criticized as deficient in the following aspects;

  - The Plan relies on a future reduction of movement of the main waste dump and stabilization of the lake outfall channel.

  - Possible blockages of the Clinton Creek channel due to localized slides and gradual or periodic discharges from the lake, because of erosion of the outlet control, are not considered.

  - The Plan depends on the assumption that the tailings will reach a more stable configuration in the valley bottom and implies that only a limited transport capacity of Wolverine Creek will minimize the impact on its downstream sector.

  - Possible more rapid (progressive) erosion and downcutting of tailings blocking the valley bottom is not considered.

  - The sediment transport model referenced in the report may have seriously over-estimated the sediment transport capacities of local streams. A thorough review of this analysis is required.

  - The report does not discuss the probable range of impacts on the Clinton Creek and Wolverine Creek valleys and avoids a review of possible hazards.

- ° Conditions of the Porcupine and Snowshoe Dumps are not reviewed.

- ° The Plan does not present any contingency measures or actions which may have to be undertaken if a "worse case" scenario occurs.

b) That the mining company be requested to review their position regarding participation in actions which may be required if the behavior of embankments and their impacts on streams significantly exceed the impacts predicted in their submission.

c) That the mining company be requested to address the above concerns, either as an addendum to the existing submission or in a revised report.

d) That the Board seeks advice regarding the public (government) participation in actions and measures which may be necessary for the protection of the public in the case of a major impact on the streams and the environment.

Respectfully submitted,

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Milos Stepanek, M.Sc., P. Eng.
Principal Consultant

NORTHWEST HYDRAULIC CONSULTANTS LTD

R.H. Cooper, P. Eng.

MS/jlw#7

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In addition to the "Abandonment Plan" contained in the Klohn Leonoff 1986 report, a number of other documents, reports and published data were used. These are listed, chronologically and according to main subjects, below.

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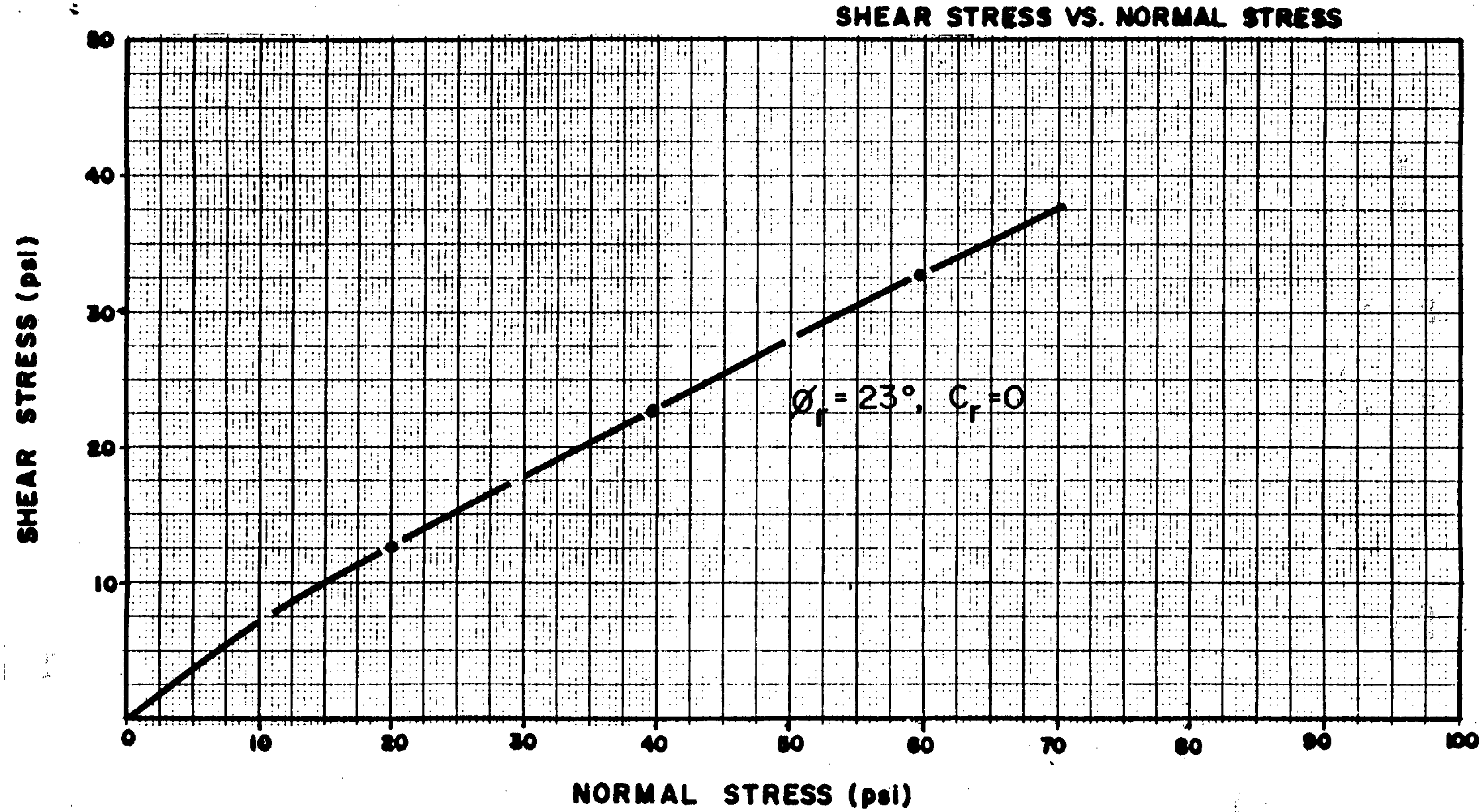
APPENDIX A

