Golder Associates
CONSULTING GEOTECHNICAL ENGINEERS

SECOND REPORT TO CASSIAR ASBESTOS CORPORATION LTD. ON STABILIZATION MEASURES FOR MINE CLOSURE

CLINTON MINE YUKON TERRITORY

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1. INTRODUCTION

At the request of Mr. G. R. Vincent, Mine Manager, Clinton Mine, Yukon Territory, the writer visited the mine between January 25 and 27, 1977. Displacements of up to 7 ft. horizontally and 11 ft. settlement had been recorded on the surface of the tailings pile in the previous month. The tailings pile was inspected, and a brief inspection was made of the toe of Clinton Dump and the west wall of Porcupine Pit. The recommendations contained in this report confirm those made verbally to Mr. Vincent by the writer while he was in Clinton Creek.

2. BACKGROUND

The various slopes and creek channels in the mine complex had been previously inspected by Mr. D. B. Campbell and the writer in May, 1976 in connection with developing a program for stabilizing slopes, where necessary, prior to the end of mining production. At that time, mine closure had been projected for spring, 1978. In a previous report (1), it was recommended that, among other items, monitoring programs for the measurement of surface movements in the tailings pile, and the west wall of Porcupine Pit be initiated, and monitors additional to those already being read, be set up in the toe region of Clinton Dump.

For a description of the principal features of the Clinton Mine please refer to the previous report (1). A plan of the mine is shown in Figure 1 of the report. Since the previous report (1) was prepared, the following activities, which could affect stability, have been carried out:

(i) Porcupine Pit is mined to about El. 1170. Ground water, which was encountered below El. 1230, was pumped from one well in the pit floor. Due to ravelling and small wedge failures that

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(1) Report on "Stabilization Measures for Mine Closure", draft submission May, 1976, final submission April, 1977.

had occurred on the west wall, the bench at El. 1380 had been left approximately 150 ft. wide (i.e. about 90 ft. wider than design). The mining company propose to cut back this bench eventually.

(ii) Snowshoe Pit has been mined further. The writer did not inspect this pit.

(iii) Virtually no further material disposal has been made in Clinton Dump. Instead a new dump area on the valley flat northwest of Snowshoe Pit has been established.

(iv) The local slope at the toe of Clinton Dump, adjacent to the creek channel, was trimmed to an angle of 20 degrees (2.75 horizontal:1 vertical), in the summer of 1976. In May, 1976, erosion from the flow in Clinton Creek was occurring at the toe of this slope, which was then at its angle of repose. The slope above the eroding areas was actively sloughing.

The material removed during slope trimming was dumped in the valley flat just downstream of Clinton Dump.

(v) The tailings pile has advanced in a northerly direction. The writer was advised that the two tailings conveyors were relocated approximately 100 ft. eastwards in October, 1976.

(vi) Survey measurements on surface monitors were started in the fall, 1976. The monitors are set up on the west wall of Porcupine Pit, on Clinton Dump, and on the tailings pile. Slope distances are measured using a Geodimeter Model 76 electronic distance measuring equipment*. Angles are

*Manufacturer's stated accuracy: $\pm$ (0.03 ft. + 0.005 ft. per mile)

measured with a T16 WILD Theodolite. The monitors on the dump replace eight monitors previously being read, some of which had to be removed when the slope at the toe of the dump was trimmed.

3. TAILINGS PILE - OBSERVATIONS

Photo 1 shows the east slope of the tailings pile, viewed from the instrument station used for sighting the pile monitors. This station is on a locally high point of land on the same side of the valley as the tailings pile, some 1/2 to 1 mile south of the pile.

The part of the pile that underwent creep movement and blocked Wolverine Creek in 1974, is shown nearest the camera in photo 1. Two monitors are installed in this part of the pile: No. 24 near the top, and No. 25 near the base. Monitor No. 26 is installed in an upper part of the pile where the tails were more recently deposited. This is where large settlements were known to be occurring. Initial measurements were taken on monitors Nos. 24, 25 and 26 in December, 1976. After 28 days, when large displacements had been recorded on monitor No. 26, a further monitor (No. 27) was installed near the base of the pile below No. 26.

A summary of the displacements of tailings pile monitors is given in Table I. The average horizontal movement on the monitors in the more recently deposited part of the pile is more than 3 inches per day. The upper monitor (No. 26) is settling at a rate of almost 5 inches per day. Monitors Nos. 24 and 25 the older part of the pile are showing much smaller movements, the maximum being less than 1/2 inch per day horizontal movement near the toe.

