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KLOHN LEONOFF
CONSULTING ENGINEERS

Our File: PB 3169 0101

September 12, 1986

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

Mr. Peter C. Jones
Executive Vice-President

Clinton Creek Asbestos Mine
Abandonment Plan

Dear Mr. Jones:

We are pleased to provide you with ten (10) copies of an Abandonment Plan for the Clinton Creek Asbestos Mine.

Yours very truly,
KLOHN LEONOFF LTD.

for Peter C. Lighthall, P.Eng.
Project Manager

Encl.

PCL/ld

ABANDONMENT PLAN

PROJECT: CLINTON CREEK ASBESTOS MINE

LOCATION: CLINTON CREEK, YUKON TERRITORY

CLIENT: CASSIAR MINING CORPORATION

OUR FILE: PB 3169 0101 SEPTEMBER 12, 1986

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DRAWINGS

1. SUMMARY

The Clinton Creek asbestos mine was operated by Cassiar Asbestos Ltd. (presently Cassiar Mining Corporation) from 1968 to 1978. Cassiar operated the mine under the terms of a water license administered by the Yukon Territory Water Board. This water license, which presently has an expiry date of September 30, 1987, requires that a rehabilitation and abandonment plan be submitted to the Board for approval.

Cassiar considers that work required for abandonment of the mine is essentially complete. The following work has been carried out up to the present time:

(a) Removal of all structures and final cleanup of the Clinton Creek townsite;

(b) Burning, dismantling and burial of the concentrator facilities, except for some mass concrete structures (Brinco Mining Limited, 1985);

(c) Removal of all mobile and fixed mining equipment, with the exception of the primary crusher, one shovel and one drill;

(d) Construction of rock-lined channels to convey Clinton Creek and Wolverine Creek over the waste dump and tailings piles, respectively, including repair of a failure which occurred following initial channel construction over the waste dump;

(e) Survey monitoring since 1977 to show the rates of movement of the waste dump and tailings piles;

(f) Hydro seeding of the waste dump, tailings piles and specific areas of the townsite was performed in 1979, although with limited success on the waste dump or the tailings pile.

(g) Environmental and engineering studies and water monitoring to predict and measure the impacts on lower reaches of Clinton Creek, Forty Mile River and the Yukon River of streamflow over the waste dumps and tailings piles.

Minor work to complete abandonment remains for 1986. These items include:

(a) Removal of culverts at the road crossing Clinton Creek at the upper end of the waste dump channel; and

(b) Removal of miscellaneous equipment as described in Brinco Mining Limited (1985).

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 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 stabalizing 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 essentially unaffected. It is recommended that the site be finally abandoned in 1986.

2. INTRODUCTION

2.1 GENERAL

This report presents a plan for abandonment of the minesite, waste dumps and tailings piles at the Clinton Creek asbestos mine, located 97 km northwest of Dawson City, Yukon Territory. The mine is adjacent to Clinton Creek which drains into the Forty Mile River, 4.8 km upstream from its confluence with the Yukon River. The open pit mine operated from 1968 to 1978, at which time economic ore reserves were exhausted.

The open pit was located on a hilltop on the south side of Clinton Creek, and 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-1012. Waste rock was placed in an area adjacent to the open pit by 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. The waste dump and tailings piles are shown in Photos 1 through 4 in Appendix I.

This abandonment plan is submitted to support an application from Cassiar Mining Corporation to the Yukon Territory Water Board to abandon the Clinton Creek mine property, terminate the water license and have Cassiar's water license security bond released. A water license was granted to Cassiar Mining Corporation, effective October 1, 1977, under the terms of the Northern Inland Waters Act and Regulations. The license originally had an expiry date of September 30, 1982. On September 21, 1982, the Yukon Territory Water Board extended the water license to September 30, 1987. It should be noted that Cassiar Mining Corporation did not apply for this license extension.

The proposed abandonment plan for the Clinton Creek mine focuses on the removal of minesite facilities, and assessment of the long-term stability and corresponding impact of the waste dump and tailings piles on

the Clinton Creek watershed. Abandonment of minesite facilities is discussed in Section 3; abandonment of the waste dump and tailings piles is discussed separately in Sections 4 and 5, respectively; and assessment of the environmental impact of the proposed plan is presented in Section 6.

