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KLOHN LEONOFF
CONSULTING ENGINEERS

Our File: PB 3169-0101

August 15, 1983

Brinco Mining Limited
Cassiar, British Columbia
V0C 1E0

Mr. Peter C. Jones
Manager - Cassiar Division

Clinton Creek Waste Dump

Dear Sirs:

We are pleased to enclose three (3) copies of our report on the Clinton Creek waste dump, dated August 16, 1983. As requested by Tom Milner of Brince, we are also sending two copies directly to Mr. H.F. McAlpine of the Department of Indian and Northern Affairs in Whitehorse, and one copy to Mr. M. Stepanek of Hardy Associates, Calgary.

Yours very truly,

KLOHN LEONOFF LTD.

Peter C. Lighthall, P.Eng.
Project Manager

Enclosures

PCL/jas

REPORT ON MINE WASTE DUMPS

PROJECT: CLINTON CREEK ASBESTOS MINE

LOCATION: CLINTON CREEK, YUKON TERRITORY

CLIENT: BRINCO MINING LIMITED

OUR FILE: PB 3169-0101 AUGUST 16, 1983

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DRAWINGS

1. INTRODUCTION

This report presents a review of the Clinton Creek asbestos mine waste dumps. A design is presented for improvements to the channel conveying the streamflow of Clinton Creek along the toe of the waste dumps. The report also offers recommendations for future observations of the stability of the channel in preparation for final abandonment of the waste dump.

Brinco Mining Ltd., the owners of Cassiar Asbestos, commissioned Klohn Leonoff Ltd. in early 1983 to provide geotechnical advice on the waste dump. A brief review of the dump was presented in a letter dated February 11, 1983. A site visit was made on June 8 and 9, 1983, by Peter Lighthall of Klohn Leonoff in company with Messrs. Peter Jones, Manager, and Robert Clarke, of Cassiar Asbestos. A tour of the site was made on June 9 with representatives of the Yukon Water Board, Messrs. Bud McAlpine and Al Foster and their consultant, Mr. Milos Stepanek of Hardy Associates.

A number of analyses have been carried out for this report. The work included a review of dump movement monitoring data, hydrologic analyses to determine the design flow in Clinton Creek, hydraulic design of the riprap channel protection material and estimation of material volumes and equipment time to carry out the proposed work.

2. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

2.1 CLINTON CREEK CHANNEL ACROSS WASTE DUMP

The Clinton Creek waste dump consists of argillite materials which have been placed across the valley of Clinton Creek to form a large dam that impounds Hudgeon Lake. The present channel of Clinton Creek occupies the north side of the valley, where it 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%.

Movements of the dump on its permafrost foundation have been occurring continuously since completion of dumping in 1977, although movements perpendicular to the channel across the dump have decreased from approximately 3.6 ft/year in 1978 to 1.9 ft/year in 1983. Small continuing movements must be expected, but the dump appears to be stable against rapid, massive failure.

For most of its length, the stream flows between bedrock on the left and the creeping waste dump on the right. Erosion of the right bank of the channel occurs as the creep movement of the dump tends to squeeze the channel. Gradual downcutting of the channel is inevitable, but the dimensions of the waste pile and of the channel are such that there is no danger of sudden catastrophic lowering of Hudgeon Lake. The rate of downcutting is being retarded to some extent by the accumulation of large rock fragments in the stream bed that have either eroded from the dump or been placed there deliberately.

2.2 RIPRAP RIBBED PORTION OF CHANNEL

At the upstream end of the waste dump channel, a section about 250 ft long was provided with a series of riprap cross dykes in 1981, presumably to serve as drop structures and to retard the upstream progression of downcutting. The construction drawings for that work indicate that no riprap filter was included. During spring runoff in 1982 the flow escaped from the rock-ribbed channel and eroded a new channel into the left bank around the ribbed section. By chance, that section appears to be about the only place where bedrock was not close to the surface, resulting in significant erosion and an unstable scarp in the bank. Bypassing the rock-ribbed channel probably resulted from inadequate side channel lining and from piping due to lack of riprap filter. The natural soils in this area are very fine and the downcutting of the eroded channel, which continued during the freshet of 1982, has resulted in localized scour about 8 ft lower than the adjacent rock-ribbed section.