The slope of the north face of the pile where tailings are presently being disposed is at 38 degrees to the horizontal. However, the northeast face in the vicinity of monitors Nos. 26 and 27 is 38 degrees near the top,

and 30 to 32 degrees near the base. The slope of the original ground surface now covered by the tailings pile, varies between 15 and 25 degrees (based on the topographic survey sheet). Below the toe of the pile, the ground surface slope is between 10 and 25 degrees (clinometer measruements). The crest of the pile is approximately 700 ft. higher than the Wolverine Creek valley, and the northeast face, where the greatest movements are, extends about half-way down the slope. The distance from the toe of the northeast face to Wolverine Creek is about 700 ft.

Monument No. 26 is on a bench approximately 20 ft. lower than the present working bench. From the appearance of the two benches, and from information provided to the writer during his visit, the upper bench material was disposed and spread recently, after the lower bench had settled; i.e., the lower bench did not slump fully from the present level of the upper bench. However, the lower bench has slumped to some extent, as indicated by the large settlement recorded on monitor No. 26, and the existence of many settlement cracks in the vicinity of this monitor. One such crack was visible on the surface of the upper bench, although tailings spreading and grading operations would have obliterated the crack only one or two days before. This crack extends from a point on the upper (working) bench, 100 to 150 ft. south of monitor No. 26, westwards under the east conveyor. The crack could not be seen between the two conveyors, or west of the west conveyor, but it is believed to be associated with settlement of the northeast part of the pile.

There is considerable evidence of downslope advancement of the toe of the northeast part of the tailings pile. As the toe has advanced, it has "bull-dozed" native soil ahead of it, and this soil was exposed in several locations in the form of a 6 ft. high "bank" at the toe. In some areas, the exposed soil was not frozen (however, the weather for the previous few days had been

unseasonably mild, with temperatures near 0°C). At one point on the toe, to the north of a shallow draw, there is a lobe-shaped area consisting of tailings extending about 100 ft. downslope from the toe. It would appear that this was a flow-type failure in the tailings. There is a depression in the surface of the pile immediately above this area. The trees have been broken off and knocked over in random directions within the area.

Surface cracking is visible near the toe of the northeast part of the pile. Some cracks are aligned roughly parallel to the toe of the pile, and are associated with local slumping. There is also a major crack aligned upslope passing just to the south of monitor No. 27. The writer was informed that the crack extends for the full height of the tailings pile (and is probably continuous with the system of cracks on the upper working bench), but the full extent of the crack could not be seen by the writer, due to the blanket of snow. Photo 2 shows this crack. The surface of the pile on the north side of the crack has heaved, relative to that on the south side, by about 5 ft. It is on the north side of the crack that most of the movement has taken place.

Photo 3 shows the "bulldozing" effect of the base of the pile.

4. TAILINGS PILE - INTERPRETATION OF OBSERVATIONS

The northeast part of the tailings pile (i.e. that portion to the north of the crack shown on photo 1) is slumping at the top, and moving downslope at the base. The movement is gradual, and no sudden failures are expected, except in localized areas where the surface slope is steeper than average. The exposed native soil at the base of the pile slope suggests that the seat of the movement is in unfrozen soil near the original ground surface.

If the northeast part of the tailings pile continues to move at its present rate of 3 inches per day (as measured over a 4 day period at monitor No. 27), it is computed that the toe of the pile would reach Wolverine Creek in about eight years (i.e., about 1985). However this prediction is based on very slender evidence, and the actual time taken might be much less than this.

However, provided no further tailings are placed at the top of the northeast part of the pile, the overall slope angle of the pile will become flatter as the toe advances. With a flattening of the slope, the forces tending to keep the material moving will be reduced. It is therefore possible that the pile could stop moving before the creek is reached.

It does not appear practical or reasonable to carry out any construction work at the present time to prevent the toe reaching Wolverine Creek, or to alleviate its effect on the creek if it does reach it. Such measures might consist of construction of a containment dyke, 1,000 ft. long, or installation of a culvert or spillway in the tailings to take flood flows in Wolverine Creek, and, in any case, would be costly.

In order to rehabilitate the tailings pile so that it is environmentally acceptable after mine closure, benching and seeding of the slopes is being considered. Provided that the benching results in an overall flatter slope angle, the stability of the pile should be increased.