Klohn Leonoff Ltd. has served as Consultant on the stability aspects of the waste dump and tailings deposit at the Clinton Creek mine since January, 1983. In this capacity, Klohn Leonoff has made annual site visits in June 1983, June, 1984, June, 1985 and July, 1986; prepared designs and supervised site work for repair of the Clinton Creek waste dump channel; reviewed monitoring data; considered alternative measures for erosion protection and stabilization of the waste dump and tailings piles; and carried out hydrology and sediment transport studies to predict the long-term impacts of abandonment.

2.2 AVAILABLE REPORTS

Information and analyses presented as part of the abandonment plan were extracted from engineering and environmental reports prepared for the Clinton Creek mine since shutdown in 1978. A chronological summary of those reports which are in Cassiar's and Klohn Leonoff's files is given below:

2.2.1 Engineering Analysis

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

Klohn Leonoff Ltd. (1983a), Report on Mine Waste Dumps, Clinton Creek Asbestos Mine. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1983b), Report on 1983 Remedial Works, Mine Waste Dumps, Clinton Creek Asbestos Mine. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1984a), Report on Wolverine Creek Tailings Piles, Clinton Creek Asbestos Mine. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1984b), Report on 1984 Site Visit, Clinton Creek Mine Waste Dump and Tailings Piles. Prepared for Brinco Mining Limited.

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

Hardy Associates Ltd. (1984b), Report on Wolverine Creek Tailings Piles, Clinton Creek Asbestos Mine, Review of Rehabilitation Measures. Prepared for Indian and Northern Affairs, Yukon Water Board.

Klohn Leonoff Ltd. (1984c), Letter report, October 22, 1984, on Clinton Creek Abandonment, Cost Estimates of Schemes Proposed by Hardy Associates. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1984d), Letter report, December 7, 1984, Clinton Creek Asbestos Mine, Waste Dump Abandonment. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1985a), Letter report, February 28, 1985. Clinton Creek Asbestos Mine, Wolverine Creek Tailings Piles - North Lobe, Stability Analysis for Toe Flattening. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1985b), Letter report, February 28, 1985. Clinton Creek Mine, Wolverine Creek Tailings Piles, Assessment of Rock Lined Channel. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1985c), Report on 1985 Site Visit, Clinton Creek Asbestos Mine Waste Dump and Tailings Piles. Prepared for Brinco Mining Limited.

Brinco Mining Limited (1985), Construction Summary, 19 August 1985 to 2 September 1985 on Clinton Creek Abandonment, 1985 Cleanup and Reclamation, Clinton Creek, Yukon.

Klohn Leonoff Ltd. (1986), Report on 1986 Site Visit, Clinton Creek Asbestos Mine Waste Dump and Tailings Piles. Prepared for Cassiar Mining Corporation.

2.2.2 Environmental Assessment

Environmental Protection Service (1978), An Environmental Assessment of the Effects of Cassiar Asbestos Corporation on Clinton Creek, Yukon Territory. Regional Program Report No. 79-13.

EVS Consultants Ltd. (1981), Assessment of the Effects of the Clinton Creek Mine Waste Dump and Tailings, Yukon Territory. Prepared for Cassiar Resources Limited, Vancouver, British Columbia.

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

Norecol Environmental Consultants (1985), Letter report on Clinton Creek Asbestos Mine Aquatic Impact Assessment. Included as Appendix I of Klohn Leonoff (1985d).

2.2.3 Seismicity

Stevens, A.E. and Milne, W.G. (1973), "Seismic Risk in the Northern Yukon and Adjacent Areas". Report prepared by Division of Seismology, Earth Physics Branch, Department of Energy, Mines and Resources for the Environmental-Social Program, Northern Pipelines. Information Canada Cat. No. R72-10973.