Because of the continuing movements of the waste pile, it is not practical to attempt treatment aimed at a completely erosion-resistant and stable channel. The best that can be done is to minimize erosion of the very silty and highly erodible left bank soils and to allow the overwhelming natural forces involved (i.e. the stream runoff and the gravitational movements of the right bank waste pile) to continue their progress to what will eventually become a relatively stable condition. That will be when the channel becomes sufficiently well paved with rocks and gravel from the waste dump and when the bank movements stop or become infinitesimal.

We therefore recommend that the left bank scour channel be backfilled and protected by riprap obtained mainly from the rock-ribbed channel section. A suitable riprap filter layer should be provided, probably obtainable from the supply of mill overs at the plantsite. The lining of the left bank should extend upstream to the outlet of the culverts and downstream beyond the eroded portion of the bank. The rock armouring on the low gradient portion of the channel just downstream of the culverts should be upgraded to control erosion at the outlet of Hudgeon Lake. The work should be carried out during the summer of 1983 to prevent further scour during the 1984 freshet. We recommend that the work be carried out under the supervision of an experienced field engineer.

not permitted in 1978 in Wolverine / Y.T.W.B. directive

agreed

agreed

2.3 FINAL ABANDONMENT

Brinco Mining Limited is aiming to complete reclamation of the mine facilities by 1985, after which the millsite access road crossing at the upstream end of the waste dump channel will no longer be required. The gradual downcutting expected would remove this road in the long run, but in the interests of avoiding a sudden surge in the channel, we recommend that the four 6-ft diameter culverts be removed at that time and the outlet channel be cut down to the level of the present channel downstream of the culverts. The channel in this area should be thoroughly

inspected at that time and any remedial work if required should be carried out.

Should provide erosion control works S/S to lake.

Dump movement monitoring should be continued on an annual basis up to 1985, in an attempt to improve forecasting of long term movement rates. In addition, a number of survey cross-sections of the channel should be carried out in 1983 and repeated annually through 1985 to monitor the rate of downcutting of the channel. — longitudinal profile as well

3. DESCRIPTION OF WASTE DUMP

The Clinton Creek mine, located about 100 km northwest of Dawson City, Yukon Territory, was operated by Cassiar Asbestos Corporation Ltd. from 1968 until its permanent closure in 1978. Following mine closure, Cassiar commissioned geotechnical studies and carried out remedial works to the mine waste dump so that the site would be left in a condition acceptable to the Yukon Territory Water Board. A series of rock baffles were constructed in 1981 (1989 ?) to provide erosion protection for a portion of the stream channel. In 1982, the stream escaped from the channel and caused considerable erosion of natural ground in the adjacent hillside. The Yukon Territory Water Board is concerned that the erosion be controlled and that the channel over the waste dump be placed in a stable condition before approval for abandonment is granted.

The original valley of Clinton Creek ran east-west at the mine site, with Clinton Creek flowing toward the east. The original valley was flat-bottomed, with a bottom width of about 800 ft. The site, located at approximately 64°15' north latitude, is in a permafrost region, and the fluvial soils in the valley bottom were ice-rich. Waste from the open pits to the south was end-dumped over the valley sides onto the valley bottom. Clinton Creek now flows across the dump against the north wall of the valley, where it has cut a new channel bounded by waste dump material to the south and the valley wall to the north. The dump forms a large dam across the valley, thereby impounding a body of

water up to about 85 ft deep known as Hudgeon Lake. Photograph 1 shows a view of Hudgeon Lake and the waste dump.

The material forming the waste dump consists mainly of finely broken argillite. From grain size curves included in Golder Associates' report dated July 1978, the dump contains predominantly sand and gravel size particles. Occasional boulders and cobbles of harder, more durable rocks are spread throughout the dump.

Since the completion of active dumping in 1977, movements of the dump have continued as a slow creep from horizontal spreading of the dump on its foundation. Monitoring of dump movements has been carried out since 1977. Six monuments on the dump surface are surveyed for vertical and horizontal location and, in addition, five channel closure sections are surveyed for horizontal movement. From the monitoring records, the average annual movements in a horizontal direction toward the north valley wall are as follows:

Annual Movements (ft/year)

	*Closure Sections	**Monitoring Points
1976-77	-	3.23
1977-78	4.00	4.16
1978-79	-	-
1979-80	2.96	-
1980-81	2.43	3.60
1981-82	2.15	2.52
1982-83	1.73	2.62

* 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 20, 21 (or 21A) and 22 (or 22A).

