60 357 40

KLOHN LEONOFF
CONSULTING ENGINEERS

Our File: PB 3169 0401 December 10, 1987

Cassiar Mining Corporation
2000 - 1055 West Hastings Street
Vancouver, British Columbia
V6E 3V3

Peter C. Jones
Executive Vice-President

Clinton Creek Asbestos Mine
Downstream Hazard Assessment

Dear Sirs:

We are pleased to submit six copies of our report entitled "Downstream Hazard Assessment for Mine Abandonment", dated December 10, 1987.

We trust that this study has satisfactorily addressed the concerns of Indian and Northern Affairs Canada regarding final abandonment of the mine, namely:

a) That the feasibility of lowering existing water levels be examined, and

b) That the risk to human life as a result of rapid release of water is assessed.

We look forward to discussing the results of this study with Cassiar and Indian and Northern Affairs Canada.

Yours very truly,

KLOHN LEONOFF LTD.

Peter C. Lighthall, P.Eng.
Project Manager

Encl.

PCL/ld

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

LIST OF DRAWINGS

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1. The Clinton Creek waste dump and tailings piles are considered to be in safe condition for abandonment. Monitoring of performance over the nine year period since shutdown of mining operations has shown that ongoing movements of both the waste dumps and tailings piles have decreased.

2. The channel conveying Clinton Creek over the waste dump has performed satisfactorily since repairs to the upstream rock lined section were completed in 1984. The channel is in a stable configuration. The left bank is confined by bedrock in the valley wall and the stream bed is armoured by large boulders eroded from the waste material. Some ongoing erosion continues as the dump moves toward the right bank of the channel. Survey of the channel bottom has shown only slight downcutting over the three year period 1983 to 1986.

3. Various abandonment strategies considered for the waste dump were reviewed, including lowering the water level. None of the alternative strategies considered would have any advantage over the present configuration. The potential for lowering the level of Hudgeon Lake is very limited, as lowering the channel would remove toe support and reduce the stability of the waste dump.

   As previously recommended in the Abandonment Plan submitted to the Yukon Territory Water Board, the four access road culverts at the head of the waste dump channel should be removed prior to abandonment.

4. The waste dump impounds a large body of water known as Hudgeon Lake. Hydrographic analyses and sediment transport modelling showed that a 200-year return period flood flow may cause a maximum

downcutting of 1.6 m over a 24-hr period, with only a small resulting increase in flow rates downstream. The waste dumps therefore do not represent a flood hazard to human life.

5. The tailings piles continue to move downslope into Wolverine Creek valley. Movements of the north tailings lobes have slowed, indicating it is reaching a more stable state as the toe receives support from the opposite valley wall. Movements of the south lobe continue slowly, with increasing squeezing of the channel of Wolverine Creek.

6. Abandonment strategies have also been reviewed for the Wolverine Creek tailings piles. No practical, maintenance free alternatives have been identified. It is recommended that the tailings piles be abandoned in their present state. Ongoing erosion will occur as blockage of the stream causes increased impoundment in future and the stream is forced to flow against the toe or across the surface of the tailings piles. Previous sedimentation studies have shown that the impacts of ongoing sediment transport will be limited.

7. To assess the potential hazard created by the tailings piles, a breach mechanism was postulated and a dambreak analysis was carried out to assess the downstream impacts. While such a breach is unlikely, it represents the worst case scenario for hazard assessment. The analysis showed that a breach would result in increased streamflow, with a rise in stream level of up to 1.2 m in Wolverine Creek. The peak rise near the mouth of Clinton Creek would be about 0.4 m, in the Forty Mile River a maximum of 0.1 m and in the Yukon River less than 0.1 m. The rise in stream level would occur gradually, over periods of 20 to 30 minutes, so that any person in the floodplain could easily escape.

The tailings piles therefore are not considered to represent significant hazards to human life.

8. The Clinton Creek site is extremely remote. It is totally uninhabitated in winter and is visited only occasionally in summer. The annual risk of a breach flood occurring while a person is present in the floodplain is estimated at 1:25,000, which is a very low risk. The risk to human life is nil, considering that gradually rising stream levels would give ample warning in the rare event of a breach flood.

9. It is recommended that final abandonment of the Clinton Creek site be completed in 1988.

1. INTRODUCTION

This report presents the results of a hazard assessment to determine the potential risks to human lives presented by the abandoned waste dump and tailings piles at the Clinton Creek asbestos mine, Yukon Territory.

This study is carried out in response to concerns expressed by Indian and Northern Affairs Canada (INAC) over the Abandonment Plan for Clinton Creek mine submitted in September 1986 by Cassiar Mining Corporation. The Yukon Territory Water Board, following public hearings in Whitehorse on January 20, 1987, recommended acceptance of the basic abandonment plan. The Water Board also recommended that a sum of money be set aside to establish a monitoring system with remote warning of significant rise in water levels resulting from stream blockage.

INAC, in reviewing the recommendation of the Water Board, is concerned over the potential for loss of life should either the waste dump or tailings piles fail and release a large quantity of water. In addition to requesting a review of the risk of loss of life, INAC has also requested that a course of action to lower the water levels be identified.

Klohn Leonoff has always considered the Clinton Creek site to represent a very low risk to human life. Previous studies have therefore primarily focused on water quality aspects. The study presented in this report attempts to identify potential failure scenarios for both the waste dump and tailings piles, models the downstream impacts of these failures, and shows them to represent no significant risk to human life. As well, this report also lays out the options considered for abandonment and considers the feasibility of lowering water levels, as requested by INAC.

The work for this report was carried out in accordance with Klohn Leonoff letter of proposal dated September 18, 1987 and authorized by Cassiar letter of October 14, 1987.

2. BACKGROUND

Clinton Creek Asbestos Mine is located about 100 km northwest of Dawson City, Yukon Territory. The minesite is adjacent to Clinton Creek, about 8 km upstream from its mouth on the Forty Mile River. The confluence of the Forty Mile River and the Yukon River is about 5 km downstream from the mouth of the Clinton Creek. Drawings A-4001 and A-4002 show the minesite location.

The open pit mine operated from 1968 to 1978, closing when its economic ore reserves were depleted. The open pits, the large Porcupine and the much smaller Snowshoe Pit, were located on a hilltop on the south side of Clinton Creek. Ore was transported by a cable tramway across the Clinton Creek valley to the concentrator located on a flat-topped ridge to the north of Clinton Creek, Drawing No. A-4003. Waste rock was placed in an area adjacent to the open pit dumping over the slope which forms the south valley wall of Clinton Creek. Tailings from the concentrator were deposited over the western slope of Wolverine Creek, a small tributary to Clinton Creek.

At the time of startup of mine operations in 1968, there was no regulatory process in place in the Yukon Territory. In 1972 the Northern Inland Public Waters Act was proclaimed and in 1974, following discussion regarding waste disposal operations at Clinton Creek, a Water Use License was granted. The water license came into effect in 1975 and was renewed in 1977 and again in 1982. In accordance with the terms of the water license, which expired in September 1987, Cassiar Mining Corporation submitted a rehabilitation and abandonment plan to the Yukon Water Board. The abandonment plan describes the extensive erosion protection works, cleanup and monitoring which have been completed. Cassiar considers the site to be in satisfactory condition for abandonment.

3. CLINTON CREEK WASTE DUMP

3.1 PRESENT CONFIGURATION

Waste rock from the Porcupine Pit was disposed by dumping on the slope which forms the valley wall on the south side of Clinton Creek. Originally, the valley floor was flat bottomed with a width of about 240 m, and Clinton Creek meandered along the valley bottom. As the toe of the dump reached the valley floor, it began to spread on the permafrost alluvial soils on the valley floor. As more waste material, primarily argillite, was placed on the dump, spreading of the dump continued until it filled the valley bottom. The cross-section of the waste dump illustrates the very flat surface profile. See Drawings D-4004 and D-4005.

The total quantity of waste rock in the dump is estimated as 70 million tons. The gradation of the argillite waste rock is primarily sand, gravel and cobble sizes, but with occasional boulders of relatively durable rock throughout.

In its final configuration, when waste dumping stopped in 1978, the waste rock impounded a body of water now known as Hudgeon Lake. The lake is about 25 m deep, with a surface area of 72 hectares (180 acres).

Outflow from the lake passes through four 1800 mm diameter culverts into Clinton Creek channel, which flows across the north side of the waste dump with an overall gradient of about 4.8%. The channel is bounded by the valley wall on the left bank and by the waste dump on the right. The channel has cut into the near surface weathered bedrock and now contacts relatively fresh, unweathered bedrock which is erosion resistant. Numerous large boulders eroded from the waste material serve to armour the channel bottom and dissipate the energy of the stream.

Longitudinal profiles of the channel of Clinton Creek over the waste dump were surveyed in 1983, 1984 and 1986 to monitor the rate of downcutting. These profiles shown on Drawing D-4004 showed no measurable downcutting over the three year period, although some local bed erosion is apparent. Examination of photographs taken over a number of years also confirms the slow rate of downcutting.

Monitoring of horizontal and vertical movements of a number of surface monuments on the waste dump has been carried out since 1976. As well, measurements have been made of the relative rates of movement of points on either side of Clinton Creek channel (cross-channel reference lines). Table 1 below shows that movements have steadily decreased over the 10-year period of record, to an average rate of horizontal movement in 1986 of less than 0.4 m/yr (1.2 ft/yr), with all movements being generally northward, toward Clinton Creek channel.

each

TABLE 1

*AVERAGE ANNUAL HORIZONTAL MOVEMENTS OF WASTE DUMP (ft/year)

	Cross-Channel Reference Lines	** Monitoring Points
1976-77	-	3.2
1977-78	4.0	4.2
1978-79	-	-
1979-80	3.0	-
1980-81	2.4	3.6
1981-82	2.2	2.5
1982-83	1.7	2.6
1983-84	1.5	1.8
1984-85	1.3	1.6
1985-86	1.0	1.2

* The averages shown do not include all of the same sections for each year, but are a reasonable indication of the annual trends.

** Includes points 20A, 21A and 22A.

The result of the ongoing waste dump movement is that the stream continues to erode a supply of fresh dump material on its right bank. At the recent movement rates, the volume of material eroded is estimated at less than 3000 m^3/yr. Continued armouring of the channel also continues as boulders are introduced as part of the waste.

Observations of the waste dump and channel over the period since the 1978 shutdown of the mine indicate that the dump and channel are approaching stable states. It is unlikely that movements of the dump will increase. Even at much higher rates of dump movement, however, Clinton Creek has ample capacity to transport sediment. It is improbable that future blockage of the channel from dump movements will occur.

The overall stability of the waste dump acting as an earth dam has been considered and has been shown to be satisfactory. The waste dump impounds a depth of 25 m and has a base width of about 700 m. This width is several times greater than that of an earth dam of comparable height. Golder Associates (1978) calculated a factor of safety greater than 4.0 with respect to base sliding. The granular materials in the waste dump give it a high resistance to piping failure. Hence, the waste dump must be considered stable with regard to overall failure.

3.2 ABANDONMENT STRATEGY

Numerous concepts have been considered as remedial measures for abandonment of the waste dump. None of these concepts, however, has been found advantageous over the present basic configuration of the waste dump and stream channel. The main ideas considered are discussed below.

1. <u>Lower the Level of Hudgeon Lake</u>
   The option of lowering Hudgeon Lake by any significant amount is not considered feasible. Lowering the channel level would remove support from the toe of the dump, certainly resulting in increased movement rates. This strategy is, in fact, opposite to the

solution suggested by other reviewers of the project, which is to raise the level of the channel. The only opportunity for lowering Hudgeon Lake would be to slightly cut the level of the outlet at the time of removal of the access road culverts. Such lowering would necessarily be limited to avoid impacting dump stability. It is certain that some future downcutting of the outlet will occur naturally through erosion. Lowering of the stream channel or the lake level is not recommended as an abandonment strategy.

2. Raise the Level of the Waste Dump Channel

Stability analyses have shown that to achieve a significant increase in factor of safety of the dump against continued movement in a northerly direction it would be necessary to place a fill of up to 20 m in the present channel. Such a scheme was proposed by Hardy Associates (1984) and would entail constructing a new, riprap lined channel at a higher level over the dump surface. The proposed toe support fill could stabilize the dump against movements in the cross-valley direction, but the dump may continue spreading laterally. Such spreading movements could create weaknesses in the relocated channel, leading to escapement of the flow. The flow could also escape the channel by overtopping caused by ice conditions. Any escapement of flow from the channel would result in rapid downcutting of fresh waste dump material, leading to complete failure of the channel and massive erosion.

For the above reasons, Klohn Leonoff does not support the concept of placing a stabilizing toe fill.

3. Removal of the Waste Dump

The most extreme measure considered for reclamation of the waste dump would be excavation of the waste to fully drain Hudgeon Lake. With this concept, waste would be placed as backfill in the open pit. The cost to move in the order of 25 million m^3 would be in the order of $40-$50 million and is obviously prohibitive.

4. Continue with Present Naturally Developed Channel

The present configuration of the waste dump channel is described in Section 3.1. This present configuration is considered acceptable for abandonment and will have minimal environmental impact.

Remedial works undertaken in 1983 and 1984 on the Clinton Creek channel have produced a stable channel across the waste dump. Long-term stability is provided by exposed bedrock on the left bank, and the presence of large boulders in the dump material along the right bank, which allows the formation of a self-armouring layer, as occurs in a natural stream.

Even if waste dump movement continues at about its current rate of 0.4 m/yr, the volume of material which could encroach upon Clinton Creek over the 700 m dump length is less than 3000 m^3/yr. This volume of material, even if it is all eroded, will not create an adverse environmental impact on downstream watercourses.

3.3 HAZARD ASSESSMENT

3.3.1 Scenarios Considered

The potential for rapid release of water caused by the waste dump is considered in this section. In carrying out this study, it was attempted to identify all scenarios in which the waste dump could potentially cause significant increases in flow rates in Clinton Creek. Particular emphasis was placed on identifying mechanisms which could be comparable to a "dam break", in which a sudden flood wave would be created downstream.

The scenario of overall failure of the waste dump was discussed previously in Section 3.1. The dump has been shown to have ample stability against overall failure from either base sliding or piping.

The second scenario to consider is that of blockage of the channel over the waste dump by sliding of waste material. Such a mechanism is possible, but on such a small scale as to have no noticeable impact on streamflows. Even a slide which filled the channel to a depth of 5 m would impound such a small amount of water that a breach would result only in a short-term increase in sediment load, but no large flow increase. This conclusion is supported by observation of the channel development over the years, in which material is removed from the right bank by small sliver failures. In granular materials such as the waste dump is composed of, deep seated, massive failures do not occur.

The scenario considered most likely would be that of downcutting due to a particularly large storm. A 200-year flood has been selected and the amount of down cutting expected from the resulting outflow has been calculated.

3.3.2 Hydrology

The 200-year flood for Clinton Creek was estimated based on data presented in Klohn Leonoff reports "Report on Sediment Transport Analysis" April 23, 1985 and "Report on Mine Waste Dumps" August 16, 1983. The catchment area for Hudgeon Lake was estimated to be 106 km^2. Water Survey of Canada streamflow data in the general mine region are summarized below:

TABLE 2

AVAILABLE STREAMFLOW DATA

STATION NAME	CATCHMENT AREA (km2)	PERIOD OF RECORD
Clinton Creek above Wolverine Creek	106	1964-65 (summers only)
North Klondike near the Mouth	1100	1974-83
Klondike River above Bonanza Creek	7800	1963-83
Forty Mile River near the Mouth	16600	1982-83

With the exception of the two partial years of record for Clinton Creek, there are no flow records available for small catchment area streams near the minesite.