2.3 SEISMICITY

Clinton Creek is located in an area of low seismicity. Stevens (1973) produced maps showing contours of acceleration levels for various return period. The map for a 100-year return preiod SP shows an expected acceleration equal to 6% of the acceleration due to gravity (g) at Clinton Creek. This is a relatively low level of earthquake shaking. The nearest recorded earthquakes have been at least 300 km from Clinton Creek. From this data, it is concluded that the probability is very low that earthquakes will have significant impact on the stability of the waste dump or tailings piles.

3. ABANDONMENT OF MINESITE FACILITIES

Cassiar Mining Corporation considers that work required for abandonment of minesite facilities is essentially complete. The following tasks have been completed through July, 1986:

(a) removal of all structures and final cleanup of the Clinton Creek townsite;

(b) burning, dismantling and burial of the concentrator facilities, except for some concrete structures (Brinco Mining Limited, 1985);

(c) removal of all mobile and fixed mining equipment with the exception of the primary crusher, one shovel and one drill.

Removal of the remainder of the minesite facilities and equipment is scheduled for 1986.

4. CLINTON CREEK WASTE DUMP

4.1 DESCRIPTION

Waste rock from the open pit was disposed of by dumping over the slope which forms the valley wall on the south side of Clinton Creek, Drawing No. A-1012 and Photographs 1 and 2. Originally, the valley floor was flat-bottomed with a width of about 800 ft, and Clinton Creek meandered along the valley bottom. As the toe of the dump reached the valley floor, it began to spread on the low shear strength, presumably ice-rich 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 entire valley bottom.

The total quantity of waste rock in the dump is estimated at about 70 million tons. The gradation of the dump material is primarily sand and gravel sized particles, but occasional cobbles and large boulders of relatively durable rock are found throughout the waste dump.

In its final configuration, when waste dumping stopped in 1977, the waste rock impounded a body of water now known as Hudgeon Lake. The depth of water in Hudgeon Lake is about 85 ft and its surface area is about 180 acres. Outflow from the lake currently passes through four 5 ft diameter culverts into the Clinton Creek channel which flows across the waste dump. Clinton Creek occupies the north side of the valley, where the creek has incised a channel bounded by waste dump material on the right and the valley wall on the left (directions relative to observer facing downstream). The channel has an overall gradient across the dump of about 4.5%.

15300 acre ft
19x10 m^3

4.2 MONITORING SINCE SHUTDOWN

A monitoring program for the waste dump has been implemented since completion of active dumping in 1977. The purpose of the monitoring

program is to provide data with which the long-term stability of the waste dump can be assessed and abandonment options considered. Results of monitoring show that since the completion of dumping, movements of the waste dump have continued as a slow creep from horizontal spreading of the dump on its foundation.

Seven monuments on the dump surface were surveyed annually for vertical and horizontal location and, in addition, six cross-channel reference lines were surveyed for horizontal movement. The locations of the monitoring points and cross-channel reference lines are shown on Drawing No. D-1006A. From the monitoring records, the average annual movements in a horizontal direction toward the north valley wall are as shown in Table 1.

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 data in Table 1 show clearly that movements of the dump have decreased since waste dumping was halted in 1977. All individual horizontal movement rates for the year 1985-86, are less than 1.5 ft/year.

Longitudinal survey profiles of the Clinton Creek channel across the waste dump were obtained in 1983, 1984 and 1986, Drawing No. D-1006B. No measurable downcutting was evident from these three years of survey. Examination of photographs taken over a number of years confirms that general downcutting of the Clinton Creek channel is not occurring at a fast rate. Some local bed erosion of the channel is apparent from comparison of the three profiles. However, resistance to widespread downcutting and bed erosion of the channel across the dump is provided both by the bedrock exposed on the left bank and the presence of large boulders in the dump material, which form a self-armouring bed layer, as does occur in a natural stream.

4.3 REMEDIAL WORKS SINCE SHUTDOWN

Because of the ongoing movement of the waste dump there is a continual squeezing of the stream channel along the north side of the dump and erosion by the stream at the toe of the dump. Remedial works have been undertaken on two occasions since shutdown to stabilize Clinton Creek across the dump, and to minimize erosion by Clinton Creek. One design recommendation for Clinton Creek was proposed by Golder Associates in 1978 and it was constructed in 1981. A second stabilization plan was prepared by Klohn Leonoff in 1983 and it was constructed in the fall of 1983 and summer of 1984.