SELECTED LABORATORY TEST RESULTS

DIRECT SHEAR TEST RESULTS

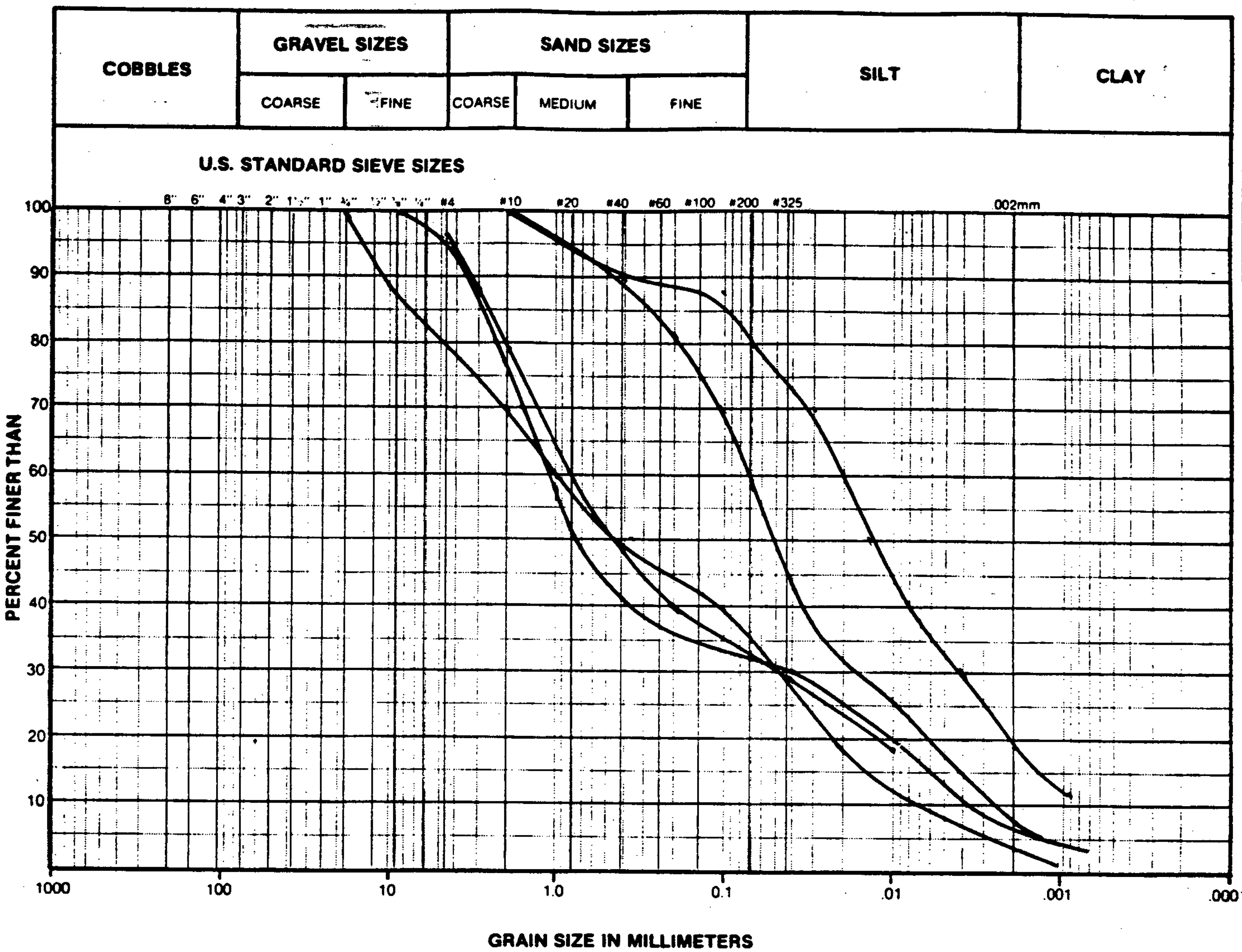


SAMPLE DESCRIPTION :

SHALE, SILTSTONE, ARGILLITE FRAGMENTS
IN SANDY, SITY AND CLAY MATRIX.

