CROWS NEST RESOURCES LTD.

TELKWA COAL PROJECT

STAGE II
GEOTECHNICAL, HYDROGEOLOGICAL & HYDROLOGICAL DESIGN REPORT

MARCH 1985

240
part 7

PA 1692 OH

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF
CONSULTING ENGINEERS

OUR FILE: PA 1692.OH

March 22, 1985

Crows Nest Resources Ltd.
Eau Claire Place
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Calgary, Alberta
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Mr. H.G. Rushton
Vice President Development

Telkwa Coal Project - Stage II
Geotechnical, Hydrogeological
and Hydrological Design Report

Dear Mr. Rushton:

We are pleased to submit four copies of our final report.

We have enjoyed working with you on this project and look forward to being of further service to Crows Nest Resources Ltd. in the future.

Yours very truly,

KLOHN LEONOFF LTD.

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
G. HARPER

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Manager, Mining Services

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part 7

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EXECUTIVE SUMMARY

INTRODUCTION

This report presents preliminary designs and geotechnical, hydrogeological and hydrological recommendations in support of a Stage II Permit Application for the Telkwa Coal Project.

The scope of work included the following:

- review of geological, hydrological and hydrogeological data
- geotechnical investigations
- groundwater investigations including packer permeability testing and installation of piezometers
- pit slope stability
- waste dump design
- design of tailings pond
- design of drainage ditches and settling ponds
- design of groundwater control measures
- presentation of designs and recommendations

Results of the data review and field investigations show that the project site comprises variable thicknesses of glacial till and gravel, overlying a sequence of sandstones, siltstones, mudstones and coal. The bedrock materials range from strong to very weak rocks. The mudstones are low to medium plastic.

The bedrock dips at 15°-20° to the east and is structurally dominated by a number of north-south trending reverse faults and normal faults which trend north-south and east-west.

The bedrock is generally of low permeability and contains no stratigraphically definable aquifers. The groundwater table is at or close to ground surface over much of the eastern part of the project site. Open or breccia filled fault zones are expected to be the only significant conductors of groundwater.

RECOMMENDED PRELIMINARY DESIGN

Pit Slopes

Pit slopes have only been considered for #3 Pit. The highwall is located on the east side of the pit and will trend north-south. Conditions for highwall stability are favourable as the major structural discontinuities, the north-south trending faults and the bedding planes both dip east. Highwall slopes up to 100 m high may be cut at an overall 60° angle. Locally, secondary faults may require flatter high wall angles over short sections.

Horizontal drains will be required to reduce groundwater pressures where the highwall is more than 50 m high.

The footwall will be parallel to the bedding planes and will dip at 20° to the east. To prevent instability, footwall strata should not be undercut. Pressure relief wells will be required in the footwall to reduce the risk of floor heave.

Overburden slopes in glacial till may be cut at 2H:1V.

Waste Dumps

Waste dumps will be constructed in out-of-pit and in-pit locations. Out-of-pit dumps may be constructed by end dumping in lifts. Lift thicknesses and berm widths should be adjusted to maintain an overall 2H:1V slope. Foundations should be stripped of topsoil and overwet materials. Uphill construction is recommended to minimize overburden stripping. Deleterious and sulphur rich materials may be placed in isolated cells within dumps to minimize the potential for acid drainage. These materials should be compacted in 1 m lifts.

In-pit dumps in #3 Pit should be constructed with north-south trending slopes dipping into the footwall at 1.6H:1V and east-west trending slopes at 2.25H:1V. All wet and loose material should be removed from the foundation area before construction.

Pit Dewatering

Groundwater inflows into the pits will be small with average flows of approximately 50 m^3/hour being expected. Short duration exceptional flows when fault zones are intersected may effectively double the inflow rate. Infiltration should be collected by means of ditches and sumps. Pumping capacity requirements will be dictated by inflows from direct precipitation. Average pumping requirements will range from 90 m^3/hr in year 1 to a maximum of 120 m^3/hr in years 19 and 20. Emergency pumping capacity will be required to handle major precipitation events. Water will require pumping to drainage ditches and passing through settlement ponds prior to discharge.

Surface Water Management

Head water diversions are recommended to divert all uncontaminated surface runoff from the up hill side of the mine area. The diversions are designed in accordance with the Ministry of Environment Regulations.

Interceptor ditches will minimize the contamination of surface water in the mine area and prevent release of untreated water to natural water courses. All contaminated water will be held in settlement ponds with sufficient detention time for suspended matter to be removed. Discharge points will be monitored to ensure that clarified water meets water quality standards.

Tailings Pond

Fine tailings from the wash plant will be stored in a tailings pond. Clarified water will be recycled to the plant for use as process water.

The dam will be constructed by the downstream method of mine waste rock and faced with glacial till and will have an ultimate height of 18 m.

A 6 m high starter dam will be constructed of glacial till.

Tailings will be discharged from the uphill end of the pond and clarified water will be reclaimed by a barge mounted pump.

Seepage through the pond floor will be minimized by the use of filters, and wells will be installed to monitor seepage from the pond.

RECOMMENDATIONS FOR FURTHER INVESTIGATION

The designs presented in this report are appropriate to the present stage of the project. Further work will be required during the detailed design phase of the project and some additional data collection will be required to confirm assumptions made during the Stage II preliminary design.

Hydrology

The level of data available is adequate for detailed design with the exception of monitoring data for Hubert Creek. A large proportion of the project site lies within the Hubert Creek catchment. It is recommended that concurrent precipitation and continuous stream flow monitoring be carried out for a minimum period of 1 year. The data will be used to determine the surface run off potential of the site and may result in more economic designs for the drainage system and settling ponds.

All existing stream gauging and climate monitoring should be continued.

Waste Dumps

The preliminary design for the proposed out-of-pit waste dumps are based on assumed foundation conditions. During the detailed design phase of the project site investigations should be carried out at the two out-of-pit waste dump sites to determine foundation conditions. The preliminary waste dump designs will be confirmed or modified as appropriate and the amount of overburden stripping determined.

Tailings Pond

Investigations should be carried out during the detailed design phase of the project to determine foundation conditions in order to confirm the preliminary tailings dam design.

In addition, design of a filter system will be required to control seepage from the pond and to prevent migration of fines into the gravel aquifer.

Groundwater

The groundwater monitoring currently in progress should be continued. Water quality sampling and testing programs should also be continued. Field pH measurements should be made on all water samples collected.

Plantsite and Rail Spur Foundations

Site investigations will be required at the detailed design stage to determine foundations conditions for the plant site and rail spur.

Make Up Water Intake

Site investigations will be required at the detailed design stage to determine design parameters for an infiltration gallery or well type make up water intake.

Haul Road Crossing for Goathorn Creek

Site investigations and hydraulic design will be required at the detailed design stage for a haul road crossing for Goathorn Creek.

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KLOHN LEONOFF

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1.0 INTRODUCTION

1.1 The Project

Crows Nest Resources Ltd. (CNRL) proposes to develop a coal mining operation near Telkwa, British Columbia. Plans call for the development of several open pit mines located both sides of Goathorn Creek, a tributary of the Telkwa River.

Based on current reserves the project will have a life of over 20 years at a production rate of 800,000 to 830,000 clean tonnes of coal per annum.

Six open pit mines will be developed. Pits No. 1, 2, 4, 5 and 6 will be small, typically 600 m x 600 m. The bulk of the reserves will be worked by #3 Pit, approximately 2800 m x 750 m located east of Goathorn Creek. Pit #3 will be worked throughout the life of the project and will be supplemented by production from the other pits worked in rotation.

During the early years of the project, rock waste will be placed in an out-of-pit dump. In later years the majority of the waste will be disposed of in in-pit dumps.

Run of mine coal will be processed in an on-site wash plant and the clean coal product will be transported by rail to Ridley Island.

Details of the location of the open pits, waste dumps, plant site, and sedimentation ponds are shown on Drawing D-0104.

1.2 The Assignment

Klohn Leonoff Ltd. were retained by CNRL to provide geotechnical, hydrological and hydrogeological consulting services with respect to the following aspects of the project:

- Groundwater and Pit Dewatering
- Site Drainage
- Surface Water Hydrology
- Sediment Pond Design
- Tailings Pond Design
- Process Water Supply
- Waste Dump Design
- Pit Slope Stability

This report discusses investigations carried out and presents designs in support of CNRL's application to Environment and Land Use Committee of B.C. for Stage II of the project assessment process.

There is a marked reduction in precipitation at lower elevations; the winter precipitation inferred from snow course surveys at 1480 m elevation on the east slope of Hudson Bay Mountain (located 14 km north of the minesite), is nearly 200% greater than precipitation precipitation measured at Smithers Airport which is located at the foot of the same mountain. The Telkwa and Bulkley Valleys, including the project site, are not subject to the high precipitation typical of maritime climates.

The climate at the minesite is considered to be similar to that at several nearby meteorologic stations in the Bulkley River Valley with long term records, as the temperature and precipitation records of these stations do not appear to differ significantly from the stations in the Telkwa River Valley, with only short term records.

2.2.2 Meteorologic Stations

There are numerous meteorologic recording stations in the Bulkley and Telkwa River Valleys near the project site, as shown on Drawing B-0105. Relevant details of these stations including period of record, elevation, aspect, recording agency and distance from the minesite, are given in Table 2-1.

Only the Telkwa River and the CNRL stations are located within the limits of the project site and its drainage area. However, their data alone are insufficient for establishing long term trends and extreme event projections, because the period of record is too short.

The CNRL station was installed in November, 1983 and is being operated in support of the Stage II mine development permit application. The precipitation data recorded at this station will be very useful during final design in conjunction with concurrent local stream flow data, for establishing rainfall-runoff relationships.

2.2.3 Precipitation

Precipitation Data

Precipitation data is available at all of the stations listed in Table 2-1. The short term stations located in the Telkwa River Valley were used to check for any obvious trends relative to the precipitation measured at several long term meteorologic stations in the Bulkley River Valley. Several other short term meteorologic stations located in the Bulkley Valley were included to assess the effects of elevation and slope on precipitation. Other long term stations in the Bulkley River Valley were used to assess variations in precipitation within the Bulkley Valley.

The Smithers Airport precipitation data was selected to represent the plantsite area and the lower minesite area because it is a principal meteorologic station incorporating a Knifer snow gauge to determine reliable winter precipitation records. Unlike the other long term stations, it is located on the west side of the Bulkley Valley and has a similar aspect and elevation to the minesite.

TABLE 2-1

INVENTORY OF WEATHER STATIONS

STATION	STA. NO.	TOTAL[1] RECORD YEARS	PERIOD YEAR	TYPE[2]			ELEV. m	AGENCY	DIST. FROM SITE km	ASPECT	LAT/LONG.
				P	PI	T					
1. Smithers	1077471	3	1945-48	X		X	497	AES	16	E	54° 47'/127° 10'
2. Smithers A	1077500	42	1942-83	X	X	X	524	AES	22	E	54° 49'/127° 11'
3. Smithers 4E	1077508	6	1969-75	X		X	578	AES	16	W	54° 47'/127° 05'
4. Smithers CDA	1077505/470	30	1938-68	X		X	515	AES	11	SW	54° 44'/127° 06'
5. Telkwa	1078070	46	1922-68	X		X	682	AES	16	SW	54° 39'/126° 50'
6. Telkwa Round Lake	1078080	1	1968-69	X		X	579	AES	12	SW	54° 41'/126° 55'
7. Telkwa Woodmore Rd.		2	1982-83					AES	-		
8. Telkwa Maclure Lake	1078074	11	1964-74	X			640	AES	12	SW	54° 44'/127° 01'
9. Topley Landing	1078209	22	1962-83		X		722	AES	64	E	54° 49'/126° 10'
10. Houston	1073612	4	1970-74	X		X	587	AES	45	N	54° 23'/126° 43'
11. Houston CDA	1073615	7	1957-64	X		X	585	AES	45	N	54° 23'/126° 40'
12. Quick	1076638	22	1962-83	X	X		533	AES	14	NE	54° 37'/126° 54'
13. Campfire	107260	3	1974-77	X			646	ASB	12	N	54 37 50/127 18 15
14. Gassy Jack	107259	3	1974-77	X			585	ASB	6	N	54 38 45/127 12 00
15. Telkwa R.	107146	3	1974-77	X		X	725	ASB	3	N	54 36 15/127 07 42
16. Bulkley 1500	107123	2	1967-69			X	466	ASB	14	W	54 45 19/127 07 25
17. Bulkley 1700	107124	2	1967-69	X		X	515	ASB	13	W	54 44 48/127 06 23
18. Bulkley 1900	107125	2	1967-69	X		X	595	ASB	14	W	54 45 23/127 05 17
19. Bulkley 2100	107126	2	1967-69	X		X	659	ASB	14	W	54 45 26/127 05 48
20. Coal Mine	107263	3	1974-77	X		X	508	ASB	6	N	54 41 10/127 04 55
21. Coal Mine 1	107147	1	1967-68	X			686	ASB	6	N	54 35 47/127 09 15
22. Webster	107145	1	1967-68	X			549	ASB	4	N	54 40 18/127 06 00
23. Windfield	107262	3	1974-77	X		X	1055	ASB	21	S	54 37 45/127 27 30
24. Washout	107261	3	1974-77	X			689	ASB	20	N	54 36 30/127 25 55
25. Kathlyn	107113	5	1967-69 1974-77	X		X	756	ASB	23	E	54 49 23/127 15 12

1 - Including years of missing data

2 - Type of weather station
P - records daily total precipitation
PI - records precipitation intensity
T - records temperature

Annual Precipitation

The mean annual precipitation at the northern part of the project site is estimated to be 510 mm based on a 42 year record at Smithers Airport. This compares with other nearby long term meteorologic stations in the Bulkley River Valley as noted below:

Station	Record (years)	Mean Annual Precipitation (mm)
Smithers Airport	42	509
Smithers 4E	7	435
Smithers CDA	30	485
Telkwa	46	431
Telkwa Maclure Lake	11	437
Houston CDA	7	478
Quick	18	472

This comparison shows little variation of mean annual precipitation in the vicinity of the project site.

As indicated in Table 2-1, there are several other short term stations in the Telkwa River Valley including the Telkwa River station located at the minesite. "Normalized" mean annual precipitation rates have been estimated for these stations by the Air Studies Branch (ASB) of the B.C. Ministry of the Environment, based on regression relationships with precipitation measured at Smithers Airport. The mean annual precipitation rate of 510 mm estimated above is somewhat higher than these normalized rates.

Precipitation records at Smithers Airport are higher than the concurrent precipitation recorded at the new on-site CNRL meteorologic station in 1984. However, the differences are not considered significant as the data collected at most of these stations is seasonal and the period of record is too short to provide reliable estimates of long term annual precipitation.

The Smithers precipitation data are representative of the northern half of the project site. Precipitation is probably somewhat greater at higher elevations in the southern half of the project site. The effect of elevation on summer precipitation is apparent on the east side of the Bulkley Valley where seasonal precipitation was measured at three 'Bulkley' stations at elevations 515 m, 595 m and 659 m. The seasonal precipitation at the highest station was 7% higher than the lowest station during the 1967 to 1969 period of record. That is equivalent to about 5% increase per 100 m of elevation.

The precipitation gradient is greater on the west side of the Bulkley River Valley at higher elevations due to spillover of Maritime air masses. A gradient of 10% increase in annual precipitation per 100 m rise in elevation is estimated for the project area.

Monthly Precipitation

The estimated monthly mean total precipitation and mean total rainfall at the plantsite and lower minesite are based on the record at Smithers Airport (1942 - 1983) and are presented below:

Month	Total Rainfall (mm)	Total Precipitation (mm)	Month	Total Rainfall (mm)	Total Precipitation (mm)
Jan	8.7	56.5	July	47.6	47.6
Feb	5.0	30.0	Aug	40.1	40.1
March	5.9	23.6	Sept	48.5	48.7
April	14.2	20.2	Oct	53.5	59.8
May	31.5	32.3	Nov	22.8	54.5
June	41.5	41.5	Dec	8.8	54.4

The estimated variation of monthly precipitation and monthly rainfall is illustrated on Drawing A-0106. The pattern of low precipitation in early spring and high precipitation in fall and early winter, is also exhibited at all of the other local year-round meteorologic stations. As illustrated on Drawing A-0106, April is the driest month and October, November, December and January are the wettest months.

Rainfall Intensity

Extremes of high intensity rainfall were estimated for the project site based on the Smithers Airport data as follows:

Duration	Mean Annual (mm)	10 Year Peak (mm)	200 Year (mm)
5 min	2.8	5.6	11
10 min	4.3	9.0	17
15 min	5.0	9.9	18
30 min	6.8	12	22
1 hour	9.1	16	29
2 hours	12	21	36
6 hours	18	29	48
12 hours	22	35	58
24 hours	27	43	71

The Modified Gumbel method was used to compute the return periods using the 24 hr. rainfall data. The resulting frequency curve is shown on Drawing A-0107.

The shorter duration rainfall intensities were determined from the Intensity-Duration-Frequency (IDF) curves given on Drawing A-0108. The curves are based on IDF curves provided by the Environment Canada Atmospheric Environment Service (AES), adjusted to account for 24 hour precipitation.

The design 24 hour peak annual rainfall rates given above are similar to the rates calculated for other meteorologic stations in the region as noted below.

Station	Record (Years)	Elev. (m)	Mean Annual (mm)	10 Year Peak (mm)	200 Year Peak (mm)
Smithers Airport	42	524	27	43	71
Smithers CDA	30	515	28	43	71
Quick	20	533	26	43	72
Telkwa	46	682	25	40	69
Telkwa-Maclure	10	640	29	47	77

No adjustment is made for change in elevation because short duration thunderstorm rainfall intensity is relatively independant of orographic effects. High intensity rainfall is most likely to occur in summer from June to October.

Snow

The estimated monthly snowfall is based on the Smithers Airport data and is shown on Drawing A-0106. The Smithers Airport records are considered representative of the northern half of the project site. Snowfall is expected to be somewhat greater on the southern half of the project site which extends to 860 m elevation, and the upstream catchment area which extends to 1220 m elevation.

The mean annual snowfall at Smithers airport is 180 mm (equivalent water depth) which accounts for 35% of the mean annual total precipitation.

There are no snow course survey stations at the project site. Near by data is available from Smithers Airport (Elev. 500 m) and Hudson Bay Mountain (Elev. 1480 m). The Smithers Airport data are probably representative of the northern part of the project site but are of too short a duration to be of value. The Hudson Bay Mountain Station is at too high an elevation to be representatiove of the project site. Snow course data have not been used for design purposes.

2.2.4 Temperature

Monthly Temperatures

The temperatures at the project site are highly dependant on elevation. The Smithers Airport data recorded at 525 m elevation are considered to be applicable to the northern part of the project site where elevations range from 540 m to 560 m. The short term Telkwa River data recorded at 725 m elevation is applicable to the mid-elevation project site area.

Relevant monthly temperature statistics for these reference meteorologic stations are given in Table 2-2. As indicated on the table, temperatures at Telkwa River are about 2°C lower, on average, than temperatures at Smithers Airport.

2.2.5 Evaporation

Data

In the absence of representative pan evaporation data at nearby meterorological stations, lake evaporation has been estimated using a Thornthwaite Climatic Water Balance Analysis based on Smithers Airport temperature data. The estimated annual total lake evaporation is 550 mm which is considered representative of the northern part of the project site. The annual distribution is as follows.

Period	Lake Evaporation (mm)
Nov-Apr	52
May	77
June	107
July	123
Aug	104
Sept	62
Oct	28
TOTAL	553

TABLE 2-2

MONTHLY TEMPERATURE STATISTICS

SMITHERS AIRPORT AND TELKWA RIVER METEOROLOGIC STATIONS

°C

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
DAILY MAXIMUM													
Smithers Airport	-6.8	-0.4	3.9	9.9	15.4	18.9	21.3	20.6	15.7	9.0	0.8	-3.9	8.7
Telkwa River	-9.7	-3.0	1.5	8.0	13.8	17.5	20.1	19.3	14.1	6.8	-1.7	-6.8	6.6
DAILY MINIMUM													
Smithers Airport	-15.1	-10.1	-6.4	-1.7	2.5	6.0	8.1	7.6	4.0	0.5	-5.5	-11.2	-1.8
Telkwa River	-16.6	-11.7	-8.2	-3.6	0.3	3.7	5.8	5.3	1.8	-1.5	-7.3	-12.9	-3.7
DAILY MEAN													
Smithers Airport	-10.9	-5.3	-1.3	4.2	9.0	12.5	14.7	14.1	9.8	4.7	-2.3	-7.6	3.5
Telkwa River	-13.1	-7.4	-3.3	2.2	7.1	10.6	13.0	12.3	8.0	2.6	-4.5	-9.8	1.4
EXTREMES OF RECORD AT SMITHERS AIRPORT													
Maximum	15.6	11.7	15.6	24.3	31.1	33.9	34.4	33.9	30.6	22.2	15.6	11.5	34.4
Minimum	-43.9	-35.6	-33.3	-18.3	-7.2	-2.2	-1.1	-2.2	-6.7	-15.6	-31.7	-36.7	-43.9

SOURCE:	Atmospheric Environment Service Air Studies Branch	Smithers Airport Telkwa River	1942-1983 1967-1977, normalized to Smithers Airport

2.2.6 Wind

Smithers Airport is the only meteorologic station in the vicinity which records wind speeds. A detailed statistical breakdown of data from this station is presented in the Stage I submission for the project.

Wind speeds and wind direction at the project site may be somewhat different from those recorded at Smithers Airport because of differences in local topography and aspect. However, wind speeds at the project site and the Airport are expected to be similar as they are caused by the same weather systems.

A statistical analysis of peak annual wind speeds was carried out for purposes of estimating wave height and wave runup at the proposed tailings pond and settling ponds. Maximum annual 1 hour wind speeds were used to estimate the following wind speeds by Modified Gumbel frequency distribution.

Recurrence Interval (years)	Peak Annual 1 Hr. Wind Speed (km/hr)
mean	50
10	61
50	72
100	76
200	80

2.3 Surface Water Hydrology

2.3.1 General

Section 2.3 addresses the surface hydrology of the project site, the impact of the mine on the existing fluvial system and the derivation of hydrologic parameters for design of the mine and plant facilities.

Details of the regional hydrologic setting, watershed morphometry, low flow conditions, flood hazard assessments and flood flow characteristics of nearby rivers and creeks are presented in "Hydrology Component - Stage I Studies" dated September 1983, prepared by M. Miles and Associates Ltd. for Crows Nest Resources Ltd. Project site specific parameters presented below were derived by Klohn Leonoff Ltd.

2.3.2 Local and Regional Drainage

Local and regional watersheds are shown on Drawing D-0109. As shown, the plantsite and part of the minesite presently drains into Hubert Creek which is a small tributary of the Bulkley River. Part of the minesite drains directly into the Telkwa River several kilometres upstream of its confluence with the Bulkley River. The remainder drains into the lower reaches of Goathorn Creek, near its confluence with the Telkwa River.

Runoff from the project site flows to the Bulkley River via Hubert Creek and Telkwa River. The drainage area of the Bulkley River upstream of its confluence with the Telkwa River is about 7500 km^2 comprising mountainous terrain of the eastern Coast Mountains.

The Telkwa River drains 1200 km^2 of mountainous terrain in the Bulkley Range of the eastern Coast Mountains. The drainage area includes the north slopes of the Telkwa Range, the south slopes of the Hudson Bay Range and the east slopes of the Howson Range. The headwater areas are relatively steep with numerous glaciers occuring above elevations 1800 m.

The Goathorn Creek drainage area covers 132 km^2 comprising the northeast slopes of the Telkwa Range. Like the Telkwa River Basin, elevations range from 515 m to over 2300 m, with several north facing glaciers occuring at the steep headwater areas. Tributary creeks include Tenas Creek (63 km^2), Four Creek (18 km^2) and Cabinet Creek (55 km^2).

The Hubert Creek drainage basin is located east of the Goathorn Creek drainage basin and drains 44 km^2 of the lower northeast slopes of the Telkwa Range. Elevations range from 515 m to 1400 m. Unlike the Telkwa River and Goathorn Creek basins, the drainage area comprises relatively gentle slopes.

2.3.3 Streamflow Data

The Water Survey of Canada (WSC), lists 32 active and inactive stream gauging stations within a 40 km radius of the project site. Table 2-3 provides a list of these stations indicating the WSC station number, period of record, catchment area, proximity to the site and the latitude and longitude. The locations of stations with more than 5 years of records are shown on Drawing B-0110.

CNRL have installed a number of water quality monitoring stations near the site and are periodically measuring stream discharge at four of these stations, including Tenas Creek, Four Creek, Cabinet Creek and Hubert Creek. However the periodic discharge data are not suitable for hydrologic analysis because continuous streamflow monitoring is required to measure the highly variable discharge on creeks of such small size.

TABLE 2-3

INVENTORY OF STREAM GAUGING STATIONS

STATION	STA. NO.	RECORD YEARS	PERIOD YEARS	CATCHMENT AREA km^2	DIST. FROM SITE km	LAT/LONG
Bulkley R. nr. Hazelton	08EE 001	23	1915-16, 28-52	12300	74	55.15.32/127.36.10
Bulkley R. nr. Hubert	" 002	2	1915, 16	7490	10	54.38.55/126.58.25
Bulkley R. nr. Houston	" 003	23	1930-82	2380	39	54.23.45/126.42.30
Bulkley R. at Quick	" 004	51	1930-82	7360	15	54.37.05/126.53.55
Bulkley R. nr.Smithers	" 005	8	1915, 46-52, 71	8940	15	54.46.58/127.07.59
John Brow Cr. nr. Smithers	" 006	2	1947-49	79	42	55.00.37/127.19.58
Hospital Cr. nr Hazelton	" 007	1	1948-49		75	55.15.16/127.39.04
Goathorn Cr.	" 008	22	1960-82	132	at site	54.38.50/127.07.20
Richfield Cr.	" 009	9	1964-74	173	53	54.30.59/126.20.04
Kathlyn Cr.	" 010	12	1967-79	24.6	19	54.48.45/127.12.05
Kathlyn Lk.	" 011	10	1968, 71-80	-	19	54.49.03/127.11.55
Simpson Cr.	" 012	10	1969-71, 74-82	13.2	19	54.48.36/127.12.09
Buck Cr.	08EE 013	9	1973-82	580	41	54.23.52/126.39.04
Canyon Cr.	" 014	9	1973-82	256	18	54.48.26/127.07.49
Foxy Cr.	" 015	1	1974/75	16.1	74	54.12.46/126.15.30
Lu Cr.	" 016	1	1974/75	7.25	74	54.12.29/126.15.53
Waterfall Cr.	" 017	1	1974/75	-	73	55.14.45/127.35.26
Maxan Cr. above Bulkey Lk.	" 018	5	1974-79	368	69	54.21.25/126.10.12
Maxan Cr. at outlet Maxan Lk.	" 019	2	1974-76	246	74	54.19.10/126.06.59
Telkwa R.	" 020	7	1975-82	368	25	54.36.10/127.29.42
Cygnet Cr. at Adams Rd.	" 021	1	1978 R	10.4	22	54.50.54/127.04.34
Deep Cr.	" 022	1	1978-79 R	89.9	20	54.35.32/126.50.03
McKinnon Cr.	" 023	1	1978-79	-	18	54.47.59/127.13.19
Cygnet Cr. above Diversion	" 024	1	1979	6.73	23	54.51.05/127.04.22
Nanika R.	08ED 001	12	1950-52, 72-82	741	82	53.55.50/127.27.10
Morice R. nr. Houston	" 002	22	1929, 61-82	1910	62	54.07.05/127.25.26
Morice R. at Mouth	" 003	1	1971	4270	38	54.22.56/126.44.24
Fulton R. at Mouth	08EC 002	26	1929, 45-70	1400	64	54.48.50/126.10.15
Pinkut Cr.	" 004	22	1929, 61-82	862	113	54.24.52/125.25.26
Fulton R. at Fulton Lk. Narrows	" 005	3	1960-63	1340	56	54.48.25/126.18.00
Morrison R.	" 008	5	1965-70	414	79	55.10.20/126.18.10
Fulton R. at Outlet Channel Man Lake	" 009	3	1967-70	332	41	54.54.00/126.39.00

Stations located on the rivers or creeks affected by the project include the following:

Creek/River	Sta. No.	Record (yrs.)	Catchment Area (km^2)
Goathorn Creek	08EE 008	22	132
Telkwa River	08EE 020	7	368
Bulkley River	08EE 004	51	12,300

The station on Goathorn Creek is located within the project area. Flow data is therefore directly applicable to the reach of river through the project site.

The station on the Telkwa River is located just below Tsai Creek and measures discharge from 30 percent of the entire Telkwa River Basin. The Telkwa River data could therefore not be applied directly to the lower reach at the mouth of Goathorn Creek as its catchment is located much further west of the project site and is mainly at high elevation. About 50% of the catchment exceeds 1500 m elevation.

The station on the Bulkley River is located at Quick about 10 km upstream of the mouth of Hubert Creek and about 14 km upstream of the mouth of Telkwa River.

2.3.4 Annual Runoff

Mean Annual Runoff

Mean annual runoff per unit area varies significantly in the region. Higher runoff occurs at higher elevation, in drainage basins located at the western side of the region and in drainage basins with soil conditions which inhibit infiltration. Low runoff occurs in drainage basins at lower elevations, to the east of the region with permeable soils.

Eleven local gauged drainage basins with long periods of record have been compared as follows:

Drainage Basin	Elevation High-Medium-Low	Location East-Central-West of minesite	Mean Annual Runoff (mm)
Bulkley River @ Quick	H	C	584
Simpson Creek	H	C	609
Kathlyn Creek	H	C	277
Nanika River	H	W	1182
Morice River	H	W	1238
Telkwa River	H	C	1203
Goathorn Creek	H	C	425
Canyon Creek	M	C	264
Richfield Creek	L	E	241
Pincut Creek	L	E	200

The project site is located in the lower part of Goathorn Creek at generally low elevation (610 - 915 m). At low elevations the runoff is expected to be considerably less than that gauged for the whole of the Goathorn Creek and is expected to be similar to the runoff gauged at the other low and medium elevation catchments, Canyon Creek, Richfield Creek and Pincut Creek. The overall gradient of the project site is approximately 1:16 which is similar to Richfield and Canyon Creeks but considerably flatter than the overall gradient for Goathorn Creek. The southern half of the project site is covered by till and is estimated to have a mean annual runoff of 250 mm, similar to Richfield and Canyon Creeks. The northern half of the project site is overlain by highly pervious gravel and sands and is estimated to have a mean annual runoff of 150 mm.

Annual Runoff Variations

Runoff yield on the Goathorn Creek basin has ranged from 326 mm to 595 mm over a period of 22 years of record.

Extreme wet year total annual runoff has been estimated for the plantsite and minesite based on a statistical analysis of the Goathorn Creek annual runoff data, assuming that runoff variation at the minesite and plantsite would be proportional to that of the gauged Goathorn Creek Basin. The results of this analysis follow:

Condition	Annual Runoff (mm)		
	Goathorn Ck.	Plantsite Area	Upper Minesite Area
Mean	425	150	250
10 Year Wet	525	190	310
50 Year Wet	620	220	365
100 Year Wet	660	230	385
200 Year Wet	700	250	410

Seasonal Variation in Runoff

The seasonal variations in runoff on the Bulkley River near Quick, Telkwa River below Tsai Creek, and Goathorn Creek are shown on Drawing B-0111. Peak monthly discharge occurs in May on Goathorn Creek; May and June on the Bulkley River; and in June and July on the gauged upper Telkwa River basin.

The mean annual seasonal variation in runoff from the project site has been estimated based on monthly runoff measured on Richfield Creek and the results are shown on Drawing B-0111. The headwater area of Richfield Creek is at lower elevation than the headwater areas of Goathorn Creek but somewhat higher than the minesite catchment. Maximum monthly discharge is expected to occur in May. The mean monthly discharge in May is about 50% of the mean annual discharge.