The recommendation by Golder Associates (1978) was to construct a rock lined section, incorporating energy-dissipating weirs, near the upstream end of the channel to act as a barrier against progressive downcutting. This section of rock weirs was constructed in 1981. During spring runoff in 1982, Clinton Creek escaped the channel formed by the rock

lined section and eroded a large scarp in native soil on the left bank (relative to an observer facing downstream). Klohn Leonoff (1983a) prepared a design for repair and modification of this rock-lined section. The design included backfilling of the eroded channel, which was then bypassing the weir section, and placing geotextile filter and riprap along the left bank of the channel to protect the erodible zone. Also, the revised design of the riprapped channel section provided for heavy riprap and geotextile filter along the left bank, a riprap apron at the outlet culverts from Hudgeon Lake and riprap lining without filter on the right bank. A sketch of the site prior to these remedial works, and design recommendations for the channel prepared by Klohn Leonoff are shown on Drawing No. D-1002A. Photographs of the site before and after the 1983 stabilization measures were implemented on Clinton Creek are shown in Appendix I, Photographs 5 and 6.

This section of the Clinton Creek channel across the waste dump has been stable since 1983 and has withstood a relatively high spring runoff flow in 1985.

4.4 ABANDONMENT STRATEGY

Development of an abandonment plan for the waste dump requires that its long-term stability be assessed. The primary consideration is whether or not waste dump movement will continue to occur and impinge upon the Clinton Creek channel. If additional movement of the waste dump does not occur, then the existing riprapped channel provides long-term stability for Clinton Creek across the dump. If waste dump movement continues, two questions must be addressed:

(a) What is the effect of dump movement on the stability of the Clinton Creek channel; and

(b) What is the effect of dump movement on downstream conditions in the Clinton Creek watershed.

These concerns are addressed based on engineering analyses and monitoring undertaken since mine shutdown.

As shown in Table 1 in Section 4.2, monitoring of the waste dump indicates movement has occurred since mine shutdown. Movement of about 4 ft was measured initially for 1977-78, while measurements in recent years are much less, averaging about 1.4 ft for 1984-85.

Golder Associates in their report of July, 1978 considered various strategies for treatment of the Clinton dump. Among these strategies was a scheme referred to as the "Cadillac" treatment, which would increase the Factor of Safety of the dump against base sliding to 1.25. The scheme involved backfilling of the Clinton Creek channel and constructing a raised, riprap-lined channel atop the present channel. This proposal included placement of 460,000 yd^3 of waste dump fill and 21,000 yd^3 of riprap as well as other miscellaneous works. The cost, in 1978 dollars, was estimated at $590,000. This would probably equate to about twice that amount, or over $1 million, in 1986 costs. Golder did not recommend implementation of this scheme because they considered the cost excessive. Instead, Golder recommended the less costly scheme of providing a rock-lined section at the head of Clinton Creek channel to prevent rapid downcutting. This scheme, discussed previously in Section 4.3, was implemented and subsequently modified under the direction of Klohn Leonoff.

Hardy Associates (1984a) prepared a proposal for permanent stabilization measures for the Clinton Creek channel and waste dump area in a report to the Yukon Territory Water Board. An overview of Hardy's scheme is presented below together with an assessment by Klohn Leonoff (1984c, 1984d) of the proposed plan.

Hardy recommended that the dump be stabilized by placing a toe support fill in the present Clinton Creek channel and constructing a new riprap-lined channel over the top of the fill. It was estimated that a suit-

able toe support fill would require raising the elevation of the channel across the waste dump by about 15 m above its current level. This increase in elevation of the channel would cause a corresponding rise in the water level of Hudgeon Lake located immediately upstream.

It is Klohn Leonoff's opinion that the measures proposed by Hardy Associates may increase the hazard of erosion of the waste dump and also would be very expensive. The proposed channel would be constructed in a new location on top of erodible fill material so that any escapement of flow from the channel would probably result in rapid downcutting, leading to complete failure of the channel and massive erosion. The proposed toe support fill might be successful in stabilizing the dump against movements in the cross-valley direction, but the dump may continue spreading laterally. Such spreading movements of the dump 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.