Unit flows were prepared based on the North Klondike River records and are presented in the following table:

TABLE 3

UNIT FLOWS BASED ON NORTH KLONDIKE AND KLONDIKE RIVERS

Flow Event	Unit Flow ($L/s/km^2$)
2 Year Flood	220
50 Year Flood	570
100 Year Flood	650
200 Year Flood	740

The 200-year peak flood inflow was thus estimated to be 78 m^3/s for the Hudgeon Lake catchment. An associated snow melt base flow of 22.5 m^3/s was estimated from the North Klondike and Klondike River data. A duration of 9.3 hours and a time to peak of 3.5 hours was estimated based on time of concentration calculations.

3.3.3 Sedimentation

After a literature search (ASCE 1975, Breusers 84-85, Simons 1977, Unesco 1985) the Meyer-Peter and Mueller equation was selected to estimate the sediment transport capacity of Clinton Creek due to the range of material sizes present in the waste rock. A median grain size of 8.8 mm and a D_{90} of 23 mm were used. The channel through the waste dump was assumed to be trapezoidal with side slopes of 1H:1V and a bottom width of 3 m (see Drawing A-4006).

The embedment of the channel in the bedrock has reduced the upstream channel slope. It can be seen from the profile on Drawing D-4004 and the sections on Drawing A-4005 that Clinton Creek has begun to embed itself in the bedrock. For the first 340 m the slope is 0.035 and for the remaining 360 m the slope is 0.061 with an average slope of 0.048. Calculations were carried out on slopes of 0.035 and 0.048. The degradation was assumed to occur for a length of 340 m and 700 m, respectively.

A Mannings 'n' of 0.05 was selected based on photographs of the creek bed. The bed material was assumed to have a specific gravity of 2.7 and a void ratio of 0.4.

3.3.4 Results

The downcutting of Clinton Creek channel resulting from a 200-year flood was calculated by an iterative process. The sediment transport capacity of the creek was calculated in 0.5 hour increments and, at the end of each increment, the flow rate was re-calculated based on a new invert level for the lake outlet (spillway). The iterative process was continued for a 24 hour period. In the 340 m upper channel at a slope of 0.035 a volume of 6900 m^3 could be removed in the 24 hour period. If it is assumed that the material was eroded from the bottom and one side of the channel (assuming a 7 m high channel) a total depth of 1.6 m of material would be removed (see Drawing A-4006). This downcutting would occur over a 24 hour period, thus precluding a rapid failure. Drawing A-4007 shows the inflow/outflow hydrographs with the resulting lake levels and spillway levels.

If the creek were to escape the bedrock channel, assuming an average slope of 0.048 over the 700 m length, 9700 m^3 of material could be removed. This translates into a degradation depth of 1.1 m (shown on Drawing A-4006) over a 24-hour period. Again rapid failure would not be expected in this case. Drawing A-4008 shows the inflow/outflow hydrographs with the resulting lake levels and spillway levels.

No allowance was made in the sediment transport calculations for armouring of the channel. This armouring will reduce the sediment available for transport and result in less material being removed. Degradation would occur at a progressively slower rate until the combination of reduced flow and increased armouring would allow a new steady state to develop.

The above analysis indicates that even an extreme storm event would not have sufficient sediment-carrying capacity to catastrophically downcut the channel of Clinton Creek over the waste dump. The maximum rate of downcutting has been calculated as 1.6 m in 24 hours, this being in the case where the upper reach of Clinton Creek escapes the existing riprap lining and erodes through fresh waste dump material. Such a rate of downcutting will not produce a significant increase in flow, and certainly not enough to pose any threat to human life.

4. WOLVERINE CREEK TAILINGS PILES

4.1 DESCRIPTION

Tailings piles were formed by depositing, with a stacker conveyor, approximately 10 to 20 million tonnes of dry asbestos tailings from the concentrator over the western slope of Wolverine Creek, a small tributary to Clinton Creek (Drawing No. A-4003. The tailings material consists of well-graded, crushed serpentine rock containing some asbestos fibre not recovered in the milling process. Particle sizes range from about 1 inch to approximately 10% passing the #200 sieve size.

From the millsite (elevation 595 m), the valley side slopes northward at an average slope angle of about 16 to 17 to the valley bottom at elevation 396 m. The foundations of the tailings pile consist of a surface organic layer overlying a deposit of silty sandy gravel, followed by weathered bedrock. The foundation soils are frozen, except where placement of the tailings pile has altered the temperature regime.

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 Wolverine Creek at the valley bottom. A breach of this blockage occurred, resulting in transport of a considerable quantity of tailings down Wolverine Creek and into Clinton Creek. Following the failure, the stacker was relocated northward and tailings were placed on the north lobe until the mine shutdown in 1978.

4.2 MONITORING SINCE SHUTDOWN

A program for monitoring the movement of the tailings piles has been in operation since 1976. Results of monitoring showed that the north tailings lobe was moving rapidly downslope and the south tailings lobe, which failed previously in 1974, was still continuing to move slowly downslope. A plan of the tailings piles is shown on Drawing A-4009, and sections through the piles from 1978 and 1983 are compared on Drawing D-4010.

The north tailings lobe has been sliding down the valley slope at a considerable rate. The surface is highly distorted, with a continuous series of scarps from top to bottom. The toe has moved over 120 m from its position as plotted in 1978, and the tailings have now reached the valley bottom. Movements of monitoring points on the north lobe have reached maximum horizontal rates of over 30 m/yr on the lower part of the lobe. Movements appear to have reached a peak in 1983 and have slowed to a maximum observed rate of 19 m/yr in July, 1986. Monitoring points near the top indicated much lower movements of less than 0.6 m/yr. The monitor locations and rates of horizontal movement observed in July, 1986 are shown on Drawing D-4011. Prior to the 1985 site visit, a high steep face existed at the toe of the north lobe. In June, 1985 this face slumped and flattened considerably, so that the potential for rapid movement of the north lobe is reduced.

Movements of the south tailings lobe are considerably lower than the north lobe, but are still significant as the maximum movement rate observed in July, 1986 was 6.6 m/yr on monitor point 24A. The highest rates are in the lower part of the south lobe. Movements have been increasing slightly over recent years, with the highest rates recorded in 1986. The channel conveying the stream past the toe of the south lobe is being squeezed against the east valley wall by the advancing tailings pile.

4.3 REMEDIAL WORKS SINCE SHUTDOWN

In a report by Golder (1978), the following remedial works for the tailings piles were recommended:

a) Construct a rock-lined channel to convey Wolverine Creek over the tailings deposited in the creek bottom at the 1974 failure;

b) Unload the slope of both the north and south tailings lobes to improve stability of the tailings piles.

The rock-lined channel was constructed in 1978 and inspection by Klohn Leonoff during annual site visits from 1983 to 1986 show the channel has been stable to date. The channel location is shown in plan on Drawing D-4009.

The areas selected by Golder for excavation of tailings from the north and south lobes are shown on Drawing D-4009 and D-4010. The program of excavation of tailings from the toe areas was unsuccessful in arresting movement of the tailings piles. As demonstrated by results of the monitoring program, the downslope movement of the tailings piles has continued.

4.4 ABANDONMENT STRATEGY

As has been done for the waste dump, numerous strategies have been considered for abandonment of the tailings piles. These studies of various strategies have led to the conclusion that there is no practical alternative to abandoning the tailings piles in their present condition, and that the potential impacts of this present configuration will be acceptable. Studies have included carrying out a sediment transport analysis to determine the extent of sediment transport downstream in Wolverine and Clinton Creeks (Klohn Leonoff 1985).

The various strategies considered for abandonment of the tailings piles are discussed in the following sections.

1. Stream Diversion

Proposals have been discussed for carrying Wolverine Creek around the tailings piles either through tunnels or deeply buried culverts.

A tunnel would have a length of about 600 m at a cost of about \$4,000/m and, with appurtenant works such as portal construction and inlet and outlet works, would cost in the order of \$3 million. A culvert scheme may be somewhat less expensive but would have uncertainties in the stresses which may be imposed by the tailings piles.

Regardless of whether a tunnel or culvert is considered, the scheme would not be maintenance free. Ongoing inspection would be required to prevent blockage.

2. Removal of the Tailings Piles

The most direct solution would be to excavate the tailings and place them in a permanently stable location. This solution would have the advantage that no ongoing maintenance would be required. The impracticality of this solution is obvious, as the tailings volume is estimated at 10 million tonnes, or roughly 6 to 7 million m^3. The cost of removing the tailings would likely be in the order of \$2 to \$3/m^3, or a total cost of \$12 million to \$20 million.

3. Placement of a Stabilizing Toe Fill

A proposal was put forward by DIAND's consultant, Hardy Associates (1984b) to essentially construct a dam across the toe of the south lobe. The dam would provide a stabilizing weight on the toe of the south lobe and would contain any breach releases from the north lobe. The dam was proposed with culvert outlets and an emergency rock-lined spillway.

Klohn Leonoff does not support this concept because of the requirement for ongoing maintenance of such a structure. To implement solutions requiring ongoing maintenance is in conflict with acceptable abandonment strategy which is to leave the site in a maintenance free state. Also, the concept results in higher impounded water levels, with increased hazard of rapid erosion and downcutting.

4. Lowering Water levels

The possibility of lowering water levels in Wolverine Creek upstream of the tailings piles has been examined in accordance with concerns expressed in letter from INAC (September 16, 1987 and October 21, 1987).

The difficulty of lowering water levels in Wolverine Creek is similar to the situation with the Clinton Creek waste dumps. That is, eventual stabilization depends on the tailings piles receiving support by abutting against the opposite valley walls. To lower the level of the channel, therefore, is incompatible with the objective of stabilizing the tailings piles. Klohn Leonoff does not consider channel lowering to be a useful concept.

5. Abandonment in Present Configuration

The option proposed for abandonment of the tailings piles, as put forward by Cassiar in the abandonment plan submitted to the Yukon Territory Water Board, is to leave the site in its present configuration.

Monitoring of the tailings piles has shown that movements of the north lobe have decreased. The pile is approaching a more stable state and there now seems little probability that a sudden failure of either of these piles will occur. Rather, downslope movements will continue at a slow rate. Ongoing erosion of the toe will occur. However, Wolverine Creek has limited flow except during freshet, so the amount of erosion will be small. The sediment impacts of the tailings piles are expected to be limited.

4.5 HAZARD ASSESSMENT

The ongoing downslope movements of the tailings piles are expected to lead to increased impoundment of water in Wolverine Creek valley. It is expected that the stream will create a channel across the top of the blockage, and will eventually reach a configuration similar to the waste dump, with the stream confined in a channel along the opposite valley wall. This configuration is expected to be stable against overall failure. However, because of the finer gradation of the material in the tailings piles, such failure must be considered possible. Therefore, a breach mechanism has been postulated for the tailings piles and simulated using the NWS DAMBRK program.

4.5.1 Possible Breach Configurations

A literature review was carried out to obtain data on previous breach-type failures. From this review a probable breach configuration was developed and applied to the Wolverine tailings pile. The literature (Smith (1981), USBR (1983), McMahon (1981)) contains correlations between peak breach outflow and various combinations of reservoir volume, reservoir surface area, height of dam and volume of material removed during breach. Due to the height and breadth of the tailings pile and the relatively small reservoir size these correlations could not be meaningfully applied to obtain a peak breach outflow.

The approach taken in this study was to estimate a breach size based on historical breaches and also estimate a time for breach formation based on historical rates of material removal during a breach. The breach size was selected based on criteria used by B.C. Hydro (1984) for earthfill dams. The side slopes of the breach were taken to be 1H:1V with an average breach width of 2 times the dam height. Sections through the tailings piles with the assumed breach are shown on Drawing A-4010.

It was assumed that the tailings piles had reached equilibrium and stopped forward movement. As shown in Klohn Leonoff letter report dated February 28, 1985, the tailings pile will be stable with the toe of the tailings dump at an elevation of 411.6 m (1,350 ft) (shown on Drawing A-4009). Tailings pile movement would be expected to cease when the toe has reached this elevation and hence, the impoundment was thus assumed to be at elevation 411.6 m (1,350 ft). The base of the breach was conservatively assumed to be the original river valley bottom. This configuration would give the worst case scenario for a failure. A profile of Wolverine Creek is shown on Drawing B-4011 with existing and assumed tailings piles positions.

The breach formation time was obtained by using data contained in MacDonald (1984). Using the breach formation time and the volume of material removed an average rate of material removal was obtained for 20 earthfill dam failures. The highest rate was 3600 m^3/min for Buffalo Creek, a coal waste embankment dam. This was increased by approximately 30% and applied to the tailings pile resulting in a time of breach formation of 0.8 hours. Rates of material removal from other cases ranged from 3 m^3/min to 3600 m^3/min with the majority clustering between 50 m^3/min and 1300 m^3/min. Thus the value selected for this study, 4600 m^3/min is extremely conservative and will result in conservatively high flow rates. Pertinent breach information is contained in Table 4.

TABLE 4

BREACH INFORMATION

Failure elevation	El 411.6 m
Bottom elevation	El 400.0 m
Height	El 11.6 m
Top width at failure elevation	El 46.3 m
Bottom width	El 23.2 m
Time of breach formation	El 0.8 hours

4.5.2 Hydrology

It was assumed that a 200-year flood overtopped the tailings pile at the time the breach was initiated. Concurrent flows in Clinton Creek were assumed to be at the 200-year flood level. The Forty Mile River was assumed to carry a 50-year flood and the Yukon River a 10-year flood. The 200-year peak flood flow (17 m^3/s) into the impounded lake was estimated from data in Table 3 using a factor of 740 L/s/km^2 and a catchment area of 23 km^2. The high inflow into the impounded lake would increase the expected downstream flooding. The high flows downstream would cause the flood wave to travel faster and arrive at any downstream location sooner than if downstream flows were smaller. Initial flows are presented in Table 5.

TABLE 5

INITIAL HYDROLOGICAL CONDITIONS

Inflow to impounded lake (catchment area 23 km^2)	17 m^3/s
Outflow downstream of tailings pile	17 m^3/s
Flow from Clinton Creek at confluence with Wolverine Creek (routed through Hudgeon Lake) (local catchment area 119 km^2)	53 m^3/s
Lateral inflow into Clinton Creek 6.0 km D/S of impoundment (local catchment area 49 km^2)	36 m^2/s
Flow in Forty Mile River at confluence with Clinton Creek	9 350 m^3/s
Flow in Yukon River at confluence	11 000 m^3/s

4.5.3 Channel Configuration

River cross-sections were estimated from existing topographic maps and from photographs. From the tailings pile to the confluence with Clinton Creek 1 inch = 200 ft mapping was available. From this confluence to the confluence of Forty Mile River and the Yukon River 1:50 000 mapping was used. Based on site observations, the bed widths of Wolverine and Clinton Creeks were assumed to be 3.7 m and 4.6 m, respectively.

4.5.4 Results

The peak breach outflow obtained was 157 m^3/s. A stage rise of 1.2 m was obtained at the toe of the tailings dump. Table 6 presents the results of the DAMBRK simulation. Drawing A-4012 presents these results on a location plan.