2.3.5 Flood Discharge

Flood runoff on the Bulkley River near Telkwa is controlled by snowmelt. Maximum daily, and peak instantaneous discharges are caused by snowmelt or by snowmelt combined with rain.

The Goathorn Creek drainage basin is smaller and steeper than that of the Bulkley River and is more prone to peak floods caused by rainstorms. However, like the Bulkley River the more extreme floods occur during snowmelt.

The upper Telkwa River basin is at relatively high elevation and has steep slopes. This area is subject to heavy precipitation, consequently the flood peaks on the upper Telkwa River basin are dominated by rainfall runoff, producing much greater extreme flood peaks than snowmelt. Though the lower Telkwa River is not gauged, it is expected that the annual flood peaks would be caused by either rainstorms or snowmelt because the total Telkwa River Basin, like Goathorn Creek, is composed of both high elevation headwaters and lower elevation areas with flatter slopes.

Annual Maximum Daily Discharge

A frequency analysis of annual maximum daily discharges was carried out for 10 selected basins with eight or more years of stream flow data. The Modified Gumbel Distribution which includes an upward adjustment for small sample size, was utilized for this analysis.

Frequency analyses of flood data on selected gauged creeks and rivers were carried out for both rainfall floods and snowmelt floods. The results in terms of discharge per unit area are given on Table 2-4.

TABLE 2-4

FREQUENCY OF SNOWMELT AND RAINSTORM FLOODS

River Basin*	Drainage Area km^2	Annual Maximum Daily Discharge (m^3/s) Snowmelt Flood Mean	10 Year	200 Year	Rainstorm Flood Mean	10 Year	200 Year
Goathorn Cr.	132	13.9	25.1	44.9	9.2	16.0	28.5
Telkwa R.	368	71.0	105.0	165.0	67.1	158.0	308.0
Richfield Cr.	173	14.4	24.2	41.1	3.4	8.2	16.4
Simpson Cr.	13.2	1.9	2.8	4.4	1.2	2.1	3.8
Buck Cr.	580	49.9	75.4	121.0	6.2	12.0	22.0
Canyon Cr.	256	19.5	30.2	48.6	5.3	9.0	15.3
Kathlyn Cr.	24.6	0.9	1.4	2.3	0.7	1.1	1.9
Nanika R.	741	115.0	156.0	230.0	112.0	215.0	392.0
Bulkley R.	7360	581.0	802.0	1180.0	-	-	-
Pinkut Cr.	862	39.7	68.1	118.0	-	-	-

* Upstream of stream gauging station.
See Drawing B-0110 and Table 2-3.

The snowmelt discharges of Table 2-4 were divided into three groups; high elevation basins with steep topography located west of the site, lower elevation basins with gentle slopes located east of the high Coast Mountain Range and those basins whose catchment included both high and low elevations areas. The mean, 10 year and 200 year annual maximum daily discharges per unit area are shown on Drawings A-0112.

Drawing A-0015 shows the estimated 200 year annual maximum daily rainfall flood discharge variation with basin area. The best fit lines representing the high and low elevation basins are much steeper than those for the mean, 10 year and 100 year return periods reflecting the effect of local high intensity rainfall on small areas. As indicated on Drawing A-0115 the daily rainfall flood discharge potential on the lower elevation basins is much less than that of the high elevation basins. The daily snowmelt flood discharge potential falls between these limits.

The project catchments are like the other lower elevation basins with respect to elevation, topography and location however, the project catchments have a small elevation range resulting in a greater annual maximum daily snowmelt discharge per unit area. The annual maximum daily snowmelt flood discharges for the project site, as shown on Drawing A-0112, A-0113 and A-0114 are therefore assumed to be 50% greater than that of the other low elevation basins to account for the smaller elevation range.

The resulting design annual maximum daily discharges for several catchment sizes at the project site, are indicated below:

Catchment Area (km^2)	Annual Maximum Daily Discharge (m^3/s)		
	Mean	10 Year	200 Year
1	0.17	0.26	0.41
2	0.33	0.50	0.79
5	0.78	1.20	1.90
10	1.50	2.30	3.62

Annual Maximum Peak Instantaneous Discharge

Peak instantaneous discharges are required for design of diversions, inteceptor ditches and flow control structures because these flows may be significantly higher than mean daily discharges.

On large river basins such as the Bulkley River which are dominated by snowmelt floods, peak flood discharges are nearly equal to the respective daily river discharges.

Smaller basins such as Goathorn Creek and Telkwa River respond more quickly to rainstorms and variations in the rate of snowmelt. As a result, peak instantaneous discharges are significantly greater than mean daily discharges.

Rainfall flood peaks on small watersheds are highly dependant on shape of catchment, channel gradients, topography, vegetation cover rainfall intensity and rainfall time distribution. Rainfall flood peaks cannot therefore be reliably estimated by regional analysis of other larger drainage basins. Peak instantaneous discharges were estimated by the U.S. Soil Conservation Service (SCS) curve number method. A curve number of 70 was selected based on a calibration of the rainfall/runoff model using other nearby gauged drainage basins. The results of this analysis for the 10 and 200 year recurrence rainstorms are given on Drawing A-0116.

Peak instantaneous snowmelt flood peaks for the project site catchments were estimated by factoring upward the projected maximum daily snowmelt discharges given on Drawings A-0112, A-0113 and A-0114. The results are given on Drawing A-0117. The factors were determined by analysis of the annual maximum daily and annual peak instantaneous snowmelt discharge of several local gauged watersheds. The ratio of extreme peak instantaneous snowmelt flood discharge to extreme maximum daily discharge, for equal recurrence intervals, was plotted in terms of basin area. A best fit line was drawn to extrapolate the ratio to the smaller project catchment areas.

The peak instanteaneous discharges computed for Goathorn Creek are of interest for design of a mine haul road crossing on Goathorn Creek. Extreme peak instantaneous discharges were estimated by the Gumbel frequency distribution using annual peak instantaneous snowmelt discharges. The results of this analysis follow.

Recurrence Interval	Peak Instantaneous Discharge (m^3/s)
Mean Annual	19
10 Year	33
50 Year	48
100 Year	53
200 Year	60

2.3.6 Flood Hazard Assessment

A flood hazard assessment by flood plain mapping was carried out by Environmental and Planning Associates, for the Stage I Application.

Except for one river crossing on Goathorn Creek and a water intake on the Telkwa River, mine facilities will not be located on any of the areas classified as having even rare flood occurrances. Flood protection of the river crossing and the water intake are discussed in Sections 5.3.3 and 5.2.5 which deal with the design of these facilities.

2.3.7 Low Flow Conditions

A regional analysis of low flow on the major rivers and creeks near the project site was carried out in 1983 by the Hydrology Section, Water Management Branch, British Columbia Ministry of Environment. Table 2-5 presents the results of that study applied to the three main rivers and creeks near the project site. Minimum measured daily discharge data are also included in Table 2-5.

2.3.8 Ice Conditions

WSC stream gauging records show that ice forms on Goathorn Creek in October or early November and breaks up in April or early May. Ice forms on the Telkwa River at the gauging station below Tsai Creek in late November or December and generaly breaks up in February or March. WSC personnel report that river ice forms to a maximum thickness of about 0.8 m.

Maximum ice thicknesses on small lakes such as the proposed tailings pond and settling ponds are expected to range from 0.8 m to 1.2 m, depending on the snow cover.

TABLE 2-5

FREQUENCY ANALYSIS OF MINIMUM 7-DAY AVERAGE DISCHARGE

River/Creek	W.S.C. Station No.	Drainage Area (km^2)	Period of Record	Length of Record (years)	Minimum Observed Daily Discharge (m^3/s)	Minimum 7-day Average Discharge (m^3/s) for Specific Return Periods					
						*	2 years	10 years	20 years	30 years	50 years
Bulkley River at Quick	08EE004	7,360	1931-83	38	10.5	1	86.0	64.9	60.2	57.9	55.4
						2	22.8	13.7	11.9	11.1	10.1
Telkwa River Below Tsai Creek	08EE020	368	1976-83	6	0.68	1	10.3	6.32	-	-	-
						2	1.62	0.874	-	-	-
Goathorn Creek near Telkwa	08EE008	132	1960-83	21	0.066	1	0.867	0.531	0.457	0.421	0.382
						2	0.145	0.073	0.057	0.050	0.041

Note: * Analysis based on the period:
1. August to September,
2. November to April.

2.3.9 Existing Hydrologic Balance

The existing average annual hydrologic balance conditions at the proposed plantsite (Elev. 550 m) and at the proposed upper minesite (Elev. 850 m) have been estimated based on the design climatic and hydrologic parameters presented previously in this report. The results are given below:

Elevation m	Precipitation mm	Evapotranspiration (mm)	Groundwater Inflow mm	Runoff mm
550	510	355	5.	150
850	660	403	7.	250

The estimated evapotranspiration of 355 mm to 403 mm compares with the potential evapotranspiration of about 560 mm.

3.0 GEOLOGICAL AND GEOTECHNICAL INVESTIGATIONS

3.1 Geology of Project Site

3.1.1 Bedrock Stratigraphy

The Telkwa coal leases comprise a triangular shaped area approximately 5 x 9 km in the valley of Goathorn Creek near its confluence with the Telkwa River.

The lease area occupies an outlier of the Skeena Group of lower Cretaceous age and comprises a typical coal bearing sequence of siltstone, mudstone, sandstone, shale and coal. Sporadic volcanic activity occurred throughout the period of deposition of the Skeena Group and thin bands of volcanic tuffs are found within the sediments.

The sedimentary coal bearing sequence is underlain by an undifferentiated group of volcanic rocks known as the Hazelton group. This group comprises andesite, trachyte and basalt with associated tuffs and breccias. The volcanic rocks outcrop to the south east and south west of the lease area. The northern margin of the lease area is marked by late Cretaceous age intrusive igneous rocks.

3.1.2 Structural Geology

Faulting

The project area is situated on the Skeena Arch which trends northeast - southwest and separates the Jurassic age sedimentary rocks of the Bowser basin in the north and the Nechako basin to the south. Published reports indicated that major valleys such as the Bulkley River valley lie along fault zones.

The project area is dominated by a series of sub-parallel north-south trending reverse faults which dip to the east. The structure is further complicated by a number of normal faults some of which trend north-south and some east-west.

Bedding and Joint Patterns

Average bed dip and dip direction has been measured down the drill holes and these data are summarized below:

Discontinunity Set	Dip Angle	Dip Direction
Bedding Planes	20° ± 10°	065° ± 25°
Joint Set A	34°	258° ± 20°
Joint Set B	50° ± 5°	085° ± 10°
Joint Set C	50° ± 5°	135° ± 5°

The average dip angle for the project site is 20° with variability of ±10° between drillholes. Inspection of the CNRL logs shows that there is little variation in dip down individual drillholes due to drag folding, although isolated occurences of drag folding have been found.

3.1.3 Surficial Deposits

Bedrock at the project site is overlain by variable thicknesses of glacial till and outwash gravels.

The till occurs in the southern part of the project site on the higher elevation ground and varies from 0 - 10 m in thickness. In the valleys of the major creeks, till deposits up to 20 m have been observed. The till comprises a silt with some clay, a little sand and a trace of gravel. The material is low to medium plastic and dense. The till is interbedded with sand and gravel deposits.

The northern part of the project site, near the proposed tailings pond and wash plant sites, is underlain by outwash sand and gravel deposits up to 20 m thick.

3.2 Field and Laboratory Investigations

3.2.1 General

More than 200 test holes have been drilled by CNRL for the purposes of evaluating coal reserves. Approximately 190 of the test holes were fully cored, the remainder being drilled with a tricone bit and cored through the coal zones. All test holes were geophysically logged with a variety of tools including Gamma Ray, Long Spaced Density, Caliper Multi-Channel Sonic, Neutron-Neutron and Dipmeter. All test holes were lithologically logged by CNRL geologists. Some geotechnical data were collected by CNRL geologists and are stored in computer file form.

During the 1982 and 1983 field seasons, selected test holes were used for detailed geotechnical and hydrogeological investigations. The test holes used and the data collected are summarized in Table 3-1. The locations of the test holes are shown on Drawing D-0118.

As part of the 1983 investigation program, two large test pits were excavated in order to collect bulk samples of coal from several seams. One of the test pits was inspected by a Klohn Leonoff geological engineer. The locations of the test pits are shown on Drawing D-0018.

3.2.2 Investigation of Overburden Materials

Samples of glacial overburden materials were collected from test holes 255, 256, 257, 259 and 261. Locations of the test holes are shown on Drawing D-0018. Test hole logs are presented in Appendix I.

Test holes were drilled through the overburden using a tricone bit; samples were taken at 3.0 m intervals using an open tube drive sampler with a drop hammer. The overburden proved to be dense and considerable difficulty was experienced in obtaining samples. The disturbed samples obtained by this method were sealed to preserve the moisture content and transported to the laboratory.

3.2.3 Investigation of Bedrock Materials

Test holes 335 and 336 were drilled during the 1983 field season under the supervision of Klohn Leonoff engineers. The test holes were drilled using a rotary coring rig equipped with wire line tools and water circulation.

TABLE 3-1

SUMMARY OF GEOTECHNICAL AND HYDROGEOLOGICAL TEST HOLES

Year	Test Holes	Data Collected
1982	255	Overburden materials sampled, packer tests in coal seams, piezometer installed.
	256	As above.
	257	As above.
	259	Overburden material sampled.
	261	Overburden material sampled.
	258	Packer permeability tests in coal piezometer installed.
	265	As above.
1983	335	Bedrock core logged and sampled. Packer permeability tests on continuous basis and piezometers installed.
	336	Bedrock core logged and sampled. Packer permeability tests carried out.
	312	Piezometer installed (by CNRL).
	313	As above.
	318	As above.
	323	As above.
	325	As above.
	342	As above.
	343	As above.
	344	As above.
	345	As above.
	347	As above.
1984	406	As above.
	410	As above.
	412	As above.

The test holes were advanced through the unconsolidated overburden material using a tricone bit. Steel casing was set to the top of the bedrock. The test holes were drilled in bedrock using an HQ double tube barrel with a diamond bit.

Continuous core was obtained from test holes 335 and 336 was logged on site by Klohn Leonoff geological engineers. Point load index tests were carried out on selected core samples and representative samples of core were shipped to the laboratory for testing. The test hole locations are shown on Drawing D-0118 and the logs and Point Load Index test results are presented in Appendix I.

Several additional test holes were geotechnically logged by CNRL staff and these data are available on computer file. Additional core samples were taken from other test holes drilled during the 1982, 1983 and 1984 investigations for laboratory testing purposes.

3.2.4 Investigation of Bedrock Permeability

Bedrock permeability was investigated during the 1982 and 1983 investigations.

In 1982 falling head permeability tests were carried out in standpipe piezometers installed in selected coal horizons in test holes 255, 256, 257, 258 and 265. Details of piezometer completions are presented in Appendix II. Each piezometer was developed and falling head tests were carried out to determine the permeability of the response zone. The results of the permeability tests are summarized in Table 3-2.

In addition, seven through the bit packer permeability tests were carried out in test holes 255 and 258 in order to determine permeability in selected coal horizons. During the 1983 investigation, additional packer permeability testing was carried out. Continuous profiles of packer tests were carried out in test holes 335 and 336 to provide information on the mass permeability of coal and interburden bedrock materials. Results of the packer tests are summarized in Table 3-2. Details of the test procedures and detailed test results are presented in Appendix II.

3.2.5 Test Pit Program

A test pit was excavated by CNRL during the 1983 exploration program to collect bulk samples of coal from the major seams and to investigate the rippability of the bedrock.

The test pit was approximately 600 m long, 30 m wide and up to 30 m in depth located as shown on Drawing D-0118. The test pit was excavated from east to west i.e. up dip, and was formed at lower elevations as two pits; the east pit recovering coal from #7 seam and above, the west pit recovering from #6 seam and below.

Slopes in glacial overburden were cut at 2H:1V and were observed to be stable although the unprotected till was eroding badly from rainfall.

Bedrock slopes were cut at 30° to 75° to the horizontal, and ranged from 10 m to 30 m high. Slopes at the eastern end of the test pit were cut in highly weathered mudstone and were standing at 30°. At this location the apparent dip of the bedding was 18° into the pit. Slopes were steeper at the western end of the test pit and were standing at 55° to 60°. The bedrock at the western end of the pit was lower in the sequence and generally moderately weathered.

Bedding dip and dip direction were measured at eight locations on the north and south walls of the test pits and are as follows:

Discontinuity Set	Dip Angle	Dip Direction
Bedding Planes	14° ± 10°	50° ± 20°
Joint Set A	62° ± 20°	212° ± 20°
Joint Set B	84° ± 5°	122° ± 20°

TABLE 3-2

PERMEABILITY TEST RESULTS

Drill Hole	Test Section	Test Type	Material	Coefficient of Permeability (k) m/sec
255	91.7 - 93.9	Packer	Coal	5×10^{-7}
255	107.9 - 110.3	Packer	Coal	6×10^{-7}
255	114.9 - 121.0	Packer	Coal	2×10^{-8}
255	138.4 - 139.9	Piezometer	Coal	3×10^{-8}
256	157.9 - 159.4	Piezometer	Siltstone	7×10^{-9}
257	28.8 - 31.1	Piezometer	Coal	3×10^{-8}
258	44.5 - 46.3	Piezometer	Coal	5×10^{-9}
258	45.7 - 48.0	Packer	Coal	6×10^{-8}
258	50.6 - 52.9	Packer	Coal	7×10^{-9}
258	64.3 - 69.2	Packer	Coal	2×10^{-8}
258	114.9 - 121.0	Packer	Coal	2×10^{-8}
335	10.7 - 14.3	Packer	Coal/Mudstone/ Sandstone	4×10^{-7}
335	17.0 - 20.4	Packer	Coal/Mudstone	8×10^{-8}
335	21.9 - 23.0	Packer	Siltstone	2×10^{-7}
335	27.6 - 32.6	Packer	Mudstone/Siltstone	6×10^{-9}
335	32.1 - 38.7	Packer	Mudstone/Siltstone	5×10^{-7}
335	38.2 - 44.8	Packer	Mudstone	1×10^{-10}
335	41.3 - 44.8	Packer	Mudstone/Coal	1×10^{-10}
335	48.9 - 50.9	Packer	Mudstone/Coal	1×10^{-10}
335	50.9 - 57.1	Packer	Mudstone	1×10^{-10}
335	57.1 - 62.1	Packer	Mudstone/Coal	1×10^{-7}
335	67.2 - 72.2	Packer	Siltstone	1×10^{-10}
335	73.2 - 81.4	Packer	Siltstone/Mudstone	1×10^{-10}
335	85.5 - 91.4	Packer	Coal	2×10^{-8}
335	92.5 - 96.6	Packer	Mudstone	1×10^{-10}
335	96.2 - 102.7	Packer	Mudstone/Coal	1×10^{-10}
335	102.3 - 108.8	Packer	Siltstone	1×10^{-10}
335	108.4 - 114.9	Packer	Siltstone	1×10^{-10}
335	114.5 - 121.0	Packer	Sandstone	1×10^{-10}
336	9.1 - 14.0	Packer	Mudstone	1×10^{-10}
336	17.0 - 20.4	Packer	Mudstone	1×10^{-10}
336	20.1 - 26.5	Packer	Siltstone	1×10^{-10}
336	26.1 - 32.6	Packer	Mudstone	1×10^{-10}
336	32.2 - 38.7	Packer	Siltstone	1×10^{-10}
336	38.2 - 44.8	Packer	Siltstone	1×10^{-10}
336	44.4 - 50.9	Packer	Siltstone	1×10^{-10}
336	50.4 - 57.0	Packer	Siltstone	1×10^{-10}
336	56.5 - 63.0	Packer	Siltstone/Mudstone	1×10^{-10}
336	63.6 - 69.8	Packer	Coal/Mudstone/ Sandstone	1×10^{-8}
336	71.9 - 75.3	Packer	Siltstone	1×10^{-10}
336	77.9 - 87.4	Packer	Siltstone/Mudstone	1×10^{-10}
336	90.0 - 99.6	Packer	Sandstone	1×10^{-10}

3.2.6 Laboratory Testing Program

Laboratory tests were carried out to determine the engineering properties of key materials at the minesite. The following tests were performed on overburden materials:

Water Content
Atterberg Limits
Grain Size Analysis

Detailed descriptions, water contents and Atterberg limit results are provided on the test hole logs in Appendix I. Results of the grain size analyses are presented in Appendix III.

The following tests were carried out on bedrock material:

Atterberg Limits
Direct Shear Tests
Slake Durability
Sulphate Soundness
Unconfined Compression Tests

Results of the Atterberg limits and unconfined compression tests are presented on the test hole logs in Appendix I, with other test results presented in Appendix III.

3.3 Engineering Geology and Lithology of the Bedrock Sequence

The rocks of the Telkwa Basin comprise sediments typical of coal bearing formations. Five major rock types have been identified and their percentage occurence in the test holes drilled is as follows:

Sandstone	27%
Siltstone	34%
Mudstone	25%
Coal	11%
Igneous	1%
Miscellaneous	2%

3.3.1 Sandstones

The following sandstone lithologies have been identified:

SS 1 The sandstones designated SS 1 are very fine grained green to grey in colour, massively bedded and range from moderately weak to moderately strong. The rock is generally calcite cemented with local secondary glauconite cementing. Locally, the sandstones are friable and contain minor quantities of pyrite. This is the most commonly occuring sandstone on the property.

SS 2 Sandstones designated SS 2 are fine to medium grained, light grey to brown, thickly bedded and moderately strong.

SS 3 Sandstones designated SS 3 are pebbly sandstones, light grey to brown in color.

3.3.2 Siltstones

The siltstones are typically grey, thinly laminated to thinly bedded, ranging in strength from very weak to moderately strong rocks. The siltstones are commonly interbedded with mudstone or sandstone horizons and the bedding is often undulating; small calacreous nodules and calcite veins are common.

3.3.3 Mudstones

The mudstones are dark grey and massive. They are variable in composition and are locally carbonaceous, silty, sandy and tuffaceous. The mudstones vary from fresh to completely weathered. Strengths range from very weak to moderately weak.

3.3.4 Coal

The coal is high volatile Bituminous A rank and comprises dull, bright and brilliant bands and high ash content bands. The coal is generally hard with cubic and conchoidal fractures. Pyrite is frequently visible in the core. Detailed composition varies widely from seam to seam. The coal is classified as moderately weak rock.

4.0 GROUNDWATER

4.1 Introduction

This part of the report characterizes the hydrogeology and groundwater conditions of the proposed Telkwa Coal Project Site and presents estimates of groundwater inflows to the open pits.

4.2 Summary of Existing Data

The regional geology of the Telkwa-Smithers area has been mapped by the Geological Survey of Canada (Armstrong, 1944; Tipper, 1976; Tipper and Richards, 1976 and Tipper, et al, 1979). The regional hydrogeology and groundwater resources have not been investigated. However, groundwater resources in the vicinity of Telkwa Village have been investigated for water supply purposes and the results of these investigations are available in unpublished reports by Livingston Associates and Campbell.

Records of waterwells drilled in the Telkwa and Smithers area are held by the Groundwater Section, Water Management Branch of the B.C. Ministry of Environment. Review of the records indicates that none of these wells are located in the vicinity of the mine site, and therefore are of little practical application to this development.

4.3 Field Investigations

Details of the field investigations are presented in Section 3.2.4.

4.4 Water Quality

4.4.1 Rural Water Supplies

Twenty three rural households within 3 km of the mine area obtain their domestic water supplies from groundwater, either by means of dug wells (2 to 6 m depth) or by drilled wells generally less than 50 m in depth. The locations of the wells and details of the water supplies are presented on Drawing D-0119.

The dug wells are commonly constructed with a 900 mm diameter galvanized corrugated steel pipe as a casing. The drilled wells are cased with steel pipe generally 150 mm in diameter, and may have a well screen or slotted length of pipe as an intake. All wells appear to be producing water from surficial deposits rather than bedrock. Some wells on the flood plain of Goathorn Creek Valley are installed in channel sand and gravel deposits having limited groundwater yielding potential (L. Hart and L. Parks for example). Such wells provide marginal water supplies for domestic water purposes. A group of residents located on a sand and gravel plain to the northeast of the mine site obtain water supplies from the surficial sand and gravel deposits which comprise a productive aquifer.

During the period September 11 to 15, 1984, samples of water supplies were collected for chemical analysis from several domestic wells in the vicinity of the mine site. Samples were collected and preserved in accordance with procedures recommended by Can Test Ltd. and as described with the test data in Appendix II. It is noted that field determinations of acid pH (less than 7) are inconsistent with with measured levels of bicarbonate alkalinity (HCO_3). The shift of sample pH to the higher lab values is indicative of post-collection sample chemistry changes which may have given rise to an increase in bicarbonate alkalinity at the expense of carbonic acid content. Drawing A-0120 illustrates the common ionic composition of the groundwater supplies. The water supplies are of a calcium magnesium bicarbonate type with only minor amounts of sulfate and chloride salts. The predominance of Ca, Mg and HCO_3 affects the water quality by imparting hardness which ranges between 48 and 416 ppm. Hardness is not a significant factor in terms of water consumption by humans, however 13 of the 24 domestic well water supplies tested have hardness in excess of the accepted limit of 120 ppm (Environment Canada Water Quality Source Book, 1979). Iron content ranges up to 9 ppm and in 11 of the 24 well waters exceeds the 0.3 ppm maximum acceptable limit recommended by Health and Welfare Canada (1978) and Environment Canada (1979). Several samples also indicate excessive manganese content and high turbidity.

Other than the foregoing, concentrations of most dissolved metals and notably all the heavy metals are within acceptable limits for human consumption.

4.4.2 Mine Site Groundwater

Groundwater samples were obtained from piezometers installed in coal seams in test holes 255, 257 and 258.

Laboratory analyses have produced some anomalous results as follows:

pH

pH values are high, ranging from 8.0 to 11.2. The two analyses from test hole 258 give values of 10.2 and 11.2 which are considered to be due to grout contamination.

pH values are measured in the laboratory and these values may be up to 1 unit higher than the corresponding field measurement. The variation in pH values between field and lab measured values is due to exsolution of CO_2 during transportation.

Charge Balance

There are charge balance errors of over 5% on 5 of the 6 analyses carried out; this may be due to inaccuracies in the analyses or due to the presence of an additional cation present in the water but not identified in the analyses.

A groundwater sample was obtained during September 1984 from a major seepage in the area of the bulk sample test pit. The pH of this sample was determined in the field and found to be 7.0, which is slightly higher than the samples obtained from domestic wells, but lower than the samples from the piezometers.

The groundwater from bedrock sources is a sodium bicarbonate type with minor sulphate and chloride and secondary calcium, magnesium and potassium. The water is very hard with total dissolved solids ranging from 312 - 1700 ppm.

4.5 Hydrogeology

4.5.1 Groundwater Occurrence

Surficial Deposits

The best developed aquifers in the project site area are the glacial and post glacial sand and gravel deposits. Shallow, unconfined aquifers are developed in the sand and gravel deposits found in the Bulkley, Telkwa River and Goathorn Creek Valleys.

Deeper confined aquifers are developed in horizons of outwash gravels deposited directly on the bedrock surface or between successive till layers.

Wells in both confined and unconfined aquifers in Smithers and Telkwa produce up to 75 l/sec (4.5 m^3/min).

In the vicinity of the proposed plant site and tailings dam to the north and east of the pit locations, a large deposit of sand and gravel of probable glaciofluvial origin underlies a broad plain extending over some approximately 8 km^2. This deposit forms an aquifer from which residents obtain domestic water supplies from wells to depths of 20 m.

Bedrock Deposits

The permeability test results indicate that the coal beds and interburden have relatively low permeabilities. Results of the 1982 tests carried out on coal zones indicate that the coefficient of permeability (K) values of the coal range between 5×10^{-7} and 5×10^{-9} m/s. The 1983 test data from other bedrock strata indicate low permeabilities. Of the 13 tests performed in test hole 336, all but one was less than 10^{-10} m/s, or too low to measure with the available field instrumentation. The remaining test interval indicated a K of 5×10^{-8} m/s. In test hole 335, 7 of the 21 permeability values ranged from 10^{-7} m/s to 6×10^{-9} m/s and the permeability of 11 intervals was too low to measure. Permeable intervals do not appear to correlate with any particular lithologic or stratigraphic units but tend to be concentrated at shallower depths, and in the case of test hole 335, less than 40 m.

Permeability test results are summarized in Table 3-2. The packer test results from test holes 335 and 336 are presented on the logs in Appendix I.

Groundwater transmission in bedrock is largely dependent on the presence and nature of fractures. The coal beds, shales, siltstones and weathered volcanic rocks of the mine site area are generally fine grained, relatively weak bedrock materials characterized by discontinuous fractures which tend to be closed, and thus have a low permeability.

Fault zones, particularly normal faults, can be well fractured and brecciated and may serve as significant conductors of groundwater. Some of the fault zones in the mine site area are expected to fall into this category. However, fault zones may also be characterized by the presence of finely ground low permeability gouge materials which may seal fractures and hinder groundwater movement. Thus, the effect of fault zones is difficult to predict without specific investigations aimed at assessing their hydrogeologic nature.

4.5.2 Regional Groundwater Flow

In the Telkwa area the water table configuration is expected to reflect the topographic surface. Topographic highs define areas of high head and are natural groundwater recharge areas. Topographic lows, chiefly creek and river valleys, represent areas of low head and are natural groundwater discharge areas. Accordingly, groundwater flow originates in the uplands and extends downward and laterally away from the uplands toward the valleys. Between regional recharge and regional discharge areas, the course of flow paths is influenced locally by the topography and permeability of the geological materials. These conditions create local flow systems which are of significance to drainage and slope stability.

The sixteen piezometers installed within the mine site area have been monitored by CNRL staff on a regular basis. Water levels measured in the piezometers are summarized in Drawing B-D118 and show that groundwater pressures are relatively high with upward gradients and discharge areas occuring on some of the slope areas. Examples are as follows:

a) Test Hole 335 - Piezometric surface is at ground level and surface seepage is visible in two small valleys to the west of the test hole.

b) Test Hole 250 - Surface seepage adjacent to test hole 250 is indicative of upward groundwater flow.

c) Test Holes 321, 313, 323, 342 - Water levels are high in these piezometers and test hole 323 is flowing. These test holes are located in the area of the 1983 test pit. A large seepage area has developed at the western end of the test pit area. Seepage is originating largely from the #6 seam.

d) Test Holes 318, 343, 344 - These test holes are located in a sloping area in the northern part of the east mine area. The water level in test hole 315 is relatively low indicating good subsurface drainage. The higher water levels measured in test holes 343 and 344 are thought to be due to the presence of a small lake 100 metres to the south of the test holes.

e) Test Holes 345 and 347 - These test holes, located on the west side of Goathorn Creek, have relatively low water levels and thus indicate good subsurface drainage in that area.

The general regional directions of groundwater flow in the project site area are shown on Drawing B-0122. The project areas located east of Goathorn Creek are situated on the divide between the catchment of Goathorn Creek and the Telkwa River (Catchment A_2 and B respectively). It is probable that the surface divide and groundwater divide coincide with the result that groundwater recharge in the eastern mine area moves partly in a westerly direction towards Goathorn Creek and partly in a north easterly direction towards the Telkwa River. The mining areas west of Goathorn Creek lie entirely within the catchment of the Goathorn Creek and its tributary, Four Creek.

4.5.3 Groundwater Recharge

The packer tests and falling head test results indicate that the bedrock formation is of generally low permeability and therefore it is probable that the amount of infiltration is equal to a small percentage of precipitation. Infiltration has been estimated as 3% of annual infiltration made using estimated groundwater flux and a value for hydraulic conductivity derived from the packer tests. Details of the calculations supporting this estimate are presented in Appendix III.

4.5.4 Structural Modification of Groundwater Flow

Structural discontinuities such as faults, bedding planes and joints have considerable effect on groundwater flow.