Even though Klohn Leonoff is not in agreement with the design concepts proposed by Hardy Associates, Brinco Mining Limited requested that Klohn Leonoff undertake quantity and cost estimations of the proposed scheme. Results of the preliminary calculations were presented in a letter report (Klohn Leonoff, 1984c) and are reproduced in Table 2.

TABLE 2

COST ESTIMATE (1984 DOLLARS) OF WASTE DUMP REHABILITATION MEASURES PROPOSED BY HARDY

Item	Unit	Quantity	Unit Cost	Total Cost
Mob and Demob	l.s.	-	-	30,000
Channel				
Excavation	m^3	40,000	$ 2.00	80,000
Riprap Filter	m^3	3,000	$10.00	30,000
Riprap	m^3	10,000	$50.00	500,000
General Fill-Borrow and Place	m^3	300,000	$ 1.75	525,000
Engineering				
Topographic Survey	l.s.	-	-	5,000
Investigation for Riprap Source	l.s.	-	-	5,000
Analysis and Design	l.s.	-	-	30,000
Construction Inspection and Survey	l.s.	-	-	50,000
ESTIMATED TOTAL (1984 DOLLARS)				$ 1,255,000
		SAY		$ 1,300,000

Klohn Leonoff's cost estimate of $1.3 million for the proposed stabilization scheme is more than 2.5 times the amount estimated initially by Hardy Associates. Most of the difference in cost can be attributed to:

(a) the estimated volume of required fill is double the fill requirement considered by Hardy Associates;

(b) the excavation required for the permanent channel would be an extra cost, since this material would be stockpiled until completion of the channel and then re-handled to fill the existing channel.

Because of the high cost of the stabilization scheme proposed by Hardy Associates, and because the plan may actually increase the potential over the long-term for channel erosion across the waste dump, Klohn Leonoff does not support the proposed stabilization scheme. Alternatively, an abandonment plan is proposed which allows for some movement of the waste dump towards the Clinton Creek channel and for the subsequent erosion of this material.

The primary reasons for Klohn Leonoff's recommendation of such an abandonment plan are as follows:

(a) 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.

(b) Even if waste dump movement continues at about its current 1.5 ft per year, the volume of material which could encroach upon Clinton Creek over the 2,300 ft dump 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. Details of the sediment transport dynamics of Clinton Creek, and discussion of the environmental impact of the proposed abandonment scheme, are presented in Section 6.

In summary, the Clinton Creek waste dump is considered to be in an acceptable condition for abandonment. No further remedial works or monitoring are recommended. The culverts at the outlet of Hudgeon Lake which pass flow into the Clinton Creek channel should be removed as the final stage of abandonment. Culvert removal is recommended to prevent problems resulting from possible future plugging.

5 WOLVERINE CREEK TAILINGS PILES

5.1 DESCRIPTION

Tailings piles were formed by depositing, with a stacker conveyor, approximately 10 to 12 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-1012 and Photographs 3 and 4). 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. The angle of internal friction of the tailings (Golder, 1978) ranges from over 40° at low confining stresses to 33° at higher stresses. The deposited tailings form a crust so that dust from the tailings piles does not occur.

From the millsite (elevation 1,950 ft), the valley side slopes northward at an average slope angle of about 16° to 17° to the valley bottom at elevation 1,300 ft. 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 argillite bedrock. The depth of silty sandy gravel soils decreases with elevation, from about 40 ft near the top of the slope to being virtually absent near the bottom. 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. Following the failure, the stacker was relocated northward and tailings were placed on the north lobe until the mine shutdown in 1978.

dam breach May 13/74 8:30 → 10:30 pm

5.2 MONITORING SINCE SHUTDOWN

A program for monitoring the movement of the tailings piles has been in operation since 1976, although none of the existing reference points provide continuous records since that time. Results of monitoring showed that the north tailings lobe was moving rapidly downslope (eg. 77 ft in 1978) 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 D-1004C, and sections through the piles from 1978 and 1983 are compared on Drawing D-1005A. Monitoring records from the tailings piles are included in reports by Golder (1978) and Klohn Leonoff (1984a, 1984b, 1985c, 1986).