No further tailings should be placed at the top of the northeast part of the pile, i.e., at the end of, or to the east of, the January, 1977 location of the east tailings conveyor. The effect of placing tailings in this area would be to accelerate slope movement, and might result in sudden slope failure. During the writer's visit to the site, preparations were being made to relocate the conveyors to the northwest (i.e., approximately parallel to the ground contours). This direction diverges from the upper reaches of Wolverine Creek, and

any movements within the tailings pile after it has been extended in this direction, should not affect the creek.

The writer was advised that an estimated 4 million tons of tailings will require disposal, between January, 1977 and mine closure. Bearing in mind that the ground surface to the northwest is higher than that to the north or northeast, the average vertical thickness of the tailings pile in the northwesterly direction is expected to be about 150 ft. It would appear therefore that the tailings pile will extend a further 500 to 1,000 ft., and appropriate lengths of conveyor extension will be required.

Measurements should be taken on the four tailings pile monitors at regular intervals at least twice a month. An inspection should be made of the tailings pile as soon as the snow has gone, and again in late fall, 1977, to assess whether any new cracks are developing. The prediction made above as to the future rate of movement of the tailings pile is very approximate, and these measurements and observations will provide adequate warning of an increase in movement.

The movement of the pre-1974 portion of the tailings pile has now virtually ceased. To reduce the downcutting of the tailings by Wolverine Creek, the creek channel could be lined.

5. CLINTON DUMP

Four surface monitors (Nos. 19 to 22) have been installed in the toe area of Clinton Dump, and one in the mid-area of the dump, at least 80 ft. back from crests of locally steep slopes within the dump. One monitor (No. 23) is in the mid-area of the dump. A summary of the movements of the dump monitors is given in Table II.

As indicated in Table II, the toe of Clinton Dump is still experiencing some movement in a generally radial direction, relative to the mid-area of the dump. The maximum measured rate of movement is about 1/4 inch per day, which is somewhat less than that being measured by other methods on the former monitors (Nos. 1 to 8). Since the readings on the two sets of monitors were taken over different time periods, it is not possible to say whether the difference in the measured rates of movement is due to general deceleration of dump movement, or because the more recent monitors are located further from the crests of locally steep slopes within the dump.

Large cracks aligned in a roughly north-south direction still exist in the toe area of the dump, mostly on the bench above the main access road to the millsite. As indicated in the May, 1976 draft report, these cracks are considered to be the result of graben development.

There was no evidence of any instability of the slope at the base of the dump, forming the south bank of Clinton Creek channel. This slope was trimmed in the summer of 1976. However, the slope was heavily blanketed with snow during the writer's visit, and it was not possible to properly inspect it. Close observation should be kept on the channel slope during spring break-up, 1977, to check for any excessive erosion.

The local slope between the main access road bench and the bench above is steep in places, (more than 50 degrees to the horizontal with heights of more than 30 ft.). Unless the slope is flattened, local failure and sloughing can be expected. However, the lower bench is very wide, and any such failures should not impair the stability of the channel bank.

Readings on the dump monitors should continue at monthly intervals.

6. PORCUPINE PIT

Five surface monitors are installed on each of the upper two benches of the west wall of the pit. These monuments are sighted from an instrument station (about 2,000 ft. distant) above the east wall. The apparent movement on seven of the ten monitors over a 2 month period was less than the measuring accuracy of the instrument. A summary of the measurements is given in Table III.

Surface ravelling in the easily fractured argillite is still occurring on the interbench slopes of the west wall. The slope between El. 1380 and 1470 appears particularly prone to ravelling, since considerably more debris has accumulated on the El. 1380 bench since the writer's previous visit in May, 1966.

Material from surface ravelling should be removed from the benches as practicable in order to restore bench catchment. In particular, material should be removed from the El. 1380 bench before this bench is cut back to design width and mining proceeds to final pit floor elevation.

7. CONCLUSIONS AND RECOMMENDATIONS

1. The northeast part of the tailings pile is moving gradually downslope.
2. There is little evidence to suggest (a) that the movement will stop, or (b) that it will accelerate. No sudden mass movement is foreseen.
3. If the tailings pile continues to move at its present rate, it could take about 8 years to reach Wolverine Creek. However, the pile might stop moving before the toe reaches the creek.
4. No further tailings should be disposed of at the top of the northeast part of the pile, and the conveyors should be relocated away from this area.

5. It is considered impracticable to carry out measures to arrest the movement of the tailings pile.

6. Measurements should be made of tailings pile monitor movements at least twice a month.

7. The tailings pile should be inspected soon after snowmelt in 1977, and again in late fall.

8. A continuing, updated review should be made of all monitor measurements and other observations of surface cracking, slumping, etc., on the tailings pile.