Sedimentary formations are hydraulically anisotropic with hydraulic conductivity along bedding planes being greater than conductivity across the bedding planes. In weak rocks such as those occurring in the mine site area joints are generally poorly developed and tend to be discontinuous. In such formations anisotropy is greater than in competant formations.

In the eastern mining area where pits #1, 2 and 3 will be developed, bedding dips at 7° to 20° E. Groundwater flow in the western area of #3 pit is across the bedding planes and will be impeded by the relatively tight nature of the joints. Flow in the eastern part of #3 pit and in pits #1 and #2 will be down dip towards the east.

The regional groundwater flow is modified by faults which offset beds and thus affect the continuity of the permeability of the formation.

The mine site east of Goathorn Creek is affected by a complex system of northwest/southeast trending normal and reverse faults which divide the area into a number of discrete blocks. Several faults have been intersected by drillholes and have been inspected by CNRL geologists. A major fault affecting #6 seam was seen in outcrop during the excavation of the test mine in 1983. It has not been possible to predict the local effects of faulting on groundwater distribution. Normal faults in sandstone and coal tend to produce a permeable coarse fault breccia; in some cases however, normal faults are tight and clean. Reverse faults vary from tight to infilled. Where infill material is present it takes the form of a clay gouge. In the more competent materials such as the sandstones, movement associated with reverse faults appears to have taken place along joint and bedding planes.

4.6 Groundwater Inflow Estimates

4.6.1 General

Groundwater inflow estimates have been calculated for the #3 Pit. This is the best defined pit in geological terms and it will contribute the major part of the coal to be mined throughout the mine life. The opening cut for the #3 Pit will be located at the northern end of the pit and the pit will be developed toward the south.

The inflow estimates are based on hydrogeological parameters selected on the basis of the permeability tests and a review of other geological data. It should be noted that the particular aquifers are not definable on a stratigraphic basis, and the fault zones, which are probably the most significant groundwater conductors, also are not explicitly definable. The selected hydrogeological parameters are as follows:

specific yield - 3%
storage coefficient - 0.0001
fault zone coefficient of permeability - 1×10^{-4} m/s

The glacial drift and the near surface bedrock to a total depth of 30 to 50 metres together are probably the most permeable hydrogeological unit. Below this depth the bedrock appears to become less permeable with fewer fractures. The coal beds, judging from the few permeability tests performed, do not serve as aquifers and the mudstone and siltstone interburden, although fractured, have even less permeability than the coal. Thus, the entire sequence is considered to have a low permeability and contains no definable aquifers.

As pit excavation proceeds, generally small amounts of groundwater can be expected to discharge from the pit walls into the pit. Occasionally, well fractured zones, including fault zones, will be intersected and will have the potential of yielding flows of water considerably larger than average pit wall drainage flows. However, because of limited storage within fractured zones and limited recharge potential, groundwater flow rates from fracture zones will diminish rapidly.

The groundwater inflows estimated in the following sections are based on the following sources of groundwater:

- Drainage from the excavated rock mass over the life of the pit.
- Drainage from the footwall as a result of depressuring by drainage holes required to ensure footwall stability.
- Discharge of groundwater from the pit highwall and endwalls.
- Infiltration to the groundwater system within the area of influence of the pit.
- Extraordinary inflows from fault zones.

4.6.2 Drainage of Excavated Rock Mass

Assuming an average stripping ratio of 7:1 and an annual raw coal production of 1.1 million tons per year, 7.8 million cubic metres of rock will be excavated annually. Assuming a specific yield of 3 percent (i.e. the amount of gravity drainage from the material), it is estimated that 234,000 m^3 of groundwater will be released annually from the excavated material into the pit.

4.6.3 Footwall Drainage

As pit excavation proceeds, the unloading of the underlying strata will induce upward movement of groundwater through the footwall into the pit. However, because of the low permeability of the footwall materials, additional vertical drainage by means of boreholes will be required in order to relieve footwall pore pressures and to maintain floor stability. Excluding fault zones, drainage of the footwall will contribute a relatively small amount of groundwater to the pit.

The footwall inflows are dependant on the thickness of material excavated from above the footwall, the difference in groundwater pressures between the water table and the footwall, the volume of rock beneath the footwall subject to depressuring, and the groundwater storage coefficient. For estimating purposes the storage coefficient is assumed to be 0.0001, a value which typifies confined groundwater conditions and the water table is assumed to be at ground surface.

The following are estimates for footwall inflows over the life of the mine:

Footwall Depth Interval (m)	Inflow (m^3/m^2*)	Footwall Area (m^2)	Inflow (m^3)
0 - 25	0.01	350,000	3,500
25 - 50	0.09	350,000	31,500
50 - 75	0.25	350,000	87,500
75 - 100	0.48	350,000	168,000
		Inflow Total	290,500

* m^3 of water/m^2 of footwall
(Total footwall area is estimated to be 1.4 million m^2 and is assumed to be apportioned equally amongst the four depth intervals.)

The total inflow of 290,500 m^3 over the 20 year life of Pit 3 is equivalent to an average of 14,500 m^3 annually.

4.6.4 Highwall and Endwall Drainage

As excavation proceeds, groundwater from the highwall and endwalls will move toward and discharge into the pit. Groundwater discharge is likely to be more significant in the upper 50 metres where the permeability appears to be largest. Overall, however, in view of the prevailing low rock permeability, pit wall dewatering will occur at a slow rate and will be limited in lateral extent. This inflow estimate assumes that horizontal drain holes will be provided to ensure slope stability required, particularly in the lower slope areas below a depth of 50 metres, and that the drains will dewater the rock mass behind the pit wall above a 20 degree slope drawn from the toe of the pit wall.

On this basis, assuming an average high wall height of 100 m and a specific yield of 3 percent, the drainage water, per metre length of high wall, can be estimated by a simple volume calculation as follows:

$$\begin{aligned} \text{inflow} &= 100 \times \frac{100}{\tan 20^\circ} \times 0.5 \times 0.03 \\ &= 412\ \text{m}^3\text{/metre length of highwall.} \end{aligned}$$

Given a highwall length of 2,800 m, the inflow will amount to 1.154 million m^3 over 20 years or 57,700 m^3 annually.

Endwall drainage will add a significant component to this inflow during the first 5 years as the northwall is established and drained. Allowing for an average endwall height of 75 m and a northwall length of 1200 m over a 5 year period, inflows would amount to 236 m^3/metre length of wall or 56,600 m^3 per year.

The southwall will also drain ahead of excavation to some extent but given the slow rate of drainage and the state of continual advancement of the face, the amount of inflow is likely to be relatively small. This inflow component is assumed to be accounted for as drainage from excavated rock. However, as the advancing pit approaches the southern limit of the pit, an additional inflow from drainage of the southern endwall spread over the last two years of pit operation will occur. At 236 m^3/m length of wall and for a 400 metre wall length, the inflow will amount to 47200 m^3 annually.

4.6.5 Groundwater Infiltration

Pit inflows will be affected by surface infiltration close to the pit. The area of influence of the pit will increase gradually each year as the pit size increases and as adjacent groundwater pressures gradually decline over time due to drainage to the pit. An assessment of water level drawdown in the vicinity of the pit indicates that dewatering effects after 1 year of drainage will not be significant beyond 100 m from the pit boundary. In local areas where fracturing is well developed and provides higher permeability, the zone of influence may extend beyond this distance within a year. For the purpose of estimating the inflow contribution from infiltration it has been assumed that the ultimate zone of influence will extend to a distance of 500 m from the pit boundary with several exceptions. In the southeastern area of the pit, the ultimate radius of influence is taken as the surface catchment boundary defined ground rising to elevation 990 m. To the north of the pit the boundary of influence is assumed to be midway between pits 2 and 3. The zone of influence to the west of the pit is negligible in view of the proximity of the valley slope of Goathorn Creek. On this basis, the ultimate recharge area outside the pit boundary is estimated to be 2.8 million m^2. The ultimate pit area is estimated to be 2.1 million m^2.

For estimating purposes it is assumed that over the 20 year operating period the pit area is developed linearly and pit recharge area will expand linearly.

Thus the recharge area for year 1 is taken as 5 percent of 4.9 million m^2, for year 2 10 percent of 4.9 million m^2 less the pit area developed during year 1 (5 percent of 2.1 million m^2) and so on through to year 20. The resulting annual pit inflow from recharge ranges from 3,750 m^3 in year 1 to 44,500 m^3 in year 20.

4.6.6 Exceptional Inflows From Fault Zones

Exceptional groundwater inflows will occur when the pit intersects major fault zones. However, because there are no major aquifers in the minesite area there is limited potential for recharge to fault zones and therefore discharge from faults will diminish over time. Assuming a fault zone permeability of 10^{-4} m/s, an average zone width of 10 m and an effective fault zone drainage area of 1000 m long by 500 m wide, such a fault can be expected to discharge in the range of 100 to 1000 m^3/day. Given the limited storage capacity within the fault zone and limited recharge potential, it is likely that exceptional flows from fault zones will diminish over a period of a few months. Although 2 or 3 fault zones may be intersected by Pit 3, it can be assumed that no more than one zone will be contributing exceptional inflows to the pit at any one time.

4.6.7 Total Groundwater Inflows - Pit 3

Total annual groundwater inflows in the first 5 years are expected to be high due to excavation of the relatively long north wall. Following drainage of the north wall, the annual inflows should drop in year 6, but then gradually increase as the area of influence of the pit expands, resulting in an increased annual recharge component.

Thus the annual groundwater inflows over the life of Pit #3 are expected to vary over a relatively small range, from 421,000 m^3 to 498,000 m^3 (175 to 210 igpm).

Table 4-1 summarizes estimated groundwater inflows to Pit 3.

TABLE 4-1

SUMMARY OF ESTIMATED GROUNDWATER INFLOWS, PIT 3

Year	Excavated Rock (m^3)	Footwall (m^3)	Highwall (m^3)	North & South Endwalls (m^3)	Infiltration (m^3)	Inflows from Faults (m^3)	Totals (m^3)
1	234,000	14,500	57,700	57,700	3,750	100,000	467,650
2	234,000	14,500	57,700	57,700	5,900	100,000	469,800
3	234,000	14,500	57,700	57,700	8,000	100,000	471,900
4	234,000	14,500	57,700	57,700	10,200	100,000	474,100
5	234,000	14,500	57,700	57,700	12,300	100,000	476,200
6	234,000	14,500	57,700	-	14,500	100,000	420,700
7	234,000	14,500	57,700	-	16,600	100,000	422,800
8	234,000	14,500	57,700	-	18,700	100,000	424,900
9	234,000	14,500	57,700	-	20,900	100,000	427,100
10	234,000	14,500	57,700	-	23,000	100,000	429,200
11	234,000	14,500	57,700	-	25,200	100,000	431,400
12	234,000	14,500	57,700	-	27,300	100,000	433,500
13	234,000	14,500	57,700	-	29,500	100,000	435,700
14	234,000	14,500	57,700	-	31,600	100,000	437,800
15	234,000	14,500	57,700	-	33,700	100,000	439,900
16	234,000	14,500	57,700	-	35,900	100,000	442,100
17	234,000	14,500	57,700	-	38,000	100,000	444,200
18	234,000	14,500	57,700	-	40,200	100,000	446,400
19	234,000	14,500	57,700	47,200	42,300	100,000	495,700
20	234,000	14,500	57,700	47,200	44,400	100,000	497,800

4.6.8 Pits 1 and 2 Inflows

Detailed estimates of groundwater inflows to each pit development have not been carried out. Although certain hydrogeologic parameters and pit dimensions vary to a degree amongst the several pit areas, the hydraulic conductivity, groundwater storage and natural recharge characteristics of Pits 1, 2 and 3 are very similar. These are the major governing controls on groundwater inflows. Thus, for mine planning purposes it can reasonably be assumed that annual groundwater inflows to Pits 1 and 2 will fall within the limits estimated for the first 5 year development of Pit 3.

4.6.9 Pits 4, 5 and 6 Inflows

Inflows to Pits 4, 5 and 6 have not been estimated. For Pits 4 and 5 mining will advance westward and the pits will develop essentially as benches into the valley slope of Four Creek. In view of the relatively small size of the pits and their location on the valley slope the groundwater inflows will be relatively small, and significantly less than estimates for Pit 3. Pit water can best be discharged by ditching with water being directed to a settling pond to control sediment content.

The groundwater conditions and scale of operations in Pit 6 will be comparable to the north end of Pit 3. Detailed groundwater estimates have not been made for this pit. However, assuming a 5 year mining operation for Pit 6, the groundwater inflows are expected to be similar in magnitude to those for the first 5 years of operation in Pit 3.

4.7 Direct Precipitation to Pit 3

The amount of precipitation falling directly into the pit is dependant on the excavated area of the pit. No waste will be placed in #3 pit during years 1 to 5. The waste from years 6 to 10 will be dumped in the area mined in the first 5 years of operation. From year 6 onwards it is assumed that the area of pit open will remain the same as the area open at year 5.

During the construction of the in-pit waste dumps some precipitation will infltrate the waste and the remainder will run off into the open pit area. For the purposes of estimating it is assumed that the pit area, comprising the area being mined and the area being actively backfilled, increases in size during the first 8 years of operation and thereafter, remains constant as shown in Table 4-2.

Annual inflow, 24 hour maximum and 48 hour maximum inflows are presented in Table 4-2. Inflows are based on annual precipitation of 510 mm and an evaporation rate of 30%.

TABLE 4-2

Year	Pit Area (m²)	Annual Inflow Precipitation (m³)	Maximum 24 Hour Inflow (m³)	Maximum 48 Hour Inflow (m³)
1	100,000	35,700	1,890	2,240
2	200,000	71,400	3,780	4,480
3	300,000	107,100	5,670	6,720
4	400,000	142,000	7,560	8,960
5	500,000	178,500	9,450	11,200
6	600,000	214,200	11,340	13,440
7	700,000	249,900	13,230	15,680
8	800,000	285,600	15,120	17,920
9-20	800,000	285,600	15,120	17,920

4.8 Effect of In-pit Waste Dumps on Pit Inflows

As waste rock is placed in the pit behind the mining operation, groundwater inflows which previously reported directly to the open pit will be intercepted by the waste rock. In addition, precipitation will infiltrate the surface of the waste rock and begin to establish saturated groundwater conditions.

The hydraulic characteristics of the waste material are not known, but in general because of segregation during dumping operations, coarse materials are likely to be concentrated near the base of the dump lifts and finer materials in the upper part. Thus, alternating layers of coarse and fine materials will create variations in permeability with the coarser more permeable layers behaving as horizontal drains. As the waste dump increases in height, and the rock progressively degenerates in quality due to weathering, consolidation and permeability reduction will occur.

Within the operating life of the mine, the waste dumps will serve as water storage reservoirs. As discussed in 4.6.2 approximately 7.8 million m^2 of waste will be produced per year. Assuming that 10 percent of the waste volume is available for moisture storage approximately 780,000 m^3 of water storage space would be created annually by the waste dumps. If the waste is placed over an area of

100,000 m^2 each year, and progressively over the nominal 2.1 million m^2 of Pit 3 in 20 years, then a rough estimate of the storage volume and anticipated volume of accumulated recharge can be made as indicated in the following:

Year	Cumulative Waste Dump Area (m^2)	Accumulated Recharge (m^3)	Cumulative Waste Material (m^3)	Total Storage Volume (m^3)
1	100,000	10,200	7,800,000	780,000
2	200,000	20,400	15,600,000	1,560,000
3	300,000	30,600	23,400,000	2,340,000
4	400,000	40,800	31,200,000	3,120,000
5	500,000	51,000	39,000,000	3,900,000

Accumulated recharge is the amount of water which infiltrates the waste pile from direct precipitation. For loose dumped rock fill material the infiltration is estimated to be 20% of precipitation (510 mm pa). As illustrated above, the volume of recharge is small compared to the available storage volume. Rainfall falling directly onto in-pit waste dumps is therefore likely to be retained in the waste material as groundwater and will not make a significant contribution to pit inflows.

Waste materials will also retard and/or intercept pit wall inflows, thus progressively reducing the amount of water reporting to pit sumps from the backfilled areas.

4.9 Pumping Capacity - Pit 3

It is recommended that pumping capacity be installed to handle regular inflows, exceptional fault inflows and average precipitation. Reserve pumping capacity should be available at the minesite to handle major rainfall events. The size of reserve pumping capacity is an operational decision, but all contaminated water pumped out of the pit must be clarified. For the purposes of sizing sedimentation ponds it has been assumed that reserve pumping capacity will be sized to handle the maximum 48 hr precipitation event.

Pumping capacity requirements are presented in Table 4-3 and are summarized below:

Recommended Installed Pumping Capacity:	120 m^3/hr (440 igpm).
Recommended Reserve Pumping Capacity:	50 m^3/hr (180 igpm) in year 1, to 400 m^3/hr (1470 igpm) in year 8-20.

TABLE 4-3

PUMPING CAPACITY REQUIREMENTS - PIT 3

Year	Regular Inflows (m^3/hr)	Fault Inflows (m^3/hr)	Average Precipitation Inflows (m^3/hr)	Recommended Total Installed Pumping Capacity (m^3/hr)	Recommended Available Reserve Pumping Capacity (m^3/hr)
1	42	42	4	88	47
2	42	42	8	92	93
3	43	42	12	97	140
4	43	42	16	101	187
5	43	42	20	105	233
6	37	42	24	103	280
7	37	42	28	107	327
8	37	42	32	111	373
9	37	42	32	111	373
10	38	42	32	112	373
11	38	42	32	112	373
12	38	42	32	112	373
13	38	42	32	112	373
14	39	42	32	113	373
15	39	42	32	113	373
16	39	42	32	113	373
17	39	42	32	113	373
18	40	42	32	114	373
19	45	42	32	119	373
20	45	42	32	119	373

5.0 SURFACE WATER CONTROL

5.1 Hydrologic Water Balance

Disruption of Natural Drainage

The mine drainage plan will necessarily alter local drainage patterns but will not significantly affect the overall basin drainage system. The net changes to the existing local drainage areas are shown on Drawing D-0123 and are relatively small as shown on Table 5-1. Changes to flow conditions of the local creeks will therefore be negligible.

TABLE 5-1

CHANGE IN DRAINAGE BASIN DUE TO PROJECT DEVELOPMENT

Drainage Basin	Existing Drainage Area (km^2)	Revised Drainage Area (km^2)	Net Change in Drainage Area (km^2)
Tenas Ck.	63	63.2	+0.2
Goathorn Ck.	132	138.1	+6.1
Hubert Ck.	44	43	-1.0
Telkwa R.	1200	1201	+1.0

Surface Water Runoff

Clearing operations, open pit excavation, construction of waste dumps and mine reclamation can be expected to affect the quantity of surface water runoff from the site due to changes in evapotranspiration and infiltration. Land clearing will increase the runoff from the site because evapotranspiration will decrease. Disturbance of surficial soils will increase the runoff yield because infiltration will decrease. Open pit excavation will increase the water yield because both evapotranspiration and infiltration will decrease.

The development of waste dumps will affect the water yield. Initially, infiltration will be high in loosely placed spoil materials relative to existing conditions in which the infiltration is restricted by dense till subsoil and high local water tables.

After grading and topsoiling, the infiltration rate will decrease depending on the degree of compaction. Evapotranspiration from the waste dumps will be less than at present until vegetation is fully developed after reclamation.

Although a significant change in the local hydrologic water balance can be expected through the life of the mine, the ultimate disturbed area will be only 9.4 km^2. Areas of local drainage basin disturbance are as follows:

Drainage Basin	Ultimate Disturbed Area as Percentage of Total Drainage Basin
Goathorn Ck.	4.2%
Hubert Ck.	8.6%

5.2 Design of Surface Water Handling Facilities

5.2.1 Headwater Diversions

Headwater diversions are provided to minimize the quantity of contaminated surface runoff by diverting all uncontaminated surface runoff from the drainage area upslope of the mine areas. Drawing D-0124 shows the locations of the headwater diversions and indicates catchment areas, flow capacities and flow velocities. Typical sections and design details are provided on Drawing D-0125.

A single diversion will be required for the mine area west of Goathorn Creek and two diversions will be required for the mine area east of Goathorn Creek.

A total of 1.5 km^2 of catchment will be diverted on the west side of Goathorn Creek. Surface runoff is returned to Goathorn Creek via Tenas Creek. This diversion would cause only a 2% increase in the Tenas Creek catchment.

A total of 6.2 km^2 of catchment is diverted on the east side of Goathorn Creek. About 1.1 km^2 is diverted around the north end of the main pit and 5.1 km^2 is diverted southward into a tributary of Hubert Creek.

The headwater diversions are designed in accordance with Ministry of Environment regulations. The following criteria have been included:

a) The diversions are located at least 50 m from the edge of mine facilities.
b) The diversions will handle the 200 year flood with a minimum of 0.4 m freeboard.
c) The diversions are designed to be non-erodible during the peak instantaneous flow of a 10 year flood. Channel armouring is provided where the maximum velocity during the 10 year flood exceeds 1.5 m/s.

5.2.2 Interceptor Ditches

The primary function of the interceptor ditches is to intercept potentially contaminated runoff from the mine area and to convey it to settling ponds.

Runoff from 1.1 km^2 will be intercepted and routed to Settling Ponds #3 and #4 east of Goathorn Creek. On the west side of Goathorn Creek, runoff from 6.2 km^2 in the pit area will be intercepted by one interceptor ditch system leading to Settling Pond #2. The waste dump area will be drained mainly by existing waterways to Settling Pond #1. Another interceptor ditch system located north of the mine area will intercept runoff from 2.4 km^2 from the plantsite, haul-road and local catchments and will discharge into Settling Pond #5.

The locations of the proposed interceptor ditches is shown on Drawing D-0124. Catchment areas, design capacities and flow velocities are also indicated on the drawing. Typical sections and design details are shown on Drawing D-0125.

Like the headwater diversions, the interceptor ditches are designed to handle the 200 year flood with a minimum of 0.4 m freeboard. No armouring is required for these channels because the flow is directed through settling ponds before release.

Interceptor ditches cannot be provided for pits #4 and #5 because they are located alongside the relatively steep valley walls. Instead, special pit excavation measures will be implemented to provide in-pit water handling as discussed further in Section 5.2.4.

5.2.3 Roadside Ditches

Roadside ditches are provided for the haul road in the Goathorn Creek Valley. Ditches lined with coarse gravel will be provided on both sides of the haul road to channelize the runoff without causing erosion. Design details are provided on Drawing D-0125.

These measures are not required elsewhere alongside haulroads in the mine area because all roadside drainage will be ultimately collected by interceptor ditches and conveyed to settling ponds.

5.2.4 Settling Ponds

General

Settling ponds will be provided to trap suspended sediment and channel bed load before release of clarified surface runoff into the streams. Runoff from the mine, waste dumps, plantsite and haul roads will be collected by the interceptor ditches and conveyed to five ponds located as shown on Drawing D-0124.

Clarification of the contaminated water will be by unaided settling. Should this prove insufficient, flocculents will be added at the pond intakes to enhance clarification.

Interceptor Ditches are not provided for Pits #4 and #5 located on the west side of Goathorn Creek because the pitwall is too close to the valley wall. Construction techniques employed during clearing, stripping and pit excavation at these two pits will ensure that all surface runoff flows into the pit. Operations will begin by opening a trench on the downslope (east) side of each pit. Small ditches will be built on the north and south sides of the pits to ensure that all runoff from the disturbed area is directed into the pit. During operations, surface runoff collected in these pits will be pumped to Settling Pond #4. After these pits have been mined out, Settling Ponds will be built inside the pits and surface water will be released into Goathorn Creek by a spillway channel.

Settling Ponds #1 to #4 are single cell ponds. Settling Pond #5 incorporates two cells, one for relatively coarse sediment and one for fine sediment. A small dugout will be provided ahead of the main pond to trap the coarse sediment originating in the plantsite. This will enable easy removal of the significant quantities of coarse sediment expected from the plantsite. Settling ponds will be constructed ahead of any clearing, stripping or pit excavation.

The plan layout, elevation/volume curve and elevation/area curve of each settling pond is shown on Drawings D-0126 and B-0127.

Sizing and Design

The settling ponds are designed in accordance with the B.C. Ministry of Environment guidelines as outlined in the publication "Guidelines for the Design and Operation of Settling Ponds used for Sediment Control in Mining Operations" dated 1980.

Two representative, near surface samples of glacial till, were analyzed for grain size distribution, erodibility and clarification rate. The grain size distributions shown in Appendix II indicate a substantial fraction of fine silt and clay. However, it is anticipated that sediment transport will include relatively little wash load as the predominant bed load would be composed of fine sand and agglomerated clay/silt particles.

The regulations require that the concentration of total suspended solids in the settling pond discharge does not exceed 50 mg per litre providing that the area background concentration is not exceeded. This criterion applies to flows up to the 10 year, 24 hour flood.

The settling ponds are sized to remove the 0.006 mm diameter sediment size and provide detention times of 16 to 44 hours during the 10 year flood. The drainage area, inflow rate, required pond area and detention times for each pond are indicated on Table 5-2.

TABLE 5.2

SIZE OF SETTLING PONDS

Pond No.	Catchment Area	Mean Daily* 10 Year Flow	Required Pond Area	Detention Time
	(km^2)	(m^3/s)	(km^2)	(hours)
1	4.6	1.12	0.056	44
2	6.9	1.66	0.084	16
3	0.7	0.18	0.009	31
4	0.5	0.13	0.007	17
5	2.5	0.63	0.032	20

* Mean daily flows are used because of the relatively long detention time of the ponds.

The required size of settling ponds were determined by the following formula:

$$A = \frac{Q}{Vsc}$$

Where A = Required pond area

Q = Average 10 year flood discharge during the pond retention time.

Vsc = Settling velocity of the smallest sediment size to be removed

The settling velocity of the critical sediment size is determined by Stokes' Law. The critical size of sediment to be removed can be determined from the grain size distribution of the suspended sediment and from the suspended sediment concentration entering the settling pond.

In the absence of reliable predictions of sediment concentration and grain size distribution of suspended sediment, a simplified approach was employed as recommended in the Guidelines for Design at Settling Ponds. A settling velocity of 2×10^{-5} m/s was selected to provide removal of the suspended sediment to 0.006 mm diameter. Thus all suspended sediment except clay particles and very fine silt will be removed from solution by settling. The quantity of fine silts and clays not removed by settling is expected to be relatively small.

Erosion and Sediment Yield

The rate of soil erosion was estimated by the Universal Soil Loss Equation to be 3300 m^3/km^2 per year based on 40% of the catchment area being disturbed by mining activities.

The quantity of sediment delivered to the various settling ponds will be smaller than the erosion rate due to sediment storage enroute. The annual quantity of sediment delivered to each settling pond is determined as follows

$$S = 3300\ m^3/km^2 \times \text{Area } (km^2) \times \text{Delivery Ratio}$$

The Delivery Ratios are expected to range from 20% to 33% for the various size catchments.

The quantities of sediment delivered annually to each settling pond are given in Table 5.3.

Table 5.3

SEDIMENT YIELD AND SEDIMENT STORAGE CAPACITIES

	Settling Pond				
	1	2	3	4	5
Catchment Area (km^2)	4.6	6.9	0.7	0.5	2.5
Delivery Ratio	0.21	0.20	0.33	0.33	0.25
Sediment Yield (m^3/yr)	3,200	4600	770	550	2100
Sediment Storage Capacity (m^3)	130,000	24,000	9,500	1,300	12,000

Flood Control and Freeboard

The ponds are designed to pass the 200 year flood with 0.7 m to 1.0 m freeboard. The 0.7 m freeboard will contain the wave runup of the significant wave height (0.4 m) generated by a 100 year, 1 hour wind of speed 76 km/hr.

Open channel spillway outlets are provided on Setting Ponds #1, #2, & #5 capable of passing debris and ice.

Culvert outlets are provided on Settling Ponds #3 & #4 to provide erosion free passage down the steep valley walls of Goathorn Creek. Debris control structures will be provided at the inlets to minimize risk of blockage. An earth cut emergency spillway is provided at each of these ponds to assure failsafe operation. A 1.0 m freeboard is provided to assure adequate freeboard in the event that culvert blockage requires flow over the emergency spillway.

Snowmelt inflow hydrographs were computed for the 200 year flood and are given on Drawing A-0128. These flood hydrographs were routed through the ponds to determine maximum outflow and maximum pond level. The results are given in Table 5-4.

TABLE 5-4

200 YEAR FLOOD ROUTING THROUGH SETTLING PONDS

200 Year Flood	Settling Pond				
	1	2	3	4	5
Maximum Outflow (m^3/s)	3.2	4.0	0.45	0.35	1.8
Maximum Flood level above Spillway Invert (m)	0.36	0.5	0.61	0.53	0.31
Maximum Water Elevation (m)	554.4	601.5	701.6	733.0	552.3

Details of the spillway channel and culvert outlets are presented on Drawings D-0124 and B-0127.

Design of Dykes

Five dykes ranging from approximately 2.0 m to 4.0 m in height will be required to impound water for the settling ponds. Each dyke will be constructed with a 2:1 upstream face and 2.5:1 downstream face with a crest width of 4 m. The dykes will be constructed of Zone A material as defined below. Dykes over 3 m high will incorporate a 0.5 m thick drain of Zone C material at the downstream toe. Details of the dyke design are shown on Drawing D-0126.

> Zone A material shall be well graded glacial till with a minimum of 20% passing the 0.075 mm seive. The material shall contain no rock fragments larger than 150 mm.
>
> Zone C material shall be designed to act as a filter between the Zone A material and the foundation material.

Zone A material should be placed in lifts not greater than 0.25 m in thickness and be compacted to 98% of maximum density as determined by test ASTM D-698 at ±2% of optimum moisture content.

Each dyke will be provided with a spillway set approximately 1.0 m below the dyke crest. Dykes #3 and #4 will incorporate culverts within the embankment. Careful construction procedures and the use of selected material will be required in order to minimize the risk of piping around the culverts. These matters will be addressed at the detailed design stage of the project.

Settling Pond Operation

Each settling pond will be operated in accordance with B.C. Ministry of the Environment regulations as follows:

1) Baffles will be located at the inlet of the pond to spread the inflow and reduce its velocity.

2) Accumulated sediment will be cleaned out when 50% of the pond volume is lost to sediment storage or when the surface area is reduced by 20% on account of delta deposits. Sediment will be disposed of by burial. Clean-out will be carried out during dry periods when runoff is minimal.

3) Flocculants will be added at the pond inlet if unaided settlement is insufficient to meet the allowable discharge suspended sediment concentration of either 50 mg per litre during a 10 year, 24 hour flood or the area background suspended sediment concentration.

4) Dewatering, if required, will be provided by pumping.

5) The spillway channel outlets will be cleared of snow and ice before snowmelt each spring.

6) The ponds, dams, spillway outlets, culvert outlets and inlet baffles will be inspected for deterioration 3 times per year, once during the freshet.

7) Discharge water quality will normally be monitored monthly. During the freshet, water quality will be monitored weekly. Additional monitoring will be carried out during rainstorm floods.

5.2.5 Goathorn Creek Crossing

During the later stages of mining operations, a crossing will be required across Goathorn Creek to provide haul road access to pits #4, #5 and #6.

The crossing will be designed to pass the 200 year peak instantaneous flow of 60 m^2/s and will comprise three 2700 mm structural plate corrugated metal pipe culverts. A spillover section on the haul road alongside the crossing will provide emergency protection against culvert blockage or an unusual flood. Culvert inlets and outlets will have concrete headwalls to prevent erosion and uplift.

The crossing will be constructed of select rock waste and will be provided with rip rap protection.