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 400 ft 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 100 ft/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 62 ft/yr in July, 1986. Monitoring points near the top indicated much lower movements of less than 2 ft/yr. The monitor locations and rates of horizontal movement observed in July, 1986 are shown on Drawing D-1004C. 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 21.5 ft/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.

5.3 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 1985 show the channel has been stable to date. The channel location is shown in plan on Drawing D-1004C and Photograph 4 shows the channel in operation.

The areas selected by Golder (1978) for excavation of tailings from the north and south lobes are shown on Drawing D-1004C and D-1005A. 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.

5.4 ABANDONMENT STRATEGY

An abandonment plan for the north and south lobes of the tailings pile must assess their long-term stability. In general, the abandonment strategy must consider whether the tailings piles are stable in their present state or, if not, can additional remedial measures be undertaken to make the piles stable permanently. If long-term stability cannot be ensured, then the consequences of further downslope movement of the tailings piles must be assessed.

Results of monitoring the tailings piles show that downslope movement is still occurring, and that self-stabilization of the piles will not occur in the near future. One proposal for undertaking additional remedial works to stabilize the tailings piles was prepared by Hardy Associates (1984b) for the Yukon Territory Water Board. An overview of the scheme, and an assessment by Klohn Leonoff (1984c) of the proposed plan, is included below.

For the Wolverine Creek tailings piles, Hardy was postulating a catastrophic failure of the north tailings lobe into the Wolverine Creek valley. The environmental impact of this postulated catastrophic failure being a sudden rush of water across the south tailings lobe, resulting in heavy downstream sedimentation similar to or worse than that caused by the initial failure of the south tailings lobe. To guard against such a failure, Hardy proposed the construction of a dam built with tailings material at the location of the south tailings lobe. The purpose of the dam being: to stabilize the south lobe by providing additional toe support, and to contain the sudden release of water. The proposed dam would have a crest elevation of 1,425 ft (about 90 ft above the existing Wolverine Creek channel at the toe of the south lobe), a crest width of 20 ft, and 4 horizontal to 1 vertical side slopes. Two 900 mm diameter culverts would be installed in the dam and a rock-lined spillway would be constructed. In addition to the dam, Hardy stated that additional stabilizing fill would be required on portions of the south lobe where the dam is low.

Klohn Leonoff has not undertaken a detailed technical review of the proposal, however, we are concerned with the concept of the stabilization structures' ability to perform maintenance free following mine abandonment. In particular, we feel such key structures as culverts and spillways, especially in an environment where slides may occur upstream, would require a regular monitoring program to ensure they are operating properly. Such a program would be in conflict with acceptable

abandonment strategy to leave the site in a state which is maintenance free over the long term.

While Klohn Leonoff was not necessarily in agreement with the design concepts proposed by Hardy Associates, Brinco Mining Limited requested that Klohn Leonoff undertake quantity and cost estimates for the proposed scheme. Results of the preliminary calculations were presented in a letter report (Klohn Leonoff, 1984c) and are reproduced in Table 3.

TABLE 3

COST ESTIMATE (1984 dollars) FOR CONSTRUCTION OF STABILIZING DAM AT TOE OF SOUTH TAILINGS LOBE

Item	Unit	Quantity	Unit Cost	Total Cost
Mob and Demob	l.s.	-	-	30,000
Foundation Preparation	l.s.	-	-	5,000
Drainage Blanket (mill overs)	m^3	8,000	$ 6.00	48,000
Compacted Fill	m^3	260,000	$ 2.25	585,000
Stabilizing Fill	m^3	50,000	$ 1.75	87,500
Spillway				
Excavation	m^3	3,500	$ 2.00	7,000
Riprap	m^3	2,000	$ 50.00	100,000
Riprap Filter	m^3	700	$ 10.00	7,000
Culvert Pipes	m	3380	$ 75.00	28,500
Engineering				
Site Investigation	l.s.	-	-	15,000
Design	l.s.	-	-	25,000
Construction Inspection and Survey	l.s.	-	-	50,000
ESTIMATED TOTAL (1984 dollars)				$ 988,000
			SAY	$1,000,000

Our preliminary cost estimate of $1,000,000 for the proposed stabilization scheme is over three times the figure estimated by Hardy Associates. Most of the difference in cost is due to:

a) our estimate of compacted fill required for the dam is more than twice the volume considered by Hardy;

b) placing a drainage blanket for the dam and riprap for the spillway; and

c) our estimate of the length of culvert required to pass through the dam is nearly double the length estimated initially.