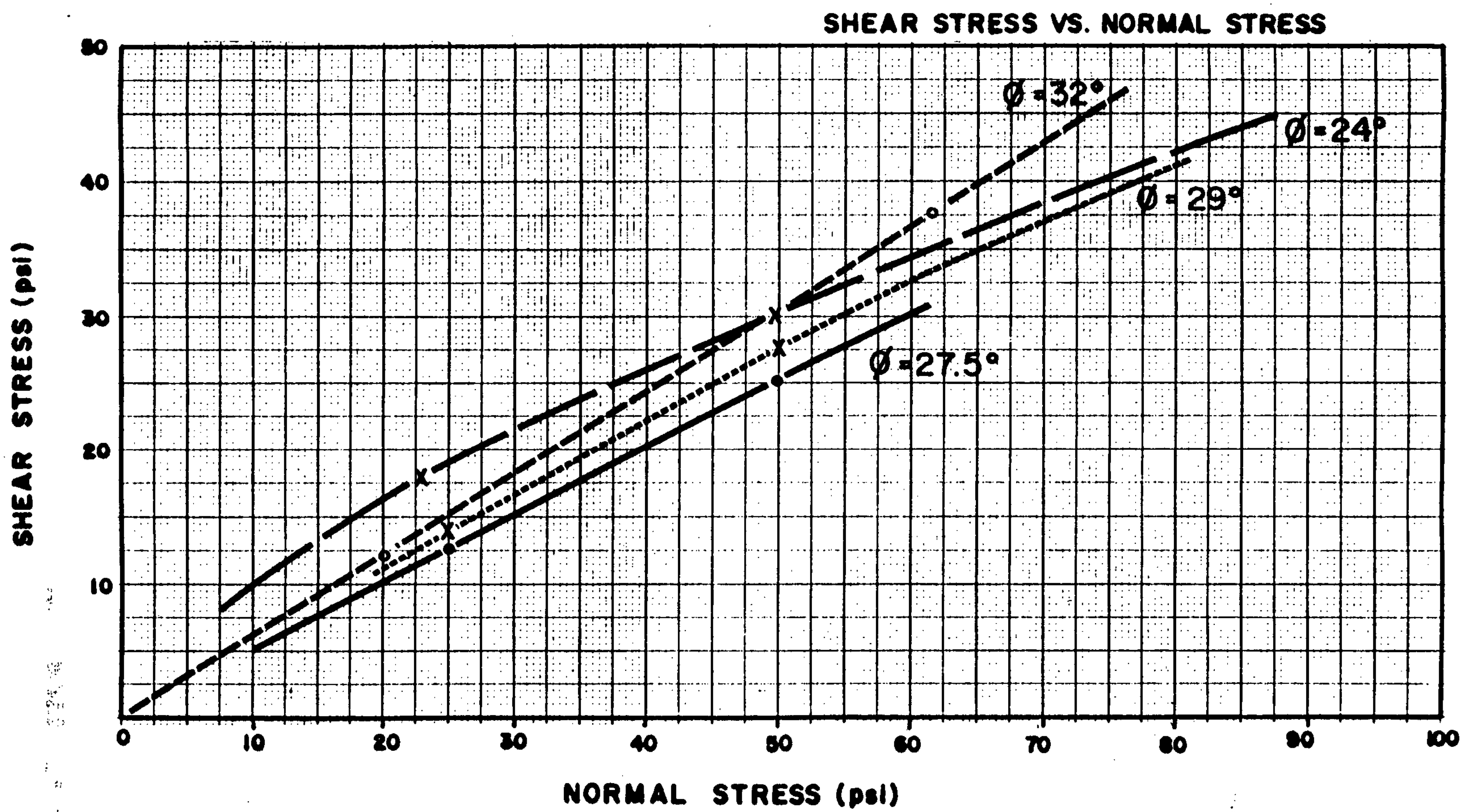
Tested by HARDY, Dec 77.

CLIENT NORTHERN AFFAIRS PROGRAM	CASSIAR ASBESTOS MINE		
geo-engineering (M.S.T.) LTD.	TITLE COLLUVIUM		
	SCALE As shown	PROJECT No. G 052-2	FIGURE A-1



CLIENT NORTHERN AFFAIRS PROGRAM	**CASSIAR ASBESTOS MINE**
geo-engineering (M.S.T.) LTD.	TITLE: OVERBURDEN FLUVIAL – LACUSTRINE GRAIN SIZE ANALYSIS
SCALE: As shown	PROJECT No. G 052-2
	FIGURE A-2