5.3 Surface Water Supply

5.3.1 Plant Water Balance

The plant water balance as estimated by CNRL is given below:

INFLOWS	
Moisture in Raw Coal	10 m^3/hr
Total Plant Water Demand (Reclaim & Make Up)	43
Total	53
OUTFLOWS	
Moisture in Coarse Refuse	8
Moisture in Clean Coal	8
Water in Tailings Slurry	37
Total	53

5.3.2 Make Up Water Supply

The make up supply system will provide full plant make up water during plant start up and during periods when water cannot be reclaimed from the tailings pond. During periods of normal operation, make up water will supplement reclaim water. Full make up will require 43 m^3/hr but peak demand during start up may be as high as 100 m^3/hr.

Make up water may be extracted from the Telkwa River downstream of its confluence with Goathorn Creek. Withdrawal of make up water is expected to have minimal effect on flows in the Telkwa River. The nearest stream gauge on the Telkwa River is located 25 km upstream of Goathorn Creek as shown on Drawing B-0110. The minimum flow recorded at the station is 0.65 m^3/sec (2448 m^3/hr). Flow near the plantsite is expected to be considerably greater due to the increased catchment size. The peak make up water demand is expected to be only 1% of the 10 year extreme minimum daily flow.

5.3.3 Make Up Water Intake

Two alternative intake schemes have been considered:

(a) An infiltration gallery located beneath the river bed.
(b) A series of shallow wells located alongside the river.

Shallow well intakes are recommended as they are less susceptible to flood damage and less likely to be blocked by the high suspended sediment load of the Telkwa River.

It is expected that 2-4 wells 20 m deep will be required but this will be confirmed at the detailed design stage.

6.0 WASTE DUMPS

6.1 Introduction

This section of the report presents recommendations for the disposal of rock waste materials in both in-pit and out-of-pit locations.

The stripping and stockpiling of topsoil and unconsolidated overburden materials is discussed in the Project Environmental and Reclamation Report.

6.2 Waste Dump Areas and Mining Schedule

Mining will start at the north end of #3 Pit and the waste will be placed in an out-of-pit dump. Pits #1 and #2 will be worked successively to supplement production from #3 Pit. Waste from #1 and #2 Pit will also be placed in the out-of-pit dump. In approximately year 6 reserves in Pits #1 and #2 will be exhausted and at that time waste from Pit #3 will be directed to Pits #1 and #2. As Pits #1 and #2 become backfilled the continuing stream of waste will be directed to the out-of-pit dump until sufficient working space is available in #3 Pit to permit in-pit waste disposal.

Pits #4, #5, and #6 will be worked in succession during the latter stages of the project. Waste from #4 Pit will be placed in an out-of-pit dump. Waste from #5 Pit will be used to backfill #4 Pit and #5 Pit will be backfilled with waste from #6 Pit.

Two out-of-pit waste dumps will be required for the project. Proposed locations for the dumps are shown on Drawing D-0104. The East dump will be used for the disposal of waste from Pits #1, #2 and #3 and will have a capacity of 57 million m^3. The West dump will be used for disposal of waste from Pits #4, #5 and #6 and will have a capacity of 5.5 million m^3.

On the basis of the current project plans, the two out-of-pit dumps will have sufficient capacity to contain all waste rock not placed in in-pit dumps.

6.3 Dump Site Conditions

6.3.1 East Dump

The east dump covers an area of about 1.6 km^2 of ground which slopes gently, at about 5°, to the north. South of the site the ground steepens as it rises in elevation. A number of sinuous morainal ridges exist on the site.

The waste dump area is covered with a thin layer of topsoil directly overlying a till consisting of silt, sand, gravel and cobbles. The upper 1 m of the till is weathered; below the weathered zone the till is dense. The depth of till at the site is about 15 m, however, large variations in the till thickness may be expected. The till is underlain by sedimentary bedrock.

The area is moderately well drained by a number of small ephemeral streams. Occasional depressions exist where drainage is poor and the ground remains saturated most of the year. The lower part of the waste dump site is cleared and used for growing hay. The upper, south part is forested with poplar and coniferous trees.

Geological and groundwater conditions will be confirmed by site investigation during the detailed design stage of the project.

6.3.2 West Dump

The west dump covers an area of about 0.4 km^2 of flat lying ground which slopes at about 2° to the north.

It is expected that the subsoil strata will be similar to the east dump site. The 1:5000 topographic map does not indicate the presence of any drainage courses across the proposed area and drainage is expected to be similar to the East Dump site.

Foundation conditions will be investigated at the detailed design stage of the project.

6.4 Material Characteristics

6.4.1 Foundation Materials Out-of-Pit Dumps

Topsoil and organic material will be stripped from the foundation area of the dumps prior to dump construction.

Foundation materials for both sites consist of a dense silt, sand and gravel till. On the basis of visual examination, the strength of this material is estimated to be $\phi' = 30^\circ$ (effective angle of internal friction). The till is low to non plastic and as such little or no pore pressure is expected to build up due to dump construction. Stability has been analysed assuming an r_u range of 0 to 0.2 for pore pressure response. (r_u is the pore pressure divided by overburden pressure.)

6.4.2 In-Pit Foundation Conditions

The footwall of the #3 Pit will consist of the rock stratum underlying the #2 seam. This rock varies considerably over the pit area ranging from a sandstone to a mudstone. Stress relief due to unloading of the footwall is expected to cause break up of the footwall, especially where groundwater is present.

In order to provide a consistent and safe design for the in-pit waste dumps a conservative effective angle of internal friction of $\phi' = 17^\circ$ has been selected for footwall material based on laboratory tests on the mudstone material.

6.4.3 Waste Materials

Waste rock will consist of a heterogeneous mixture of sandstone, siltstone and mudstone. The type of material being wasted will depend on mine scheduling. Waste materials will consist of three general types as follows:

a) Moderately strong to moderately weak fine grained sandstone of average uniaxial compressive strength 40 MPa and a maximum uniaxial compressive strength of 100 MPa.

b) Very weak to moderately strong siltstone and siltstone interbedded with mudstone. Uniaxial compressive strengths range from 12 MPa to 100 MPa with an average of 35 MPa.

c) Very weak to moderately weak mudstone. Uniaxial compressive strengths range from 12 MPa to 40 MPa.

Relative proportions of these materials for the mine life are given below:

a)	Sandstone	31%
b)	Siltstone and Siltstone-Mudstone interbedded	40%
c)	Mudstone	29%

The geotechnical properties of the waste materials are a function of the relative proportions of the material types in the dump, the dump height, and degree of breakdown of materials. Table 6-1 summarizes the geotechnical properties of the materials. The laboratory test results are presented in Appendix III.

TABLE 6-1

SUMMARY OF GEOTECHNICAL PROPERTIES OF WASTE MATERIALS

	Material			
Parameter	Mudstone	Siltstone	Sandstone	Average Design Value
Unconfined Compressive (MPa) Strength[1]	12-40	35	40	35
Slake Durability %	81-89	98-99	98-99	-
Sulphate Soundness % Lost	N/A	N/A	78-100	-
Friction Angle Ø'° [2]	29-33	31-33	31-33	32
Dry Density Fill				1800 kg/m^3
Breakage Factor[3] % at 2 MPa	30-40	20-30	20-30	30
Unit Weight Mg/m^3	2.53	2.57	2.53	-

1. Based on point load index tests indicated on test hole logs Appendix I, and unconfined uniaxial compressive strength tests, Appendix II.
2. Based on method of Barton & Kjaernsli (1981) using d_{50} = 200 mm, U.S.C. given above, rough rock, porosity n = 40%, n = 0.5 - 2 MPa, and Ø = 29°.
3. Breakage factor estimated on basis of comparative studies with work by Marsal (1967).

Friction Angle

A friction angle of Ø' = 32° has been selected for waste dump design based on the uniaxial compression tests. Using the method of Barton and Kjaernsli, shear strengths for the waste are expected to range from 29° to 33° depending on the confining stress.

Slake Durability

The slake durability tests indicate that on wetting and drying the mudstone will breakdown to fine to medium gravel sized particles. The siltstone and sandstone exhibited minimal tendancy to degrade in this manner. The test results are presented in Appendix III.

Sulphate Soundness

Magnesium Sulphate Soundness tests were carried out on selected sandstone specimens. The test results indicated that these rocks are sensitive to chemical weathering with 78% - 100% loss during the test.

Crushing Strength

Six uniaxial unconfined compression tests were completed as shown in Appendix III. Point load tests were conducted on selected core samples. The results are presented on the test hole logs in Appendix I. The average and design values are based on these test results and on visual examination of the rock cores.

Rock fill which is subject to stress due to the height of fill above will break down due to crushing of particles. The amount of particle breakdown due to confining load has been quantified (Marsal 1967) by a breakage parameter B; where B is the percent of particles by weight which will undergo some crushing. The interbedded rocks forming the waste have an average unconfined compressive strength of 35 MPa. At confining loads of 1.5 MPa (75 m fill height) the B value is 30% to 40% for the shale and 20% to 30% for sandstone and siltstone. This parameter is important in assessing the longterm permeability of the dumps and the requirement for rock drains in the dumps as discussed in Sections 6.5 and 6.6.

6.5 Design of Out-of-Pit Dumps

6.5.1 General

The out-of-pit waste dumps are designed as free draining loose rock fills. Dumps up to 100 m in height may be constructed with overall 2:1 slopes. Waste material should be placed in horizontal lifts, by end dumping. Lift thickness may be adjusted to suit operational conditions but may be up to 30 m. End dumped waste will stand at the angle of repose which is expected to be 32° (1.6:1). Safety berms should be constructed between lifts to mainatin the overall 2:1 slope.

Foundation preparation will be required to control the development of progressive failures in the waste dumps. All topsoil and overwet or weak soils should be removed from the toe area. Actual stripping requirments will be determined following the site investigation.

Deleterious and sulphur rich plant waste may be placed in the dumps. These materials should be placed in isolated cells within the dumps in 1.0 m lifts and compacted.

Details of the waste dump design are presented on Drawing D-0129.

6.5.2 Stability Analyses

Stability analyses have been carried out to determine the factor of safety against deep seated instability and surface instability.

The site is located in a Zone 2 seismic area as shown on the Seismic Zoning Map of Canada. Estimated peak ground acceleration for an earthquake with a 100 year return period is 0.06 g.

Stability analyses have been carried out both with and without allowance for seismic conditions.

The following minimum factors of safety against deep seated waste dump failure have been adopted:

Static Case (non earthquake) - FoS = 1.3
Seismic loading case - FoS = 1.1

The analysis of deep seated failure were carried out using Janbu's method of slices. Infinite slope analysis was used for smaller instabilities. The design parameters for waste material and foundation materials are presented in Section 6.4. Design parameters and stability analysis results are summarized on Table 6-2.

The results of the analyses show that the out-of-pit waste dumps have an adequate overall factor of safety against deep seated and shallow instability under seismic and non-seismic conditions. There will be potential for minor surficial instability on bench slopes under seismic conditions.

TABLE 6-2

SUMMARY OF GEOTECHNICAL PARAMETERS AND FACTORS OF SAFETY FOR POTENTIAL FAILURE MODES EAST AND WEST DUMPS

Failure Mode	Ø'° Fill	Ø'° Foundation	r_u	Factor of Safety Non Seismic Case	Factor of Safety Seismic Case
Deep Seated Translational	32	30	0.2	1.8	1.7
for 2:1 H:V Slope	32	30	0.0	1.8	1.7
Deep Seated Translational for 2:1 H:V Slope	32	30	0.2	1.5	1.45
Surface Slide 2:1 H:V Slope	32	-	0.0	1.25	1.21
Bench Instability	32	-	0.0	1.00	0.97

6.6 Design of In-Pit Dumps

6.6.1 General

Waste dumps will be constructed in all six open pits. Waste from pit #1 will be placed in pit #2. Pit #2 will be used for the disposal of some of the waste from #3 pit. Likewise only very minor amounts of waste will be placed in pits #4, #5 and #6 as they are being mined. Waste dumps will be constructed in #3 Pit from year 6 onwards, starting at the northern end of the pit and progressing southward.

The pit #3 footwall dips east at approximately 20°. In order to maintain stability on the west facing face of the #3 pit, dump construction should be started at the highwall toe and progress up dip in a westerly direction.

The in-pit dumps are designed as free draining loose rock fill dumps and should be constructed as follows:

- North south trending face. Where the footwall dip is 13° or greater to the east, north south trending faces should be 1.6:1, H:V (angle of repose).

- East west trending dump faces should be constructed with overall 2.25:1, H:V slopes. This should be achieved by placing waste in 10 m lifts. Bench angles may be at 1.6:1. Safety berms should be incorporated to acheive the overall 2.25:1 slope.

Loose and overwet material should be removed from the footwall prior to dump construction and ditches and sumps should be used to drain water away from the toe of the waste dump.

6.6.2 Stability Analysis

Stability analyses have been carried out to determine the factor of safety against deep seated and surface instability. The acceptable factors of safety are as discussed in Section 6.5.2.

It is unlikely that any major pore pressure will develop in either the foundation or the fill material due to construction of the in-pit waste dump, consequently, the effect of only a small pore pressure response of $r_u = 0.2$ was examined.

Results of the stability analysis are presented in Table 6-3.

TABLE 6-3

SUMMARY OF GEOTECHNICAL PARAMETERS AND FACTORS OF SAFETY FOR POTENTIAL FAILURE MODES, IN-PIT DUMPS

Failure Mode	Slope H:V	Ø'° Fill	Ø'° Foundation	Dip of Bedrock Into Dump	r_u	Factor of Safety Non Seismic Case	Factor of Safety Seismic Case
Deep Seated Translational	2.25:1	32	17	0	0.0	1.3	1.26
Deep Seated Translational	2.25:1	32	17	0	0.2	1.2	1.16
Deep Seated Translational	1.6:1	32	17	13	0.0	1.3	1.26
Surface Slide	1.6:1	32	-	-	-	1.0	0.97
Surface	2.25:1	32	-	-	-	1.4	1.36

Results of the analyses indicate that the design for in-pit dumps is adequate. Factors of safety for deep seated and surface instability under seismic and non-seismic conditions are acceptable for the overall waste dump. However, there is potential for minor surface instability on individual benches on the trenching faces and on the north south trending faces during construction.

6.7 Long Term Settlement

The long term settlement of mine waste depends on a variety of factors such as long term phreatic conditions, breakdown of rock particles and, as such, is difficult to predict accurately. However, experience with similar materials indicates that settlements will be in the order of 2% of fill height and will be substantially complete after about 10 years. For in pit waste which will be loose dumped, the rise in water table after completion of mining may cause some further settlement, estimated to be 3 to 5 percent. The rate of settlement will depend on the rate of rise of the groundwater table.

7.0 FINE TAILINGS DISPOSAL

7.1 Introduction

This section of the report presents the conceptual design of a tailings dam to impound fine refuse. The anticipated output of fine tailings from the process plant is 120,000 tonnes of solids per year. The tailings pond is designed to store tailings for an operating period of 20 years. A preliminary design is provided together with an outline of operating and construction procedures. At this preliminary design stage, no site investigation or materials testing have been undertaken.

7.2 Description of Fine Tailings Materials

Fine refuse will emerge from the coal preparation plant as a thickener underflow in the form of a tailings slurry with a pulp density of 36% solids by weight. The fine refuse is expected to have a top grain size of 1 mm with about 72% by weight, passing 0.15 mm (#100 sieve size) and 58% by weight, passing 0.044 mm. The gradation was provided by CNRL and is shown in Appendix IV, Plate 1.

The clay minerals fraction of the fine tailings is expected to be 95% kaolinite and illite; with 5% smectites. The relatively high percentage of particles less than 0.044 mm necessitates the use of flocculants to settle the finer sizes.

The properties of the tailings have been assessed by comparison with published data (Samaresinghe et al, 1980). The Telkwa tailings will contain a high percentage of fine particles and the gradation is at the finest limit of normal grain size distributions for fine coal tailings. Based on the published data, specific gravity for fine coal refuse varies from 1.4 to 2.4, and it is anticipated that the average specific gravity of the tailings will be about 2.0.

The dry density of coal tailings settling without flocculation normally varies from about 0.64 T/m^3 (40 lb/cu ft) to 1.2 T/m^3 (75 lb/cu ft), although densities as low as 0.3 T/m^3 (19 lb/cu ft) have been used for design elsewhere. The effect of flocculant on the settled density of the tailings can be determined in bench tests, however scaling up of test results to full scale production is difficult and tailings density in the pond will not be known accurately until the pond is in operation. For design purposes the dry density of the tailings was assumed to be 0.64 T/m^3 (40 lb/cu ft).

The volume of tailings to be stored is inversely proportional to their density, thus the assumed density relates directly to the size of impoundment required. The design assumption of 0.64 T/m^3 is a relatively low density which provides for conservatism in impoundment sizing. With tailings dam construction the dam is raised each year thereby permitting adjustments to be made should the density vary from the design value.

The permeability of the settled tailings is expected to be between 1 x 10^{-6} and 1 x 10^{-7} m/sec.

The design values for dry density, void ratio and permeability are listed below in Table 7-1.

Table 7-1

SUMMARY OF DESIGN PARAMETERS FOR FINE TAILINGS

Parameter	Design Value
Dry Density	0.64 T/m^3
Specific Gravity	2.0
Permeability	1 x 10^{-4} m/sec

7.3 Site Conditions

The proposed tailings pond site is located about 2 km north east of the mine area adjacent to the plant site as shown on Drawing D-D101. The ultimate pond will cover an area of some .56 km^2 of lightly forested ground which slopes gently at about 1° to 2° down to the east. As currently located, the toe of the finished dam abuts the proposed railway spur. It is understood that this railway line may be relocated and a minimum clearance of 100 m from the toe of the finished dam is recommended. The site was chosen because of the proximity to the process plant and the availability of a sufficiently large area to store all the tailings in one location. The site is lower in elevation than the plant thereby minimizing the head for tailings slurry pumping.

7.4 Subsurface Conditions

Based on visual inspection of the site and on information given by Pedology Consultants in their 1984 report, foundation conditions at the site are expected to comprise topsoil overlying a well graded, dense sand and gravel deposit.

An investigation of foundation conditions will be necessary at the detailed design stage.

Domestic well records indicate that groundwater in the area is at about 12.5 m depth within the gravel layer.

7.5 Tailings Pond Design

7.5.1 General

The tailings will be discharged into the tailings pond via a pipeline; the tailings will settle in the pond and the remaining clarified water will be recirculated to the process plant by pumping from a barge mounted pump.

A starter dam constructed of locally available borrow will be required to store tailings in the first year of production. The dam will be raised each year to meet storage requirements using mine waste. The height of embankment required depends on the volume of tailings produced plus additional hydraulic considerations such as flood storage and wave runup.

The volume of settled tailings produced each year is estimated at 187,500 m^3 based on the assumed density of 0.64 T/m^3. Hydraulic design criteria are outlined in the following section.

7.5.2 Hydraulic Design of Tailings Pond

Water Balance

The proposed tailings pond will operate as a closed circuit during normal hydrologic conditions. As shown on Table 7-2, there is a net water deficit for both average hydrologic conditions and the 10 year wet year. Provision is made for spill in the event of an inflow flood in excess of the 10 year return period.

The water balance analysis is based on the following operating conditions, material characteristics and hydrologic parameters.

a) Reclaim Operation:

Excess water in the tailings pond will be reclaimed to the plant from April to December inclusive. It is assumed that recirculation will not be possible during January, February and March because of significant ice thickness.

b) Hydrologic Conditions:

Annual precipitation:	
Mean	510 mm
10 Year Wet	650 mm
Annual Lake Evaporation:	
Mean	550 mm
Annual Catchment Runoff:	
Mean	150 mm
10 Year Wet	190 mm

c) Pond and Catchment Area:

	Pond Area km^2	Net Catchment Area* km^2
Starter Dam Stage	0.30	0.05
Ultimate Stage	0.50	0.12

* Pond catchment areas downstream of diversion ditched and excluding pond area.

d) Water Content of Settled Tailings is 105% (dry weight basis) or 48% solids.

e) Plant Water Balance:

Total Water to Tailings Pond in Tailings Slurry	37 m^3/hr
Makeup Water Required for Plant (may be supplied by reclaim from tailings pond or river intake)	43 m^3/hr

TABLE 7-2

ANNUAL WATER BALANCE OF TAILINGS POND

	Average Hydrologic Conditions		10 Year Wet	
	Starter Dam 1000 m^3	Ultimate Dam 1000 m^3	Starter Dam 1000 m^3	Ultimate Dam 1000 m^3
INFLOW				
Precipitation	153	255	195	325
Runoff	8	18	10	23
Excess Slurry Water[1]	86	86	86	86
TOTAL	247	359	291	434
OUTFLOW				
Evaporation	165	275	165	275
Reclaim Required to Balance Water Flows	80	84	126	159
Release	0	0	0	0
TOTAL	247	359	291	434

Notes:

1. Excess Slurry Water = total slurry water - water stored in voids of settled tailings
$= (37\ m^3/hr - 22\ m^3/hr)\ 5700\ hrs/yr$
$= 86,000\ m^3/yr.$

2. Maximum Reclaim is the rate at which water can be accepted by the plant; based on a maximum flow rate of 43 m^3/hr for 9 months of the year.

Maximum Reclaim $= 9/12 \times 43 m^3/hr \times 5700\ hrs/yr$
$= 184,000\ m^3/yr.$

Freeboard and Flood Control

Criteria

The freeboard and flood control design comply with the criteria for design of tailings impoundment as defined by the B.C. Ministry of the Environment "Guidelines for Design, Construction, Operation and Abandonment of Tailings Impoundments" 1983.

Freeboard

In accordance with the guidelines, a freeboard of 1.0 m is provided above the 200 year flood level to contain wind setup and wave rise produced during a 1 hour extreme wind of 100 years recurrence interval.

Emergency Spillway

An emergency spillway is provided to release excess water in the event that an inflow greater than a 10 year snowmelt flood occurs. The water will be discharged into a ditch leading to an existing water course below the plant site settling pond as shown on Drawing D-0124. The 5 m wide open spillway channel is designed to handle the 200 year spring flood at a flow depth of 0.1 m. With 1.0 m of freeboard the spillway invert is required to be 1.1 m below the dam crest. The spillway will be located at the north abutment of the tailings dam and will be relocated upslope as the dam is raised.

Flood Storage

The tailings pond water level will be controlled by reclaim of water to the plant as the annual water required by the plant will normally exceed the excess water which will accumulate at the tailings pond. The pond will be regulated to provide enough flood storage below the invert of the emergency spillway so that a 10 year flood will not cause spillage. Drawdown of the pond to provide a 0.4 m flood storage depth is required before snowmelt commences to store the 10 year total precipitation from November to April. Only 0.1 m flood storage is required after snowmelt to store the 10 year rainstorm.

Excess Water During Winter

Reclaim of free water to the plant is expected to be restricted to about 9 months per year because ice buildup will restrict clarification in winter. Ice thicknesses up to 1.2 m are anticipated. The average depth of freewater would increase by about 0.2 m during the three winter months when tailings slurry discharge would continue without reclaim.

Normal Free Water Depth

The recommended minimum depth of normal free water is 1.0 m to provide for clarification of slurry water.

Maximum Regulated Pond Level

The maximum regulated pond levels based on the above criteria, are shown on Drawing A-0102. As indicated on the drawing, the maximum regulated pond level before snowmelt should not exceed 1.7 m below dam crest and 0.6 m below the spillway invert. The maximum regulated pond level after snowmelt should not exceed 1.2 m below dam crest and 0.1 m below the spillway invert.

Diversion Ditch

A diversion ditch is required to minimize catchment runoff entering the pond. An initial diversion location is shown on Drawing D-0101. This diversion should be relocated uphill as the dam is raised.

The diversion should be cleaned of snow accumulation each spring to ensure that all runoff is diverted.

7.6 Tailings Dam Design

7.6.1 General

The recommended tailings dam will be constructed by the downstream method with the centreline progressing outward from the pond as the dam is raised. The starter dam will form a integral part of the main embankment. Tailings should be spigotted near the western (uphill) end of the pond and clarified water reclaimed from the eastern end of the pond, which is the area of maximum embankment height. Water would be in contact with the embankment above the settled fine tailings deposit. Dam slopes are 2:1 H:V upstream slope and a 2.5:1 H:V downstream slope with a 4 m wide crest as shown on Drawing No. D-1962-101. A 4 m thick impervious facing will be placed on the upstream slope; as potential wave heights are small no additional erosion protection is considered necessary on the dam face. In a storm, waves will erode the till facing to a limited depth before a self armouring surface forms.

The proposed dam is designed for an operating life of 20 years with a final crest elevation of about 558 m and a maximum height of about 18 m. The final crest width is set at 4 m, although intermediate crest widths may be greater for construction convenience. The final length of the dam will be about 2.4 km. The storage/elevation curve and the dam volume/elevation curve for the proposed tailings pond are shown on Drawing D-0103.

7.6.2 Foundation Preparation

All wet and organic soils should be stripped from beneath the foundation area. The exposed sand and gravel foundation should be proof rolled with at least four passes of an 8 T vibratory roller prior to fill placement.

7.6.3 Starter Dam

A starter dam constructed of borrow material is required to form an initial tailings pond. The starter dam will form an integral part of the ultimate tailings dam. The height of the starter dam is dependent mainly on providing storage for precipitation and clarification of water.

The starter dam should be constructed to an elevation of 546 m; a maximum height of 6 m. The starter dam will require fill of about 100,000 m^3 and will provide storage for 187,000 m^3 of tailings.

The starter dam and pond are shown in plan on Drawing D-0101 along with a typical dam cross section. Material types and compaction requirements are discussed in Section 7.6.4.

7.6.4 Main Tailings Dam

The main tailings dam is expected to have a maximum height of about 18 m and is shown in plan, and with a typical section on Drawing D-0101. The dam is designed with three different zones. Assumptions have been made about the availability and suitability of the various material types and these must be confirmed by investigation prior to final design.

a) Zone A is low permeability fill used to form the starter dam and a 4 m wide facing on the upstream face of the dam. The purpose of Zone A is to prevent excessive seepage through the dam. Zone A should consist of well graded glacial till with a minimum of 20% passing the 0.075 mm sieve, placed in maximum lifts of 300 mm and compacted to a minimum of 98% of maximum Standard Proctor Density at optimum moisture content ±2%.

b) Zone B is the general fill which may consist of waste rock from the mine, provided that a suitable gradation of material can be produced. The waste rock should be well graded with a maximum size of 150 mm and consist predominantly of siltstone and sandstone. Compaction specifications should be determined after a field trial to ensure an adequate density, without excessive particle breakdown and loss in permeability. It is anticipated that the material will be spread in lifts about 250 mm thick and compacted with 4 passes of a smooth drum vibratory roller with minimum static weight of 8 T.

The local sand and gravel materials may be used as an alternative to mine waste. This material has significant advantages in terms of engineering properties and may not prove significantly more expensive than the mine waste especially if rehandling of waste is necessary to produce a suitable construction gradation.

c) Zone C is a filter material. The gradation requirements for the filter will be defined when the grain size of the foundation and construction materials are known. It may be necessary to place the filter between the shell and the Zone A fill as well as above the foundation.

The dam is designed as a semi-pervious structure. Seepage will occur through the dam foundation especially in the early period of operation. The final design must address the potential for water loss, piping or excessive erosion of the foundation due to seepage water. Piezometric levels in the dam and foundation should be measured during operations to confirm that the embankment is well drained.

It is likely that material quality, particularly the waste rock quality, will vary significantly during the 20 year construction period. A program of instrumentation and to help identify problems in construction monitoring is discussed in Section 7.8. Staged construction of the tailings dam will permit observation and development of construction procedures to suit variations in material quality.

7.6.5 Seepage

The base of the proposed tailings pond consists of pervious, well graded sands and gravels. Seepage from the pond is expected to be high, particularly during the early period of pond operation. The permeability of the foundation and construction materials should be measured as part of the foundation investigation in order to calculate seepage rates through the dam and foundation to ensure the integrity of the structure. The calculations may indicate a need for design modifications to control seepage.

7.6.6 Stability

The stability of the dam will depend on the results of seepage analyses and on the strengths of the construction and foundation materials. Assuming a typical foundation and dam fill strength of $\underline{0}' = 35°$ and a phreatic line in the dam equivalent to $r_u = 0.1$ the safety factor against deep seated circular failure will excede 1.8.

7.6.7 Tailings Pond Operation

Tailings should be discharged at the uphill end of the pond. A beach of tailings will form near the discharge point and slope down towards a pool of water impounded by the dam. The location of the discharge point within the reservoir should be moved during pond operations such that tailings are evenly distributed throughout the pond.

During winter the discharge point should be centrally located where a pond of water can form. By maintaining a water pond, removal of water by reclaim may continue into the winter period and reduce storage loss due to freezing.

7.7 Pumps and Piping

A slurry pump is required in the plant to pump the tailings to the tailings pond, and a reclaim water pump is required to pump clarified water back to the plant. Approximately 2 km of pipe is required for each of the tailings and reclaim lines.

Static head from the plant to the tailings pond is negative at the starter dam level and of the order of 5 metres ultimately. To maintain the tailings in suspension in the slurry line requires a velocity in excess of 1.0 m/sec, or a maximum pipe ID of 120 mm. Use of a H.D.P.E. pipe such as Sclairpipe is common in tailings operations because of the ease of handling of the pipe. For example, a 110 mm series 100 Sclairpipe will carry the design flow at an average velocity of 1.8 m/sec and a head loss equivalent to 56 m. A centrifugal slurry pump with an electrical motor drive at a steady output of approximately 20 kW will be required.

The tailings line should be laid on the ground surface between parallel earth dykes to contain the slurry in the event of a pipe break. Dyke details are shown on Drawing D-0125.

In order to return clarified reclaim water to the plant a small pump is required. The reclaim pump should be installed on a floating barge in the pond. A pumping capacity of 43 m^3/hr should be provided to allow the complete makeup water supply for the plant to be provided from the pond in the event of a shutdown in the river water supply. A pump with a 7.5 kW motor will provide the flow required through a 125 mm nominal diameter pipe. The reclaim water pipeline should be buried to prevent freezing and to make winter-time reclaim possible.

7.8 Instrumentation and Monitoring

In order to ensure the safety and efficient operation of the tailings system the following instrumentation and monitoring of the tailings pond and dams is recommended.

a) The elevation of the tailings pond water surface should be recorded regularly.

b) Standpipe piezometers should be installed in the tailings dam and its foundation along 3 or 4 sections. The piezometers may consist of 75 mm dia PVC pipe, with a capped slotted section in the lower 2 m, with solid PVC pipe extending upward through the fill surface. The piezometers should be protected by tripods or other suitable barriers to avoid damage from construction equipment. The water levels in the piezometers should be measured and recorded monthly.

c) Measurements should be taken periodically to determine average in-situ density, specific gravity and water content of the deposited fine tailings. These measurements will provide confirmation of design assumptions or allow adjustment of future storage requirements.

d) Suitable measurements should be taken annually to estimate the tonnage or volume of tailings produced. These may include regular measurements of slurry flow rate and pulp density and/or annual profiling of the settled tailings surface.

e) Annual survey cross-sections of the tailings dam should be carried out to provide a check on construction scheduling.

Placement and compaction procedures for dam construction should be observed frequently.

f) Standard Proctor compaction tests and in situ field density tests should be performed on a regular basis to monitor fill density. A minimum of one field density test should be performed for every 1500 m^3 of fill placed. Representative gradation analyses of the dam construction materials should be obtained regularly. One test per week should be sufficient unless significant material changes occur.

g) Groundwater observation wells should be installed downstream of the tailings dam and monitored monthly to measure the static water levels and to obtain samples for water quality determinations.

h) Regular observations of the toe of the dam should be carried out to detect any visible seepage.

i) A record of all dam construction activities should be made on a shift-by-shift basis.

j) Continued liaison with a qualified geotechnical consultant should be maintained throughout the operating life of the tailings pond. Full time inspection of the construction of the starter dam by the designer is recommended. Subsequently, at least once annual inspection of the tailings dam by the designer should be made.

8.0 PIT SLOPE STABILITY

8.1 Introduction

The geological and geotechnical data collected to date is sufficient for determination of overall slope stability, however, there is insufficient geological control at the present time to identify structures of the scale which will control local slope and bench stability.