TABLE 6

SUMMARY OF TAILINGS PILE DAMBREAK ANALYSIS RESULTS

Distance From Impoundment	Base Flow m^3/s	Maximum Incremental Flow m^3/s	Maximum Stage Rise m	Time for Stage Rise Minutes
km 0.8 Toe of pile	17	140	1.2	27
km 3.4 Conf of Clinton and Wolverine Creeks	70	131	1.0	30
km 6.0	70	123	0.9	27
km 8.5 Clinton Creek Upstream of Forty Mile River	107	118	0.4	21
km 13.5 Forty Mile River Upstream of Yukon River	9500	112	0.1	21
km 15.0 Yukon River Down-stream of Forty Mile River	20400	109	<0.1	21

As can be seen on the previous table the stage rise varies from 21 minutes to 30 minutes. Due to the time necessary for breach development a 'wall of water' scenario would not occur. In the event of a breach sufficient time would be available for anyone who might be in the creek or river channel to escape to higher ground. Selected stage and discharge hydrographs are plotted on Drawings A-4013 to A-4016.

A sensitivity simulation was carried out assuming the breach bottom was limited to elevation 405.8 m. This resulted in a decrease in maximum stage rise from 40 to 50% throughout the simulated reach.

The above analysis was carried out to simulate the most severe flood breach of the tailings piles which could be postulated. This analysis has shown that the resulting downstream flows would rise significantly for a short period, but the rise would occur gradually so that any person in the floodplain would have ample warning. The analysis demonstrates that the tailings piles do not represent a significant risk of loss of life.

5. DISCUSSION OF DOWNSTREAM RISK

The rational approach to evaluating risk due to natural hazards comprises a two part procedure. The first step is to assess the hazards; the second step is to consider acceptability (Morgan, 1986).

In above sections the hazards presented by the waste dump and tailings piles have been assessed. Essentially, it is concluded that the waste dump does not present a hazard of sudden release of water, while for the tailings piles a breach mechanism leading to sudden release of water is possible. The dambreak analysis carried out has shown that this postulated breach would not be life-threatening. The buildup of excess streamflow would provide ample warning and the duration of the excess flow would be limited. It is therefore concluded that abandonment of Clinton Creek mine will not present a hazard to human life.

Regardless of the above conclusion, it is also useful to examine the probability of humans being exposed to a postulated failure event, even though their lives would not be endangered by such an event. This probability is a product of the frequency of occurrence of the event and the frequency of people being present.

A breach failure of the Wolverine Creek tailings piles occurred in 1974, during active dumping, while no breach failure has occurred in the 13 years since. Based on this period of observation, it would be reasonable to assume a 20-year return period of breach failure.

The frequency of potential exposure of humans is very limited at the remote Clinton Creek site. To estimate the use made of the area, observations of Cassiar Asbestos and Klohn Leonoff personnel familiar with the site have been used. As well, the RCMP detachment in Dawson City were contacted.

There are no permanent habitations reported either on Clinton Creek or on the Forty Mile River between Clinton Creek and the Yukon River. One cabin, that of the former caretaker of the Clinton Creek property, is situated on the left bank of the Forty Mile about 1 km downstream of the Clinton/Forty Mile confluence. This cabin is situated on a bench some 15 m to 20 m above river level and is thought to be used only occasionally in summer.

The site is virtually uninhabitated during winter months (October through April). During summer, Clinton Creek is accessible by road. Some use of the road and the bridge over the Forty Mile River at Clinton Creek are made by placer miners enroute to workings farther upstream on the Forty Mile. Occasional visits are made by local tourists or fishermen, but on the whole the site is completely deserted even during summer. It is thought that occasional canoe or boat parties may travel down the Forty Mile River from Alaska, but these expeditions are unreported as they continue down the Yukon River to Eagle, Alaska without reporting in Canada. Visitors travelling up Clinton Creek to the minesite are becoming increasingly infrequent as virtually all of the mine equipment and facilities have been removed.

To estimate a frequency of exposure, it is considered appropriate to consider only Clinton Creek itself, as further downstream the effect of a breach flood is extremely minor. The frequency of persons being in the floodplain of Clinton Creek is estimated to be in the order of seven times per year for one hour on each occasion, or seven hours per year.

The annual risk of exposure to a breach flood can then be calculated as follows:

Probability of event = 1:20

Probability of human presence (consequence) = $\frac{7}{365 \times 24}$ = 1,251

Risk = $P_{(event)} \times P_{(consequence)}$ = 1:20 x 1:1,251

≈ <u>1:25,000</u>

It is apparent that there is a very low probability of an individual simply being present during a breach flood. Such exposure is not considered to be life-theatening because ample warning would be provided of rising water level (20 to 30 minutes).

The risk calculated above can be compared to some reported risks in transportation corridors. Morgan (1986) reports an annual risk of 1:2,200 that a car will be struck by the Rubble Creek landslide on Highway 99, 80 km north of Vancouver. At Cathedral Mountain, in Yoho National Park, debris torrents occur on average once in 10 years and pass over CP Rail lines. The calculated annual risk of a passenger train being struck by a debris torrent is as high as 1:750. There is no suggestion that these are unacceptable risks, even though they represent many times higher probabilities than is represented by the abandoned Clinton Creek minesite.

From the above discussion, it is concluded that the Clinton Creek site does not represent a significant risk.

KLOHN LEONOFF LTD.

R.F. Rodman

Richard Rodman, P.Eng.
Hydraulics Engineer

Peter C. Lighthall, P.Eng.
Project Manager

REFERENCES

American Society of Civil Engineers (1975), Manual No. 54 "Sedimentation Engineering", Vito Vanoni Editor.

B.C. Hydro (1984), HGPD, "Modelling Procedures for Dam Breach Inundation Studies", Report No. H1692, April.

Breusers, H.N.C. (84-85), "Lecture Notes on Sediment Transport", International Course in Hydraulic Engineering, Delft.

Fread, D.L. (1983), "DAMBRK-The NWS Dam Break Flood Forecasting Model", Office of Hydrology, National Weather Service, Silver Spring, Maryland 20910.

Fread, D.L. (1984), "Lecture Notes on the NWS DAMBRK Model and Applications", Held in Vancouver May 17-19.

Golder Associates (1978), "Clinton Creek Operations, Mine Waste Dump and Tailings Pile", report for Cassiar Asbestos Corporation Limited.

Hardy Associates Ltd. (1984a), "Report on Clinton Creek Asbestos Mine, Waste Dump Area, Review of Rehabilitation Measures", prepared for Indian and Nothern Affairs, Yukon Water Board.

Hardy Associates Ltd. (1984b), "Report on Wolverine Creek Tailings Piles, Clinton Creek Asbestos Mine", prepared for Indian and Northern Affairs, Yukon Water Board.

Klohn Leonoff (1985), "Report on Sediment Transport Analysis, Clinton Creek Asbestos Mine, Wolverine Creek Tailings Piles", prepared for Brinco Mining Limited.

MacDonald, Thomas and Monopolis, Jennifer (1984), "Breaching Characteristics of Dam Failures", ASCE, Journal of Hydraulic Engineering, Vol. 110, No. 5, May, pp 567-586.

McMahon, George, F. (1981), "Developing Dam Break Flood Zone Ordinance", ASCE, Journal of the Water Resources Division, Vol. 107, No. WR2, October, pp 461-476.

Morgan, G.C. (1986), "Acceptability of Natural Hazards in Transportation Corriders". Transportation Geotechnique, Proceedings of Symposium on Geotechnical Aspects of Transportation Routes in Mountainous Terrain. Vancouver Geotechnical Society.

National Research Council Washington, D.C. (1950), "Applied Sedimentation", Parker Trask Editor.

Simons, Daryl B. and Senturk, Faut (1977), "Sediment Transport Technology", Water Resources Publications, Colorado.

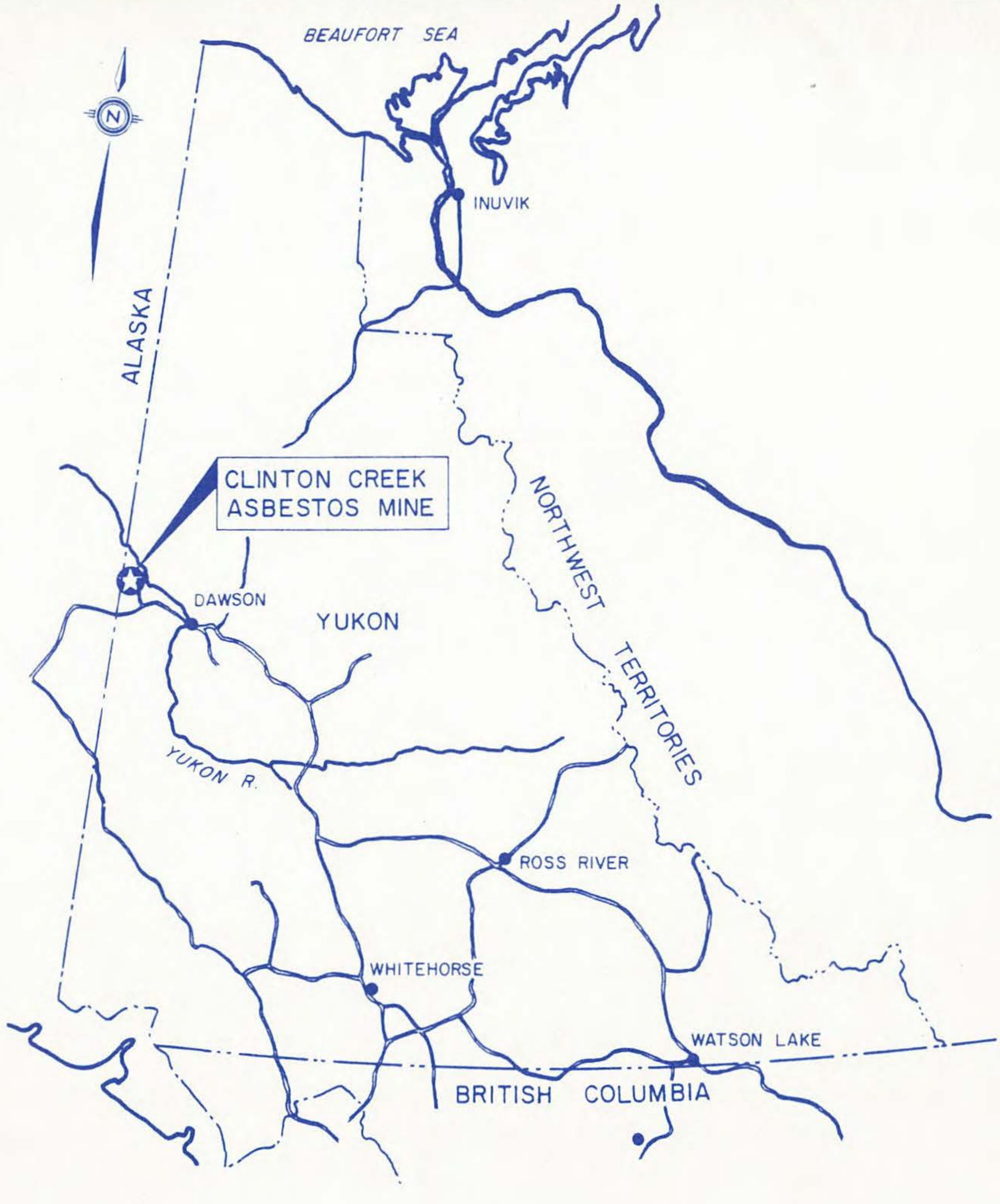
Smith, Dr. Roger (1981), "Dam Breach Wave Analysis", Presented at Seminar on "Dam Safety - Inspection and Design" Nov. 17-19, Triton College; River Grove, Illinois.

Unesco, Paris (1985), "Methods of Computing Sedimentation in Lakes and Reservoirs", Stevan Bruk, Editor, February.

U.S. Bureau of Reclamation (1983), "Guidelines for Defining Inundated Areas Downstream from Bureau of Reclamation Dams", Planning Instruction No. 83-05.

U.S. Department of the Interior Geological Survey (1985), "Floods from Dam Failures", by John E. Costa, Open-File Report 85-560, Denver, Colorado.

LIST OF DRAWINGS



AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL

SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

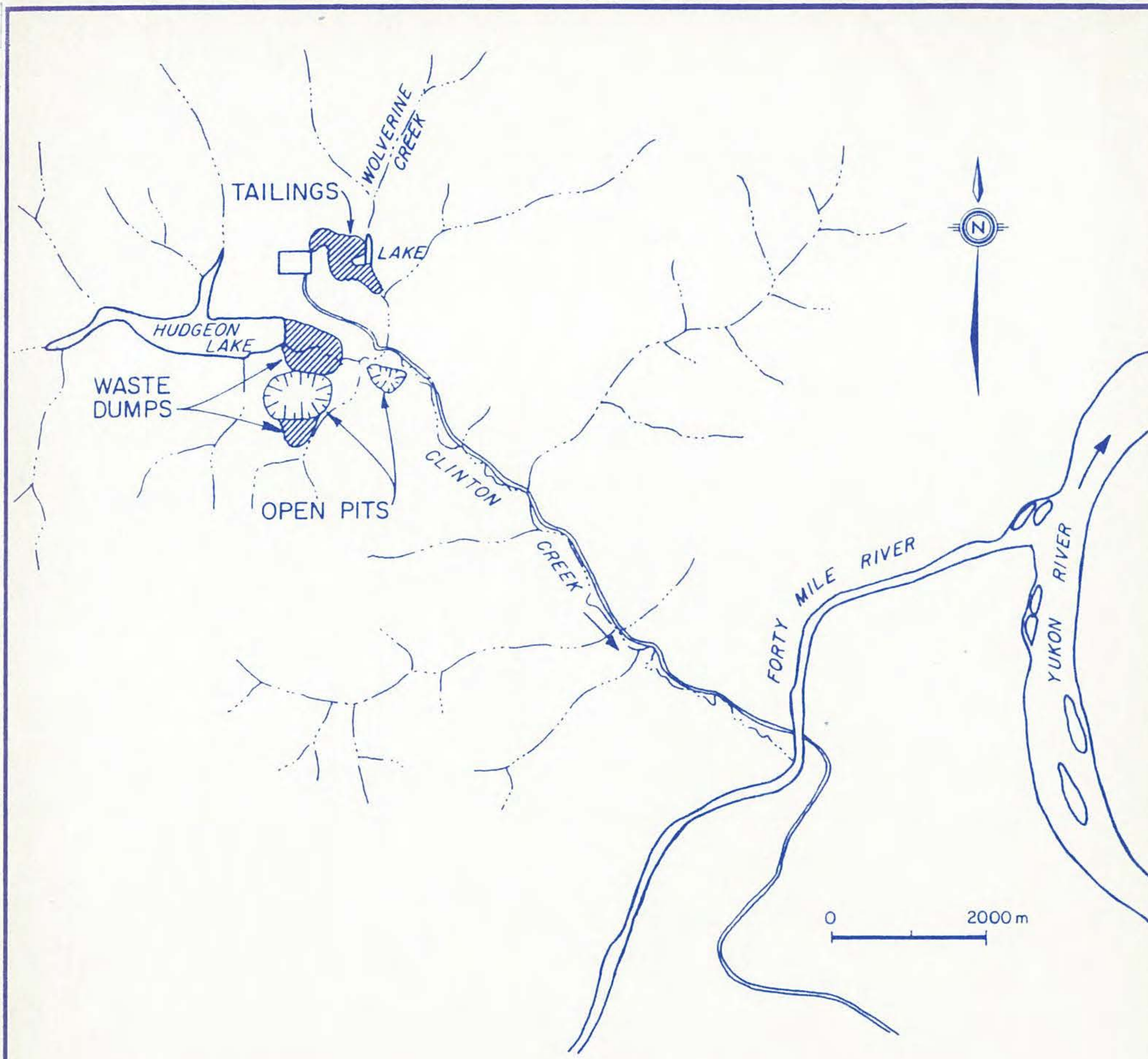
PROJECT: CLINTON CREEK ASBESTOS MINE

TITLE: KEY PLAN

CLIENT: CASSIAR MINING CORPORATION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
DEC. 10, 1987	PB 3169 04	A - 4001	