The data show that movements of the dump have decreased since 1977 when the monitoring results first became available.

The effect of the dump movement is a tendency for the dump to continually squeeze the stream channel along the north side of the dump, and for the channel to continue eroding away at the toe of the advancing dump. Active erosion of the right bank waste dump toe (note right and left are in relation to an observer facing downstream) is evident by the oversteepened slopes which occur in the dump materials. The continuing erosion exposes occasional large boulders which contribute to the armouring at the stream channel. The movements of the waste dump are evident in the cracking which can be seen on the dump surface. There are both radial cracks, from spreading of the dump, and cracks parallel to Clinton Creek channel, from movement toward the channel.

Golder Associates, in their July 1978 report on the waste dump, indicate that the dump could not, for any reasonable cost, be permanently stabilized nor the stream channel permanently protected against erosion. Their recommendation was to construct a rock-lined section in the channel, with energy dissipating weirs, which would form a barrier against progressive downcutting of the channel. The rock section was to be constructed sufficiently wide that squeezing of the channel could take place for a number of years before the flow would be restricted. The location of the rock-lined section was to be about 275 ft downstream of the four 6-ft culverts which control the present level of Hudgeon Lake. Additionally, Golder Associates recommended placement of a modest amount of coarse rock in the stream channel downstream to provide protection against downcutting.

The rock-lined section of the stream channel was constructed in the late summer of 1981. During spring runoff of 1982, Clinton Creek escaped the channel formed by the rock-lined section and eroded into

also in 1979.

native soil in the left bank adjacent to the rock-lined section. No repair work was carried out in 1982.

4. OBSERVATIONS OF CLINTON CREEK CHANNEL DURING JUNE, 1983 SITE VISIT

The level of Hudgeon Lake, at the upstream end of the waste dump channel, is controlled by four 6-ft diameter culverts which are set in the stream crossing of the access road to the Clinton millsite. The four culverts are set at different elevations. On June 8 and 9, 1983, the lowest culvert was nearly submerged at its upstream end and a second culvert was running partially full.

Downstream of the culverts is an apron of coarse rock, followed by a low gradient section of channel with a bed of cobbles and small boulders. A view downstream of the culverts is shown on Plate 2.

The present upstream end of the rock-lined section consists of a rock-fill rib of height about 6 ft, which serves to deflect the stream to the left. There deep downcutting into soft original ground has carved a channel some 8 ft lower than the rock channel level. That first rib appears to have been constructed to an elevation nearly equal to the top of the channel lining upstream, possibly causing failure by over-topping of the channel sides.

look at elev. on drawing #208 = 9

The erosion of the natural left bank materials has created an erosion scarp up to about 50 ft in height. At the upstream end of the eroded channel, bedrock appears on the left bank so that a control against further rapid erosion in that area is in place. Further downstream, soil is exposed over the entire slope adjacent to the rock-lined section. The soil appears to be a fan-shaped deposit of colluvial material which has infilled a notch in the bedrock topography (see Photograph 3).

Downstream of the rock-ribbed section, the stream has exposed bedrock in the left bank and the channel has an estimated slope of about 4.5%. A number of large rock fragments have accumulated in the channel bottom.

The right bank is bounded by waste dump material, which is oversteepened and undergoing continual minor erosion. The channel appears stable against rapid downcutting. A typical view of the channel is shown on Photograph 4. A survey profile of the channel bottom and a number of survey cross-sections of the channel should be established so that changes can be monitored over the next few years prior to abandonment.

5. HYDROLOGY

Design of riprap protection for the channel along the portion of Clinton Creek downstream from the outlet of Hudgeon Lake required an estimate of a design flood and the routing of this flood through the lake. For the relatively small drainage basin of about 40 square miles, Hudgeon Lake provides sufficient storage that a design flood with a relatively long duration must be considered. A design flood was therefore estimated which consisted of a relatively short duration rainfall event occurring in conjunction with a longer duration snowmelt event. A return period of 100 years was deemed reasonable for design in view of the low risk levels involved.