High wall, end wall and footwall stability have been considered for the #3 Pit. Slope stability for slopes 1 and 2 has not been considered but geological conditions are similar to those in Pit #3 and therefore pit slopes are expected to be similar. Insufficient data is available for Pits 4, 5 and 6 to allow an evaluation of pit slope stability to be made at the present time.

Geological interpretations made by C.N.R.L. have been used to develop a slope cross section which represents the probable large scale failure mode. Stability analyses have been carried out using the Janbu routine for non-circular failure surfaces.

8.2 Slope Design Parameters

The engineering parameters selected for use in the stability analyses are based on results of laboratory tests.

Mudstone

Mudstones occur throughout the bedrock sequence but are concentrated stratigraphically beneath each coal seam and as partings and interburden within multiple seams. The mudstone becomes very weak when wetted and softened. Occasional discontinuous slickensided surfaces have been observed.

Shear strength parameters for the mudstone footwall material have been selected on the basis of direct shear tests on remoulded mudstone material. The following parameters were selected for use in the stability analysis.

Shear Strength along bedding planes and through softened or partially slickensided mudstone.	Ø' = 17° C = 0 kPa
Average saturated unit weight	2100 kg/m^3

Bedrock Overburden Materials

The pit slopes will comprise a sequence of interbedded mudstones, sandstones, siltstones and coal. Failure through the sequence is expected to be discontinuity controlled, the overall failure plane being stepped along joint surfaces and bedding planes. The following cross bedding shear strength parameters have been selected for the bedrock overburden sequence:

Bedrock Materials	Ø' = 25° C = 300 kPa
Average Saturated Unit Weight	2100 kg/m^3

Localized faulting has reduced the shear strength of the overburden sequence. The following shear strength parameters have been selected for the bedrock overburden sequence when faulted:

Faulted bedrock	Ø' = 25° C = 0 kPa
Average Saturated Unit weight	2100 kg/m^3

8.3 High Wall Stability

The #3 Pit high wall will trend north south and will be located on the eastern side of the pit. The main continuous structural discontinuities such as bedding planes and primary faults dip east into the high wall and are generally beneficial to slope stability. Although not identified, it is probable that a west dipping series of antithetic secondary faults are associated with the primary faulting system. The secondary faults will have a detrimental effect on slope stability but are probably discontinuous.

Slope stability is assumed to be controlled by the cross-bedding strength of the overburden bedrock sequence. The potential failure surface is a curved, stepped surface comprising intersecting secondary fault and joint planes. Failure along such a failure plane will be accompanied by crushing and rotation of rock blocks along the failure plane. With high wall slopes 100 m high the stresses at the toe of the slope will be relatively small and only the weakest of the mudstones are expected to crush. The apparent cohesion of C = 300 kPa accounts for the anticipated roughness along the failure surface.

Slope failure will be accompanied by some sliding along softened footwall material. The footwall comprises either mudstone or siltstone, however, for the purpose of the analysis a mudstone footwall has been assumed.

Stability analyses have been carried out for a range of slope heights and overall slope angles. Details of the analyses are presented on Drawing B-0130.

8.4 Recommended High Wall Angles

High wall slopes up to 100 m in height may be excavated at an overall angle of 60°. In areas seriously affected by secondary faulting, long term slope stability will be controlled by the dip angle of the faults. The secondary fault area is not expected to be continuous and therefore the safe highwall angle in faulted areas is not expected to be less than 40°.

In areas of #3 Pit which will not be backfilled, long term high wall stability into the abandonment phase of the project will be a concern. To provide longterm stability, horizontal drainage wells are required to ensure that the groundwater table is maintained below a line drawn at 20° from the toe of the highwall slope.

Drainage wells should not be required where high wall slopes are to be buttressed by backfilling.

During the operating phase of the project, safety berms should be incorporated into the high wall to control local bench instability and to provide access to the slope for inspection and monitoring.

8.5 End Wall Stability

The north and south endwalls of the #3 Pit will be oriented perpendicular to the strike of the bedrock. With this orientation, the effective dip of the bedding planes is 0° relative to the end wall slopes and therefore there is no potential for planar or wedge failures of the slopes due to sliding along bedding planes.

In view of the intent to construct in-pit waste dumps against the north and south endwalls of #3 Pit there is no requirement for longterm slope stability. On the basis of the analyses shown on Drawing B-0130 the end walls may be excavated at an overall 60° angle. The requirements for safety berms are as presented for the high wall.

8.6 Footwall Stability

The bed dip angle and dip direction in conjunction with the low shear strength of the footwall material preclude the excavation of a stable low wall slope. It will therefore be necessary to extend the footwall until it daylights at the western margin of Pit #3.

The footwall strata dip angle ranges from 13° to 20° creating potential for block sliding along the bedding planes if the footwall is undercut, or if groundwater pressures below the footwall are not releived.

In order to prevent instability careful mining procedures are required to ensure no undercutting of footwall strata occurs. The installation of vertical drainage wells is required to prevent heave of the footwall.

8.7 Monitoring

Regular inspection of the pit walls should be undertaken during mining operations to identify potentially unstable areas in order that minor instabilities may be anticipated. During the first 5 years of operation, groundwater levels should be monitored to confirm that drainage of groundwater into the pit is occuring.

References

Armstrong, J.E., 1944. Preliminary Map, Smithers, British Columbia; Geological Survey of Canada preliminary paper 44-23.

Tipper, H.W., 1976, Geological Map, Smithers, B.C.; 93L; Geological Survey of Canadian unpublished map.

Tipper, H.W., and Richards, T.A., 1976, Jurassic Stratigraphy and History of North-Central British Columbia; Geological Survey of Canada; Bulletin 270, pp 73.

Tipper, et al, 1979, Parsnip River, British Columbia; Sheet 93; Geological Survey of Canada; Map 1424A.

Klohn Leonoff Ltd., 1982, Preliminary Geotechnical and Hydrogeological Data Collection Study, Telkwa Coal Project; report prepared for Crows Nest Resources Ltd.

Pedology Consultants, 1984, Soil Survey and Land Capability Evaluation of the Telkwa Coal Project; report prepared for Crows Nest Resources Limited, Calgary, Alberta.

E. Livingston Associates, 1976, Letter Report to Village of Telkwa on Village Well Water Supply.

Campbell, A., 1977, Geological Report on Groundwater Exploration in Telkwa B.C.; unpublished report.

Health and Welfare Canada, 1979, Guidelines For Canadian Drinking Water Quality 1978; report prepared by the Federal-Provincial Working Group on Drinking Water and published by the Department of National Health and Welfare.

McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979, Water Quality Sourcebook, A Guide to Water Quality Parameters; Inland Waters Directorate, Environment Canada.

References

(Continued)

Samaresinghe, M., Huang, Y.H., 1980. A Literature Review of Coal Refuse Dikes; Institute for Mining and Minerals Research, University of Kentucky.

APPENDIX I

TEST HOLE LOGS

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 810.6 m

CO-ORD LOCATION N 6053278; E 621502

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEABILITY
1.0 2.0 3.0 4.0	NOT CORED	4.15			UNDIFFERENTIATED OVERBURDEN					
5.0	1			▤	MUDSTONE - silty - very weak - slightly weathered - medium bedded - closely fissured - fissures at varying angles - grey - minor siltstone bands - medium plastic - minor ironstone and calcite seams at 8.8 m - liquid Limits = 45 Plastic Index = 23		74	25	0	
6.0 7.0	2			▤			74	37	0	
8.0	3	4.70		▤			98	33	0	
9.0 10.0	4			░	SANDSTONE - fine grained becoming coarser with depth - very weak - highly weathered - tight fissures at 30° and 70°		95	86	75	

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-335
DATE JANUARY, 1984 PLATE 1/13

KLOHN LEONOFF

K.L.C. - METRIC

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 810.6 m

CO-ORD LOCATION N 6053278; E 621502

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEABILITY
11.0	4	2.25			SANDSTONE - as above - ironstone horizons with calcite veins		95	86	75	
		0.25			MUDSTONE-very weak, highly weathered					
12.0		0.50			COAL - (seam 10) - broken fragments					
		0.40			MUDSTONE-silty, very weak, fresh, thinly bedded, minor brecciated zones					
13.0		0.70			MUDSTONE/SILTSTONE-very weak, thinly interbedded, bedding at 70° - 75°, brecciated fault at 12.95 m		89	58	60	4×10^{-5} cm/s
	5	0.50	1.10		SANDSTONE-fine grained, strong, fresh, medium bedded, grey					
14.0		1.00			SANDSTONE/SILTSTONE-very weak, fresh, thinly interbedded, mudstone bands, brecciated fault zone at 13.8 m, bedding plane at 70° - 75°					
15.0		0.40			SANDSTONE-silty, weak, fresh, massive, fissured, green					
16.0	6	1.40			MUDSTONE/SILTSTONE - very weak, fresh, medium plastic, thinly interbedded, bedding planes at 70° - 75°, occasional carbon traces and coal stringers, Liquid Limit = 45 Plastic Index = 22		97	71	40	
17.0		0.85			COAL - (seam 9)					
18.0		1.15			MUDSTONE - silty, very weak, thinly bedded, fresh, bedding planes at 60° - 80°, some slickensides, grey. Liquid Limit = 62 Plastic Index = 26					
19.0 20.0	7	1.60			COAL - (seam 8)		97	77	30	8×10^{-6} cm/s

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

JOB No PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-335
DATE JANUARY, 1984 PLATE 2/13

K.L.C - METRIC

TEST HOLE LOG

ELEV COLLAR
ELEV GROUND 810.6 m
CO-ORD. LOCATION N 6053278; E 621502

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEABILITY
	7	0.20		▥	SILTSTONE		97	77	30	
		0.55		■	COAL - (seam 8)					
21.0										
22.0	8		0.4	▥	SILTSTONE - weak - thinly bedded - fresh - minor thin mudstone horizons - minor thin sandstone horizons near base - 0.1m thick, ironstone band at 23.42 m - bedding planes at 65^{o} to 75^{o}.		98	91	70	2×10^{-5} cm/s
23.0		2.85								
24.0				▦						
25.0	9						99	91	50	
26.0					MUDSTONE/SILTSTONE - strong - fresh - thinly interbedded - minor sandstone bands - bedding planes at 65^{o} - 75^{o} - some fissures calcite filled - minor ironstone horizon at 27.80 m					
27.0										
28.0	10						99	83	40	6×10^{-7} cm/s
29.0										
30.0	11									

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 830-335
DATE JANUARY, 1984 PLATE 3/13

K.L.C. - METRIC.
KLOHNLEONOFF

TEST HOLE LOG

ELEV COLLAR
ELEV GROUND 810.6 m
CO-ORD. LOCATION N 6053278; E 621502

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	DESCRIPTION OF MATERIAL	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEABILITY
31.0	11		2.3		100	100	80	
32.0								
33.0	12			MUDSTONE/SILTSTONE - very weak - fresh - thinly interbedded - frequest thin sandstone bands below 32.5 m - bedding plane fractures at 65° - 75° - occasional slickensides or bedding planes	100	92	75	
34.0								
35.0								
36.0	13							5x10^{-5} cm/s
37.0		13.65		calcified ironstone band	100	91	60	
		0.30		SANDSTONE - comprises volcanic rock fragments, green				
38.0				MUDSTONE - silty - very weak - thinly bedded to laminated - fissured - bedding planes at 65° - 75° - occasional thin siltstone bands throughout - occasional calcified ironstone bands				
39.0	14		0.48		100	99	90	
40.0								

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-335
DATE JANUARY, 1984 PLATE 4/13

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 810.6 m

CO-ORD LOCATION N 6053278; E 621502

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEABILITY
41.0	14	3.80			MUDSTONE - as above		100	99	90	<1x10^{-8} cm/s
42.0	15	1.10			COAL - (seam 7) shale parting					
43.0		0.60			MUDSTONE - very weak - thinly bedded - frequent slickensides - carbonaceous - fresh		94	85	60	<1x10^{-8} cm/s
44.0 45.0 46.0 47.0	16	4.0	3.1		SANDSTONE/SILTSTONE - moderately strong - thinly interbedded - frequent mudstone stringers - several calcified ironstone bands - fresh - slightly fissured (ironstone band)		99	93	85	INCOMPLETE TEST
		0.15			COAL - (seam 6)					
48.0		1.25			MUDSTONE - very weak - fresh - thinly bedded - carbonaceous - thin coal stringers - slickensides on bedding planes		95	48	30	
49.0 50.0	17				COAL - (seam 6)					

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-335
DATE JANUARY, 1984 PLATE 5/13

KLOHN LEONOFF

B.L.C. - METRIC

TEST HOLE LOG

ELEV COLLAR
ELEV GROUND 810.6 m
CO-ORD LOCATION N 6053278; E 621502

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEA-BILITY
	17	2.15		■	COAL - (seam 6)		95	48	30	$<1 \times 10^{-8}$ cm/s
51.0				▤						
52.0				▤						
	18			▤			98	88	40	
53.0				▤						
				■	coal					
54.0			1	▤	MUDSTONE - silty - very weak - fresh - frequent thin sandstone and siltstone horizons - minor calcite ironstone horizons					$<1 \times 10^{-8}$ cm/s
55.0			<.1	▤						
	19			▤			100	100	90	
56.0				▤						
			1	▤						
57.0				▤						
58.0		7.60		▤						
	20	0.40	1	▤	MUDSTONE - carbonaceous, very weak, closely fissured		91	73	45	1×10^{-5} cm/s
59.0				■	COAL - (seam 6)					
60.0				■						

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-335
DATE JANUARY, 1984 PLATE 6/13

K.L.C. - METRIC.

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 810.6 m

CO-ORD LOCATION N 6053278; E 621502

DEPTH: 61.0 | 62.0 | 63.0 | 64.0 | 65.0 | 66.0 | 67.0 | 68.0 | 69.0 | 70.0

THICKNESS	POINT LOAD INDEX	DESCRIPTION OF MATERIAL
2.10		COAL - (seam 6)
1.45		MUDSTONE - silty - very weak - fresh - thinly bedded - locally carbonaceous - slickensided fractures at 10° - 30°
		COAL - (seam 6)
2.20		MUDSTONE - silty, very weak, fresh, thinly bedded, fissured, carbon fossils and coal stringers common Liquid Limit = 46 Plastic index = 25
0.60		COAL - (seam 6)
1.35		MUDSTONE - silty - very weak - fresh - thinly bedded - fissured - thin ironstone and siltstone bands
0.70		SANDSTONE - medium grained, very weak, fresh, massive, interbedded with siltstone, grey green
	1.92	SANDSTONE/SILTSTONE - thinly interbedded - very weak - fissured - fresh - grey - occasional mudstone bands - calcite filled fractures - minor ironstone bands

RUN	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.
21		100	73	35
22		97	84	35
23		98	92	65
24		98	94	70
25		95	91	60

PERMEABILITY:

1×10^{-5} cm/s

TESTS INCOMPLETED

$<1 \times 10^{-6}$ cm/s

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No PA 1692.0H

PROJECT TELKWA COAL PROJECT

LOCATION TELKWA, B.C.

HOLE No. TW 83D-335

DATE JANUARY, 1984 PLATE 7/13

KLOHN LEONOFF

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 810.6 m

CO-ORD LOCATION N 6053278; E 621902

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEABILITY
71.0	25	4.6			SANDSTONE/SILTSTONE - interbedded - as above		95	91	60	
72.0		0.95			MUDSTONE/SILTSTONE - very weak, fresh, thinly interbedded, minor sandstone and calcified ironstone bands					
73.0 74.0	26	1.95			SANDSTONE - fine grained - silty - very weak - frozen - minor mudstone, siltstone and ironstone bands		99	99	70	
75.0		1.35			MUDSTONE/SILTSTONE - thinly interbedded - very weak - fresh - distorted bedding					
76.0 77.0 78.0 79.0 80.0	27 28		1.3		SANDSTONE/SILTSTONE - medium to thinly interbedded - weak - fresh - calcite filled fissures - minor ironstone bands - gouge and rubble filled shear zone at 78.0 - 78.2 m		100 100	96 100	85 90	$<1x10^{-8}$ cm/s

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-335
DATE JANUARY, 1984 PLATE 8/13

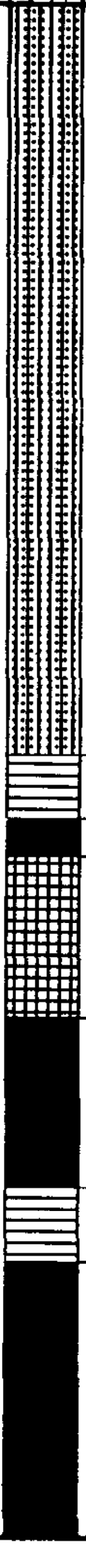
TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 810.6 m

CO-ORD LOCATION N 6053278; E 621502

DEPTH
81.0
82.0
83.0
84.0
85.0
86.0
87.0
88.0
89.0
90.0



THICKNESS	POINT LOAD INDEX	DESCRIPTION OF MATERIAL
9.10	1	SANDSTONE/SILTSTONE - medium to thinly interbedded - moderately strong - fresh - calcite filled fissure - minor sandstone band
0.45		MUDSTONE - silty, thinly bedded, very weak, fissured, medium to high plastic
0.20		COAL - (seam 5)
1.05		MUDSTONE/SILTSTONE - very weak - thinly interbedded - fissured - Liquid Limit = 51 - Plastic Index = 30
1.10		COAL - (seam 5)
0.5		MUDSTONE - very weak - interbedded with siltstone
		COAL - (seam 5)

RUN	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.
28	100	100	90
29	100	100	90
30	87	78	60
31	33	7	0
32	85	46	10

PERMEABILITY: 2×10^{-6} cm/s

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No TW 83D - 335
DATE JANUARY, 1984 PLATE 9/13

KLOHN LEONOFF

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 810.6 m

CO-ORD. LOCATION N 6053278; E 621502

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEA-BILITY
		2.10		■	COAL - (seam 5)					
91.0	33			▤	MUDSTONE - silty - carbonaceous - very weak - highly weathered - closely fissured - thinly bedded - minor coal stringers		95	0	0	
92.0	34	2.40					92	40	0	
93.0	35	0.95		▤	MUDSTONE - silty - very weak - thinly bedded - minor siltstone horizons					
94.0 95.0		1.70		▦	SILTSTONE/MUDSTONE - thinly interbedded - very weak - fissured - minor ironstone horizons with caclite veins		97	72	40	<1x10^{-8} cm/s
96.0	36	0.90		▤	MUDSTONE - silty, carbonaceous, very weak, thinly bedded, core shattered		93	55	10	
		0.50		■	COAL - (seam 4)					
97.0 98.0	37	2.10		▤	MUDSTONE - silty - carbonaceous - very weak - thinly bedded - fresh		88	16	0	<1x10^{-8} cm/s
99.0		0.60		■	COAL - (seam 4)					
100.0	38			▤	MUDSTONE - silty, carbonaceous, very weak, thinly bedded, fissured		98	25	20	

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D - 335
DATE JANUARY, 1984 PLATE 10/13

KLOHN LEONOFF

R.L.C. - METRIC.

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 810.6 m

CO-ORD LOCATION N 6053278; E 621502

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEA-BILITY
		0.85			MUDSTONE - as above					
101.0	38	0.80			COAL - (seam 4)		98	25	30	
		0.60			MUDSTONE - carbonaceous, very weak, thinly bedded, closely fissured, Liquid Limit = 46, Plastic Index = 24					
102.0	39	0.50			COAL - (seam 4)		100	79	30	
		0.55			MUDSTONE - carbonaceous, very weak, thinly bedded, closely fissured					
103.0										
104.0	40						100	99	80	
105.0					SILTSTONE/SANDSTONE - thinly interbedded - weak - fresh - minor calcified ironstone band					
106.0										$<1x10^{-8}$ cm/s
107.0	41						100	100	90	
108.0										
109.0	42						100	100	90	
110.0										

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 830-335
DATE JANUARY, 1984 PLATE 11/13

K.L.C. - METRIC.

KLOHN LEONOFF

TEST HOLE LOG

ELEV COLLAR
ELEV GROUND 810.6 m
CO-ORD LOCATION N 6053278; E 621502

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEABILITY
111.0	42						100	100	90	
112.0					SILTSTONE/SANDSTONE - as above					$<1 \times 10^{-8}$ cm/s
113.0	43						100	97	85	
114.0		11.25								
115.0										
116.0	44				SANDSTONE - fine grained - strong - massive - fresh		100	94	70	
117.0										
118.0										$<1 \times 10^{-8}$ cm/s
119.0	45						100	85	50	
120.0										

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-335
DATE JANUARY, 1984 PLATE 12/13

KLOHN LEONOFF

K.L.C - METRIC

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 810.6 m

CO-ORD LOCATION N 6053278; E 621502

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEABILITY
	45						100	85	50	↓
121.0										
122.0										
					SANDSTONE - as above		98	98	40	
123.0	46									
124.0										
125.0							98	98	98	
	47									
126.0										
127.0		13.10								

TEST HOLE TERMINATED AT 127.10 m

NOTES:

1- Invalid point load test obtained.

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No TW 83D-335
DATE JANUARY, 1984 PLATE 13/13

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 727.7 m

CO-ORD. LOCATION N 6054614; E 621382

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEA-BILITY
1.0 2.0 3.0 4.0 5.0 6.0	NOT CORED	6.1			UNDIFFERENTIATED OVERBURDEN					
7.0 8.0	1			▤	MUDSTONE - silty - very weak - moderately weathered - grey - some iron staining - core completely broken up		20	0	0	
9.0 10.0	2			▤	MUDSTONE - silty - very weak - slightly weathered - grey - closely fissured (tight fissures) - core completely shattered - Liquid Limit = 47 - Plastic Index = 27		90	84	0	↑

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

JOB No.	PA 1692.0H
PROJECT	TELKWA COAL PROJECT
LOCATION	TELKWA, B.C.
HOLE No.	TW 83D-336
DATE	JANUARY, 1984 PLATE 1/12

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 727.7 m

CO-ORD. LOCATION N 6054614; E 621382

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEA-BILITY
	2						90	84	0	
11.0					MUDSTONE - silty - very weak - moderately weathered becoming fresh below 12.0 m - grey - minor calcite veins - thin siltstone horizons below 11.0 m - localized calcified ironstone bands - random fracture angles 0° - 90° - fracture surfaces rough					
12.0										<1x10^{-8} cm/s
	3						100	81	0	
13.0										
14.0					-ironstone with calcite veins					
							100	65	0	
15.0										
	4									
16.0										
17.0										
	5				- ironstone with calcite veins		93	66	0	
18.0										
					- ironstone with calcite veins					<1x10^{-8} cm/s
	6						97	47	0	
19.0										
20.0										

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692.0H

PROJECT TELKWA COAL PROJECT

LOCATION TELKWA, B.C.

HOLE No. TW 83D-336

DATE JANUARY, 1984 PLATE 2/12

KLOHN LEONOFF

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 727.7 m

CO-ORD. LOCATION N 6054614; E 621382

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEA-BILITY
	6									
21.0	7				MUDSTONE - silty - very weak - fresh - minor calcite veins - thin siltstone horizons - localized calcified ironstone bands - random fracture angles 0° - 90° - fracture surfaces rough		106	16	0	
22.0	8						71	14	0	
23.0					- ironstone with calcite veins					$<1\times10^{-8}$ cm/s
24.0	9									
25.0							100	16	0	
26.0										
27.0	10						100	53	0	
28.0					- ironstone with calcite veins					$<1\times10^{-8}$ cm/s
29.0										
30.0	11						96	59	10	

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-336
DATE JANUARY, 1984 PLATE 3/12

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 727.7 m

CO-ORD. LOCATION N 6054614; E 621382

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEABILITY
31.0	11									
32.0							90	59	10	
33.0					MUDSTONE - silty - very weak - fresh - minor calcite veins - random fracture angles 0° - 90° - fracture surface rough - Liquid Limit = 49 - Plastic Index = 28					
34.0	12						96	70	0	
35.0										<1x10^{-8} cm/s
36.0										
37.0	13						99	74	10	
38.0		32.4								
39.0	14				SILTSTONE - sandy - very weak - fresh - closely fissured - completely shattered core		99	71	15	
40.0										

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 830-336
DATE JANUARY, 1984 PLATE 4/12

K.L.C. - METRIC.

1-53 11 78

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 727.7 m

CO-ORD. LOCATION N 6054614; E 621382

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEA-BILITY
41.0	14				SILTSTONE - sandy - very weak - fresh - closely fissured - completely shattered core - locally interbedded with fine sandstone		99	71	15	
42.0										$<1 \times 10^{-8}$ cm/s
43.0	15	5.1					100	87	40	
44.0					SANDSTONE - fine to medium grained, silty, moderately strong, fresh, grey, massive, local calcite veins					
45.0		1.4								
46.0	16				SILTSTONE - very weak - moderately weathered - completely shattered core - dark grey - local slickensides - local calcite veins		93	88	6	
47.0										$<1 \times 10^{-8}$ cm/s
48.0										
49.0	17				- probable fault zone comprising sheared and slickensided surfaces		100	82	10	
50.0										

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-336
DATE JANUARY, 1984 PLATE 5/12

TEST HOLE LOG

ELEV COLLAR
ELEV GROUND 727.7 m
CO-ORD. LOCATION N 6054614; E 621382

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEA-BILITY
51.0	17						100	82	10	
52.0 53.0	18				SILTSTONE - very weak - moderately weathered - completely shattered core - dark grey - local slickensides - local calcite veins		99	18	0	
54.0		9.20			- ironstone with calcite veins					<1x10^{-8} cm/s
55.0	19	1.20			MUDSTONE - very weak, fresh, thinly bedded, fissured, slickensides on bedding planes, grey		98	72	10	
56.0 57.0 58.0 59.0	20	3.05			SILTSTONE - very weak - fresh - thinly bedded - closely fissured - interbedded with thin mudstone horizons - distortion and slickensides on bedding planes - minor coal seams (seam 9) - minor ironstone with calcite veins		92	67	10	<1x10^{-8} cm/s
60.0					MUDSTONE - very weak - completely shattered core - grey					

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-336
DATE JANUARY, 1984 PLATE 6/12

KLOHN LEONOFF

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 727.7 m

CO-ORD. LOCATION N 6054614; E 621382

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL		FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEA-BILITY
	21	1.50		▤	MUDSTONE - as above			85	36	5	
61.0		0.25		■	COAL - (Seam 5)	Interbedded COAL AND SHALY MUDSTONE					
		0.20		▤							
		0.25		■	COAL - (Seam 5)						
				▤							
				■	COAL - (Seam 5)						
				▤							
62.0		0.30		■	COAL - (Seam 5)						
63.0		1.45		▤	MUDSTONE - carbonaceous - very weak - grey						
64.0 65.0 66.0	22	2.70		░	SANDSTONE - fine grained - silty - moderately weathered - interbedded with siltstone - light grey			100	97	10	
	23	0.70		■	COAL - (Seam 4)			10	10	0	
67.0	24	0.60		▤	MUDSTONE - carbonaceous, silty, very weak, fresh, thinly bedded, grey, Liquid Limit=41, Plastic Index=18			98	94	60	$5x10^{-6}$ cm/s
				■	COAL - (Seam 4)						
				▤	MUDSTONE - as above						
68.0		0.30		■	COAL - (Seam 4)						
		0.60		▤	MUDSTONE - carbonaceous, silty, very weak, fresh, thinly bedded, grey						
69.0		0.50		■	COAL - (Seam 4)						
70.0	25			▥	SILTSTONE/MUDSTONE - thinly interbedded, very weak, fresh, grey, slightly fissured			98	98	80	

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-336
DATE JANUARY, 1984 PLATE 7/12

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 727.7 m

CO-ORD. LOCATION N 6054614; E 621382

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEA-BILITY
		0.90			SILTSTONE/MUDSTONE - as above					
	26	0.50			COAL - (Seam 4) - dull		92	92	75	
71.0	27	1.20			SILTSTONE/MUDSTONE - thinly interbedded - very weak - fresh - ironstone band		94	90	60	
72.0										
73.0			2.4							
74.0	28						99	99	80	<1x10^{-8} cm/s
75.0					SILTSTONE - locally sandy - strong - fresh - thinly bedded - slightly fissured - some mudstone and sandstone stringers - minor ironstone horizons					
76.0							90	98	90	
77.0	29									
78.0			2.7							
79.0							98	95	80	
80.0	30									

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JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-336
DATE JANUARY, 1984 PLATE 8/12

KLOHN LEONOFF

TEST HOLE LOG

ELEV COLLAR
ELEV GROUND 727.7 m
CO-ORD. LOCATION N 6054614; E 621382

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEABILITY
81.0	30	9.35			SILTSTONE - as above		98	95	80	
82.0										
83.0	31		0.6		MUDSTONE - silty - very weak - fresh - thinly bedded - slightly fissured - grey - occasional siltstone bands - Liquid Limit = 47 - Plastic Index = 25		100	100	90	
84.0										$<1 \times 10^{-8}$ cm/s
85.0		4.10					100	100	80	
86.0	32									
87.0					SANDSTONE - fine grained - very weak - fresh - thinly bedded - local shaly horizons - local ironstone bands - carbonaceous partings - becoming more fine grained with depth - gouge filled fractures					
88.0			1				100	100	75	
89.0	33									
90.0										

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-336
DATE JANUARY, 1984 PLATE 9/12

K.L.C. - METRIC.

L-53 11 78

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 727.7 m

CO-ORD. LOCATION N 6054614; E 621382

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEABILITY
	33			100	100	75	
91.0							
92.0	34			100	88	50	
93.0			3.9				
94.0							
95.0	35			100	100	75	$<1x10^{-8}$ cm/s
96.0			4.1				
97.0							
98.0	36			100	100	90	
99.0							
100.0	37			98	98	90	

DESCRIPTION OF MATERIAL

SANDSTONE
- fine to medium grained
- strong
- fresh
- thinly bedded
- local shaly horizons
- local ironstone bands
- gouge filled fractures

- ironstone with calcite veins

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-336
DATE JANUARY, 1984 PLATE 10/12

K.L.C. - METRIC.

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 727.7 m

CO-ORD. LOCATION N 6054614; E 621382

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEABILITY
101.0 102.0	37				SANDSTONE - fine to medium grained - moderately weak - fresh - thinly bedded - grey		98	98	90	
103.0	38	17.30					100	100	80	
		0.25			SANDSTONE - medium grained, moderately weak, fresh, massive					
104.0 105.0										
106.0 107.0 108.0	39				SANDSTONE - fine to medium grained - weak - fresh - thinly bedded - slightly fissured - some shaly stringers - local gouge filled shear zones		100	87	80	
109.0 110.0	40						99	92	90	

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-336
DATE JANUARY, 1984 PLATE 11/12

K.L.C. - METRIC.

L-53 11/78

TEST HOLE LOG

ELEV COLLAR

ELEV GROUND 727.7 m

CO-ORD. LOCATION N 6054614; E 621382

DEPTH	RUN	THICKNESS	POINT LOAD INDEX	SYMBOLIC LOG	DESCRIPTION OF MATERIAL	FRACTURE LOG	TOTAL RECOVERY	SOLID RECOVERY	R.Q.D.	PERMEA-BILITY
	40	7.40			SANDSTONE - as above calcified ironstone		99	92	90	
111.0					TESTHOLE TERMINATED AT 110.54 m					

NOTE:

1- Invalid point load test result.