APPROVED: [signature]



AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL

SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: CLINTON CREEK ASBESTOS MINE

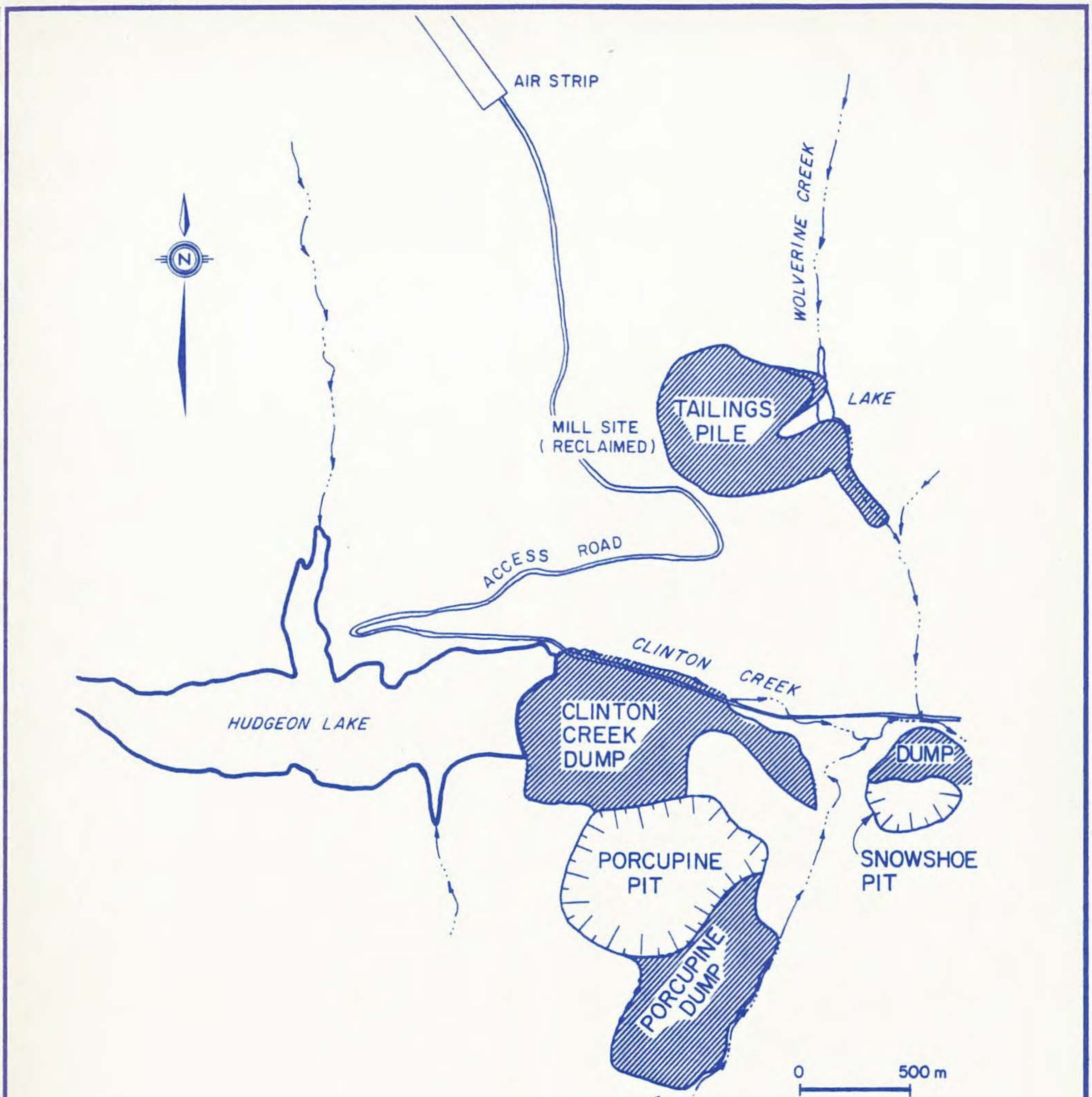
TITLE: LOCATION PLAN

CLIENT: CASSIAR MINING CORPORATION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
DEC. 10, 1987	PB 3169 04	A-4002	

APPROVED: [signature]

NCI-760



AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL

SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

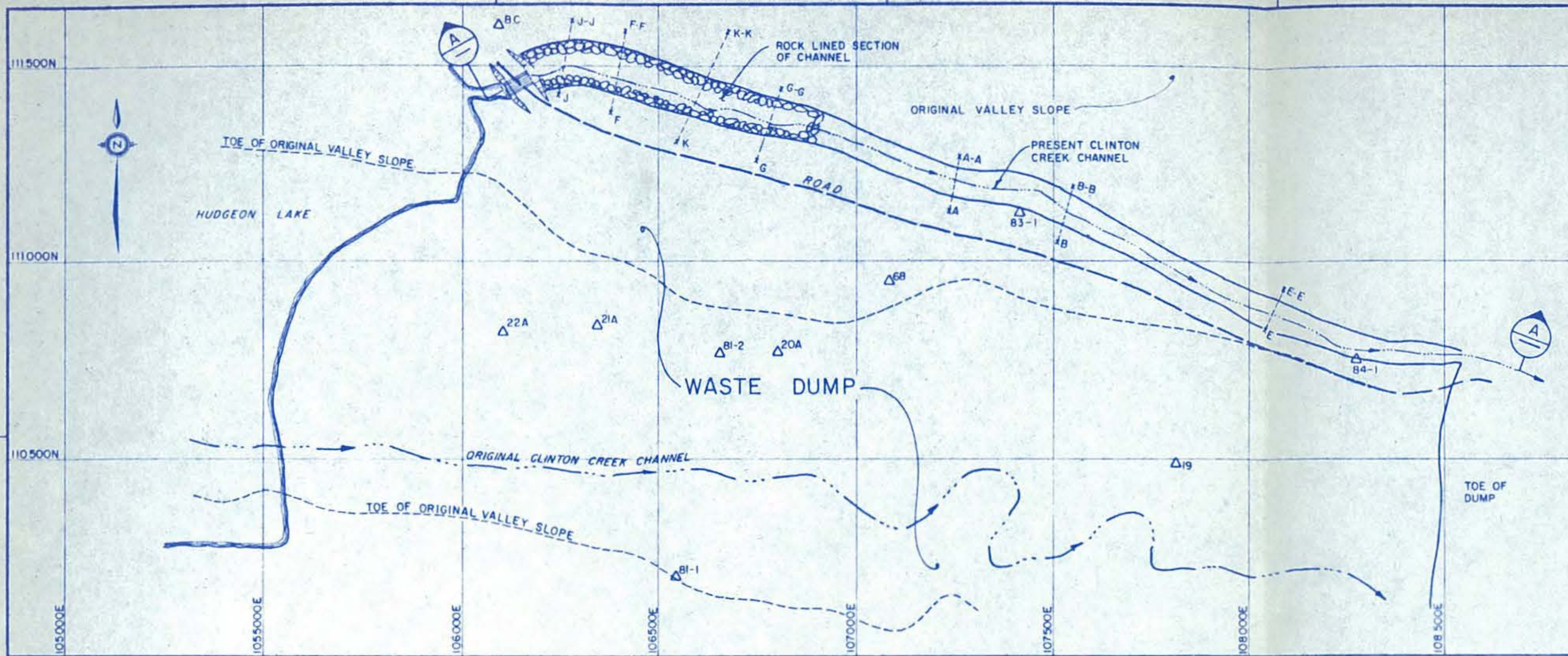
PROJECT: CLINTON CREEK ASBESTOS MINE

TITLE: SITE PLAN

CLIENT: CASSIAR MINING CORPORATION

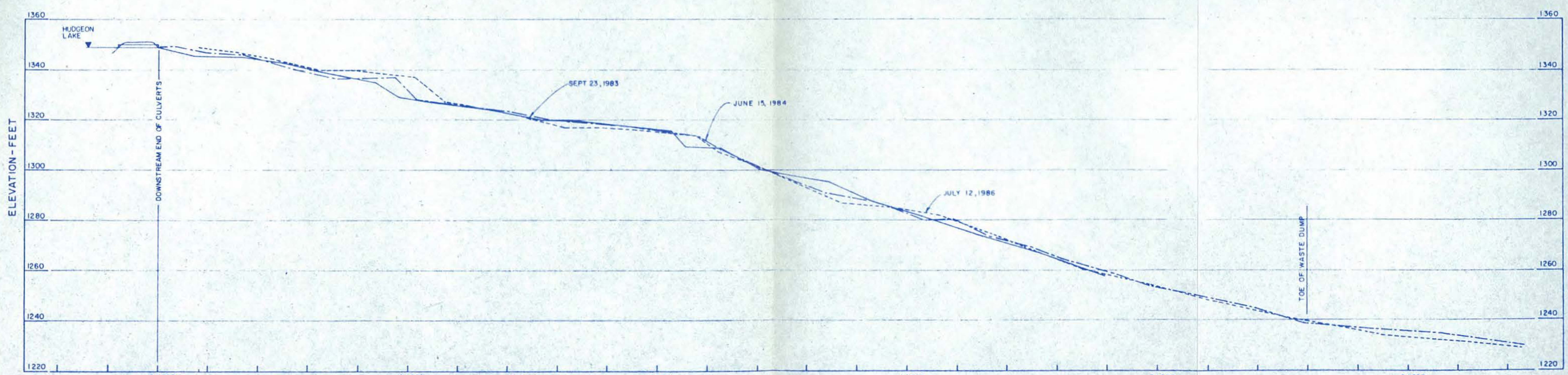
DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
DEC. 10, 1987	PB 3169 04	A-4003	

APPROVED:



PLAN

200FT 0 400FT



SECTION A

100FT. 0 200FT.

LEGEND

20A SURVEY MONUMENT

A A-A CROSS-CHANNEL REFERENCE LINE

NOTES

1. PROFILE IS PLOTTED WITH 5 TIMES VERTICAL EXAGGERATION.

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL

TO BE READ WITH KLOHN LEONOFF REPORT DATED DEC. 10, 1987

SCALE:

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

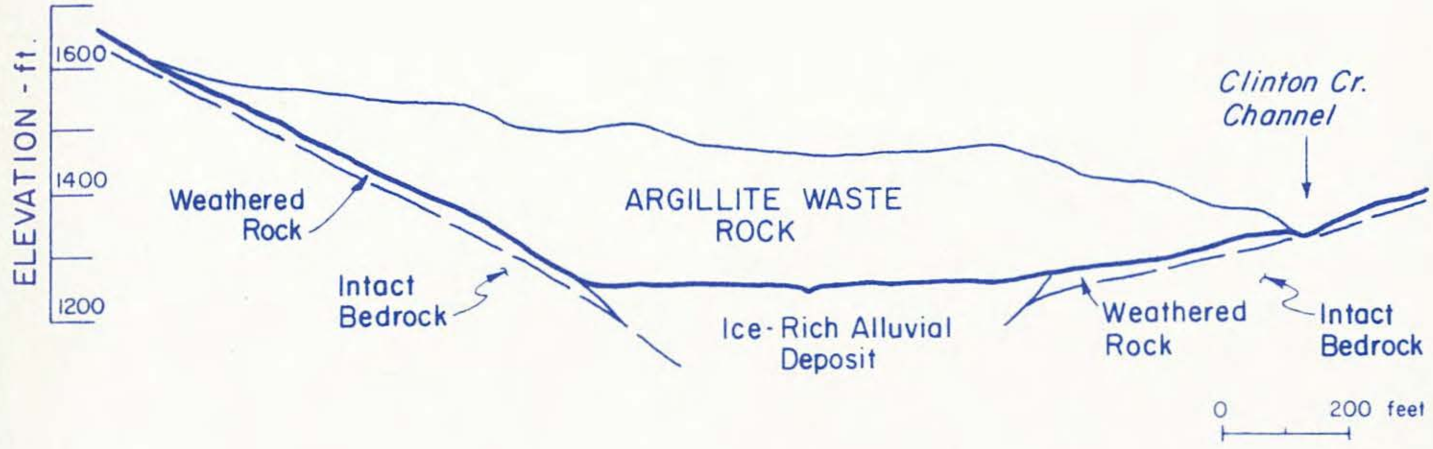
CLIENT: CASSIAR MINING CORPORATION

REV.	DATE	REVISION DETAILS	
DESIGN P.C.L.	DRAWN F.C.	DATE DEC. 1987	SCALES AS SHOWN

PROJECT: CLINTON CREEK ASBESTOS MINE

TITLE: PLAN AND PROFILE OF CLINTON CREEK CHANNEL OVER WASTE DUMP

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
DEC. 10, 1987	PB 3169 04	D-4004	