Klohn Leonoff does not support the proposed stabilization scheme for the tailings piles because long-term, maintenance-free operation, which is a requirement for abandonment, cannot be provided. Alternatively, we support an abandonment plan which allows movement of the tailings piles downslope towards Wolverine Creek, yet does not create an unacceptably adverse environmental impact on downstream watercourses.

Furthermore, the monitored movement of the north tailings lobe to date indicates that such a catastrophic failure is unlikely.

The toe of the north lobe reached the valley bottom in 1985 and, as further movement occurs, it will begin to be buttressed against the opposite valley wall. This buttressing is expected to slow the rate of movement in future. However, even this self-stabilizing tendency resulting from future movement will not eliminate erosion of the tailings piles by Wolverine Creek. Accordingly, Klohn Leonoff (1985d) undertook an analysis of sediment transport capacity through Wolverine Creek and downstream reaches of Clinton Creek. Results of this analysis, discussed in the following section on Environmental Impact of the proposed Abandonment Plan, show that any gravel in the tailings piles would be deposited locally in Wolverine and upper Clinton Creeks, but that sand and finer sizes can be transported through the Clinton Creek system.

Based on our concerns for any stabilization measures, which require monitoring following abandonment, and because our analysis shows that material eroded from the tailings piles will not create unacceptable adverse environmental impacts, Klohn Leonoff supports an abandonment plan which allows downslope movement of the tailings piles. We feel that the tailings piles are in an acceptable condition for abandonment without any additional remedial works or monitoring.

6. ENVIRONMENTAL ASSESSMENT

6.1 SEDIMENT TRANSPORT

The abandonment schemes proposed by Klohn Leonoff for both the waste dump along Clinton Creek and the tailings piles along Wolverine Creek provide for some movement of material which is then susceptible to erosion. To examine further whether these proposed schemes would be acceptable with regard to environmental impact, Klohn Leonoff (1985d) conducted a sediment transport analysis for Clinton and Wolverine Creeks. An overview of the study results are included below, and the complete text is reproduced in Appendix II.

In general, analyses concluded that eroded material coarser than gravel would be deposited locally, just downstream from either the waste dump or tailings piles, while estimated transport capacities of lower Clinton Creek and the Forty Mile River are sufficient to transport all finer material. Gravel material from the waste dump would be deposited and form a fan immediately downstream where the stream gradient flattens from about 6% to 1%. Similarly, any gravel from the tailings piles would deposit in the lower reach of Wolverine Creek and at the confluence with Clinton Creek.

Local sand deposition in Clinton Creek may occur periodically, however on an annual basis, transport capacity should be sufficient to maintain the present regime of the creek. Sands and silts reaching the Forty Mile River will, based on the relative potential transport capacities, be carried away by flows in the Forty Mile River.

6.2 FISHERIES IMPACT

Studies of the impact on fisheries of the Clinton Creek waste dump and tailings pile have been carried out by the Environment Protection Service (1978) and EVS Consultants Ltd. (1981). A review of these studies in relation to sediment transport analysis by Klohn Leonoff (1985d) was carried out by Norecol Environmental Consultants Ltd. (1985). The Norecol summary report is included for reference in Appendix II. The conclusions of Norecols report are as follows:

"The review of information has indicated that lower Clinton Creek (below Wolverine Creek) contains several species of fish and is of low to moderate productivity. The effect of tailings pile failure on the fisheries capability of this drainage depends on the speed of the failure. A slow failure will eventually sediment the stream bottom for 2 km immediately downstream of Wolverine Creek and may also affect a portion of the creek further downstream. The effect on the fish populations within the area that may be affected by slow tailing failure is uncertain. It may or may not be significant considering that fisheries resources have been enhanced as a result of Hudgeon Lake and because the rate of sediment accumulation or flushing is uncertain. A rapid failure of the tailings pile will significantly affect all of Clinton Creek downstream of Wolverine Creek making it of limited fisheries value and significantly affecting fish populations below Wolverine Creek. Flushing of the tailing material may occur during subsequent freshet periods offering the potential for some recovery of the stream".