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692.0H
PROJECT TELKWA COAL PROJECT
LOCATION TELKWA, B.C.
HOLE No. TW 83D-336
DATE JANUARY, 1984 PLATE 12/12

K.L.E. - METRIC

KLOHN LEONOFF

L-53 11/78

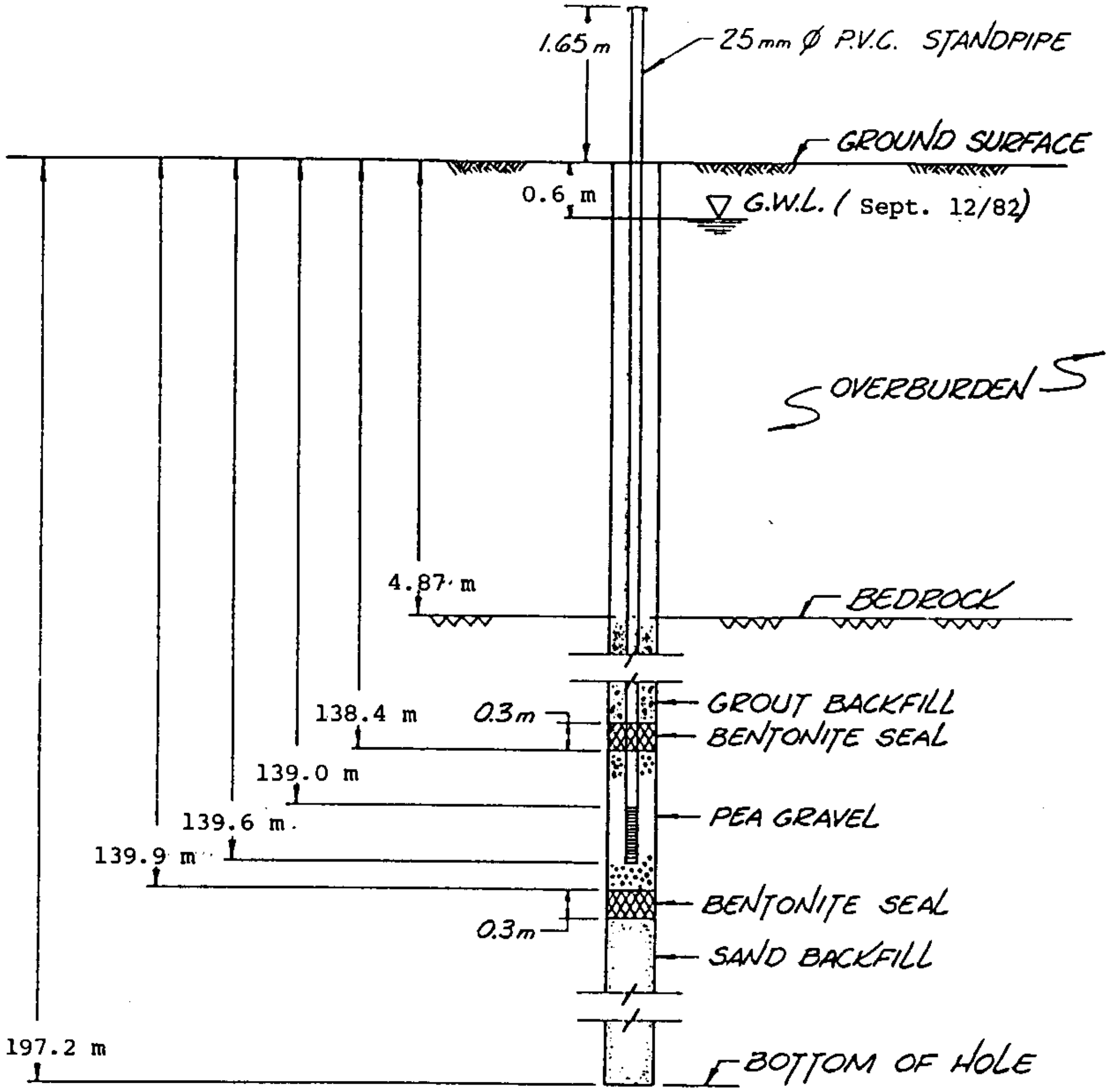
APPENDIX II

GROUNDWATER

RECORDED GROUNDWATER LEVELS

Drillhole	Ground Elevations	Tip Elevation	Groundwater Elevation July 1984
255	8D2.30	662.90	802.60
256	890.30	731.20	883.05
257	728.60	697.50	727.08
258	744.10	698.10	742.88
265	737.30	673.70	718.55
312	764.90	Blocked	
313	750.60	695.60	740.54
318	684.60	560.60	644.97
323	769.70	626.70	768.18
325	803.10	737.10	777.19
335	810.60	758.20	810.60
339	720.60	638.60	720.60
342	757.50	682.20	755.98
343	698.50	571.30	695.50
344	694.30	596.30	694.30
345	763.50	674.70	712.74
347	760.10	714.70	727.17
406	673.60	588.60	665.07
410	662.50	580.50	657.93
417	739.80	653.30	739.50

DETAILS OF PIEZOMETER INSTALLATIONS



PIEZOMETER INSTALLED
IN COAL SEAM

GROUND ELEVATION	802.30 m.
BEDROCK ELEVATION	797.43 m.
BASE OF UPPER SEAL	663.90 m.
LENGTH OF TIP	1.50 m.
TOP OF LOWER SEAL	662.40 m.

SCALE N.T.S.

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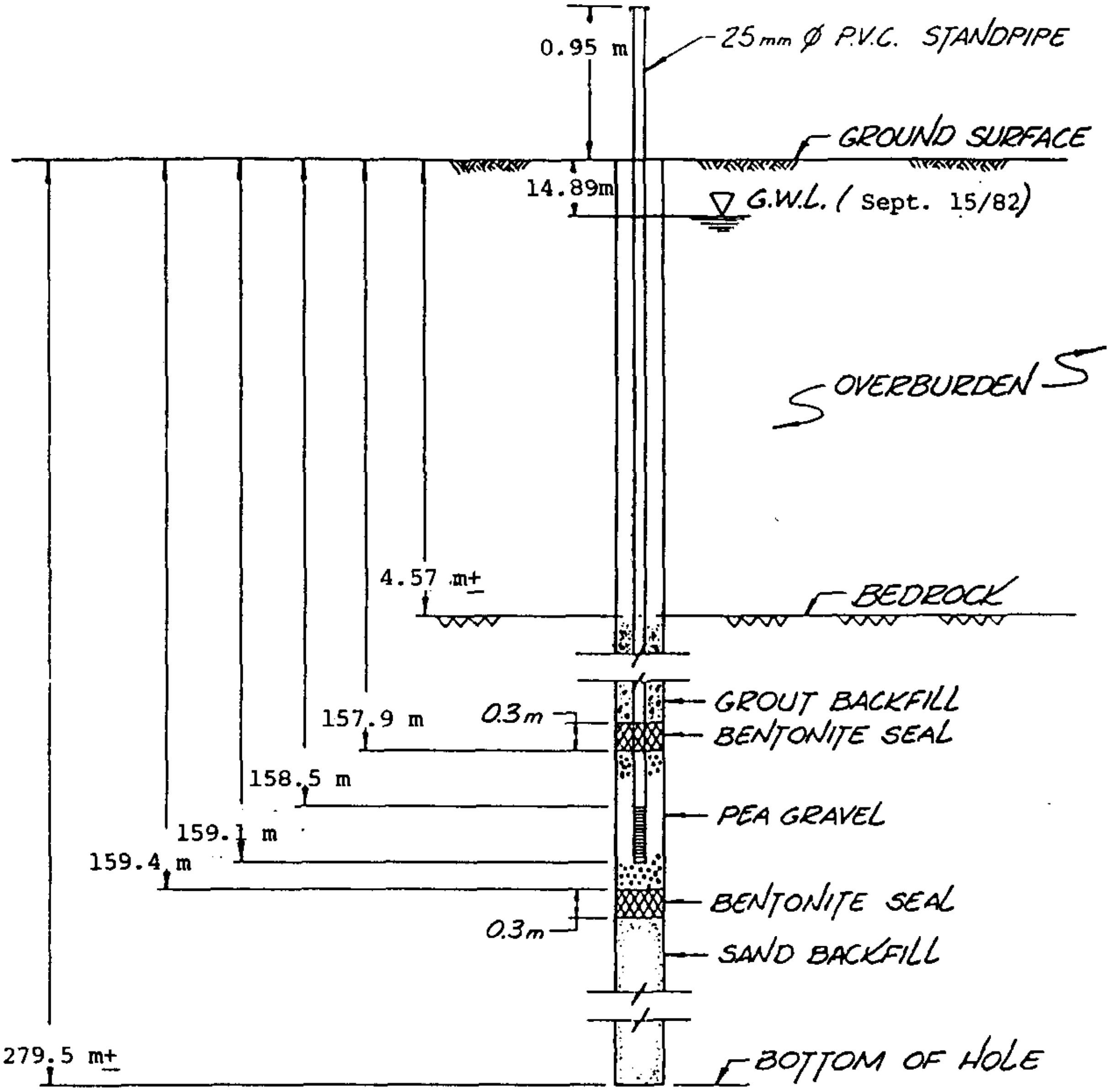
PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION - DRILLHOLE 255

CLIENT: CROWS NEST RESOURCES

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
APPROVED	1692	A Figure 1	

NCI-455-KL



PIEZOMETER INSTALLED
IN COAL SEAM

GROUND ELEVATION	890.30 m.
BEDROCK ELEVATION	885.73 m.
BASE OF UPPER SEAL	732.40 m.
LENGTH OF TIP	1.50 m.
TOP OF LOWER SEAL	730.90 m.

SCALE N.T.S.

KLOHN LEONOFF LTD.
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PROJECT: TELKWA COAL PROJECT

TITLE: DETAILS OF PIEZOMETER INSTALLATION - DRILLHOLE 256

CLIENT: CROWS NEST RESOURCES

DATE OF ISSUE:

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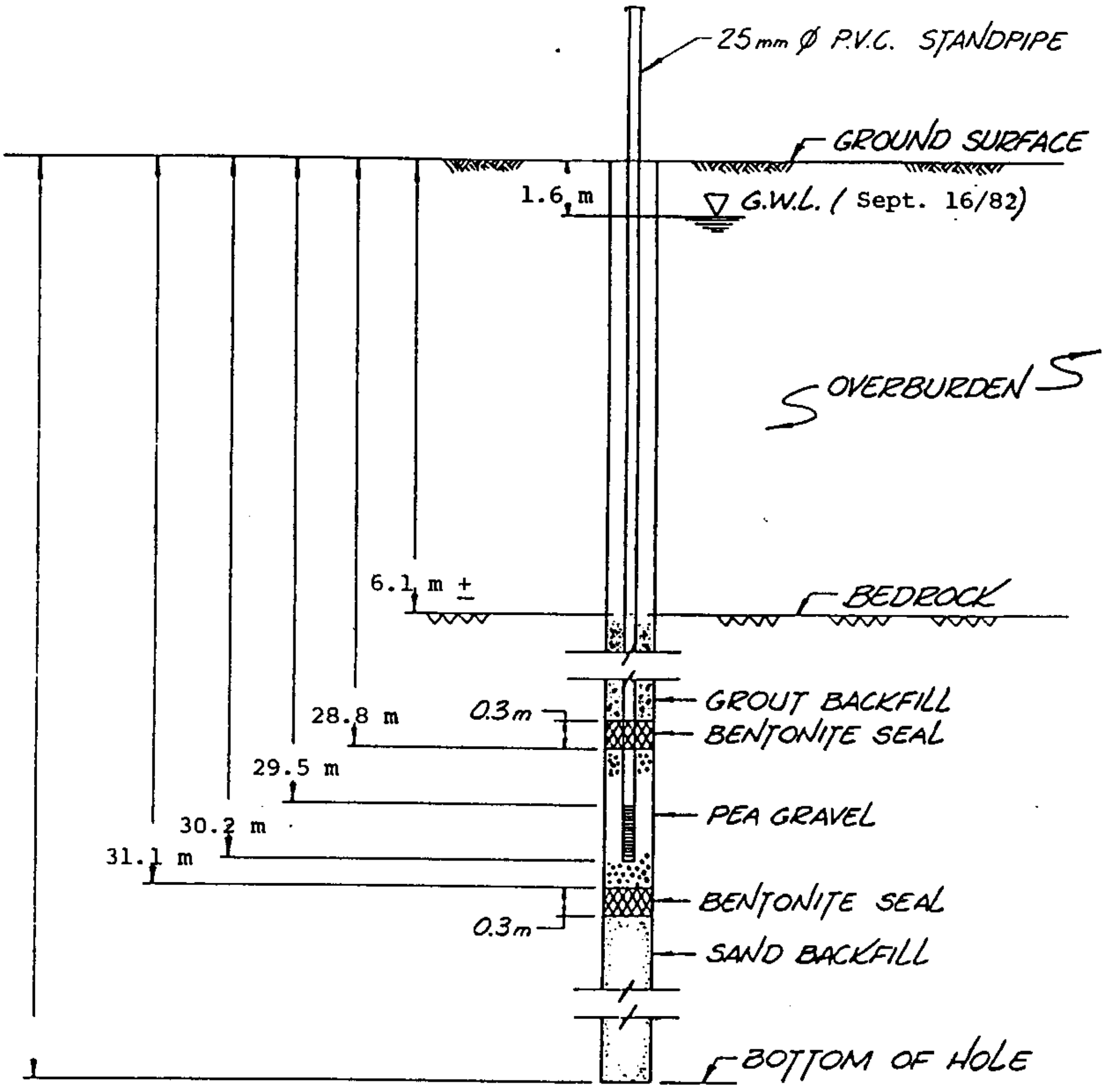
PROJECT No. 1692

DWG. No. A Figure 2

REV.



PIEZOMETER INSTALLED
IN COAL SEAM

GROUND ELEVATION	728.60 m.
BEDROCK ELEVATION	722.50 m.
BASE OF UPPER SEAL	699.80 m.
LENGTH OF TIP	2.30 m.
TOP OF LOWER SEAL	697.50 m.

SCALE N.T.S.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: TELKWA COAL PROJECT

TITLE: DETAILS OF PIEZOMETER INSTALLATION - DRILLHOLE 257

CLIENT: CROWS NEST RESOURCES

DATE OF ISSUE:
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PROJECT No. 1692
DWG. No. A Figure 3
REV.

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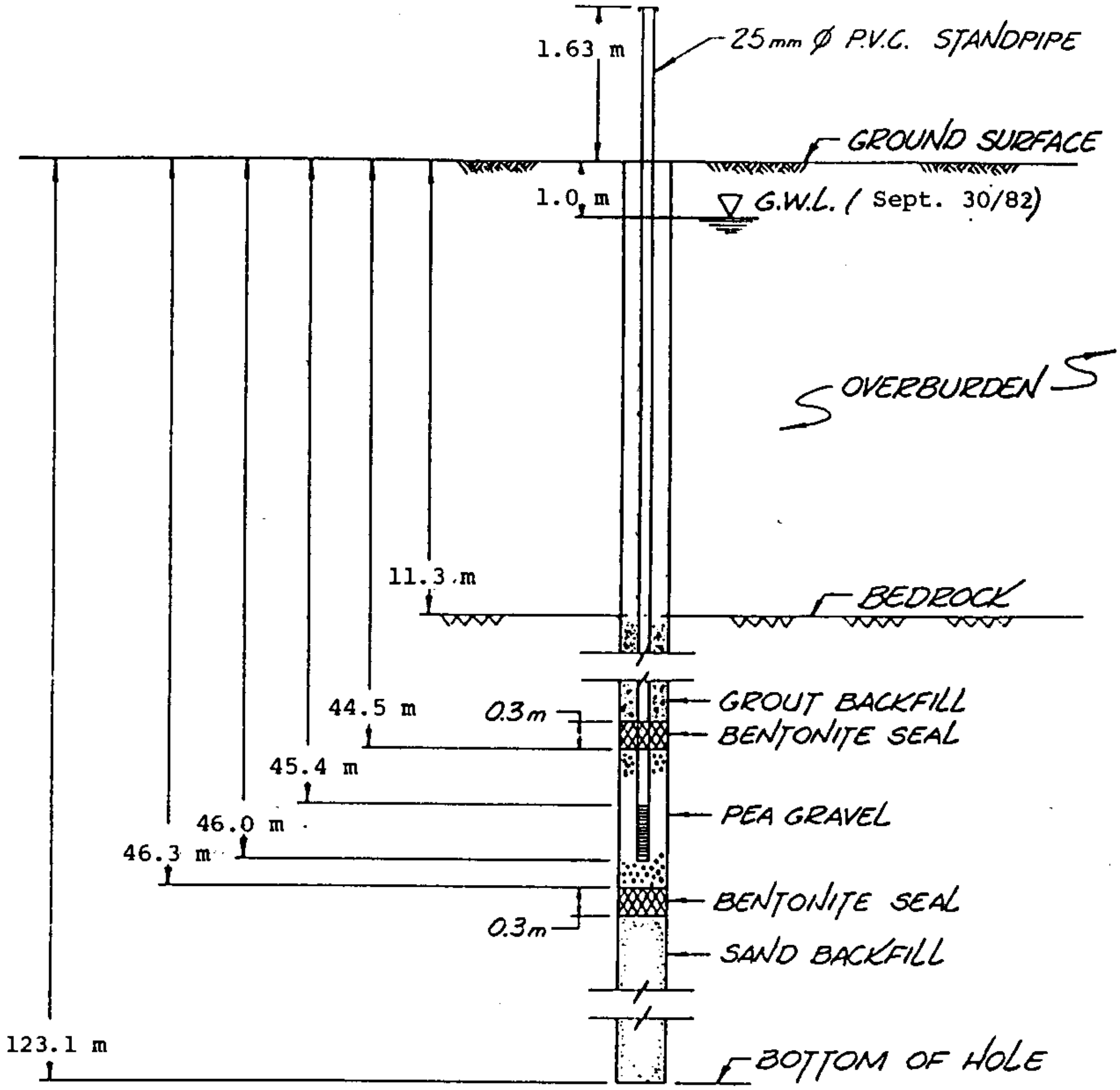

PIEZOMETER INSTALLED
IN COAL SEAM

GROUND ELEVATION	744.10 m.
BEDROCK ELEVATION	732.80 m.
BASE OF UPPER SEAL	699.60 m.
LENGTH OF TIP	1.80m.
TOP OF LOWER SEAL	697.80 m.

SCALE N.T.S.

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PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION-DRILLHOLE 258

CLIENT: CROWS NEST RESOURCES

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PROJECT No. 1692

DWG. No. A Figure 4

REV.

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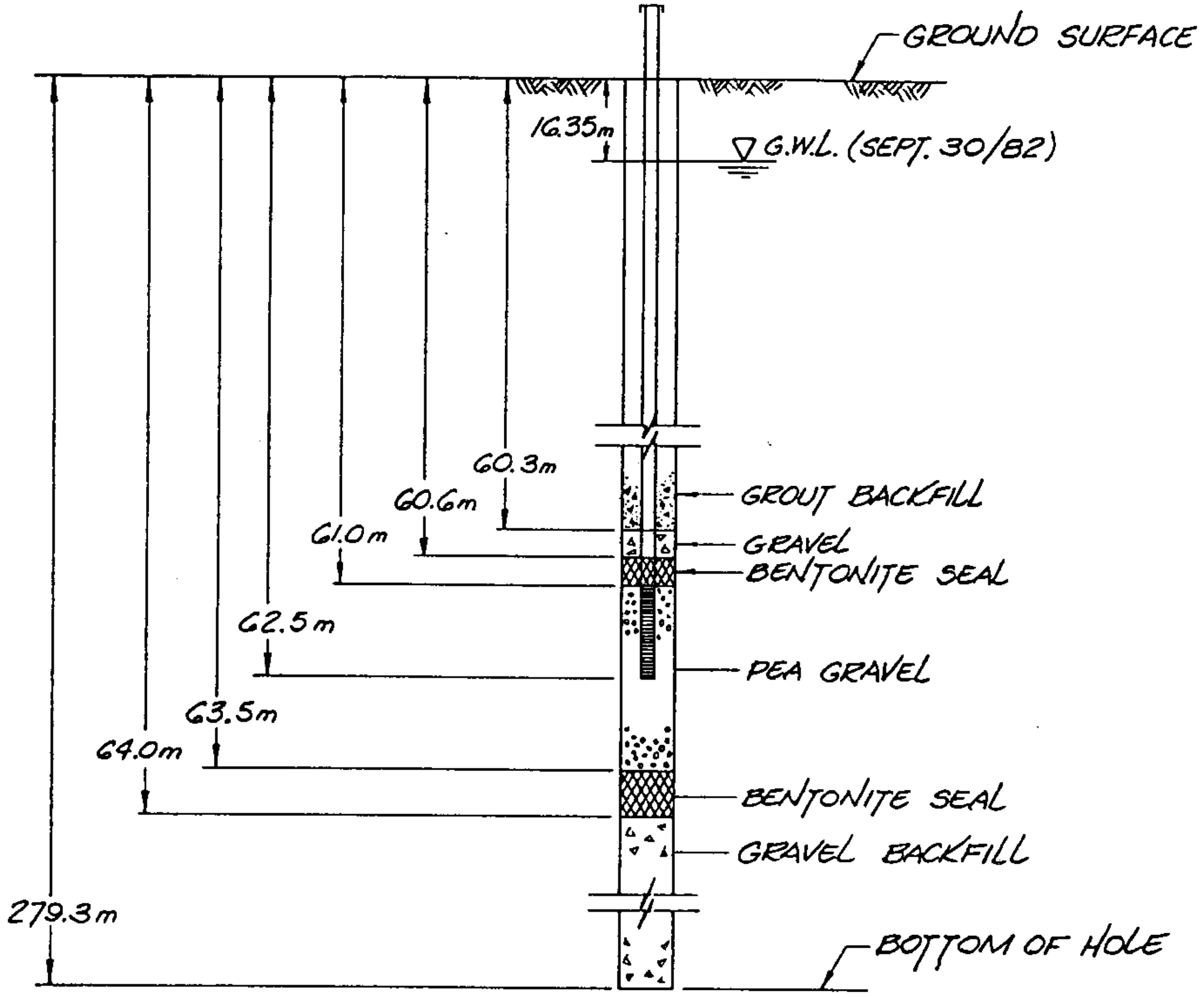

GROUND ELEVATION	737.30 m.
BEDROCK ELEVATION	UNKNOWN
BASE OF UPPER SEAL	676.30 m.
LENGTH OF TIP	2.50 m.
TOP OF LOWER SEAL	673.80 m.

PIEZOMETER INSTALLED
IN COAL SEAM

SCALE N.T.S.

KLOHN LEONOFF LTD.
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PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION - DRILLHOLE 265

CLIENT: CROWS NEST RESOURCES

DATE OF ISSUE DEC. 6/82

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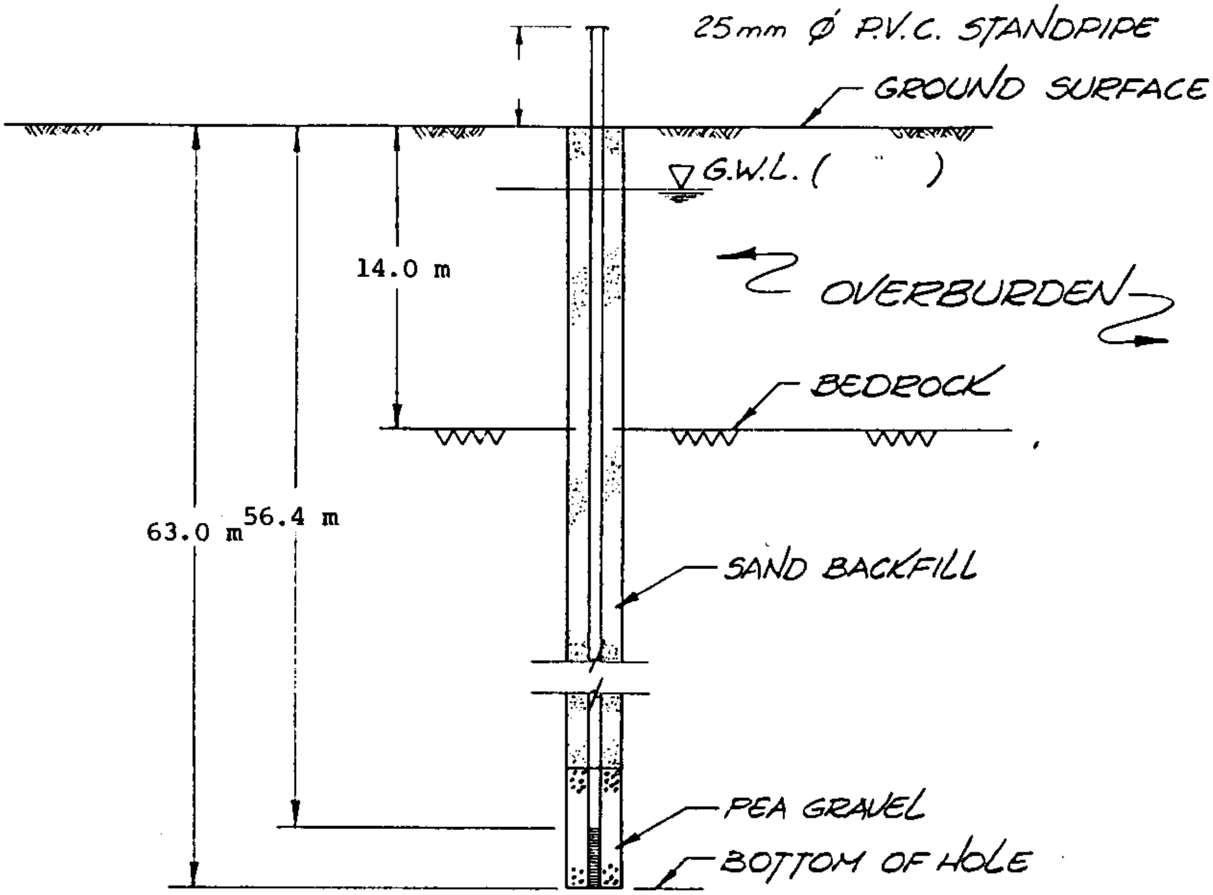
PROJECT No. 1692

DWG. No. A Figure 5

REV.

KLOHN LEONOFF



GROUND ELEVATION 764.90m.
BEDROCK ELEVATION 701.9 m.
LENGTH OF TIP 6.6 m

SCALE N.T.S.

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CONSULTING ENGINEERS

PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF STANDPIPE INSTALLATION - DRILLHOLE 312

CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE FEB. 1985
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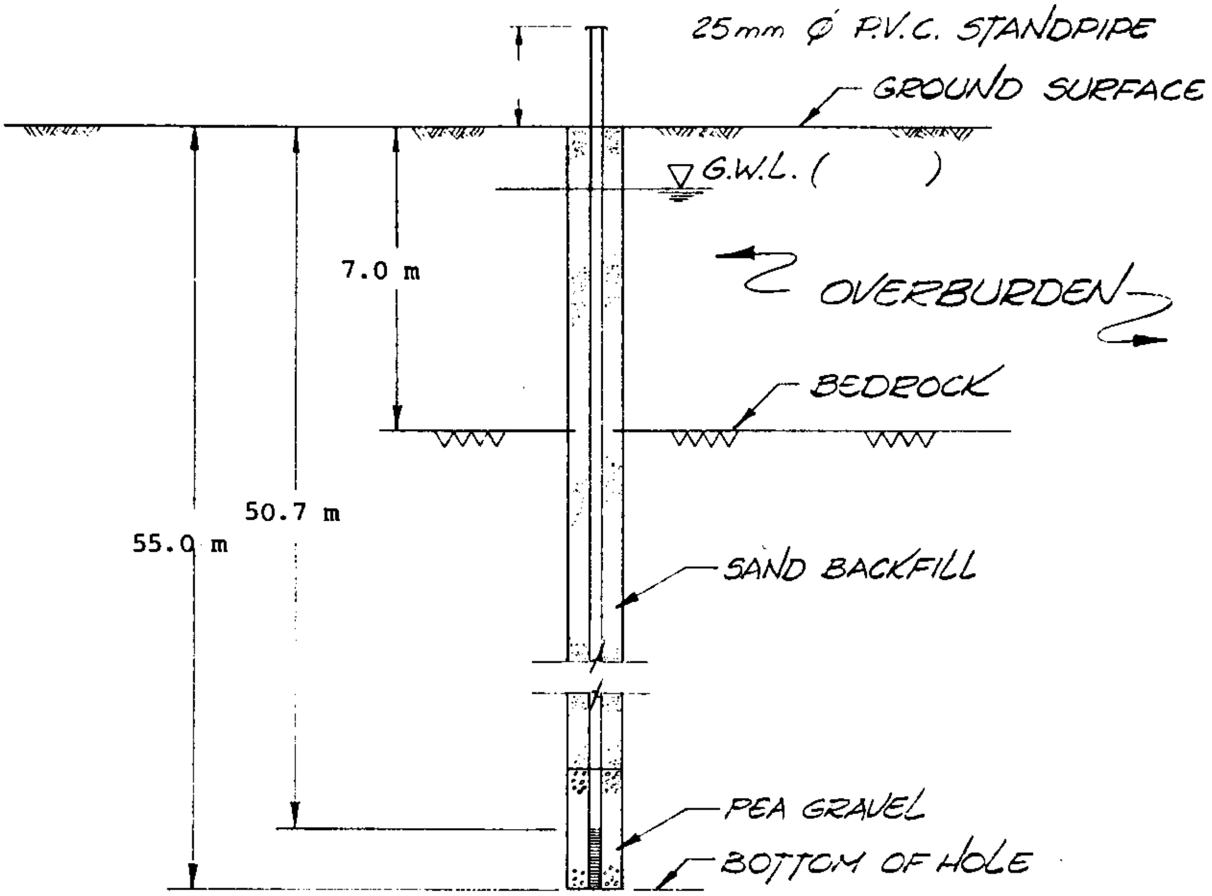
PROJECT No. PA 1692
DWG. No. A Figure 6
REV. 0

NCI-455-KL



GROUND ELEVATION 750.6 m.
BEDROCK ELEVATION 743.6 m.
LENGTH OF TIP 4.3 m

SCALE N.T.S.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT
TELKWA COAL PROJECT

TITLE
DETAILS OF PIEZOMETER
INSTALLATION - DRILLHOLE 313

CLIENT:
CROWS NEST RESOURCES LTD.