SECTION OF CLINTON CREEK WASTE DUMP

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL

SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

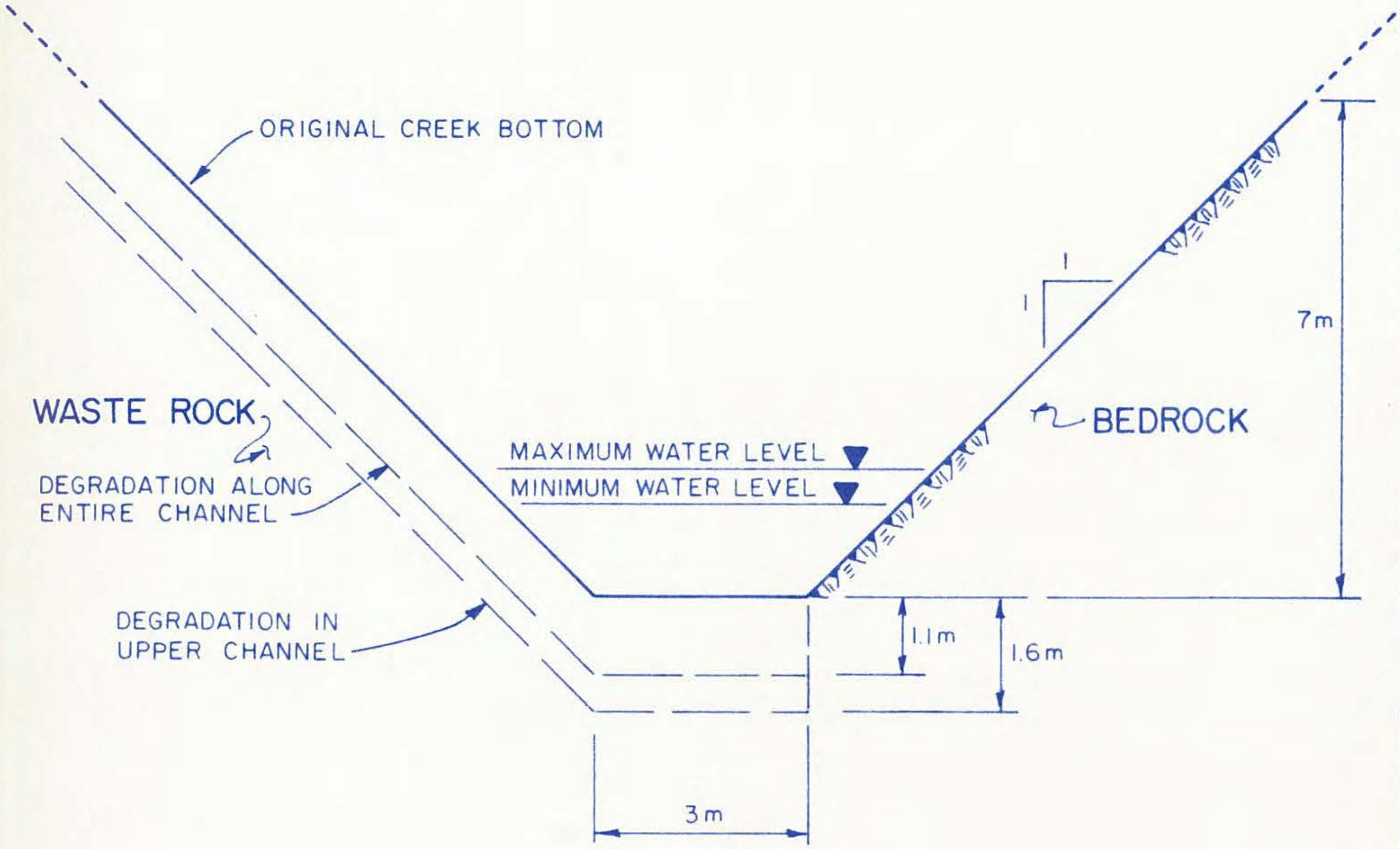
PROJECT: CLINTON CREEK ASBESTOS MINE

TITLE: TYPICAL SECTION OF CLINTON CREEK WASTE DUMP

CLIENT: CASSIAR MINING CORPORATION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
DEC. 10, 1987	PB 3169 04	A-4005	

APPROVED



AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL

SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

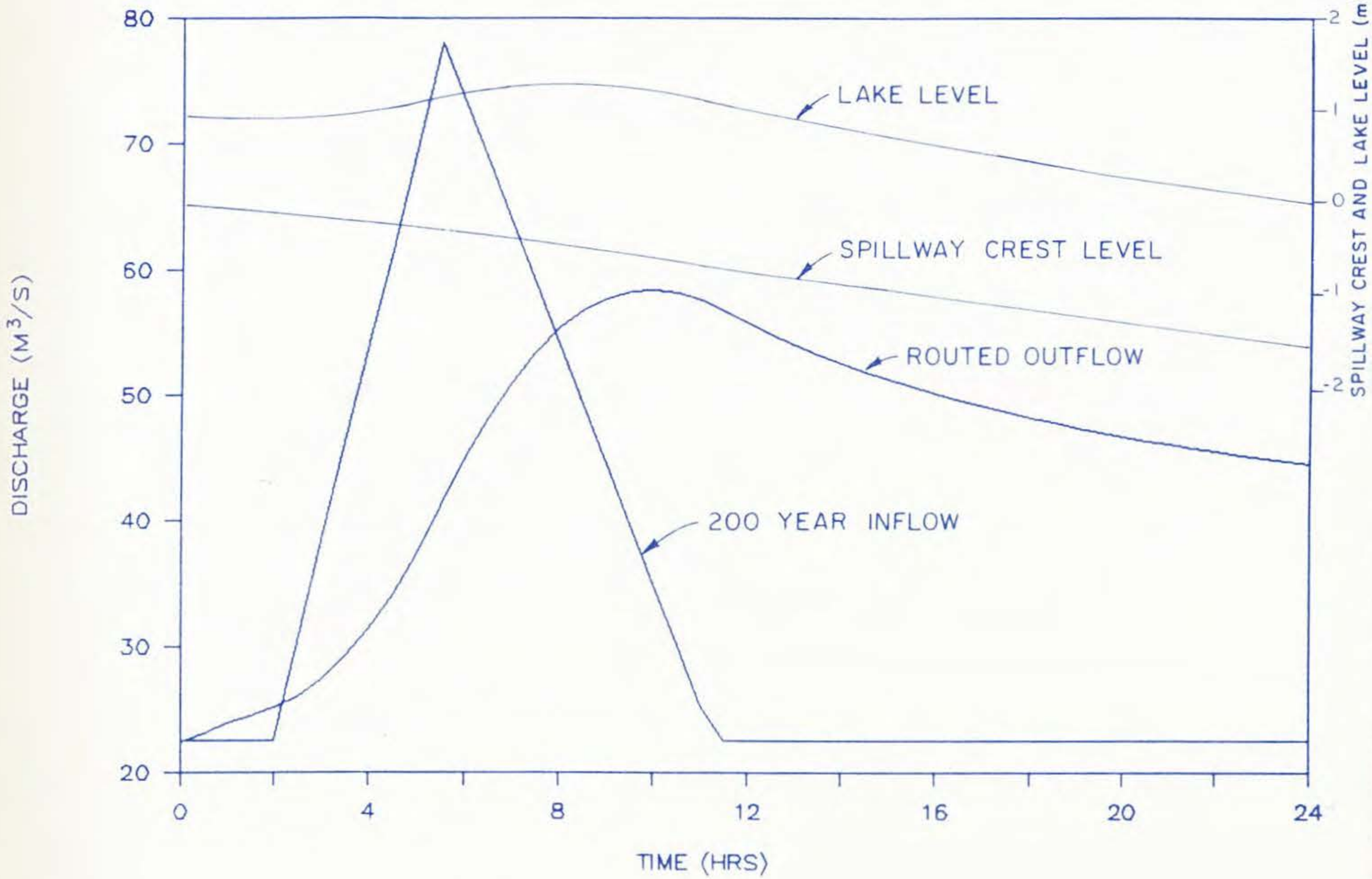
PROJECT: CLINTON CREEK ASBESTOS MINE

TITLE: SEDIMENT TRANSPORT ANALYSIS ASSUMED CHANNEL SECTION

CLIENT: CASSIAR MINING CORPORATION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
DEC. 10, 1987	PB 3169 04	A-4006	

APPROVED: K F Rodman



SLOPE OF DEGRADATION CHANNEL = 0.035

LENGTH OF DEGRADATION CHANNEL = 340 m

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL

SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

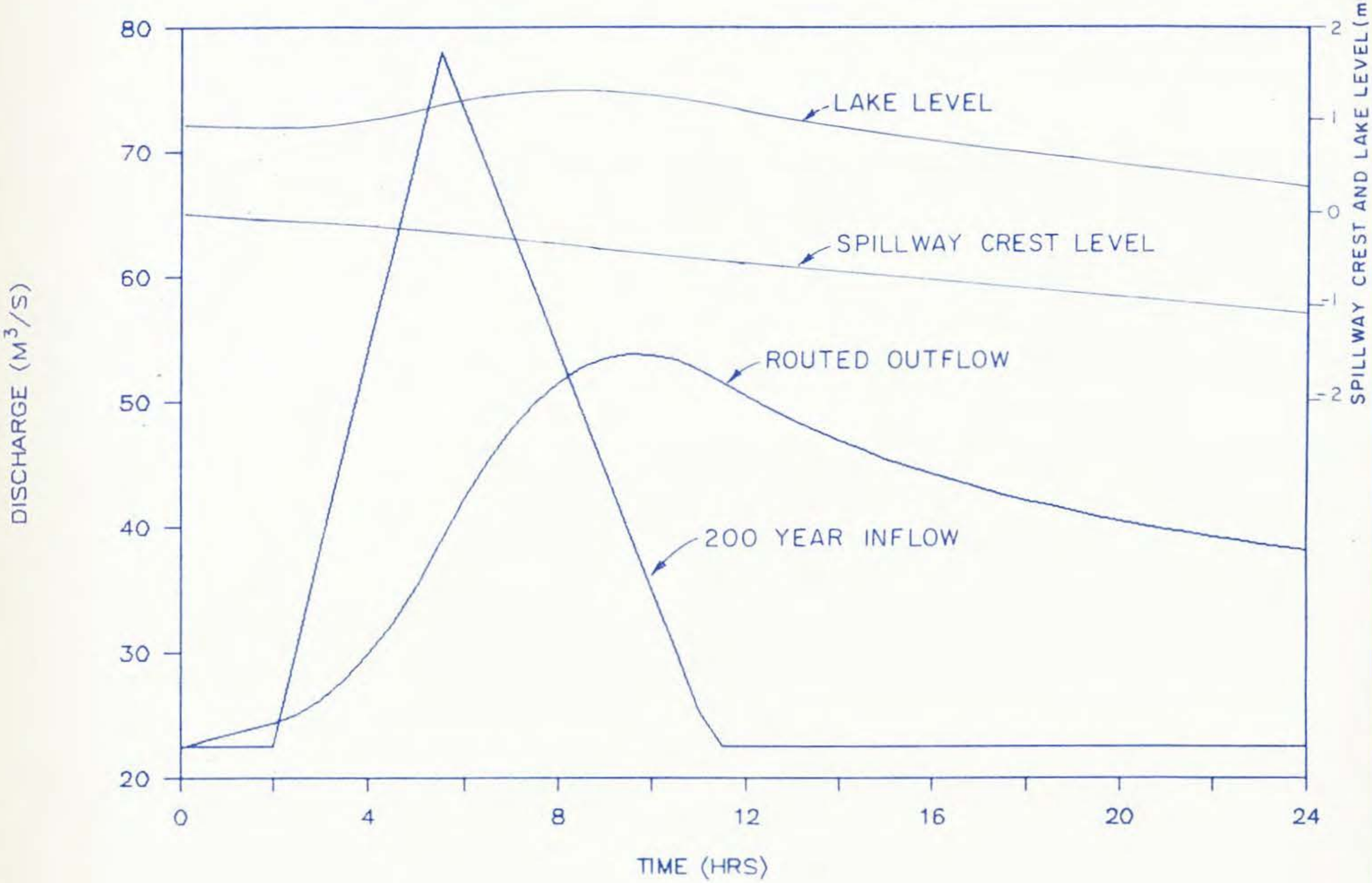
PROJECT: CLINTON CREEK ASBESTOS MINE

TITLE: WASTE DUMP - SEDIMENT TRANSPORT FLOOD ROUTING ON UPPER CHANNEL

CLIENT: CASSIAR MINING CORPORATION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
DEC. 10, 1987	PB 3169 04	A-4007	

APPROVED: R.F. Rodman



SLOPE OF DEGRADATION CHANNEL = 0.048

LENGTH OF DEGRADATION CHANNEL = 701 m

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL

SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

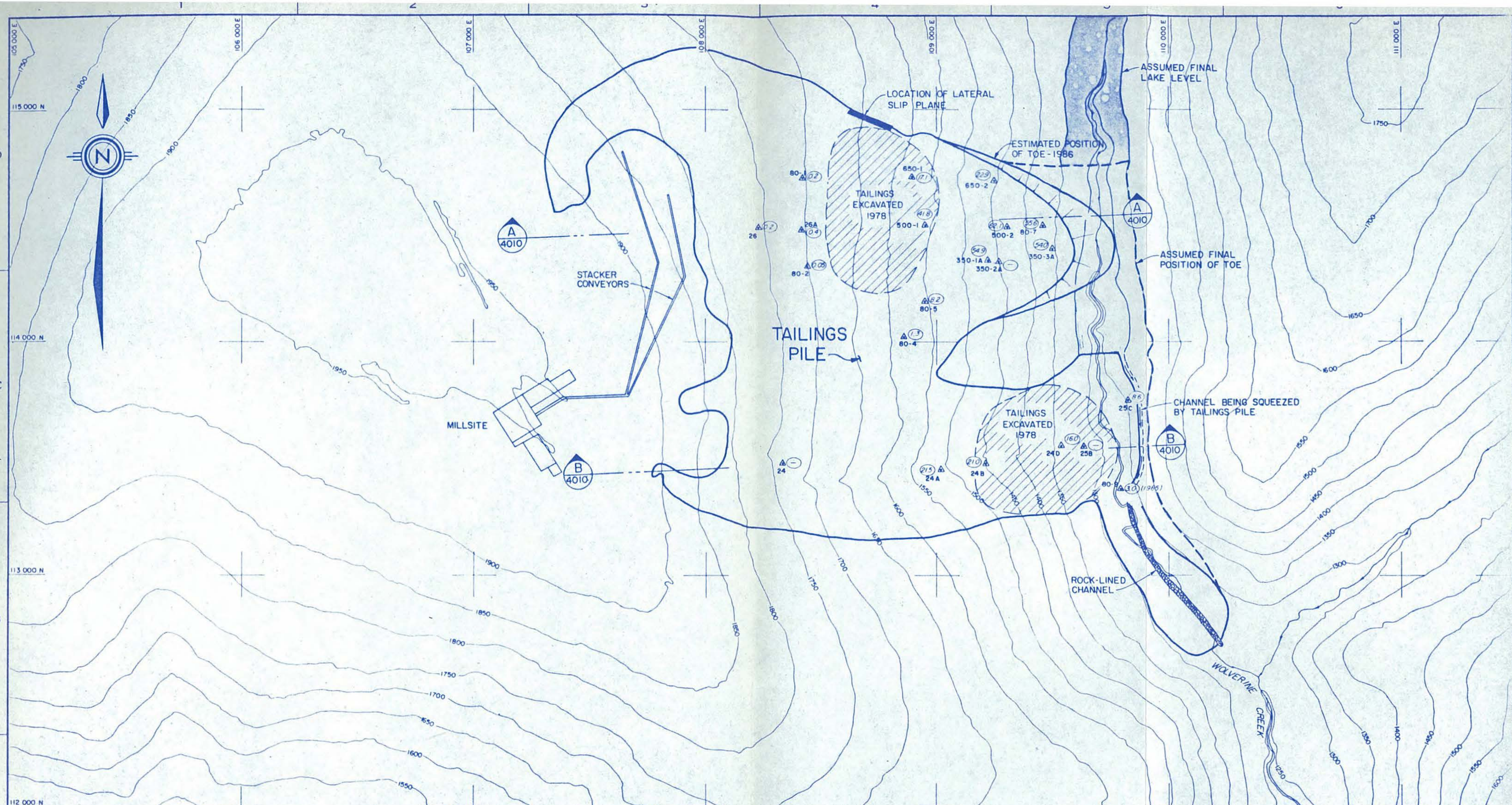
PROJECT: CLINTON CREEK ASBESTOS MINE

TITLE: WASTE DUMP-SEDIMENT TRANSPORT FLOOD ROUTING ON ENTIRE CHANNEL

CLIENT: CASSIAR MINING CORPORATION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
DEC. 10, 1987	PB 3169 04	A - 4008	-

APPROVED: RF Rodman



LEGEND

△ Monitoring Point (Rate of horizontal movement - ft/yr June 1985 to June 1986)

NOTE

TOPOGRAPHY TRACED FROM CASSIAR ASBESTOS CORPORATION LIMITED SHEET No. 223, COMPILED IN 1965 BY McELHANNEY AIR SURVEYS LTD

TO BE READ WITH KLOHN LEONOFF REPORT DATED DEC. 10, 1987

SCALE: 200 0 200 400 ft.