The above conclusions regarding fisheries impact address two scenarios of movement of the tailings piles. The first scenario of "slow-failure" is the case which is expected to occur; that is, the tailings piles will continue to move gradually downslope to fill Wolverine Creek valley bottom and minor ongoing erosion will occur. This will result in sediment accumulations for a 2 km stretch of Clinton Creek downstream of the confluence of Wolverine Creek. This is the area which has already

been impacted by the mining operations, so that little further impact on fisheries is expected as a result of slow failure of the tailings piles.

The second scenario addressed by Norecol is that of a rapid failure of the tailings piles. This scenario was considered possible in early 1985 at the time the fisheries impact summary was prepared, when a high, steep face existed at the toe of the north tailings lobe. Since that time, the toe of the pile has moved into a much flatter configuration and the rapid failure scenario does not seem possible. Therefore, the potential does not exist for the much greater impact on fisheries which would be brought about by a rapid failure.

Norecol's summary report on fisheries impacts also discusses the aspect of asbestos levels, although this is not mentioned in the conclusions quoted above. Their review of monitoring data on asbestos levels indicates that "water sampling programs were conducted by EPS and EVS Consultants but could find no evidence of elevated asbestos concentrations in the Forty Mile or Yukon Rivers attributed to Clinton Creek".

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 MINE FACILITIES

Removal and cleanup of the Clinton Creek townsite, mine facilities and equipment are essentially complete. No further work is required in this area.

7.2 CLINTON CREEK WASTE DUMP

The Clinton Creek waste dump is in a state of stable equilibrium and is suitable for abandonment. Movements of the waste dump have slowed to less than 1.5 ft/yr. The waste dump channel is protected by in situ bedrock on its left bank and by large boulders in the channel bottom. The armouring at the upstream end of the waste dump channel was repaired in 1984 and has performed satisfactorily to date. No practical alternative solution has been identified which will afford a higher degree of protection than the present configuration.

It is recommended that the waste dump be abandoned in its present configuration, with the exception that the culverts should be removed from the road crossing at the upstream end of the channel of Clinton Creek across the waste dump. Culvert removal is recommended to prevent problems resulting from possible future plugging.

7.3 WOLVERINE CREEK TAILINGS PILES

The two tailings piles on the south slope of Wolverine Creek valley will continue to move downslope for a number of years, until a significant amount of the material reaches a more stable configuration in the valley bottom. The configuration of the tailings piles is such that large, catastrophic movements would not be expected to occur. Ongoing erosion of the tailings piles will occur, but at the limited transport capacity of Wolverine Creek.

Alternative solutions have been considered for reclamation of the tailings piles; however, no solutions have been identified which can be implemented at reasonable cost and provide a safe, maintenance-free scheme suitable for abandonment. It is recommended that the tailings piles be abandoned in their present configuration.

7.4 SEISMICITY

Clinton Creek is located in an area of relatively low seismic activity, with an expected 100-year return period acceleration in the order of 6% g. This level of earthquake shaking would not be expected to have significant impact on the stability of the waste dump or tailings piles.

7.5 ENVIRONMENTAL IMPACTS

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.

Fisheries have been adversely impacted by the sediment deposited in the 2 km reach downstream of the waste dump. However, Hudgeon Lake which was formed by the waste dump is seen as an enhancement to fish rearing, and the waste dump channel provides good habitat. The overall impact on fisheries is uncertain. However, future impacts on fisheries are expected to be minor.

Monitoring of asbestos levels has shown no elevation of fibre levels in Forty Mile on Yukon Rivers.

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