DATE OF ISSUE
FEB. 1965

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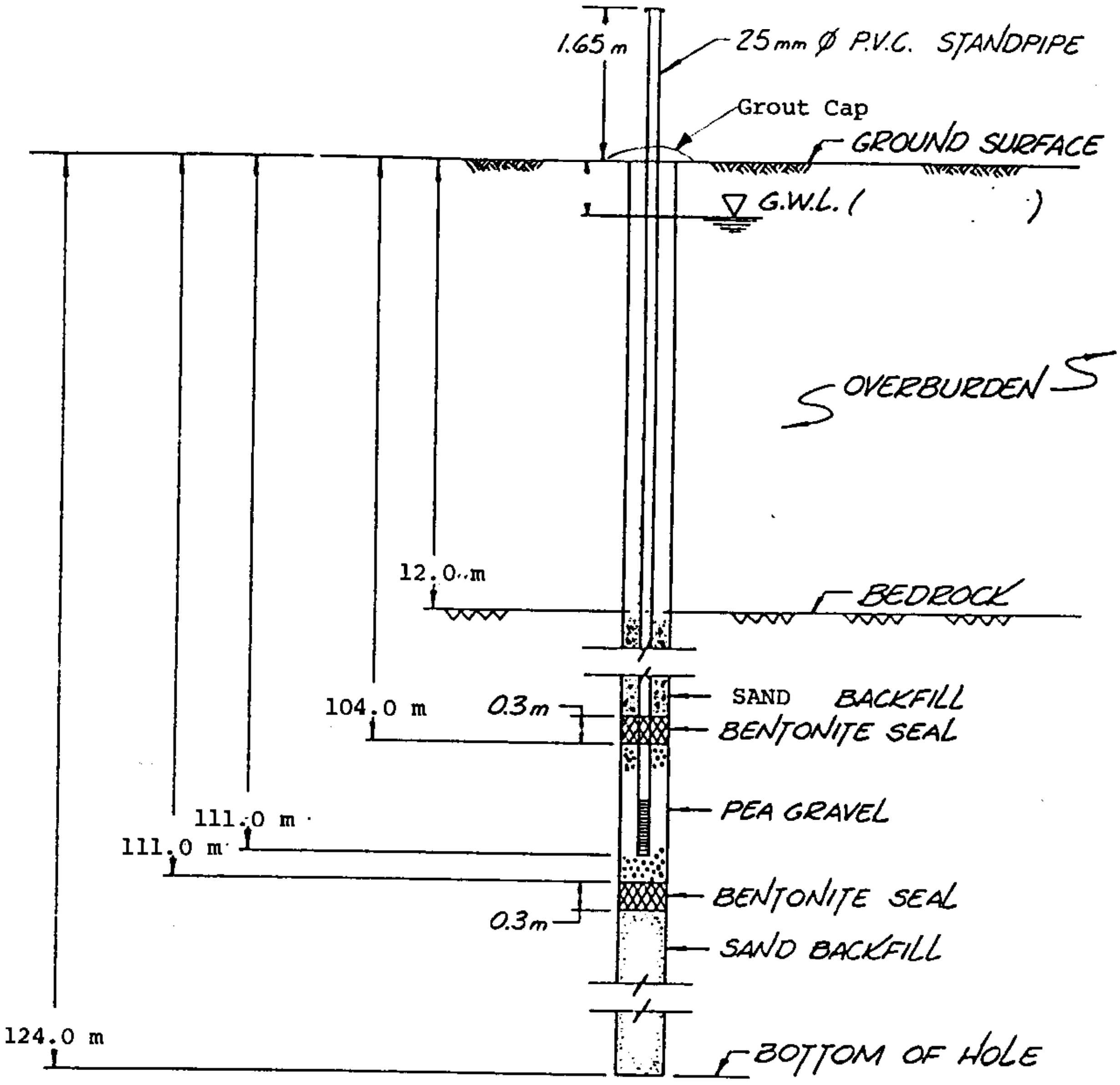
PROJECT No.
9A 1692

DWG. No.
A Figure 7

REV.
0



GROUND ELEVATION	684.6	m.
BEDROCK ELEVATION	672.6	m.
BASE OF UPPER SEAL	580.6	m.
LENGTH OF TIP	7.0	m.
TOP OF LOWER SEAL	573.6	m.

SCALE N.T.S.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION-DRILLHOLE 318

CLIENT: CROWS NEST RESOURCES

DATE OF ISSUE

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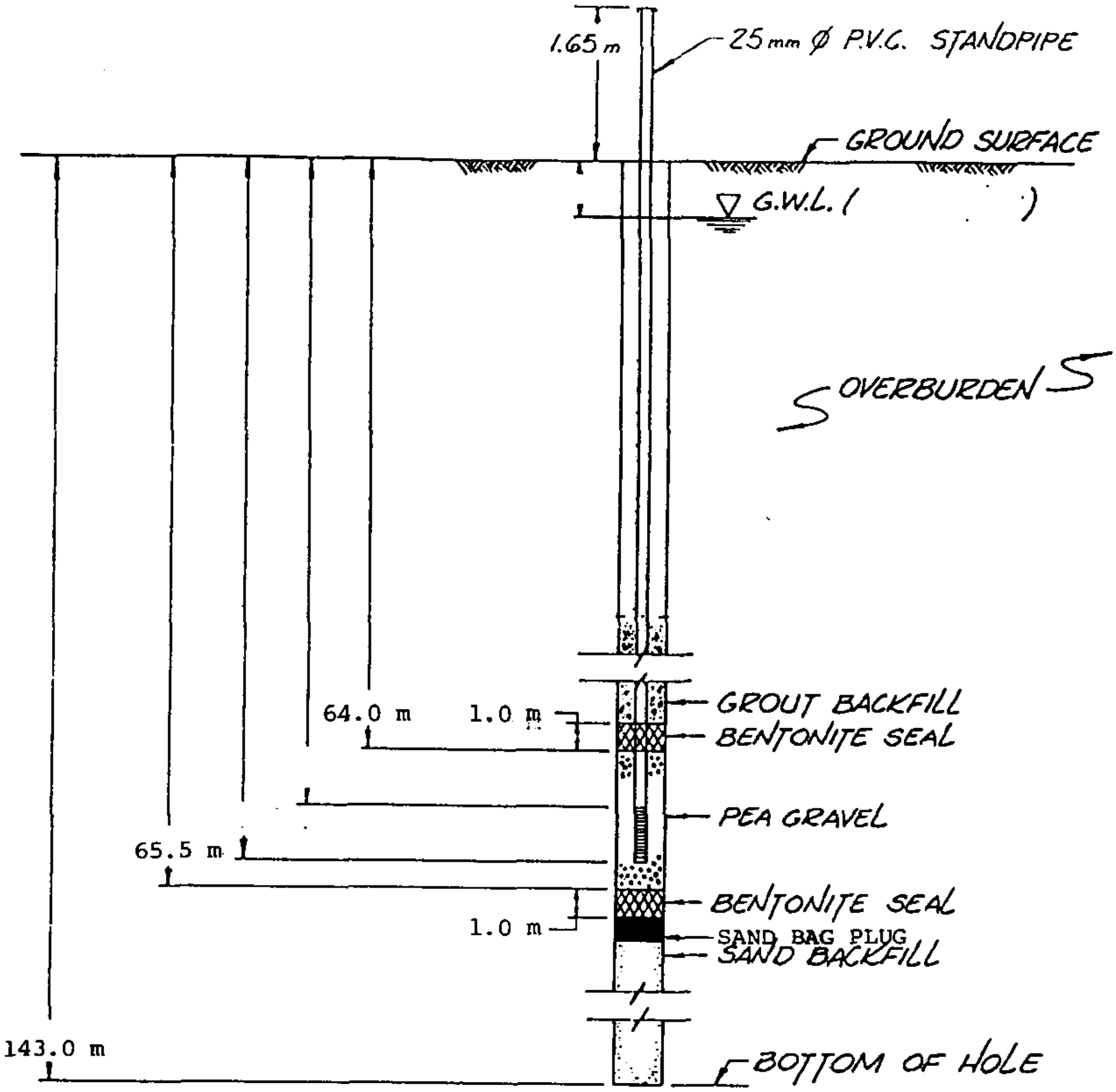
PROJECT No. 1692

DWG. No. A Figure 8

REV.

KLOHN LEONOFF



GROUND ELEVATION	769.70	m.
BEDROCK ELEVATION		m.
BASE OF UPPER SEAL	705.70	m.
LENGTH OF TIP	1.50	m.
TOP OF LOWER SEAL	704.20	m.

SCALE N.T.S.

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PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION - DRILLHOLE 323

CLIENT: CROWS NEST RESOURCES

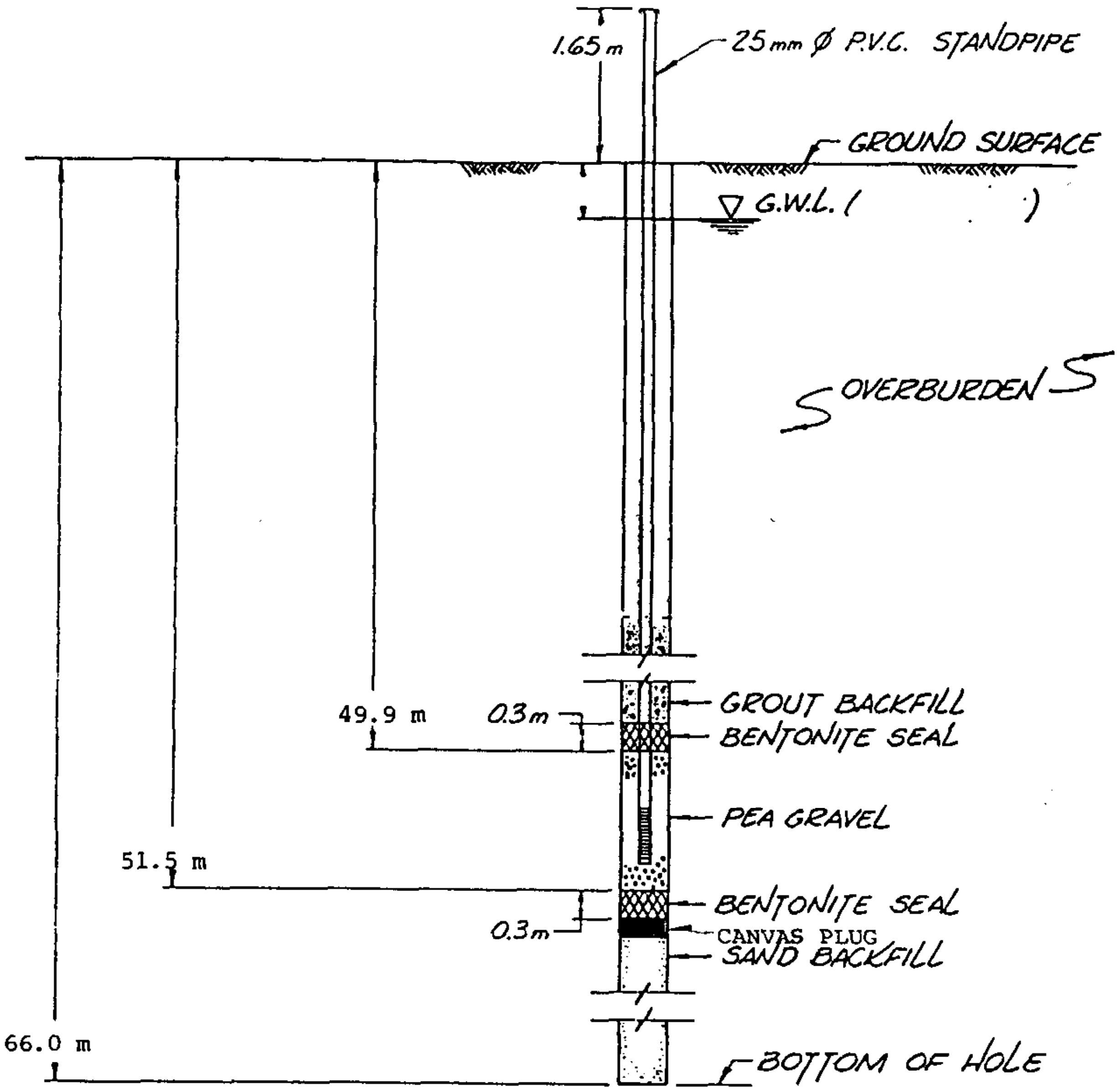
DATE OF ISSUE

APPROVED

PROJECT No. 1692

DWG. No. A Figure 9

REV.



GROUND ELEVATION	803.10 m.
BEDROCK ELEVATION	m.
BASE OF UPPER SEAL	753.20 m.
LENGTH OF TIP	1.60 m.
TOP OF LOWER SEAL	751.60 m.

SCALE N.T.S.

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PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION-DRILLHOLE 352

CLIENT: CROWS NEST RESOURCES

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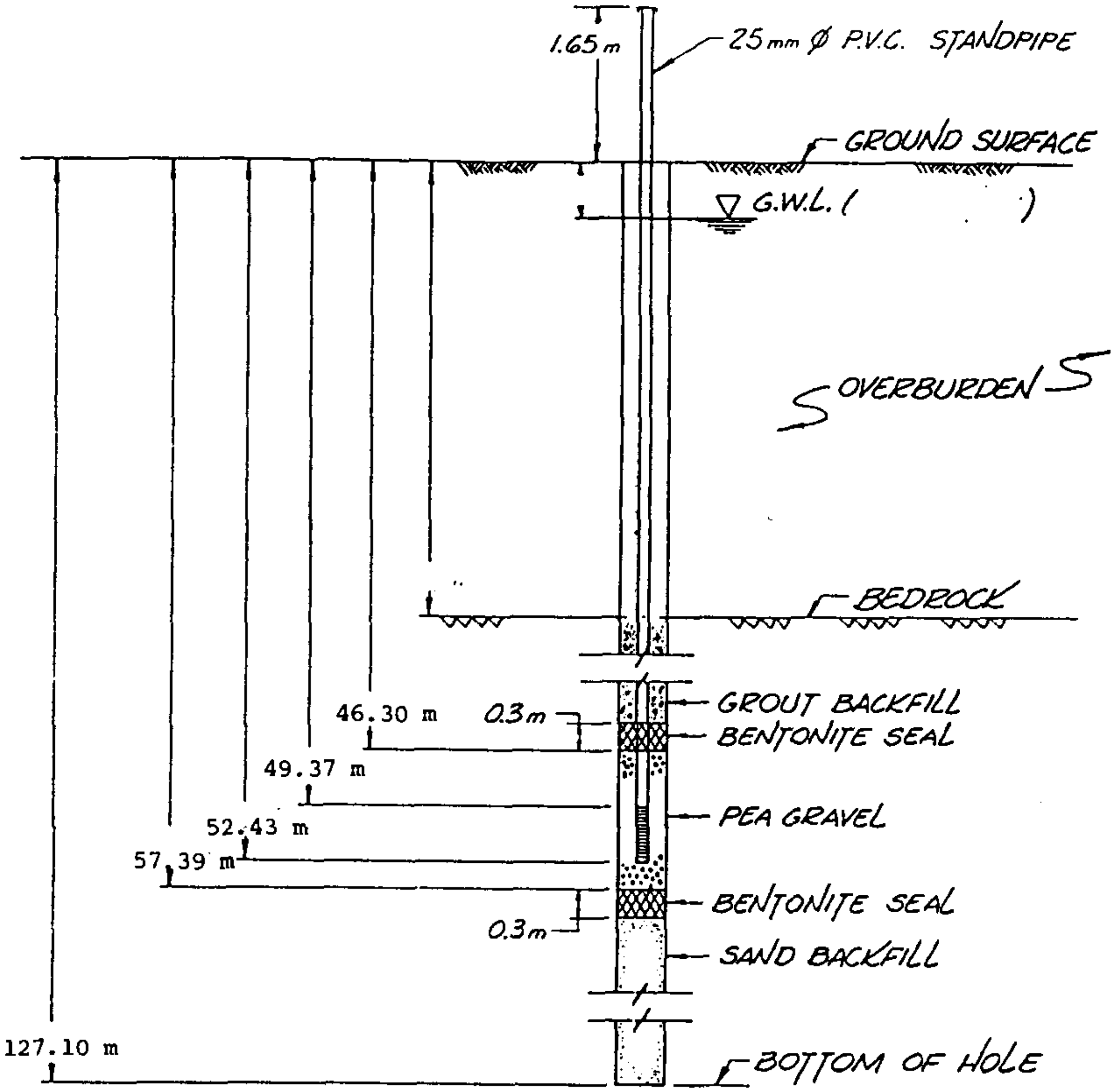
DWG. No. A Figure 10

REV.

NCI-455-KL



PIEZOMETER INSTALLED
IN COAL SEAM #6

GROUND ELEVATION	810.6	m.
BEDROCK ELEVATION		m.
BASE OF UPPER SEAL	764.3	m.
LENGTH OF TIP	3.06	m.
TOP OF LOWER SEAL	753.21	m.

SCALE N.T.S.

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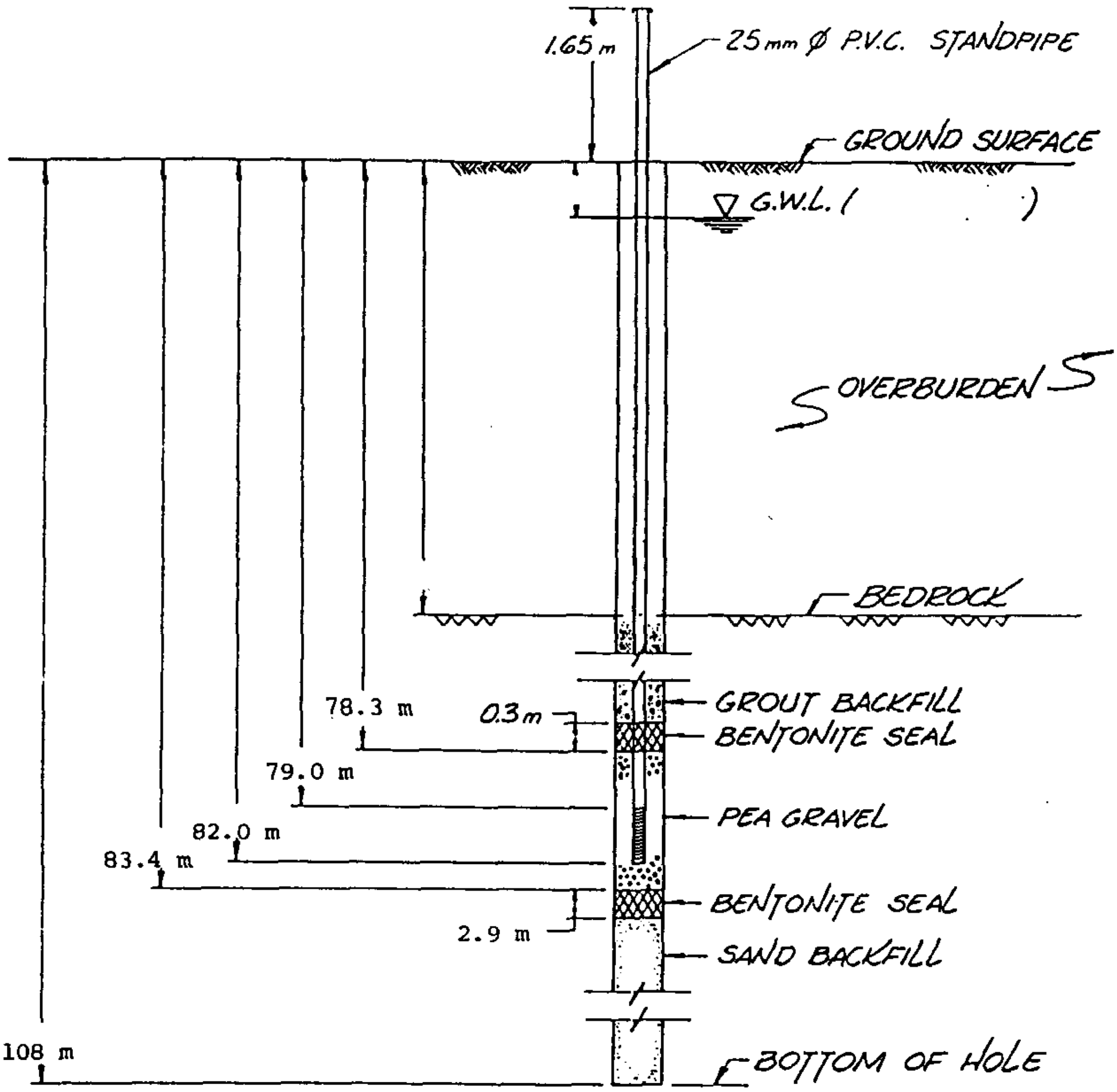
PROJECT TELKWA COAL PROJECT
TITLE DETAILS OF PIEZOMETER INSTALLATION-DRILLHOLE 335

CLIENT: CROWS NEST RESOURCES
DATE OF ISSUE
APPROVED
PROJECT No. 1692
DWG. No. A Figure 11
REV.

NCI-455-KL



PIEZOMETER INSTALLED
Below Coal Seam #2

GROUND ELEVATION	720.60	m.
BEDROCK ELEVATION		m.
BASE OF UPPER SEAL	642.30	m.
LENGTH OF TIP	3.0	m.
TOP OF LOWER SEAL	637.20	m.

SCALE N.T.S.

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PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION-DRILLHOLE 339

CLIENT: CROWS NEST RESOURCES

DATE OF ISSUE

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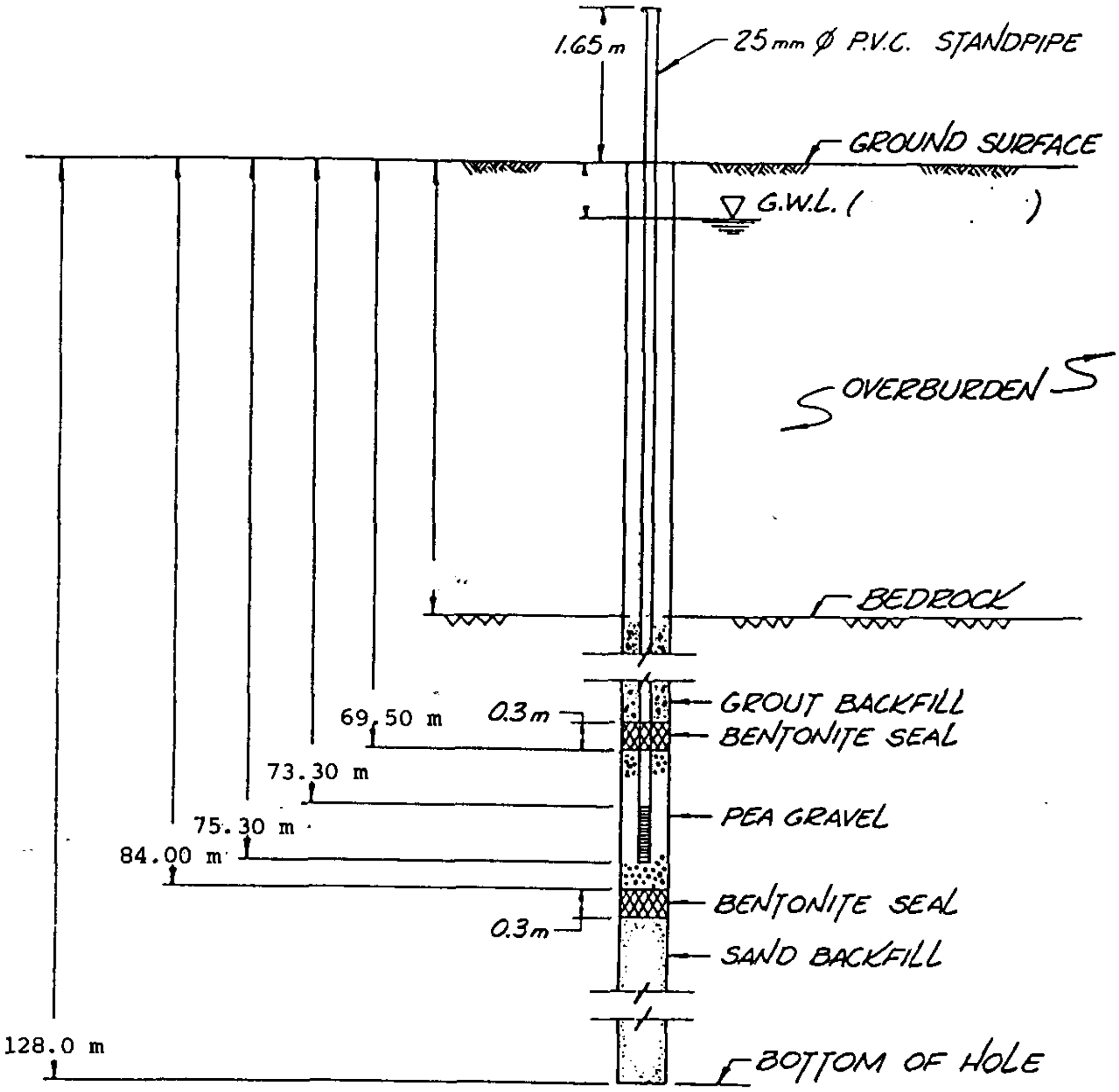
PROJECT No. 1692

DWG. No. A Figure 12

REV.



PIEZOMETER INSTALLED
IN COAL SEAM #4

GROUND ELEVATION	757.50	m.
BEDROCK ELEVATION		m.
BASE OF UPPER SEAL	688.0	m.
LENGTH OF TIP	2.0	m.
TOP OF LOWER SEAL	673.5	m.

SCALE N.T.S.

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PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION-DRILLHOLE

CLIENT: CROWS NEST RESOURCES

DATE OF ISSUE

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PROJECT No. 1692

DWG. No. A Figure 13

REV.

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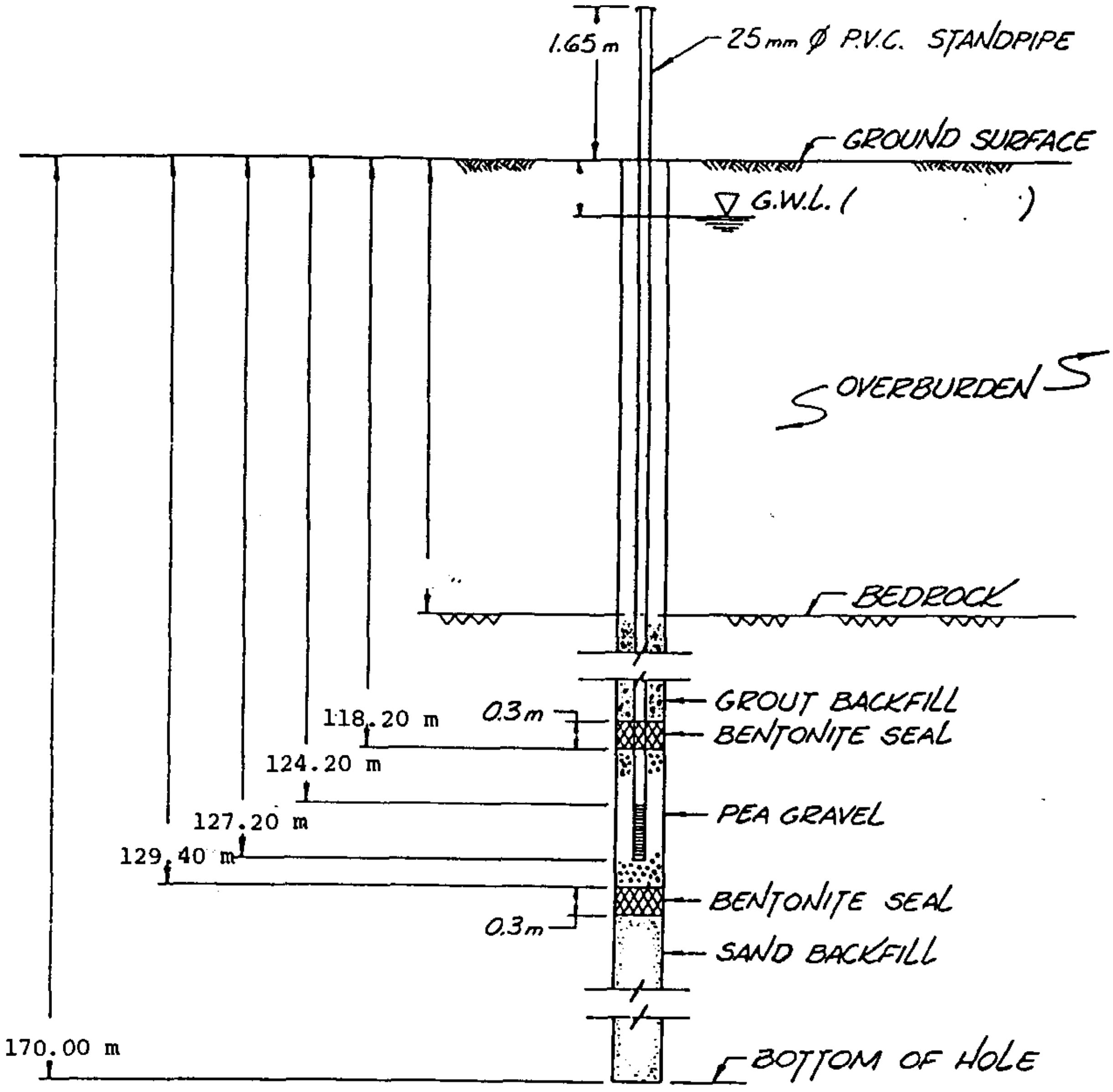


PIEZOMETER INSTALLED
IN COAL SEAM #3

GROUND ELEVATION	698.50	m.
BEDROCK ELEVATION		m.
BASE OF UPPER SEAL	580.30	m.
LENGTH OF TIP	3.00	m.
TOP OF LOWER SEAL	569.10	m.

SCALE N.T.S.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: TELKWA COAL PROJECT

TITLE: DETAILS OF PIEZOMETER INSTALLATION-DRILLHOLE 343

CLIENT: CROWS NEST RESOURCES

DATE OF ISSUE:

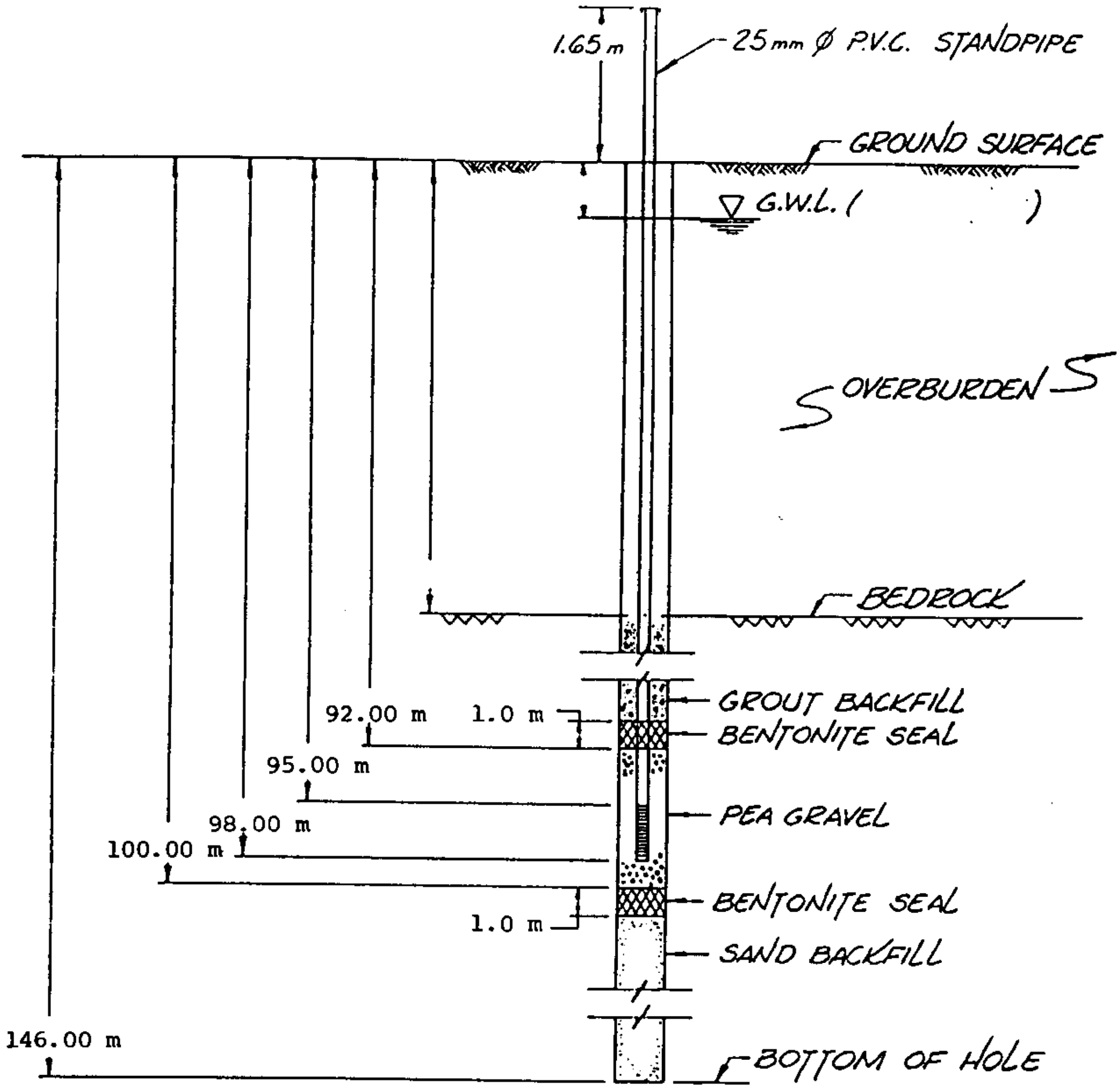
APPROVED:

PROJECT No. 1692

DWG. No. A Figure 14

REV.