REV.	DATE	REVISION DETAILS

DESIGN	DRAWN	DATE	SCALES
P.C.L.	F.C.	DEC. 1987	AS SHOWN

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL.

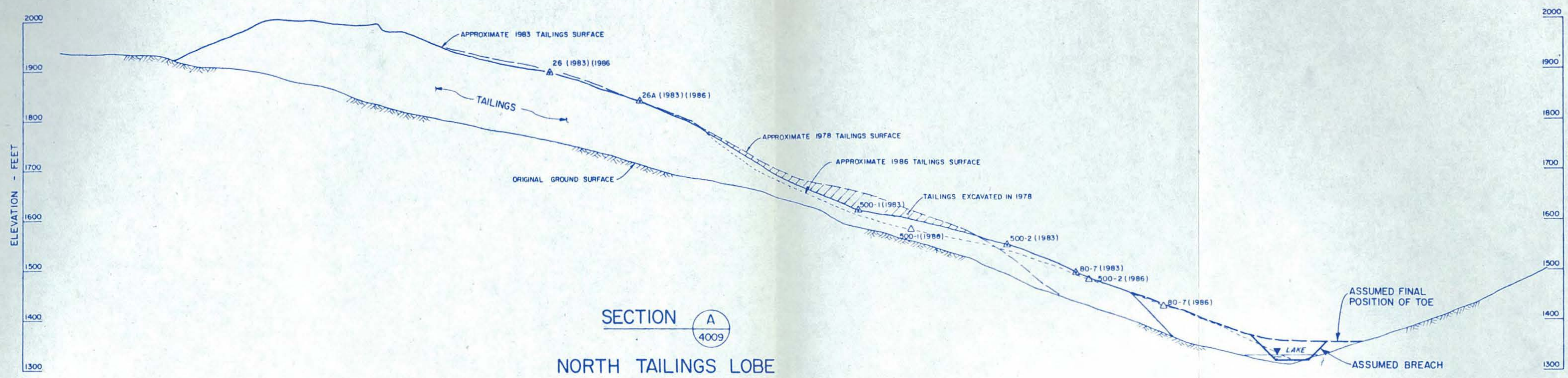
KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

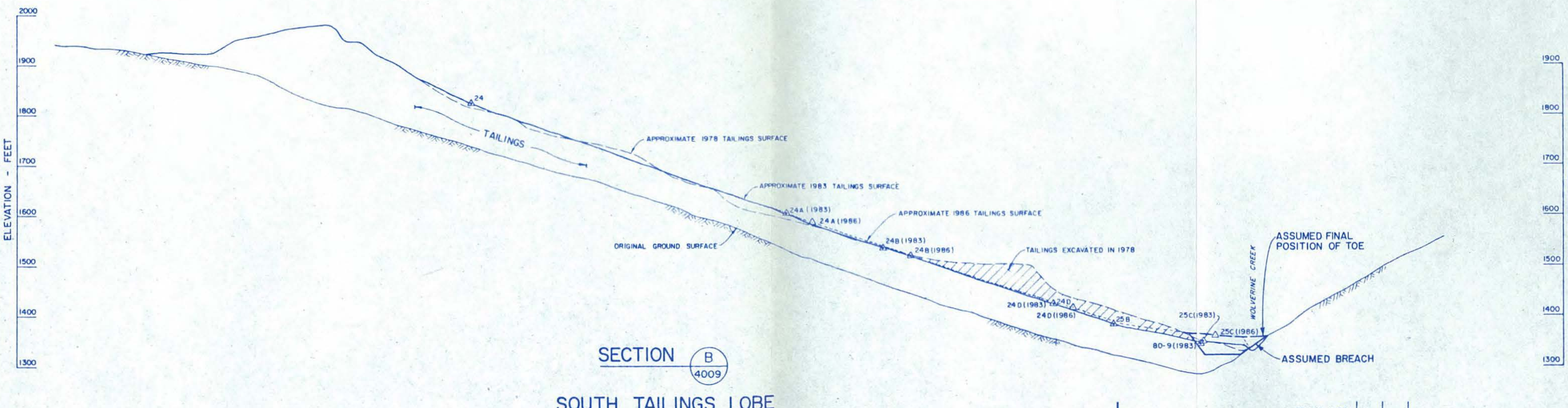
CLIENT: CASSIAR MINING CORPORATION

PROJECT: CLINTON CREEK ASBESTOS MINE

TITLE: PLAN OF WOLVERINE CREEK TAILINGS PILES

DATE OF ISSUE: DEC. 10, 1987
APPROVED:
PROJECT No. PB 3169 04
DWG. No. D-4009
REV





LEGEND

△26A Monitoring Point

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL

TO BE READ WITH KLOHN LEONOFF REPORT DATED DEC. 10, 1987

SCALE: 100 0 100 200 ft.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: CASSIAR MINING CORPORATION

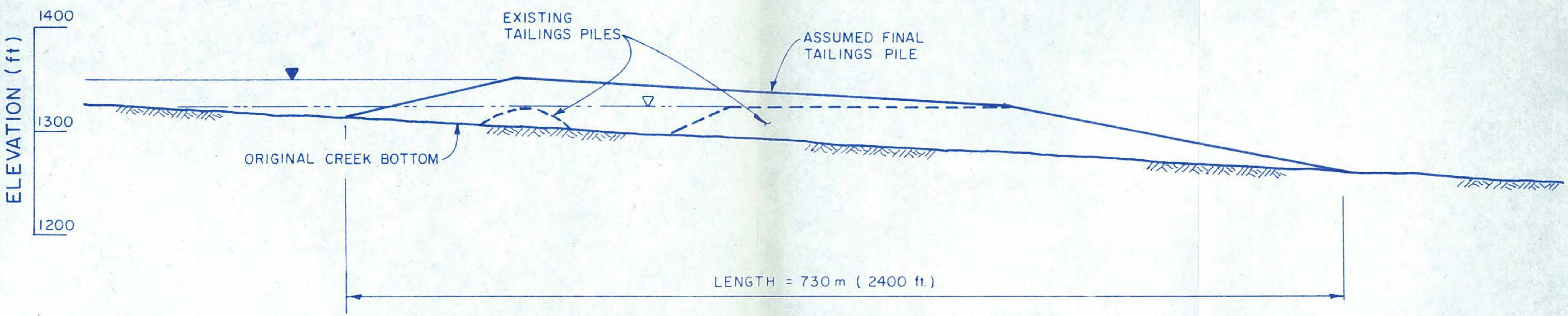
REV.	DATE	REVISION DETAILS	
DESIGN P.C.L.	DRAWN F.C.	DATE DEC. 1987	SCALES AS SHOWN

PROJECT: CLINTON CREEK ASBESTOS MINE

TITLE: WOLVERINE CREEK TAILINGS PILES SECTIONS 'A' AND 'B'

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
DEC. 10, 1987	PB 3169 04	D-4010	

APPROVED



SCALE Hor. 1" = 250'
Vert. 1" = 1000'

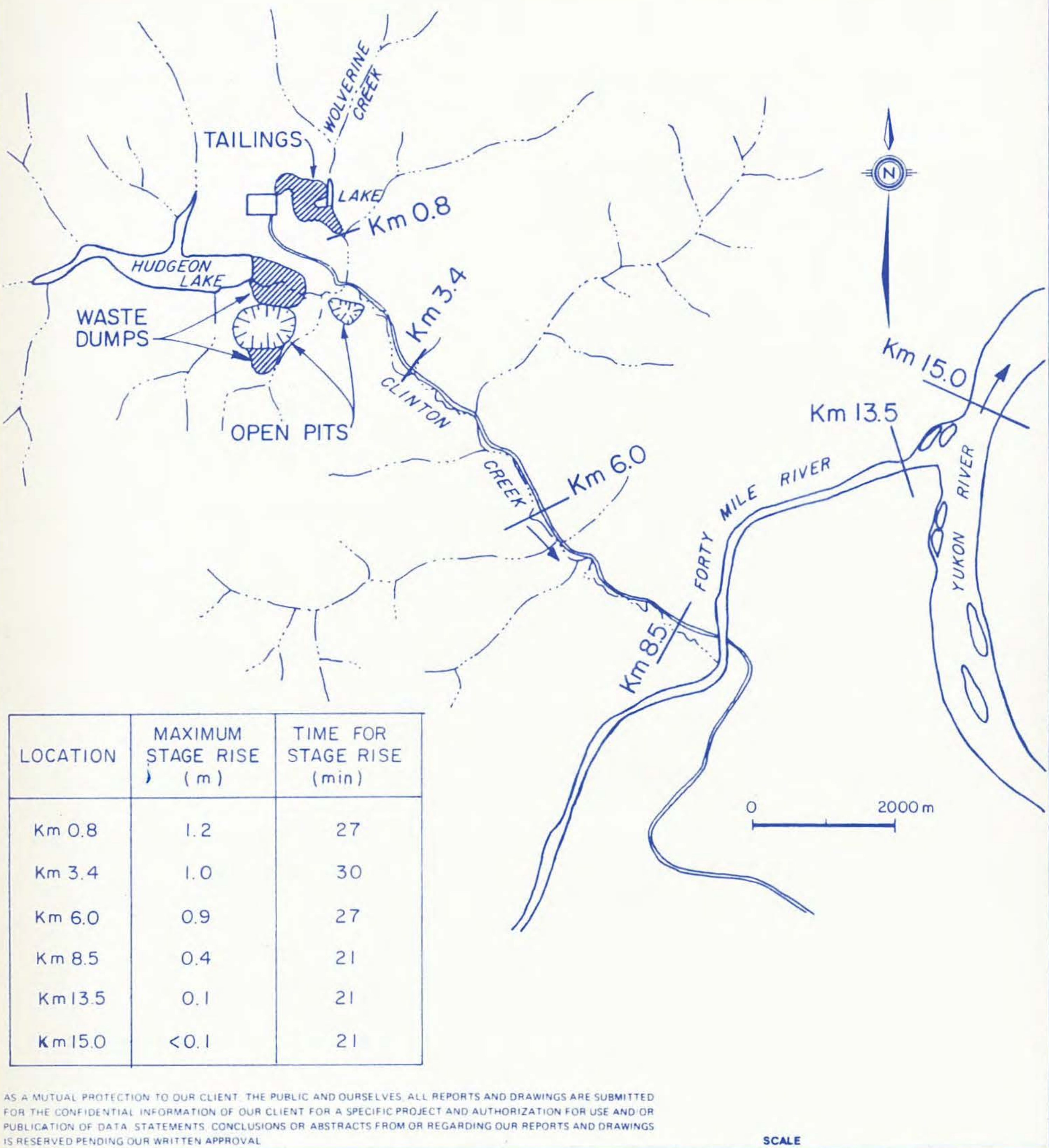
TO BE READ WITH KLOHN LEONOFF REPORT DATED DEC. 10, 1987

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT	CLINTON CREEK ASBESTOS MINE
TITLE	WOLVERINE CREEK TAILINGS PILES PROFILE OF BREACH SECTION
CLIENT:	CASSIAR MINING CORPORATION
DATE OF ISSUE	DEC. 10, 1987
APPROVED	R.F. [signature]
PROJECT No.	PB 3169 04
DWG. No.	B - 4011
REV.	

NCI - 802 - KL



LOCATION	MAXIMUM STAGE RISE (m)	TIME FOR STAGE RISE (min)
Km 0.8	1.2	27
Km 3.4	1.0	30
Km 6.0	0.9	27
Km 8.5	0.4	21
Km 13.5	0.1	21
Km 15.0	<0.1	21

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL

SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

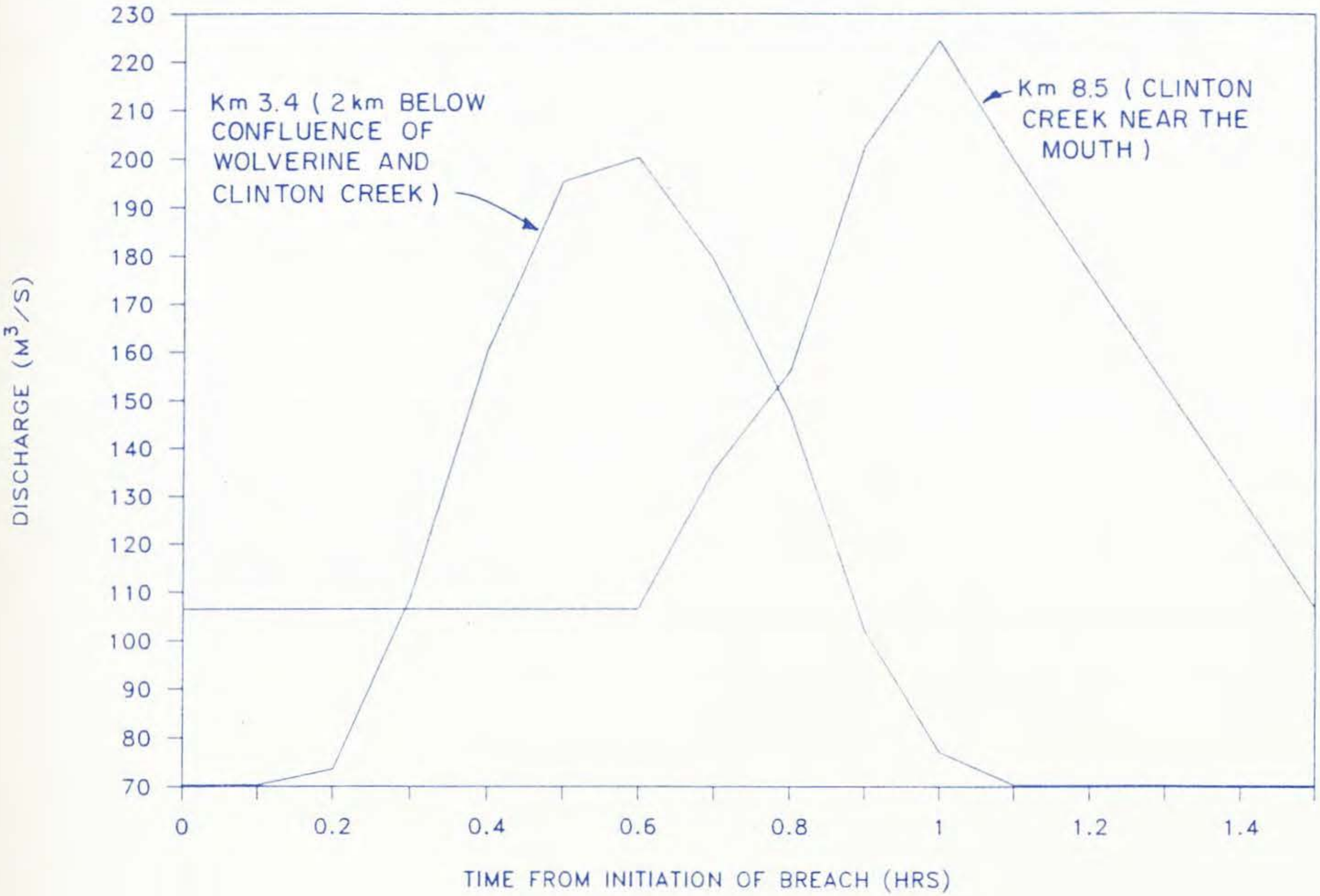
PROJECT: CLINTON CREEK ASBESTOS MINE

TITLE: LOCATION PLAN SUMMARIZING DAMBREAK ANALYSIS RESULTS

CLIENT: CASSIAR MINING CORPORATION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
DEC. 10, 1987	PB 3169 04	A-4012	

APPROVED: R.F. Rodman



SEE DRAWING A-4012 FOR LOCATION OF HYDROGRAPHS.