9. Extension of the tailings pile in a northwesterly direction is not expected to result in movements of the pile material of sufficient magnitude to affect, or to block, Wolverine Creek.

10. Monitors installed in the portion of the tailings pile that moved down into Wolverine Creek in 1974 are showing insignificant movement.

11. The toe area of Clinton Dump is still moving gradually downslope. It is also gradually spreading itself up and down the valley at a very slow rate. This almost imperceptible movement (1/4 inch per day) might continue for several years.

12. Energy dissipators (weirs) should be constructed in Clinton Creek channel at the base of Clinton Dump to prevent channel erosion.

13. Material which has ravelled and sloughed on to the benches of Porcupine Pit should be removed as practicable.

Yours very truly,

GOLDER BRAWNER & ASSOCIATES LTD.

Per: D.B. Campbell, P. Eng.

G.R. Tomlin, P. Eng. (writer)

GRT/DBC/sm

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TABLE I

TAILINGS PILE MONITORS

Monitor	24	25	26	27
Location	Near top of pre-1974 portion of pile	Near base of pre-1974 portion of pile	Top of post-1974 portion of pile	Near base of post-1974 portion of pile
N-coordinate	113482.86	113548.41	114445.33	114136.50
E-coordinate	108325.21	109538.91	108151.19	109027.10
Elevation	1831.56	1429.54	1972.28	1559.85
Date of first reading	12/23/76	12/23/76	12/23/76	1/20/77
Horizontal displacement (ft.)				
to 1/20/77	0.10	0.81	7.67	-
to 1/24/77	-	-	8.51	1.00
Average horiz. displacement (ft. per day)	0.004	0.03	0.27	0.25
Direction of horiz. displacement (approx.)	-	N80°E (Down slope)	N60°E (Parallel to pile slope & original gr. slope)	S80°E (Parallel to original gr. slope)
Settlement (ft.)				
to 1/20/77	0.04	0.09	11.02	-
to 1/24/77	-	-	12.67	0.36
Average settlement (ft. per day)	0.001	0.003	0.39	0.09

TABLE II

CLINTON DUMP MONITORS

Monitor	19	20	21	22	23
Location	In front of "dry"	Near toe of dump in vicinity of former monitor #6	Near toe of dump in vicinity of former monitor #7	Near toe of dump in vicinity of former monitor #8	Mid-area of dump
Date of first reading	11/24/76	11/24/76	11/24/76	11/24/76	11/24/76
Horiz. displacement (ft) to 1/25/77	0.59	1.32	1.34	1.53	1.20
Average horiz. displacement (ft. per day)	0.009	0.02(1)	0.02(2)	0.02(3)	0.02
Directon of horiz. displacement approx.)	N50°E (Down slope)	N30°E (Down slope)	N20°E (Slightly east of down slope)	N10°W (Down slope)	N5°E (Down slope)
Settlement (ft.) to 1/25/77	0.04	0.22	0.45	0.88	0.68
Average settlement (ft. per day)	0.0006	0.004(1)	0.007(2)	0.014(3)	0.01

NOTES: (1) Nearby monitor No. 6 was moving at 0.03 ft. per day and settling at 0.04 ft. per day from June to November, 1976.

(2) Nearby monitor No. 7 was moving at 0.03 ft. per day and settling at 0.02 ft. per day from June to November, 1976.