DIRECT SHEAR TEST RESULTS

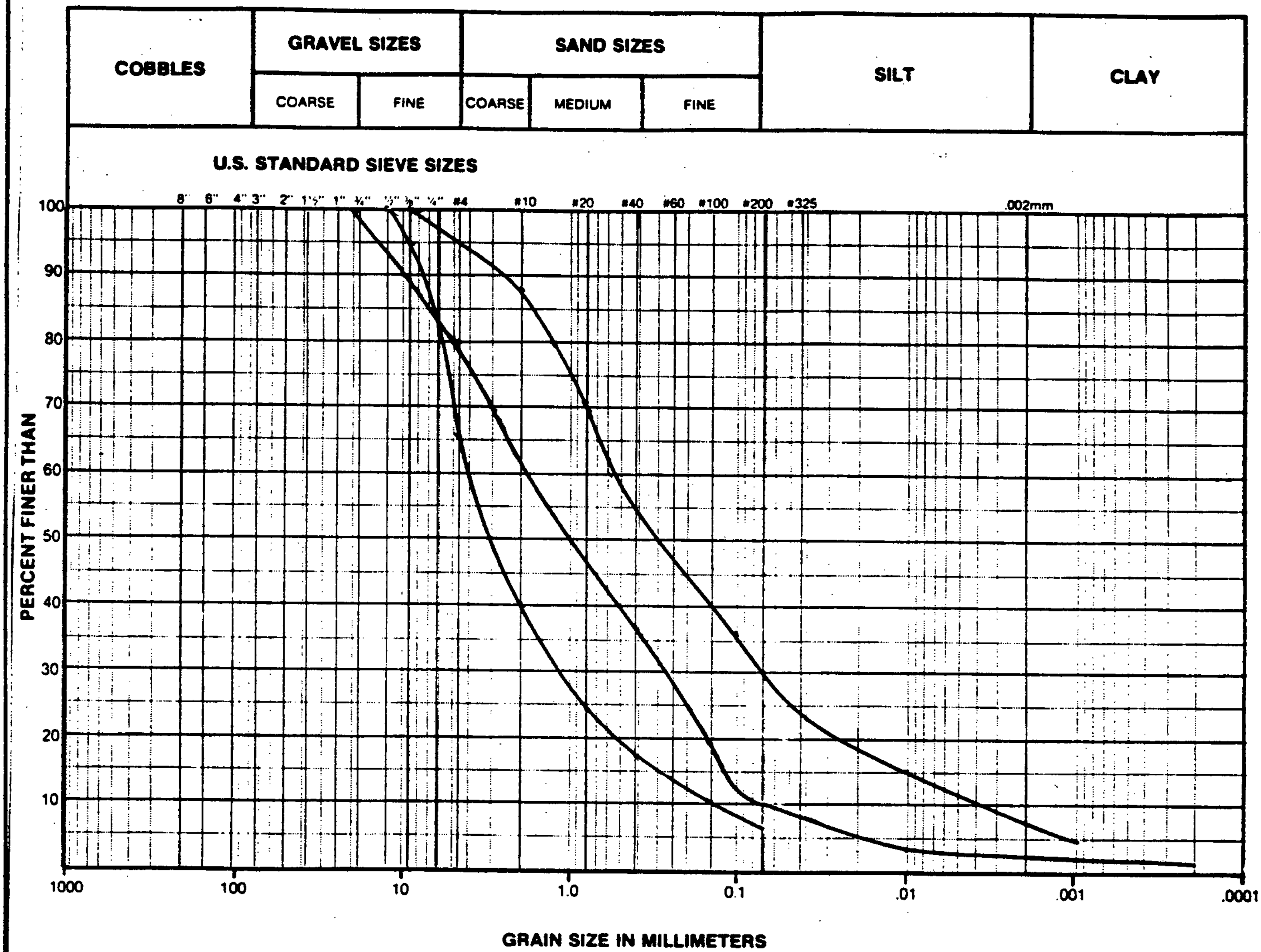


SAMPLE DESCRIPTION :