Estimation of the 100-year return period snowmelt runoff on Clinton Creek proceeded as follows:

a) Historical streamflow data available from Water Survey of Canada (WSC) were obtained for stations closest to the project site. These stations included:

Station	Period of Record	Drainage Area (sq. mile)
Clinton Creek above Wolverine Creek	1964-65	40
North Klondike River near the mouth	1974-81	425
Klondike River above Bonanza Creek	1965-81	3,010
Stewart River at the mouth	1964-81	17,700

b) A flood frequency curve was derived for the longer term station on the Klondike River, and the 100-year flood attributed to snowmelt was estimated. For comparison, analysis on the Stewart River provided similar snowmelt flood results on a unit runoff basis.

c) Annual flood peaks were compared between the Klondike and North Klondike Rivers. This analysis showed that the flood peak ratios varied with drainage area ratio to the 0.8 power, indicating higher unit runoff from the smaller North Klondike basin.

d) The 100-year snowmelt flood estimated for the Klondike River was transposed to the Clinton Creek project site by multiplying by the drainage area ratio to the 0.8 power.

The results of this analysis indicated that the 100-year return period snowmelt flood peak for the Clinton Creek basin is approximately 775 cfs (22 m^3/s). This flow would have a broad crested hydrograph extending over a period of many days.

Sufficient data were not available on Clinton Creek to estimate the 100-year flood peak that could result from a rain-on-snow event. Therefore, an analysis of recorded flood peaks from stations throughout the region was undertaken. The analysis proceeded as follows:

a) Maximum floods on record were plotted versus drainage area for gauging stations in the Yukon, interior Alaska, northern B.C. and the Northwest Territories. Results are shown on Drawing B-011 where an envelope curve is included for the nine stations closest to Clinton Creek.

b) Regression equations developed in Alaska for the region immediately adjacent to the project site were used to estimate the 50 and 100-year return period flood peaks for Clinton Creek, calculated

as 1850 cfs (52.4 m^3/s) and 2200 cfs (62.3 m^3/s), respectively. These flood estimates appear reasonable based on the flood data presented on Drawing B-1001.

The inflow 100-year flood hydrograph to Hudgeon Lake was then approximated by a relatively long duration snowmelt of 775 cfs combined with a shorter duration rainfall input which increases the peak inflow to 2200 cfs.

The design outflow hydrograph from Hudgeon Lake was calculated for two conditions: the existing 6 ft diameter culverts and a free crest outlet channel which would exist when the access road is no longer required. The larger 100-year return period outflow equal to 1200 cfs (34 m^3/s), which would occur with the road removed, was used for design of the riprap.

5. PROPOSED REMEDIAL MEASURES

The work we propose carrying out to repair the eroded left bank and control erosion of the channel is shown on Drawing D-1002. The steps are:

a) Remove the waste dump ends of the existing rock ribs and divert the stream into that area.

b) Backfill the scour channel on the left.

c) Place filters and riprap protection on left bank backfill material and in the apron on the left side of the channel bed. Improve the riprap lining of the stream channel at the outlet of the culverts.

The backfilled channel bank will be protected with a minimum thickness of 3 ft of riprap. The gradation specifications, which are compatible with the rock in the present channel, are shown on Drawing D-1002. A

not permitted for use in Wolverine Cr in 1979 - Y.T.WB.

12-inch filter layer of "mill overs", consisting of approximately 1-inch to 3-inch sizes available from a disposal pile at the concentrator, will be laid beneath the coarse rock. The filter and lining will extend to a height of 6 ft up the left bank extend about 2.0 ft into the channel.

In addition to the backfilled section of the channel, riprapping of the left bank will be extended upstream to the culverts and downstream beyond the erodible sections of the bank.

Good

but R.H.B. not protected.
- LHB works will be indirect
- Erosion u/s to lake outlet.

We recommend that the channel construction be carried out under the supervision of an experienced Klohn Leonoff field engineer. The success of the construction depends on attention to detail and the chances of success will be much higher if qualified supervision is provided.

6. ESTIMATED MATERIAL QUANTITIES AND EQUIPMENT TIME

Following are the estimated quantities of materials to reconstruct the channel:

Riprap	2300 cubic yards
Riprap bedding (mill overs)	700 cubic yards
Waste dump material (backfill of existing channel)	8000 cubic yards

It is intended that the existing rock in the channel will provide sufficient quantity for the reconstruction. The mill overs will be hauled from the disposal pile at the concentrator. Waste dump materials for backfill should be taken from the west side of the dump, facing Hudgeon Lake, rather than from immediately adjacent to the channel so as to avoid any adverse effect on stability.