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL

SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

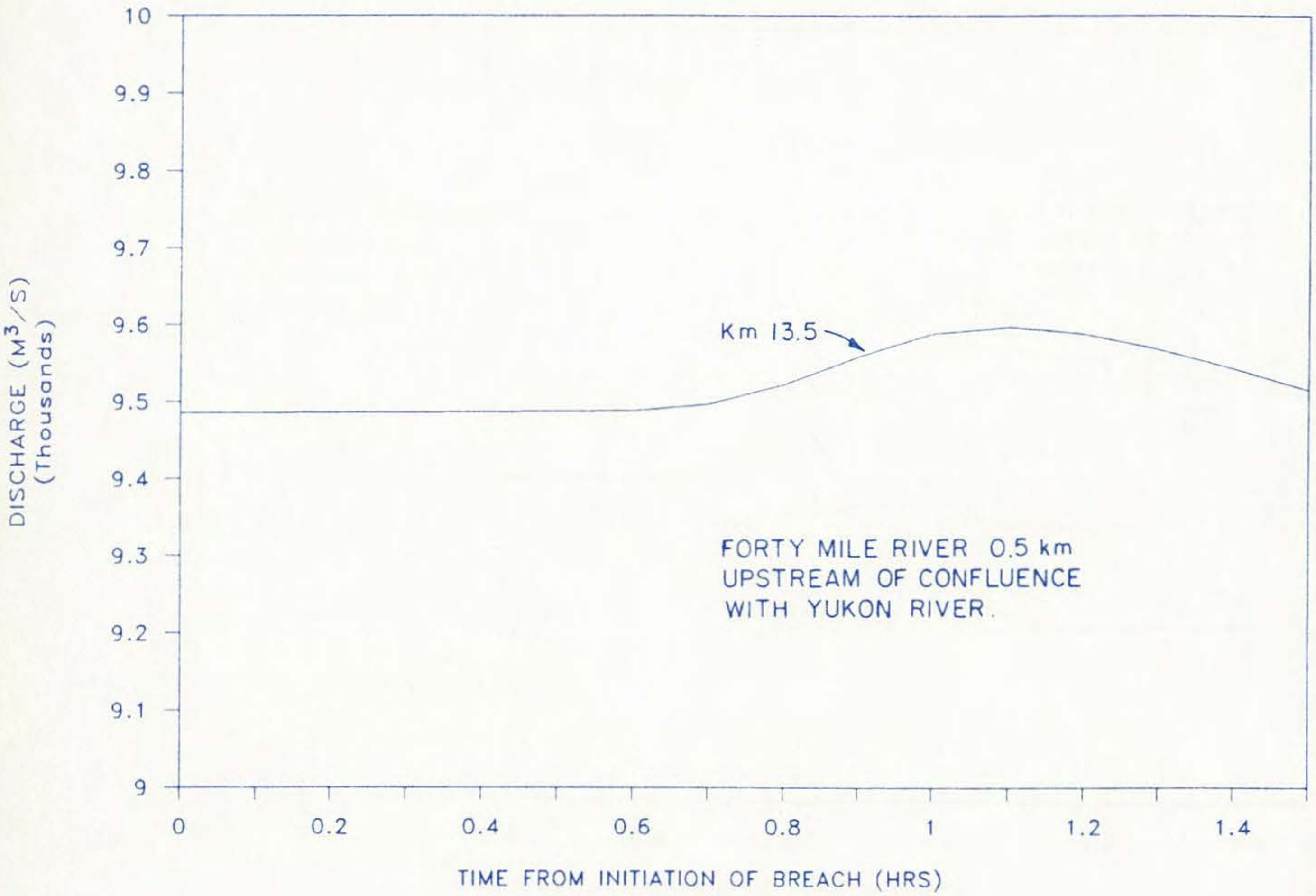
PROJECT: CLINTON CREEK ASBESTOS MINE

TITLE: DAMBREAK ANALYSIS- CLINTON CREEK DISCHARGE HYDROGRAPHS

CLIENT: CASSIAR MINING CORPORATION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
DEC. 10, 1987	PB 3169 04	A-4013	

APPROVED: R.L. Rodman

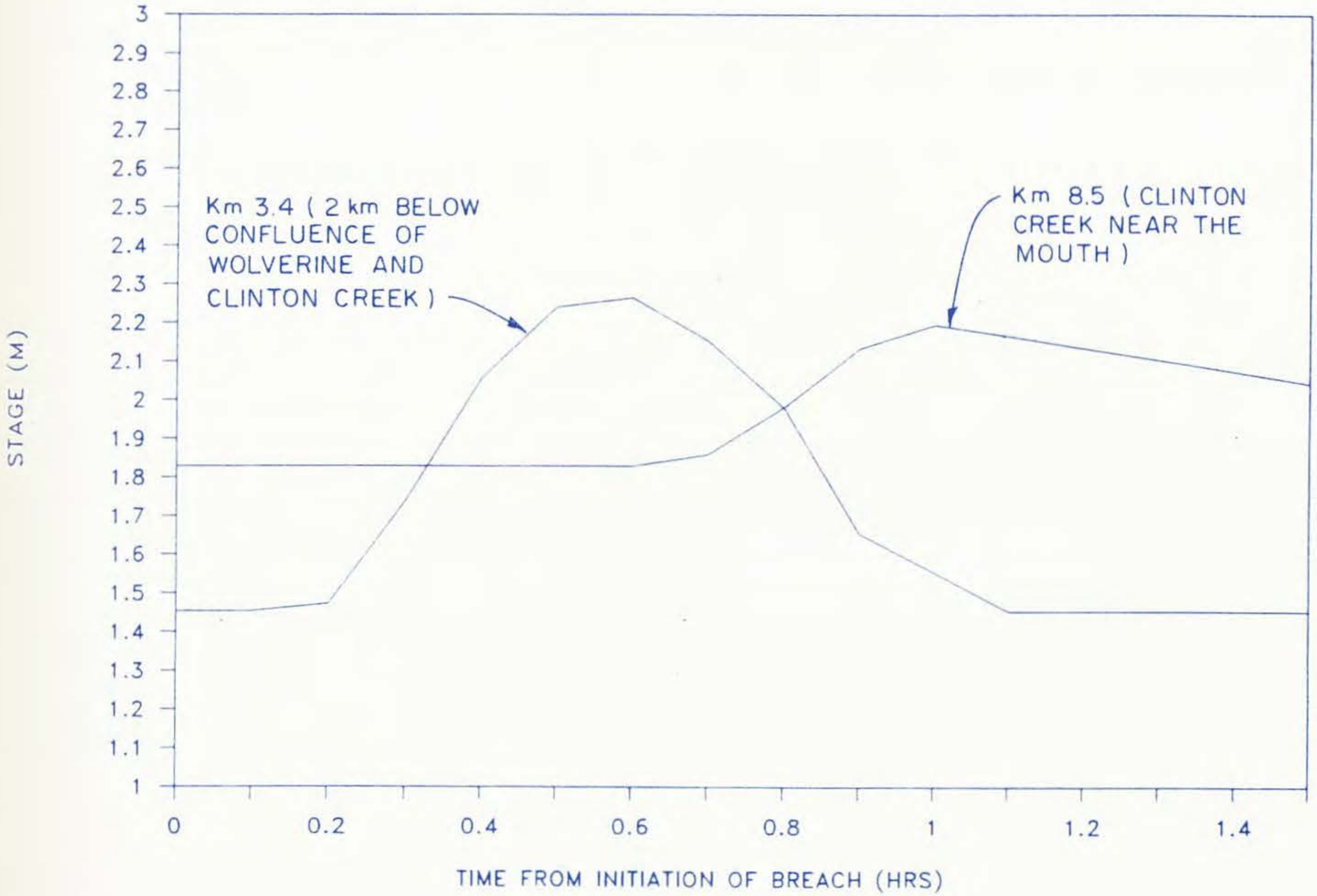


SEE DRAWING A-4012 FOR LOCATION OF HYDROGRAPH.

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL.

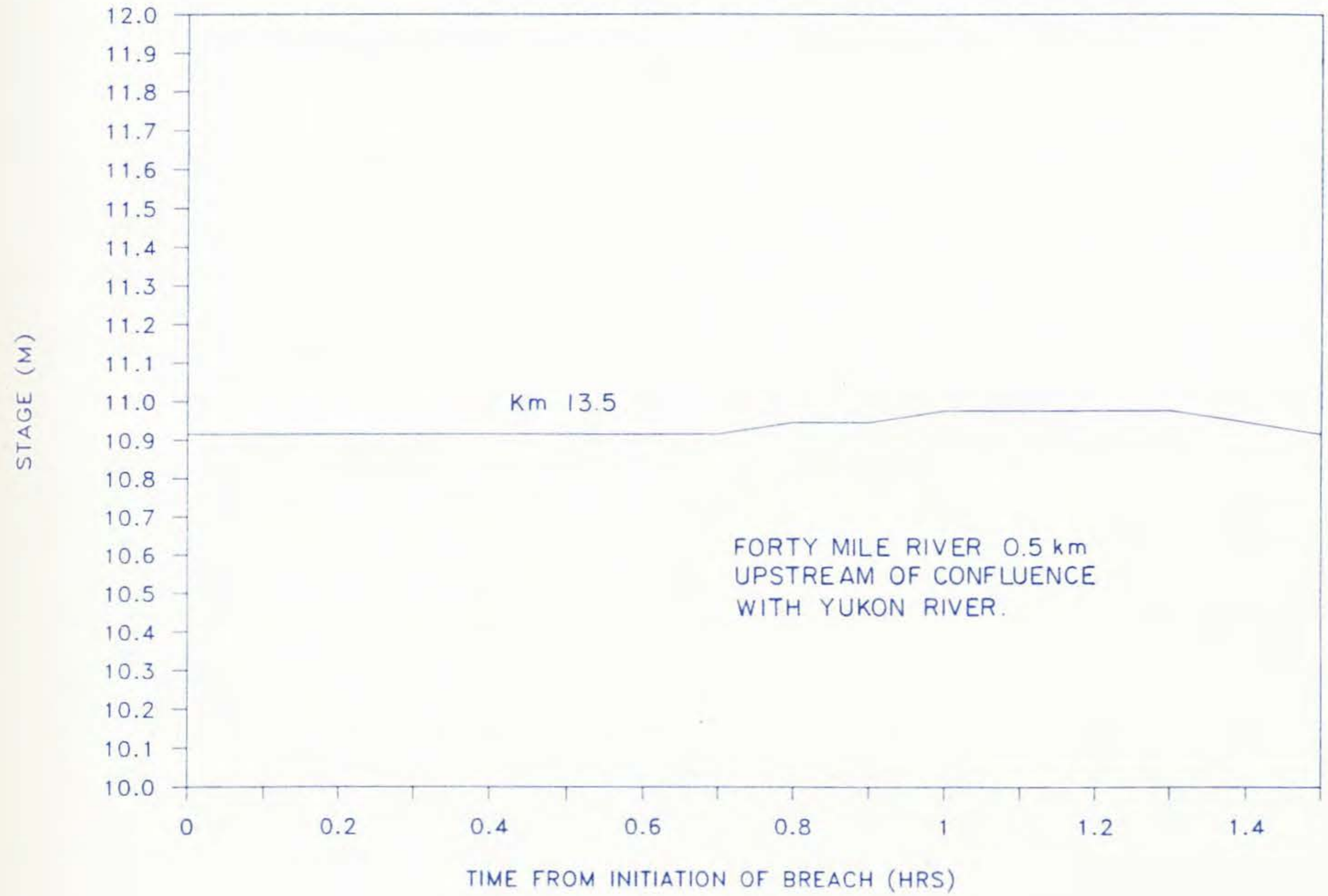
KLOHN LEONOFF LTD. CONSULTING ENGINEERS	SCALE			
	PROJECT: CLINTON CREEK ASBESTOS MINE			
	TITLE: DAMBREAK ANALYSIS - FORTY MILE RIVER DISCHARGE HYDROGRAPH			
CLIENT: CASSIAR MINING CORPORATION	DATE OF ISSUE: DEC. 10, 1987 APPROVED: R.F. [signature]	PROJECT No.: PB 3169 04	DWG. No.: A-4014	REV.

NCI-760



AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL

KLOHN LEONOFF LTD. CONSULTING ENGINEERS	SCALE			
	PROJECT: CLINTON CREEK ASBESTOS MINE			
	TITLE: DAMBREAK ANALYSIS - CLINTON CREEK STAGE HYDROGRAPHS			
CLIENT: CASSIAR MINING CORPORATION	DATE OF ISSUE: DEC. 12, 1987 APPROVED: R.F. Robson	PROJECT No.: PB 3169 04	DWG. No.: A-4015	REV.



AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL.

SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: CLINTON CREEK ASBESTOS MINE

TITLE: DAMBREAK ANALYSIS - FORTY MILE RIVER
STAGE HYDROGRAPH

CLIENT: CASSIAR MINING CORPORATION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
DEC. 10, 1987	PB 3169 04	A-4016	

APPROVED: R. T. [signature]

THIS PLAN IS NOT TO BE USED FOR DEFINING LEGAL BOUNDARIES.