SILTY SAND, LITTLE CLAY WITH SOME GRAVEL

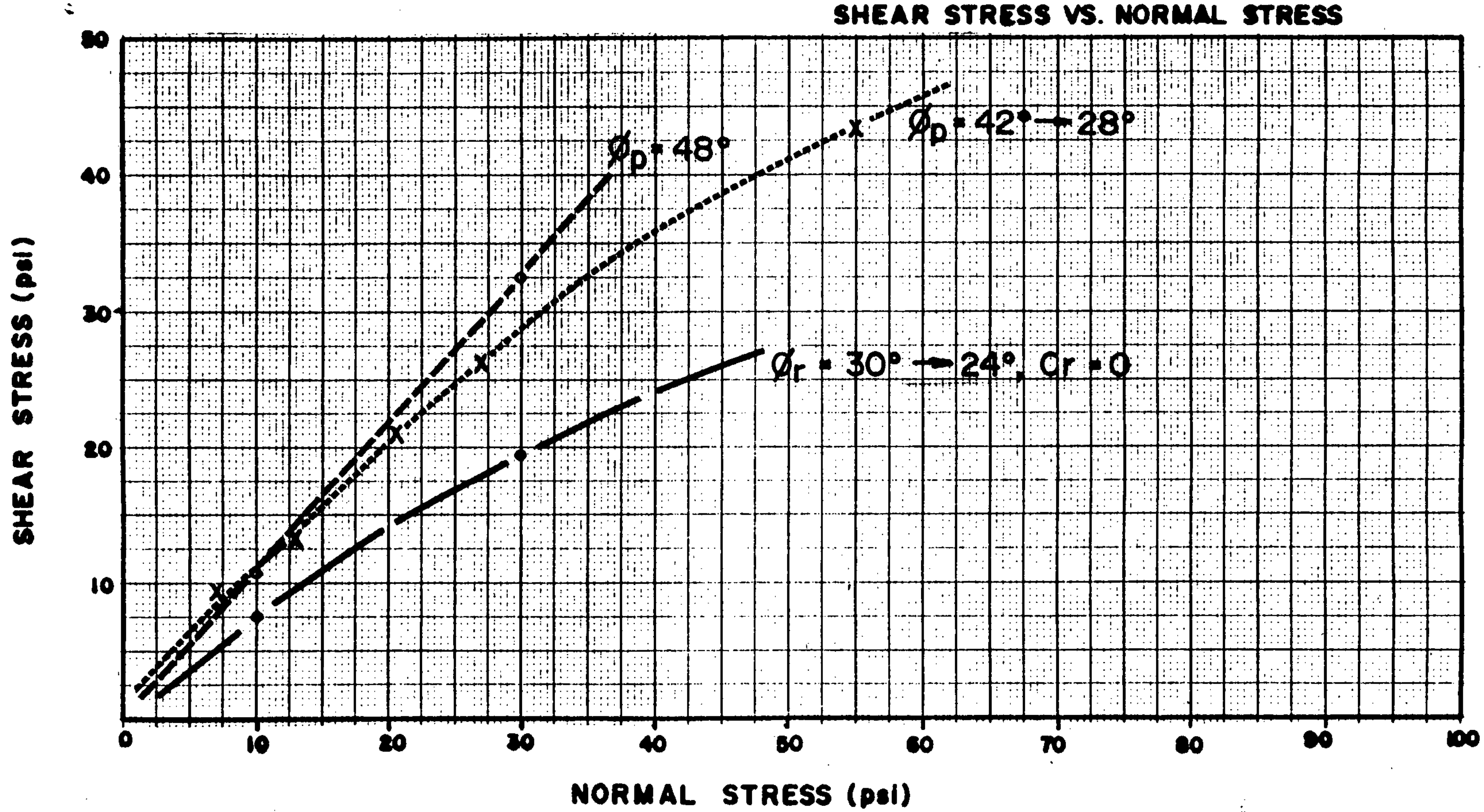
Tested by GOLDER, June 78

CLIENT	CASSIAR ASBESTOS MINE		
NORTHERN AFFAIRS PROGRAM	TITLE OVERBURDEN FLUVIAL – LACUSTRINE		
geo-engineering (M.S.T.) LTD.	SCALE As shown	PROJECT No. G 052-2	FIGURE A-3



CLIENT NORTHERN AFFAIRS PROGRAM	**CASSIAR ASBESTOS MINE**
geo-engineering (M.S.T.) LTD.	TITLE: TAILINGS MATERIAL GRAIN SIZE ANALYSIS
SCALE: As shown	PROJECT No. G 052-2 — FIGURE A-4

DIRECT SHEAR TEST RESULTS



SAMPLE DESCRIPTION :

SERPENTINE FRAGMENTS LESS THAN 10 mm
IN SIZE WITH FINE ASBESTOS FIBRE

Tested by GOLDER, June 78
and by HARDY, Dec 77

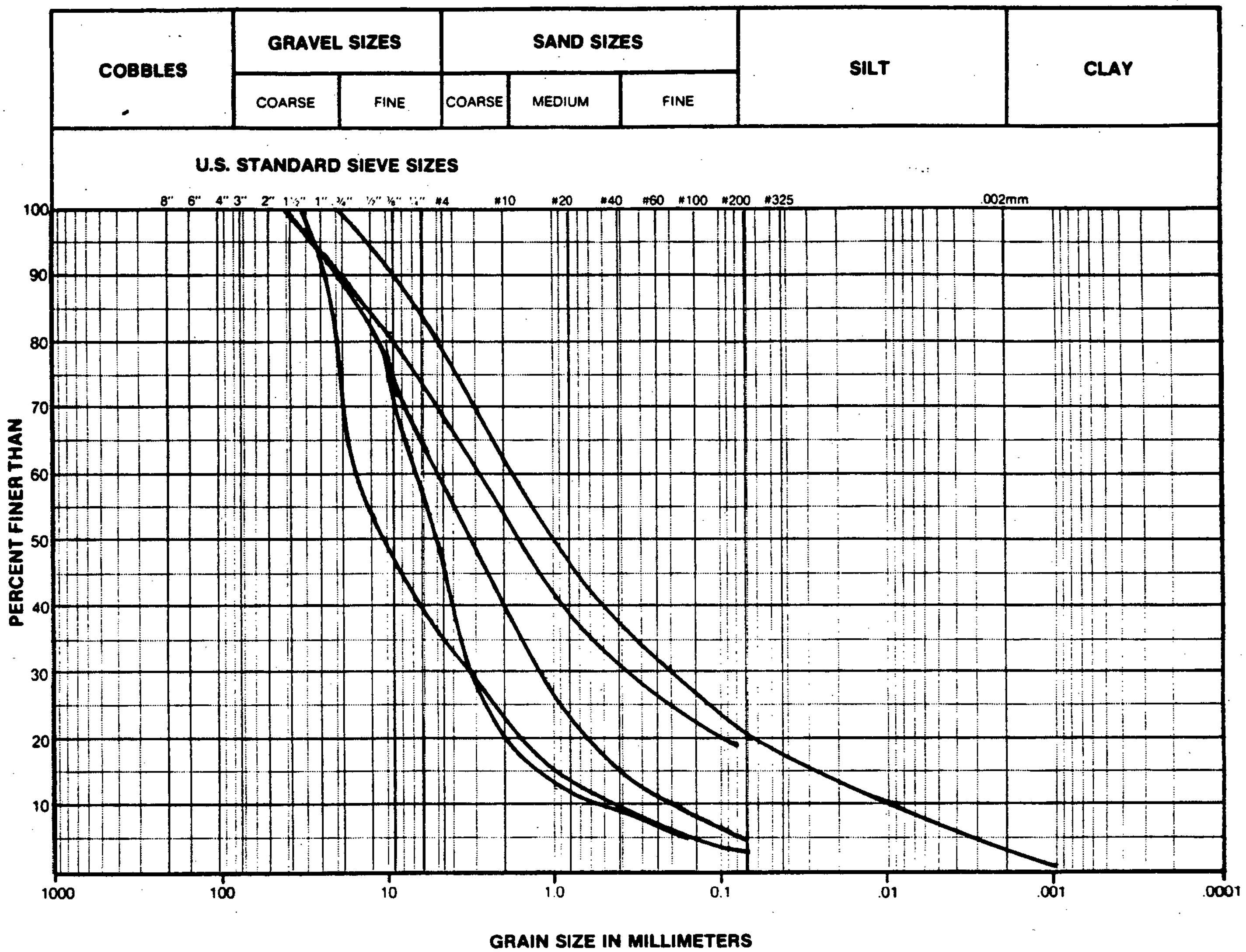
CLIENT: NORTHERN AFFAIRS PROGRAM

geo-engineering (M.S.T.) LTD.