We consider that the most efficient spread of equipment to carry out the work would be a bulldozer (D8 or equivalent), a front-end loader and two dump trucks.

The estimated equipment times to carry out the work are as follows:

		Bulldozer	Trucks	Loader
1.	Remove rock and relocate channel to right bank	5 days	-	-
2.	Backfill eroded channel	8 days	8 days	8 days
3.	Haul and place bedding	3 days	3 days	3 days
4.	Place riprap	5 days	-	-
	TOTALS	21 days	11 days	11 days

The above equipment times are estimates only. We recommend that you add a reasonable contingency for budgetting purposes.

7. FINAL ABANDONMENT

The channel improvement proposed for Clinton Creek is designed to provide erosion protection for the soft portions of the channel bank for a flood flow with a return period of about 100 years. Squeezing of the right bank of the channel will continue but probably at a diminishing rate. The rate of dump movement is presently less than 2 ft/year and appears to be decreasing. Due to the accumulated rock paving and the exposed rock in the left bank, the lower reaches of the channel already appear to be approaching equilibrium. Erosion of waste dump material will continue on the right bank, but at a diminishing rate, and a state of equilibrium equivalent to that in natural streams should be achieved in a relatively few more years.

Cassiar anticipates completing reclamation and abandonment of the mill facilities in 1985, so that the access road across Clinton Creek will no longer be required. We recommend that the four culverts at the outlet of Hudgeon Lake be removed at that time and the outlet channel be cut down to the existing level of the rock apron downstream of the culverts.

At the time the outlet culverts are removed, the channel will have had a further two years of service. The channel should be carefully inspected at that time and any remedial work required should be carried out. We would anticipate that the waste dump would then be in condition for final abandonment and the area could be returned to the public domain.

KLOHN LEONOFF LTD.

for A.M. (Tony) Melone, P.Eng. (B.C.)

Peter C. Lighthall, P.Eng. (B.C.)

AMM/PCL/jas

APPENDIX I

PHOTOGRAPHS

Photo 1

The waste dump and Hudgeon Lake, looking southeast. The outlet to Clinton Creek is at the left of the photo.

Photo 2

The apron at the outlet of the culverts, looking east.