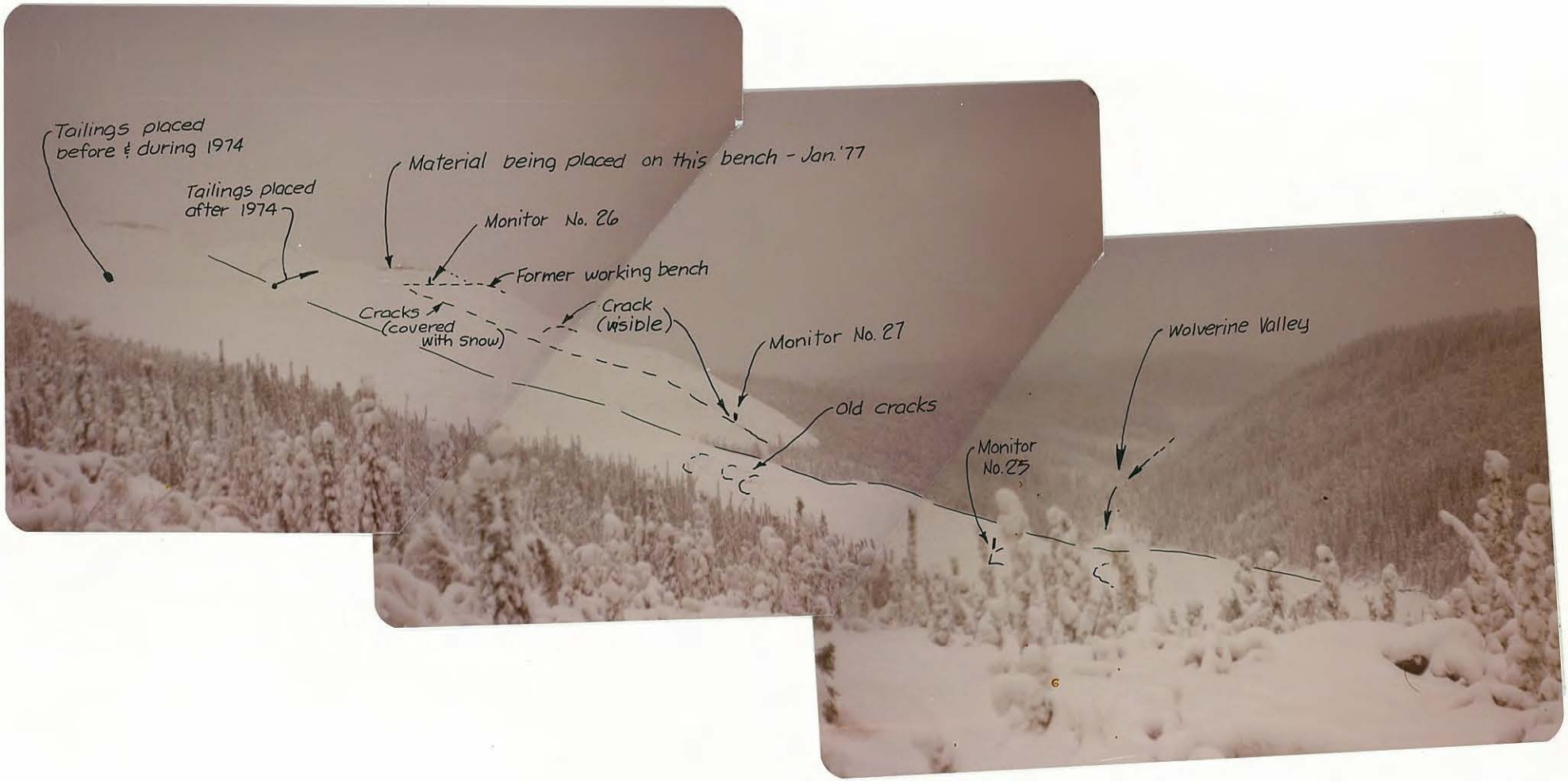
(3) Nearby monitor No. 8 was moving at 0.03 ft. per day and settling at 0.03 ft. per day from May to November, 1976.

TABLE III

PORCUPINE PIT - WEST WALL MONITORS

NOTE: Five monitors installed on El. 1740 bench (Nos. 9, 10, 11, 12, 13)
Five monitors installed on El. 1650 bench (Nos. 14, 15, 16, 17, 18)
Between Nov. 24, 1976 and Jan. 25, 1977, displacement measurements on all monitors were negligible (less than 0.03 ft.), except on monitors 11, 12 and 18, as follows:

Monitor	11	12	18
Location	El. 1740 bench	El. 1740 bench	El. 1650 bench
Date of first reading	11/24/76	11/24/76	11/24/76
Horiz. displacement (ft.) to 1/25/77	0.08	0.10	0.08
Average horiz. displacement (ft. per day)	0.001	0.002	0.001
Directon of horiz. displacment	Towards pit	Towards pit	Towards pit
Settlement (ft.) to 1/25/77	0.14 (heave)	Zero	0.02
Average settlement (ft. per day)	0.002 (heave)	Zero	0.0003



1 Looking North, across east face of tailings pile. View from instrument station. Photographs taken Jan 26/1977

2 Looking northwest from toe of tailings pile. Monitor No. 27 indicated by red flagging. Five-foot high face of crack aligned up-slope, in foreground.

3 Toe of tailings pile on north side of monitor No. 27. Exposed material at base of slope is native soil, unfrozen. Slope of tailings pile near toe varies between 32^{o} and 37^{o}.