CASSIAR ASBESTOS MINE

TITLE: **TAILINGS MATERIAL**

SCALE: As shown | PROJECT No. G 052-2 | FIGURE A-5



CLIENT

NORTHERN AFFAIRS PROGRAM

geo-engineering (M.S.T.) LTD.

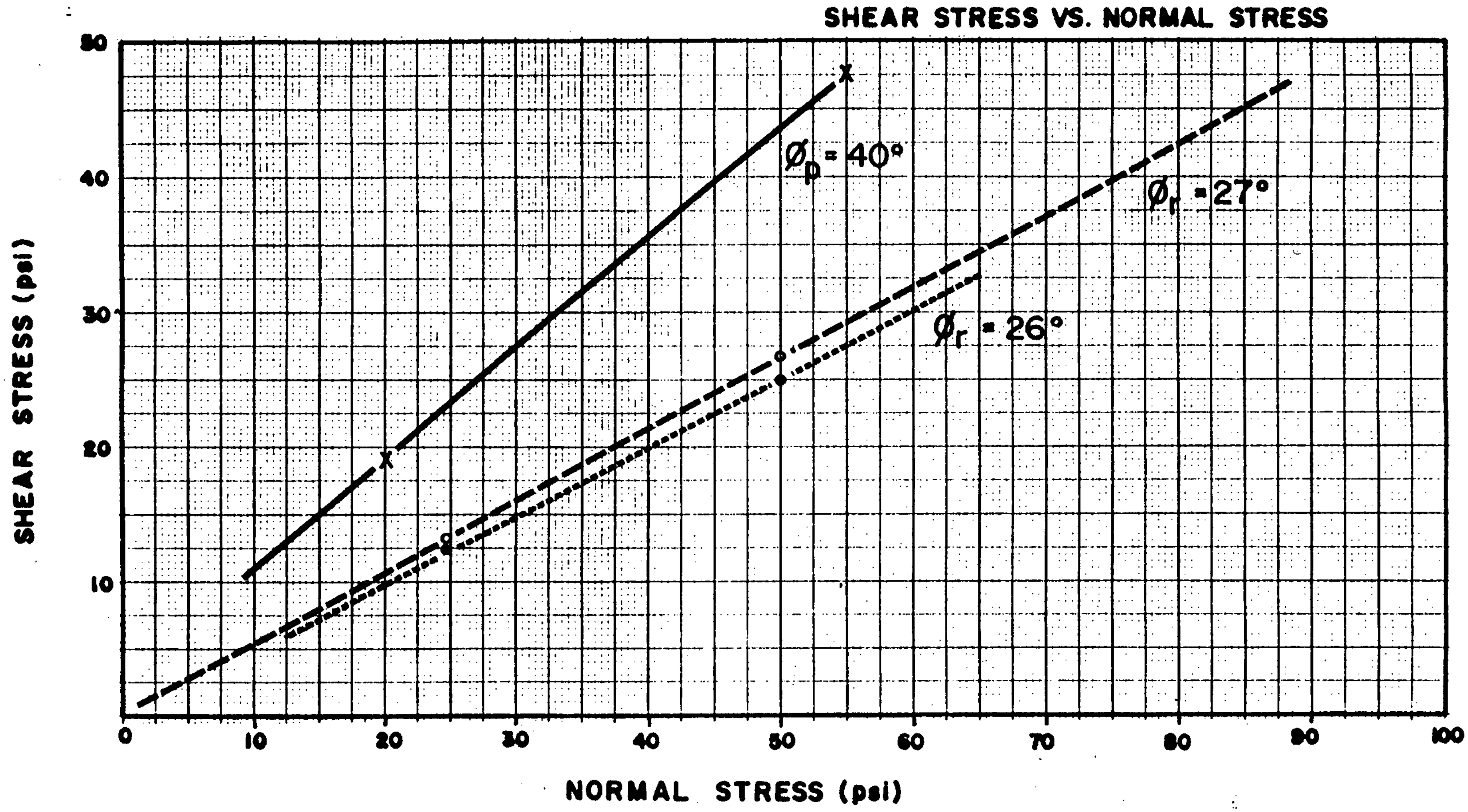
CASSIAR ASBESTOS MINE

TITLE **WASTE MATERIAL**