Photo 3

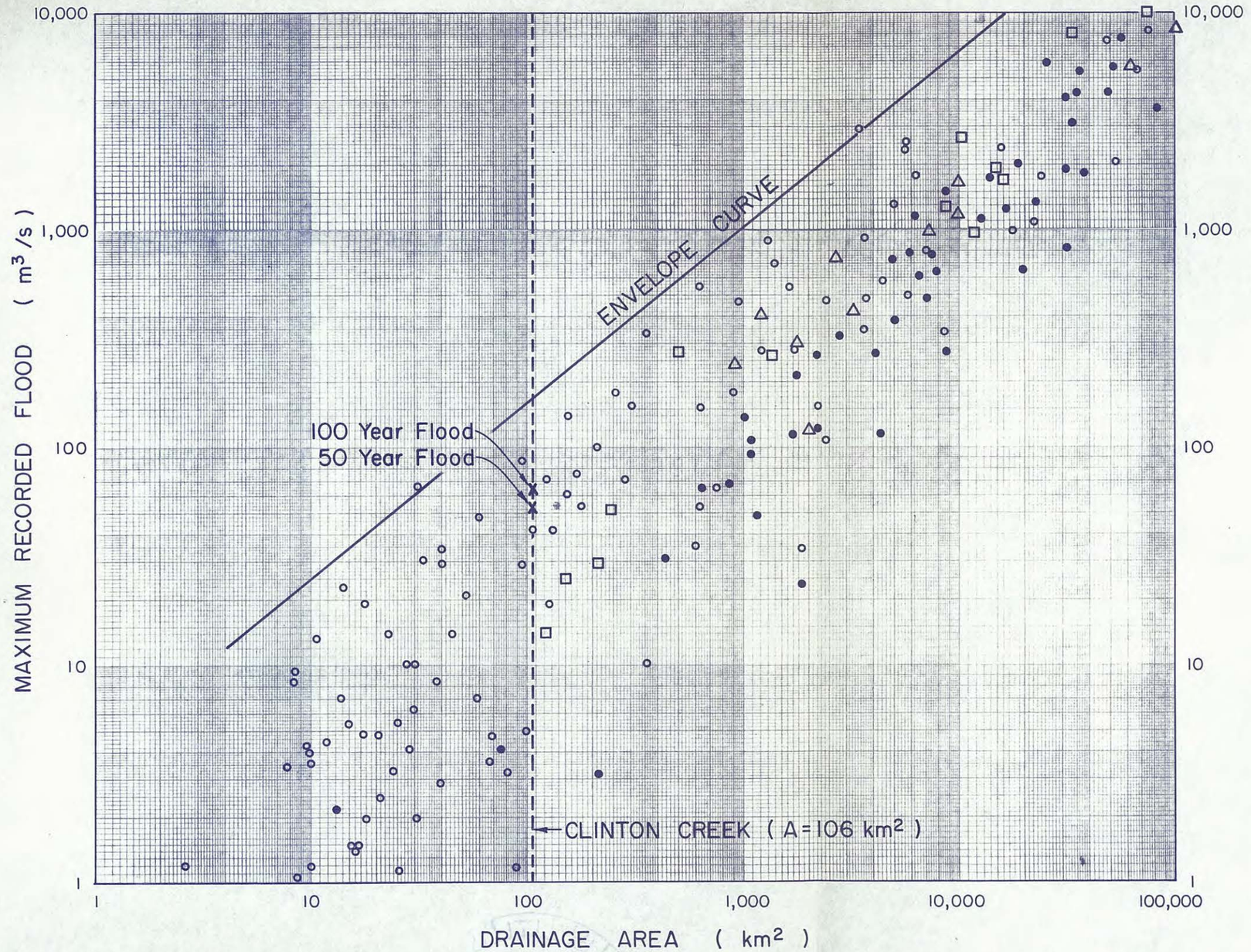
View of the eroded left bank and the ribbed channel structure, looking northwest.

Photo 4

Typical view of the Clinton Creek channel over the waste dump, looking upstream. Failed rock channel in the distance.

DRAWINGS

PB 3169 01 B-1001	-	MAXIMUM RECORDED FLOODS
PB 3169 01 D-1002	-	PLAN AND SECTIONS OF CHANNEL RIPRAP PROTECTION



LEGEND

- ● Yukon (through 1979)
- ○ Interior Alaska (through 1976)
- □ Western Northwest Territories (through 1979)
- △ Northern British Columbia (through 1979)

TO BE READ WITH KLOHN LEONOFF REPORT DATED AUG. 16, 1983

SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: BRINCO MINING LIMITED
CASSIAR DIVISION

PROJECT: CLINTON CREEK MINE WASTE DUMP

TITLE: MAXIMUM RECORDED FLOODS

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
AUG. 16, 1983	PB 3169 01	B - 1001	

APPROVED

NCI-456-K.L.

1 2 3

D

C

Access Road

Hudgeon Lake

20x

x2

3x

x4

x5

x7

x19

x18 Eroded Channel x17

x16

6x

8x

x9

10x

11x

12x

13x

x14

x15

Wooded slope

4-6 ft. diameter culverts

Rock-ribbed Channel

Clinton Creek

Mine Waste

N

SURVEY DATA

Point	Elev. (ft)	Point	Elev. (ft)
1	1344	12	1332
2	1353	13	1330
3	1354	14	1328
4	1340	15	1322
5	1341	16	1322
6	1340	17	1326
7	1337	18	1325
8	1338	19	1329
9	1343	20	1343
10	1336	21	1355
11	1334		