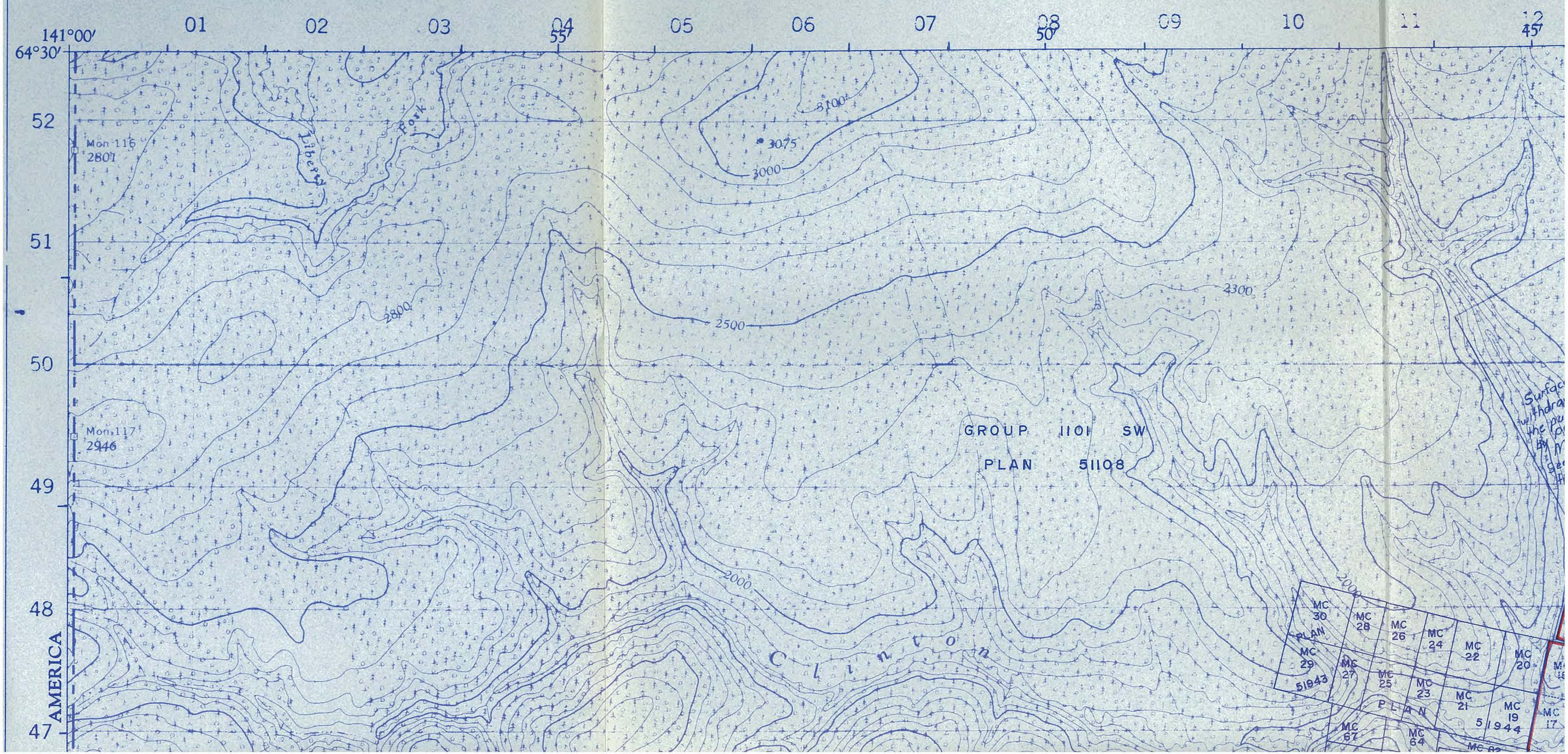
REVISED TO ....APRIL 8..............., 19.87..

e 1 0
CANADA LANDS SURV

PHOTOMAP

NATIONAL TOPOGRAPHIC SYSTEM

TERRITORIAL RESOU
CARTE DE BASE DES RESSO



1 0 1 1
LANDS SURVEYS RECORDS

RESOURCE BASE MAP
RESSOURCES TERRITORIALES

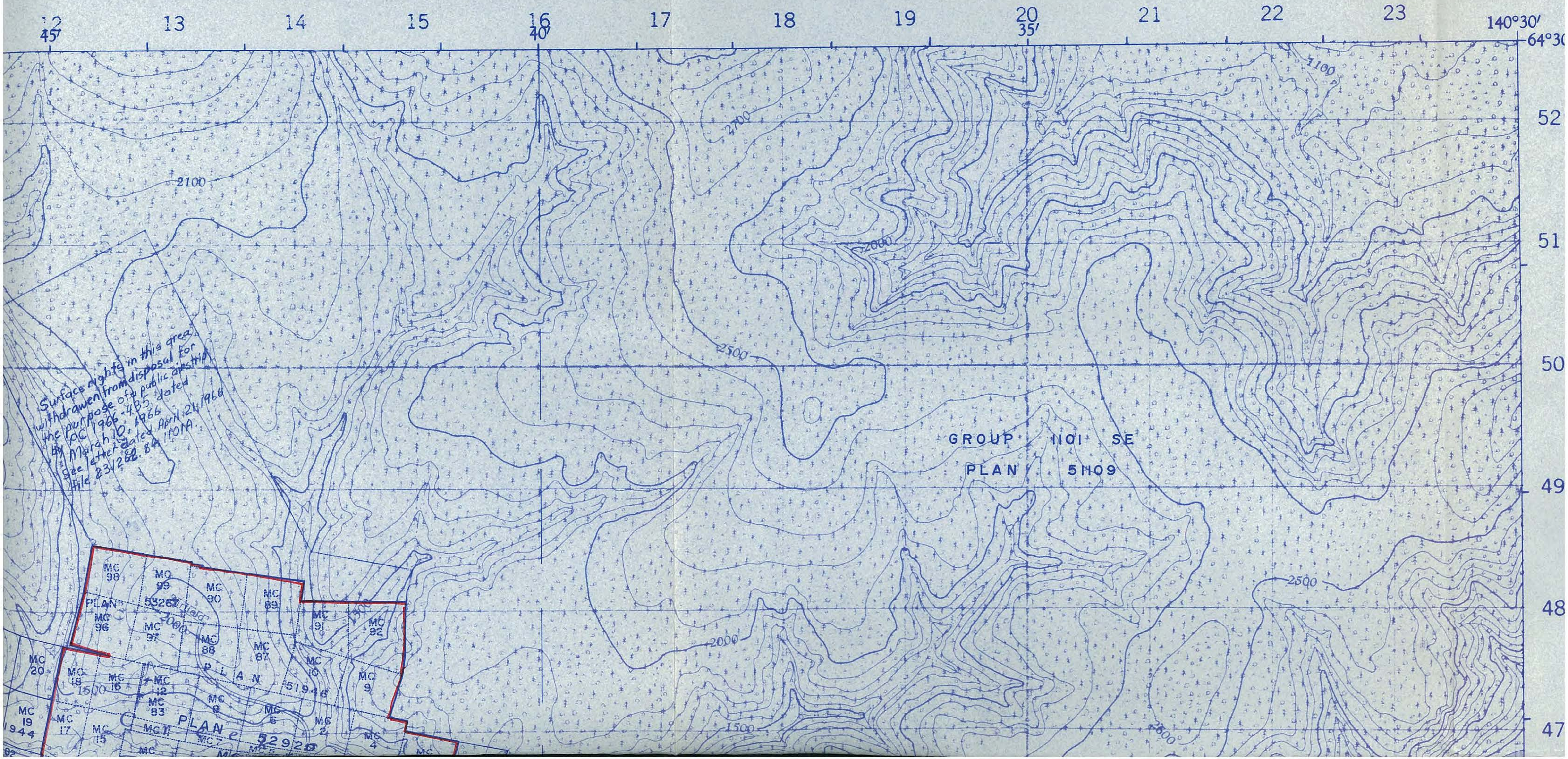
ON NE DOIT PAS SE SERVIR DE CE PLAN POUR DEFINIR LES LIMITES.

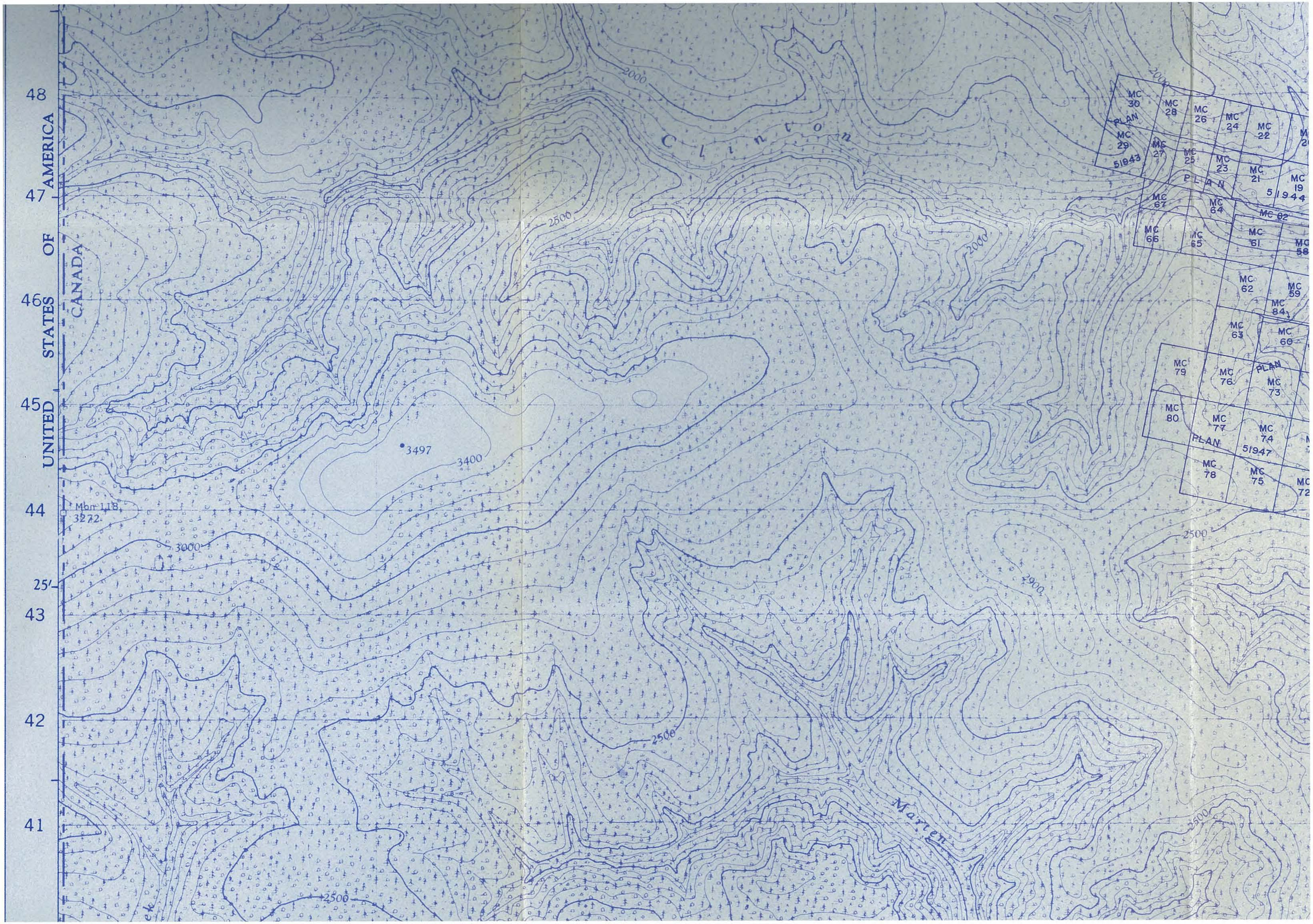
REVISE JUSQU'AU ...., 19.......

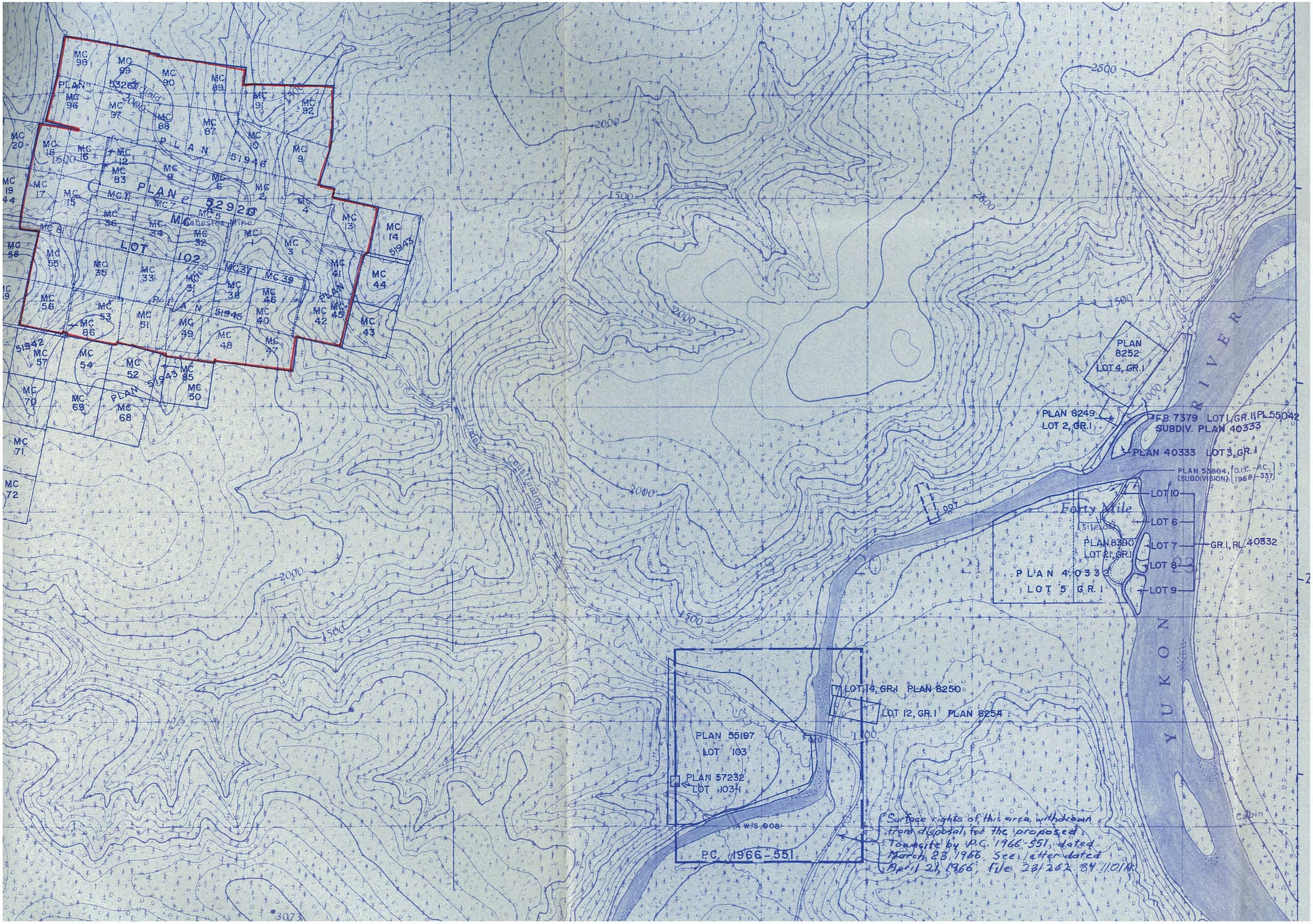
PHOTOCARTE

FIRST EDITION

SHEET 116 C




UNITED STATES OF AMERICA
CANADA
48
47
46
45
44
25'
43
42
41
Mon 118
3272
3497
3400
3000
2500
2000
2900
Clinton
Marten
PLAN 51943
PLAN 51944
PLAN 51947
MC 30
MC 28
MC 26
MC 24
MC 22
MC 29
MC 27
MC 25
MC 23
MC 21
MC 19
MC 67
MC 64
MC 82
MC 66
MC 65
MC 61
MC 58
MC 62
MC 59
MC 84
MC 63
MC 60
MC 79
MC 76
MC 73
MC 80
MC 77
MC 74
MC 78
MC 75
MC 72



PLAN 52920
LOT 102
PLAN 51946
PLAN 51945
PLAN 51943
PLAN 51942
PLAN 8252
LOT 4, GR.I
PLAN 8249
LOT 2, GR.I
F.B. 7379 LOT I, GR.I PL 55042
SUBDIV. PLAN 40333
PLAN 40333 LOT 3, GR.I
PLAN 55804 (SUBDIVISION)
Forty Mile
LOT 10
LOT 6
LOT 7
LOT 8
LOT 9
GR.I, PL. 40332
PLAN 8390
LOT 21, GR.I
PLAN 40332
LOT 5 GR.I
YUKON RIVER
LOT 14, GR.I PLAN 8250
LOT 12, GR.I PLAN 8254
PLAN 55197
LOT 103
PLAN 57232
LOT 1034
P.C. 1966-551
Surface rights of this area withdrawn
from disposal for the proposed
Townsite by P.C. 1966-551, dated
March 23, 1966. See letter dated
April 21, 1966, file 231262 84 11014.
Cabin