GRAIN SIZE ANALYSIS

SCALE As shown	PROJECT No. 0 052-2	FIGURE A-6

DIRECT SHEAR TEST RESULTS

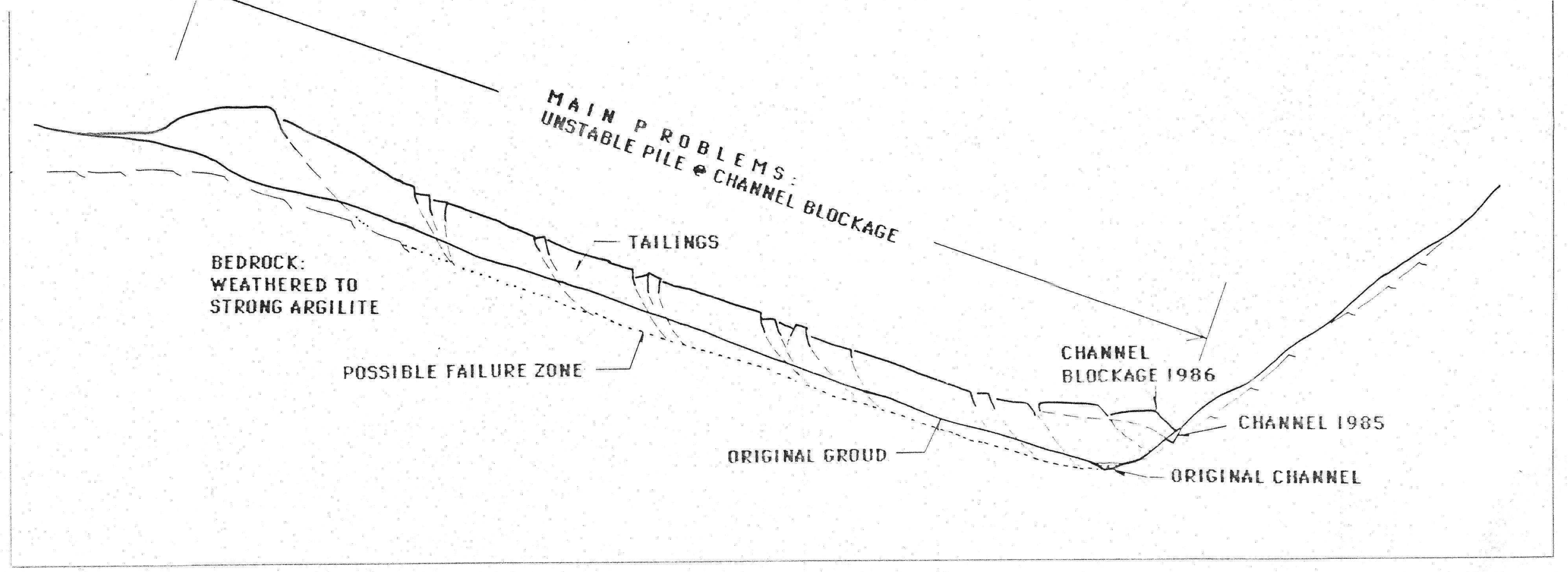


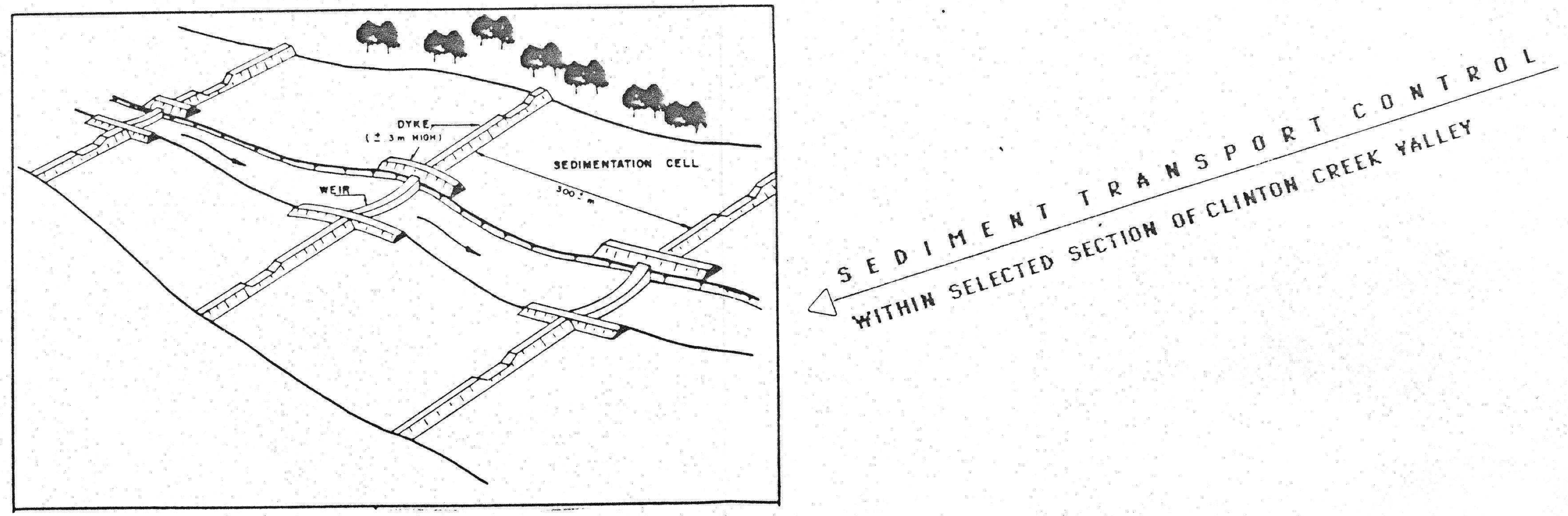
SAMPLE DESCRIPTION :

WEAK BUT MORE INDURATED THAN MUDSTONE, FRACTURED AND FLAKY, READILY SLAKING.