SKETCH OF SITE PLAN FOR EXISTING CHANNEL

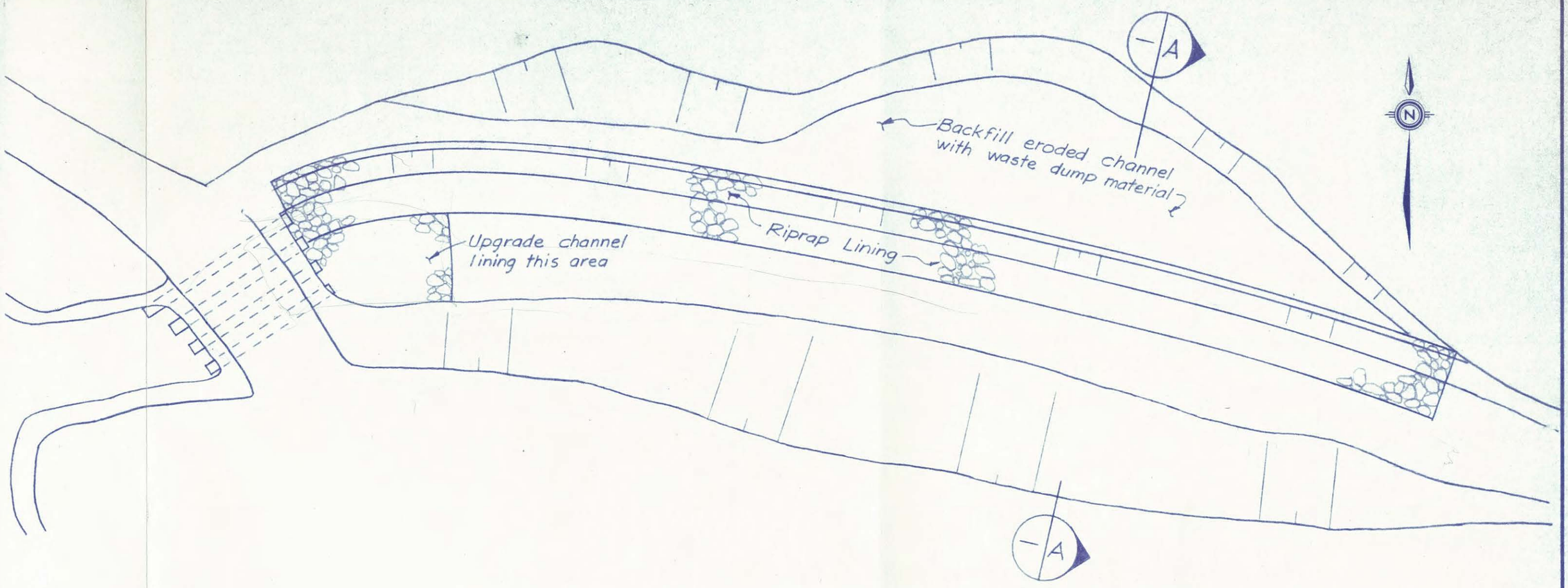
Approx. scale : 1" = 50'

1360

EET

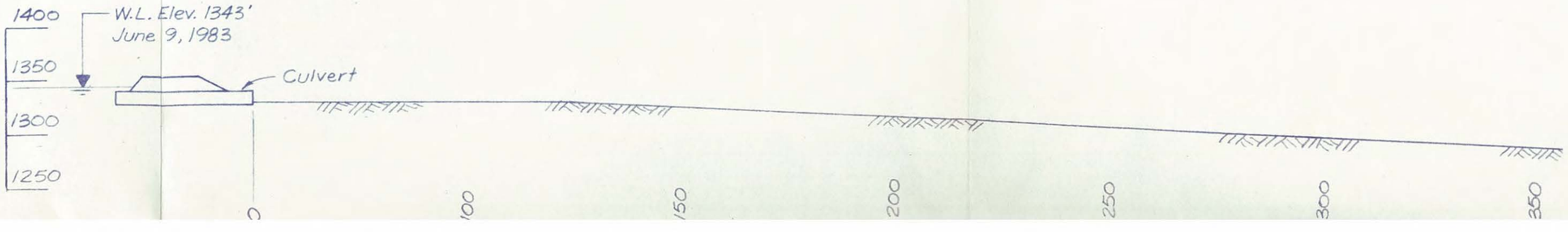
See Details below

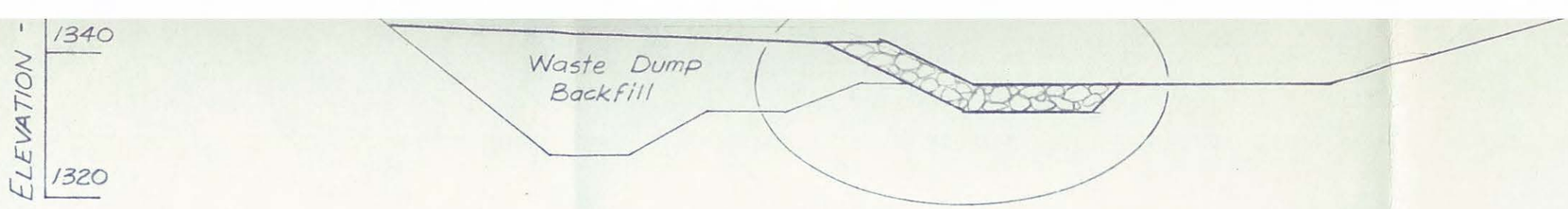
4 5 6



SITE PLAN SHOWING RIPRAP LINING OF LEFT BANK

Approx. scale : 1" = 50'

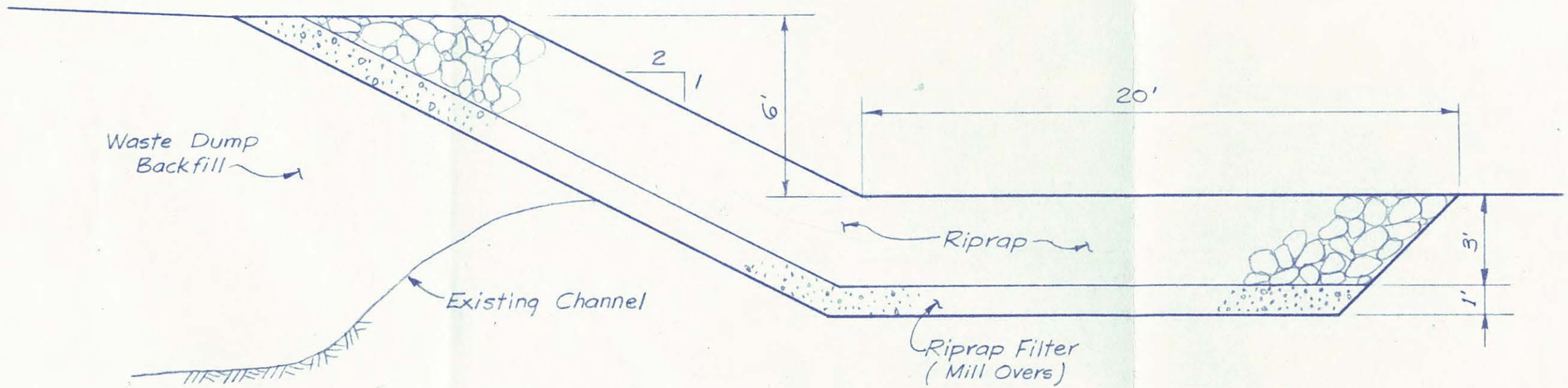




SECTION (A/—)

TYPICAL SECTION WITH RIPRAP LINED CHANNEL

Scale : 1" = 20'



DETAILS OF RIPRAP BANK LINING

Scale : 1" = 4'

B

A

NCI - 603

SKETCH OF PROFILE ALONG CHANNEL ℄

Approx. scale : 1" = 50'

NOTES

1. Plans, profile and sections are approximate, based on limited survey data, sketches of site prepared during site inspection by Klohn Leonoff and photographs of the area.

2. Backfill in existing channel should be placed in maximum 1 ft. lifts and compacted by bulldozer travel.

3. Filter material should consist of "mill overs". This material consists of 1" to 3" crushed rock available from a disposal pile at the mill site. Filter materials must be approved by the Engineer on site.

4. Riprap gradation :

% finer by wt.	rock size
100	3.0 ft.
50	1.5 ft
10	0.5 ft

5. Final alignment of riprap lining and extent of riprap placement to be approved by the Engineer on site.

TO BE READ WITH KLOHN LEONOFF REPORT DATED AUG. 16, 1983

SCALE:

REV.	DATE	REVISION DETAILS

DESIGN	DRAWN	DATE	SCALES
A.M. / P.L.	F.C.	JULY 1983	AS SHOWN

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: CLINTON CREEK MINE WASTE DUMP

TITLE: PLAN AND SECTIONS OF CHANNEL RIPRAP PROTECTION

CLIENT: BRINCO MINING LIMITED CASSIAR DIVISION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
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