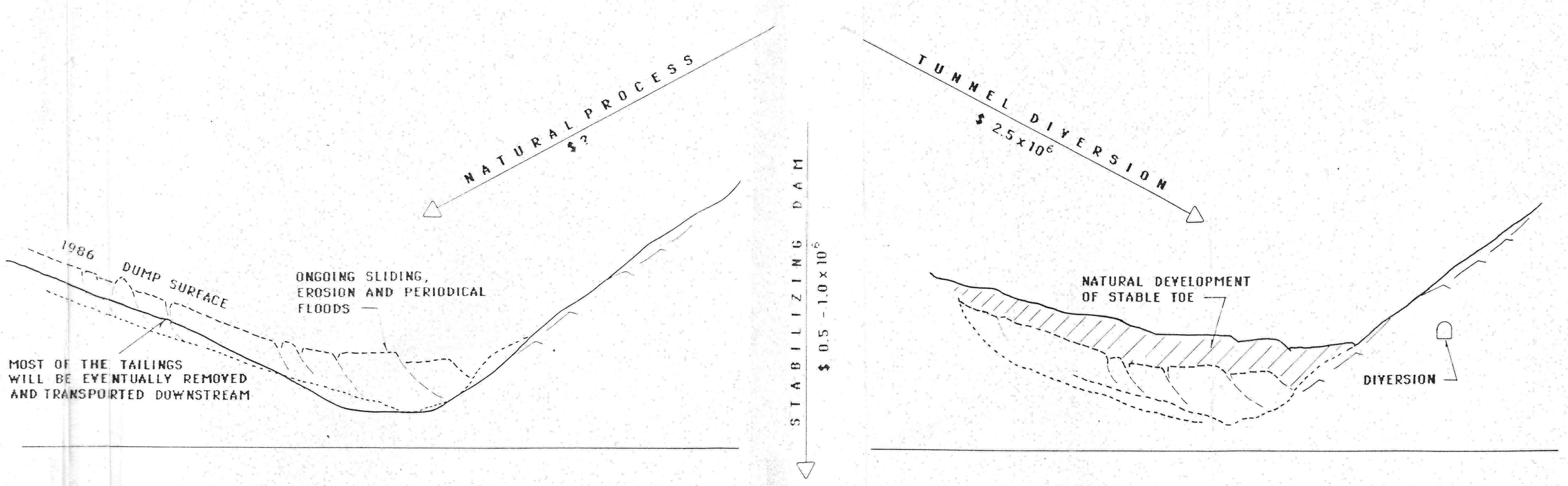
Tested by GOLDER, June 78

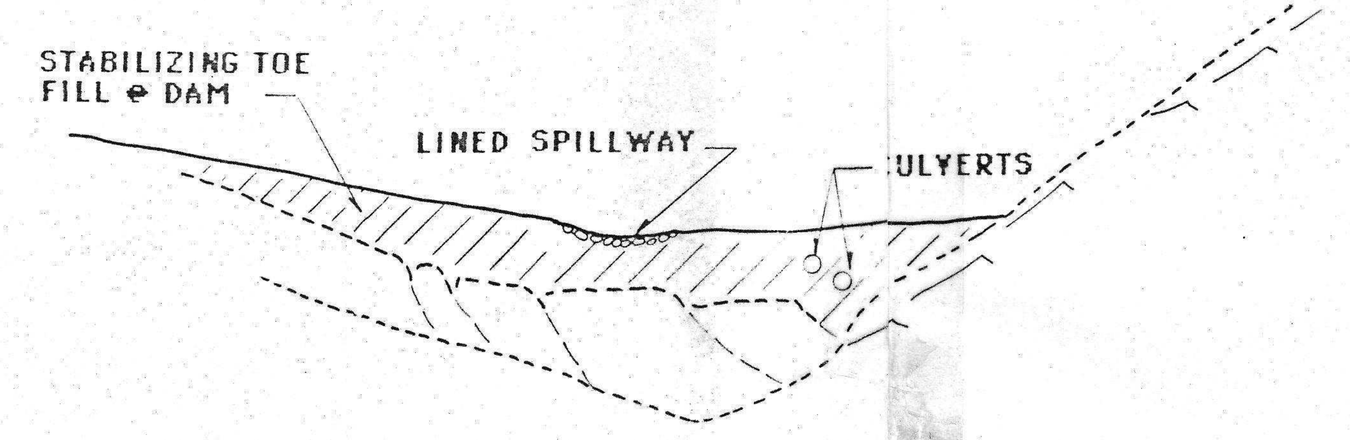
CLIENT: NORTHERN AFFAIRS PROGRAM	CASSIAR ASBESTOS MINE
geo-engineering (M.S.T.) LTD.	TITLE: BEDROCK WEATHERED ARGILLITE
SCALE: As shown	PROJECT No. G 032-2
	FIGURE A-7





POSSIBLE SOLUTIONS





CLIENT	CASSIAR ASBESTOS MINE		
NORTHERN AFFAIRS PROGRAM	TITLE WOLVERINE CREEK TAILINGS PILE CONCEPTUAL STABILIZATION MEASURES		
geo-engineering (M.S.T.) LTD.	SCALE AS SHOWN	PROJECT No. G 052-2	FIGURE 9