NCI-455-KL



PIEZOMETER INSTALLED
IN COAL SEAM #2

GROUND ELEVATION	694.30	m.
BEDROCK ELEVATION		m.
BASE OF UPPER SEAL	602.30	m.
LENGTH OF TIP	3.00	m.
TOP OF LOWER SEAL	594.30	m.

SCALE N.T.S.

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CONSULTING ENGINEERS

PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION-DRILLHOLE 344

CLIENT: CROWS NEST RESOURCES

DATE OF ISSUE

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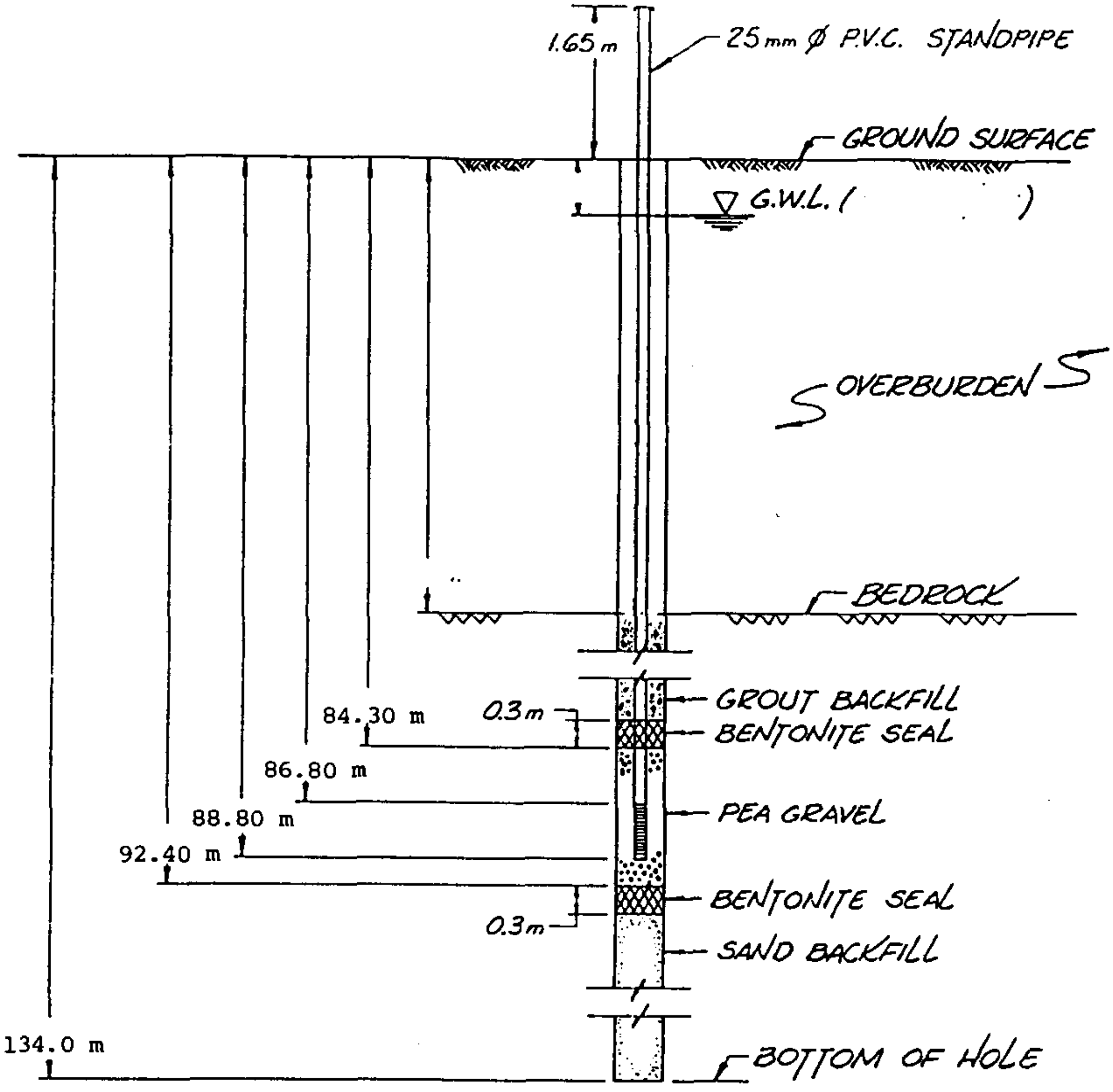
PROJECT No. 1692

DWG. No. A Figure 15

REV.

NCI-455-KL



PIEZOMETER INSTALLED

BETWEEN COAL SEAM # 2 & #3

GROUND ELEVATION	763.50	m.
BEDROCK ELEVATION		m.
BASE OF UPPER SEAL	679.20	m.
LENGTH OF TIP	2.00	m.
TOP OF LOWER SEAL	671.10	m.

SCALE N.T.S.

KLOHN LEONOFF LTD.
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PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION-DRILLHOLE 345

CLIENT: CROWS NEST RESOURCES

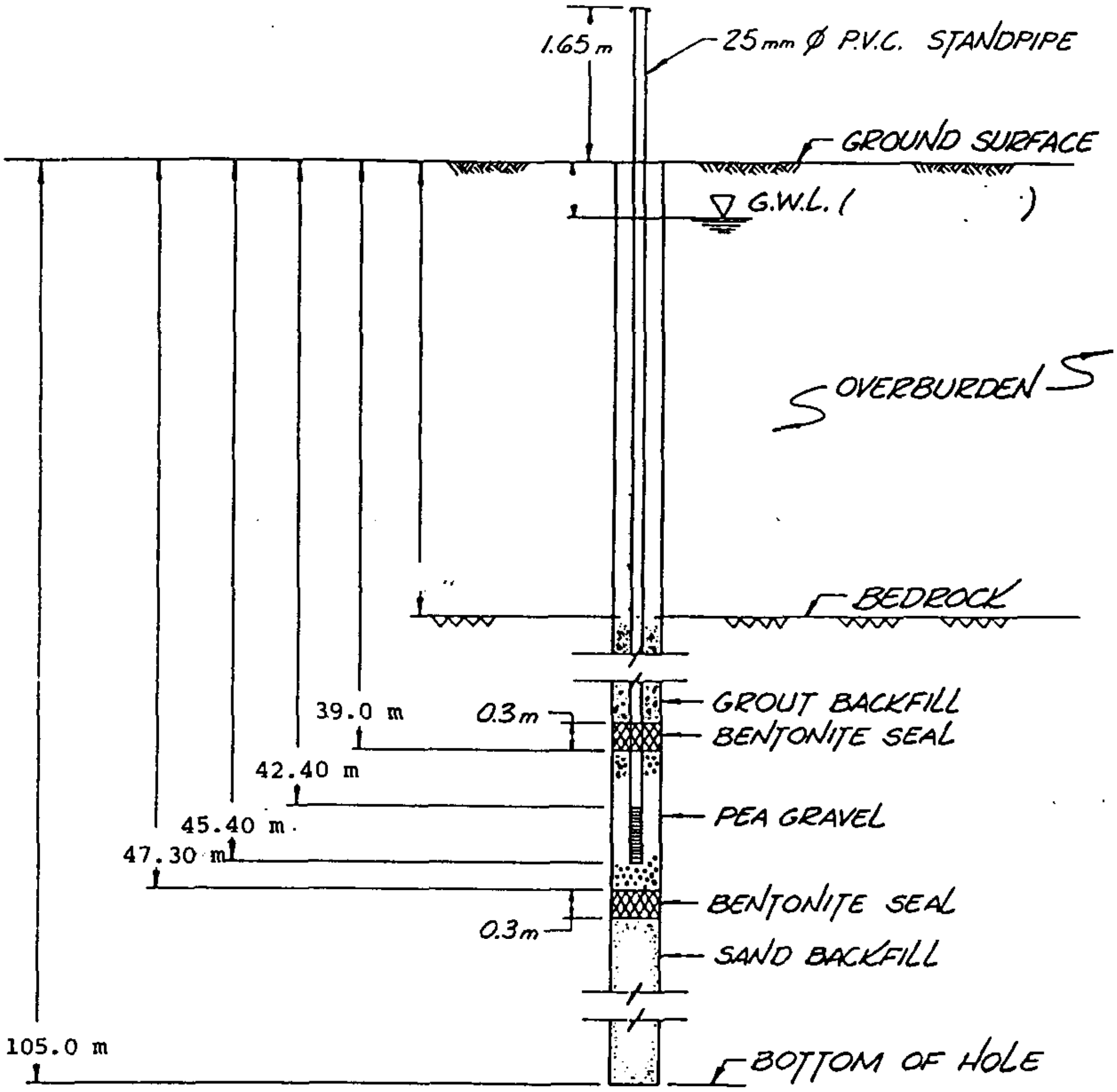
DATE OF ISSUE

APPROVED

PROJECT No. 1692

DWG. No. A Figure 16

REV.



PIEZOMETER INSTALLED
IN COAL SEAM #3

GROUND ELEVATION	760.10	m.
BEDROCK ELEVATION		m.
BASE OF UPPER SEAL	721.10	m.
LENGTH OF TIP	3.00	m.
TOP OF LOWER SEAL	712.80	m.

SCALE N.T.S.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION-DRILLHOLE 347

CLIENT: CROWS NEST RESOURCES

DATE OF ISSUE

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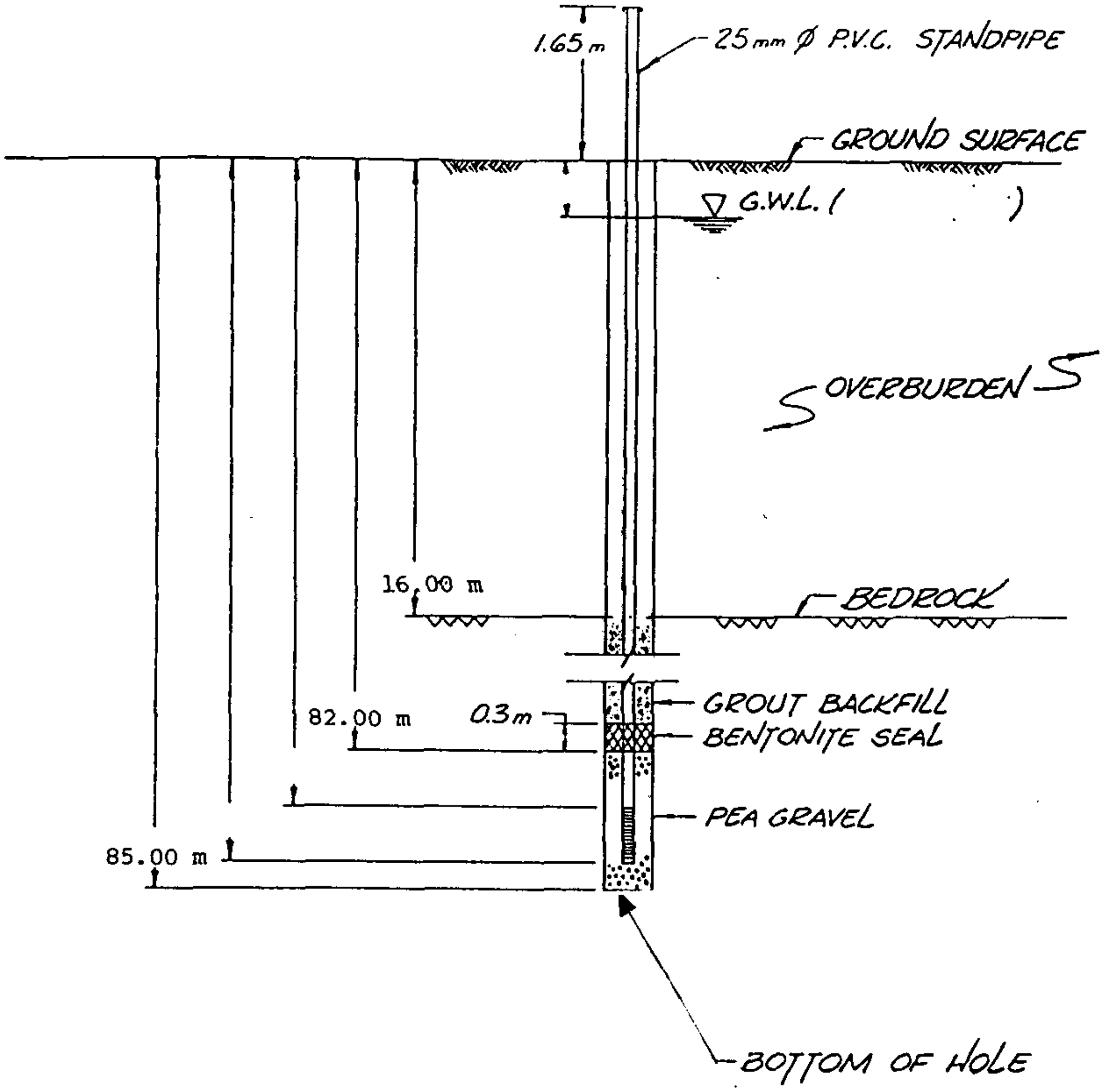
PROJECT No. 1692

DWG. No. A Figure 17

REV.

KLOHN LEONOFF

NCI-455-KL



GROUND ELEVATION	673.60	m.
BEDROCK ELEVATION	657.60	m.
BASE OF UPPER SEAL	591.60	m.
LENGTH OF TIP	3.00	m.
TOP OF LOWER SEAL	--	m.

SCALE N.T.S.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION - DRILLHOLE 406

CLIENT: CROWS NEST RESOURCES

DATE OF ISSUE

APPROVED

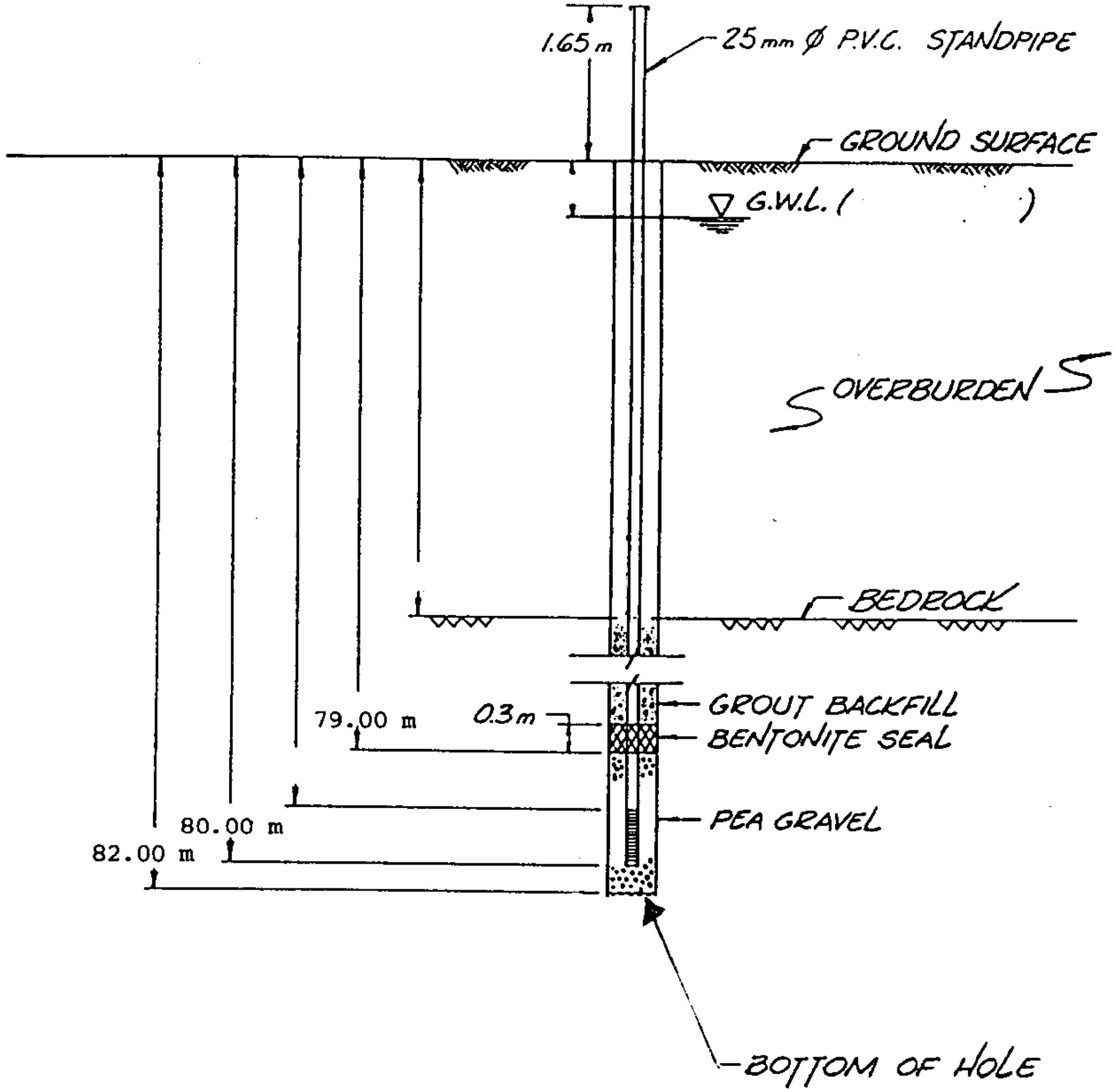
PROJECT No. 1692

DWG. No. A Figure 18

REV.

KLOHN LEONOFF

NCI-455-KL



GROUND ELEVATION	662.5	m.
BEDROCK ELEVATION		m.
BASE OF UPPER SEAL	583.5	m.
LENGTH OF TIP	1.00	m.
TOP OF LOWER SEAL	--	m.

SCALE N.T.S.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION - DRILLHOLE 410

CLIENT: CROWS NEST RESOURCES

DATE OF ISSUE

APPROVED

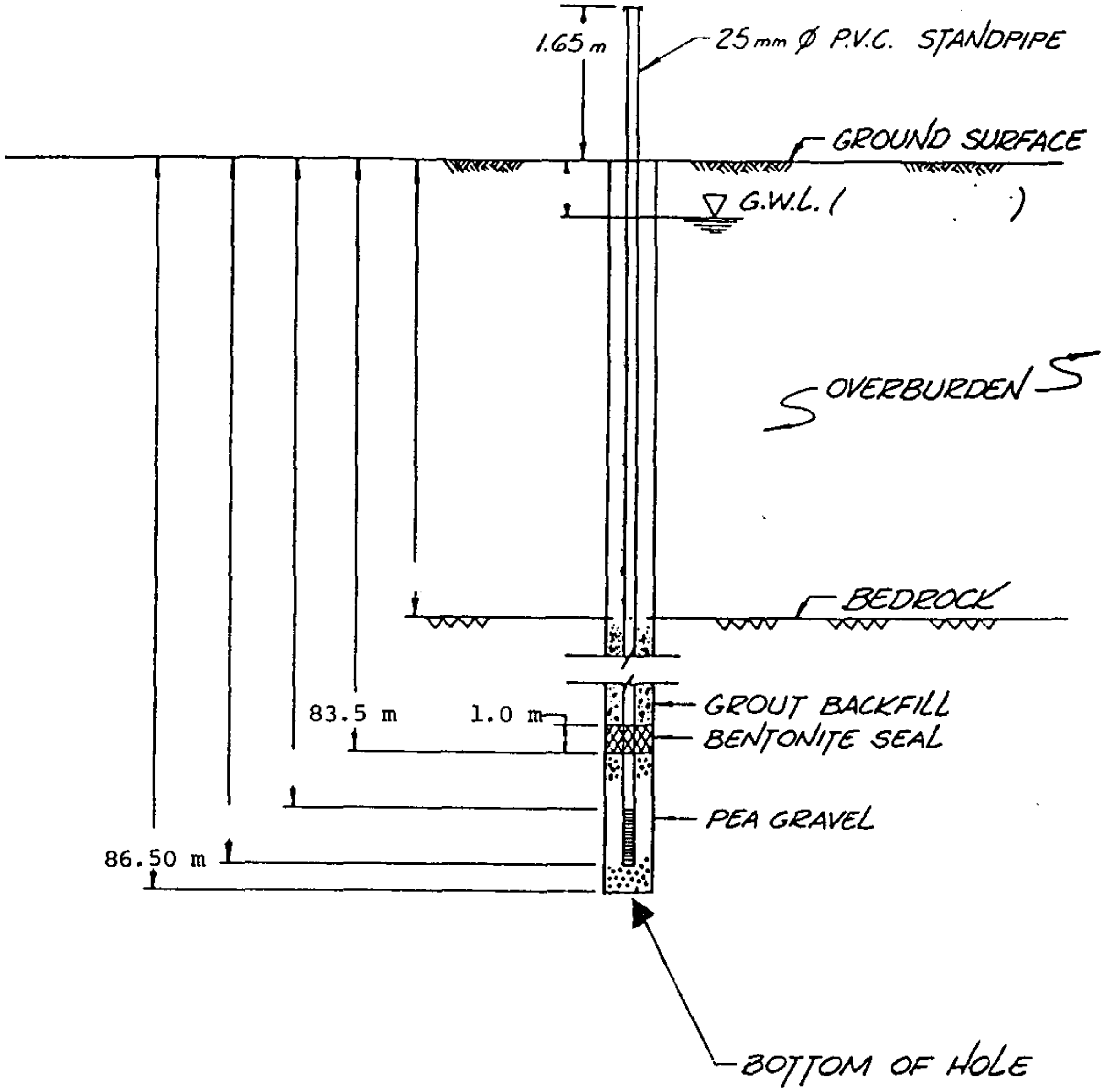
KLOHN LEONOFF

PROJECT No. 1692

DWG. No. A Figure 19

REV.

NCI-455-KL



PIEZOMETER INSTALLED
IN COAL SEAM

GROUND ELEVATION	739.80	m.
BEDROCK ELEVATION		m.
BASE OF UPPER SEAL	656.30	m.
LENGTH OF TIP		m.
TOP OF LOWER SEAL		m.

SCALE N.T.S.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT TELKWA COAL PROJECT

TITLE DETAILS OF PIEZOMETER INSTALLATION - DRILLHOLE 417

CLIENT: CROWS NEST RESOURCES

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
APPROVED	1692	A Figure 20	

NCI-455-KL

DOMESTIC WATER

QUALITY ANALYSES

CAN TEST LTD

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RESULTS OF TESTING:

SAMPLE #		5321-1	5321-2	5321-3	5321-4
CLIENT SAMPLE I.D.		1. L. Hart	2. Cosman	3. Mortenson	4. L.Langhaug
TEMPERATURE °C		-	-	-	-
SAMPLE DATE		09/12/84	09/12/84	09/13/84	09/13/84
PHYSICAL TESTS					
pH		6.90	7.00	6.85	7.85
Conductivity (micromhos/cm)		116.	149.	227.	484.
Color [Pt-Co Scale](Co)		L 5.	5.	L 5.	15.
Turbidity (NTU)		7.0	6.7	4.0	9.9
Hardness (mg/L)	CaCO3	48.	59.	117.	240
SOLIDS (mg/L)					
Total Suspended		9.5	9.0	4.0	1.0
Total Dissolved		106.	148.	204.	447.
DISSOLVED ANIONS (mg/L)					
Alkalinity: Bicarbonate	HCO3	68.0	103.	137.	293.
Alkalinity: Carbonate	CO3	Nil	Nil	Nil	Nil
Alkalinity: Hydroxide	OH	Nil	Nil	Nil	Nil
Chlorides	Cl	1.3	L 0.5	L 0.5	2.2
Sulfates	SO4	2.3	1.3	12.5	37.1
Nitrates	N	1.15	L 0.01	L 0.01	L 0.01
Nitrites	N	0.003	L 0.002	L 0.002	L 0.002
Total Dissolved Phosphates	P	0.015	0.024	0.001	L 0.001
ortho-Phosphates	P	0.013	0.021	L 0.001	L 0.001
Silica	SiO2	4.62	5.92	4.20	5.41
DISSOLVED METALS (mg/L)					
Aluminum	Al	0.054	0.12	0.018	0.029
Antimony	Sb	0.003	0.002	L 0.001	L 0.001
Arsenic	As	L 0.001	0.001	L 0.001	L 0.001
Barium	Ba	0.031	0.061	0.10	0.10
Beryllium	Be	L 0.003	L 0.003	L 0.003	L 0.003
Bismuth	Bi	L 0.5	L 0.5	L 0.5	L 0.5
Boron	B	0.043	0.027	0.019	0.036
Cadmium	Cd	L 0.001	L 0.001	L 0.001	L 0.001
Calcium	Ca	14.9	18.4	33.1	63.4
Chromium	Cr	L 0.001	L 0.001	L 0.001	L 0.001
Cobalt	Co	L 0.001	L 0.005	L 0.005	L 0.005
Copper	Cu	0.001	L 0.001	L 0.001	L 0.001
Iron	Fe	0.16	0.69	0.057	0.79
Lead	Pb	L 0.001	L 0.001	L 0.001	L 0.001
Magnesium	Mg	2.60	3.10	8.12	19.4
Manganese	Mn	0.032	1.56	0.005	0.29
Molybdenum	Mo	L 0.005	L 0.005	L 0.005	L 0.005
Nickel	Ni	L 0.005	L 0.005	L 0.005	L 0.001
Phosphorus	PO4	L 0.4	L 0.4	L 0.4	L 0.4
Potassium	K	0.42	1.05	0.32	1.38
Selenium	Se	L 0.001	L 0.001	L 0.001	L 0.001

RESULTS OF TESTING: (CON'T)

SAMPLE #		5321-1	5321-2	5321-3	5321-4
CLIENT SAMPLE I.D.		L. Hart	Cosman	Mortenson	L.Langhaug
DISSOLVED METALS (mg/L) (CON'T)					
Silicon	SiO2	7.79	10.3	7.59	11.9
Silver	Ag	L 0.005	L 0.005	L 0.005	L 0.005
✓Sodium	Na	1.66	1.87	3.97	18.1
Strontium	Sr	0.065	0.084	0.12	0.34
Tin	Sn	L 0.030	L 0.030	L 0.030	L 0.030
Titanium	Ti	L 0.006	L 0.006	L 0.006	L 0.006
Vanadium	V	L 0.010	L 0.010	L 0.010	L 0.010
Zinc	Zn	4.77	9.57	0.032	0.015
TOTAL METALS (mg/L)					
Aluminum	Al	0.79	0.26	0.11	0.058
Antimony	Sb	0.003	0.002	L 0.001	L 0.001
✓ Arsenic	As	L 0.001	0.002	L 0.001	L 0.001
Barium	Ba	0.039	0.065	0.10	0.10
Beryllium	Be	L 0.003	L 0.003	L 0.003	L 0.003
Bismuth	Bi	L 0.5	L 0.5	L 0.5	L 0.5
Boron	B	0.046	0.044	0.055	0.14
✓Cadmium	Cd	L 0.001	L 0.001	L 0.001	L 0.001
Calcium	Ca	15.3	18.7	33.7	63.9
✓Chromium	Cr	L 0.001	L 0.001	L 0.001	L 0.001
Cobalt	Co	L 0.005	L 0.005	L 0.005	L 0.005
✓ Copper	Cu	0.011	0.018	0.015	0.018
✓ Iron	Fe	1.57	2.99	1.08	1.00
Lead	Pb	L 0.001	L 0.001	L 0.001	L 0.001
Magnesium	Mg	2.38	3.12	8.12	19.5
✓ Manganese	Mn	0.058	1.58	0.013	0.29
Mercury	Hg	L 0.00005	L 0.00005	L 0.00005	L 0.00005
Molybdenum	Mo	L 0.005	L 0.005	L 0.005	0.005
✓ Nickel	Ni	L 0.005	L 0.005	L 0.005	L 0.005
✓Phosphorus	PO4	L 0.4	L 0.4	L 0.4	L 0.4
Selenium	Se	L 0.001	L 0.001	L 0.001	L 0.001
Silicon	SiO2	10.7	11.1	7.71	12.0
Silver	Ag	L 0.005	L 0.005	L 0.005	L 0.005
Sodium	Na	1.72	1.88	4.01	18.1
Strontium	Sr	0.067	0.085	0.12	0.34
Tin	Sn	L 0.030	L 0.030	L 0.030	L 0.030
Titanium	Ti	0.024	0.007	L 0.006	L 0.006
Vanadium	V	L 0.010	L 0.010	L 0.010	L 0.010
✓ Zinc	Zn	5.00	10.5	0.061	0.047
POLLUTANT TESTS (mg/L)					
Total Phosphate	P	L 0.02	L 0.02	L 0.02	L 0.02
Ammonia Nitrogen	N	0.037	0.073	0.027	0.034
Total Phenolics as Phenol		L 0.001	L 0.001	L 0.001	L 0.001
OTHERS (mg/L)					
Ferrous Iron	Fe	0.54	1.13	0.31	1.24
✓Dissolved Oxygen	O2	-	-	-	12.0

mg/L = milligrams per liter (= ppm, parts per million)
L = Less than = Not Detected

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RESULTS OF TESTING:

SAMPLE #		5321-5	5321-6	5321-7	5321-8
CLIENT SAMPLE I.D.		5. Bragg	6. Metzler	Test Pit Seepage	8. Silveira
TEMPERATURE °C		-	7.0	10.5	8.0
SAMPLE DATE		09/12/84	09/13/84	09/14/84	09/13/84
PHYSICAL TESTS					
pH		7.20	7.35	8.55	8.05
Conductivity (micromhos/cm)		281.	452.	724.	463.
Color [Pt-Co Scale](Co)		L 5.	L 5.	L 5.	15.
Turbidity (NTU)		1.2	0.60	4.8	1.6
Hardness (mg/L)	CaCO3	135.	237	157.	220
SOLIDS (mg/L)					
Total Suspended		L 0.5	0.8	20.	L 0.5
Total Dissolved		252.	415.	691.	414.
DISSOLVED ANIONS (mg/L)					
Alkalinity: Bicarbonate	HCO3	162.	278.	460.	271.
Alkalinity: Carbonate	CO3	Nil	Nil	18.4	Nil
Alkalinity: Hydroxide	OH	Nil	Nil	Nil	Nil
Chlorides	Cl	14.1	20.5	0.55	1.86
Sulfates	SO4	5.90	4.9	33.9	32.7
Nitrates	N	1.55	3.63	L 0.01	L 0.01
Nitrites	N	L 0.002	L 0.002	0.018	L 0.002
Total Dissolved Phosphates	P	L 0.001	0.006	0.035	0.013
ortho-Phosphates	P	L 0.001	0.002	0.028	0.012
Silica	SiO2	5.28	7.08	5.68	7.10
DISSOLVED METALS (mg/L)					
Aluminum	Al	0.061	0.021	0.11	0.021
Antimony	Sb	L 0.001	L 0.001	L 0.001	L 0.001
Arsenic	As	L 0.001	L 0.001	0.001	L 0.001
Barium	Ba	0.11	0.22	0.21	0.092
Beryllium	Be	L 0.003	L 0.003	L 0.003	L 0.003
Bismuth	Bi	L 0.5	L 0.5	L 0.5	L 0.5
Boron	B	0.030	0.023	0.15	0.030
Cadmium	Cd	L 0.001	L 0.001	L 0.001	L 0.001
Calcium	Ca	37.4	73.5	34.6	64.7
Chromium	Cr	L 0.001	L 0.001	L 0.001	L 0.001
Cobalt	Co	L 0.005	L 0.005	L 0.005	L 0.005
Copper	Cu	0.008	0.10	L 0.001	0.006
Iron	Fe	L 0.030	L 0.030	L 0.030	0.66
Lead	Pb	L 0.001	L 0.001	L 0.001	L 0.001
Magnesium	Mg	9.98	12.6	16.9	13.9
Manganese	Mn	L 0.003	L 0.003	0.15	0.34
Molybdenum	Mo	L 0.005	L 0.005	L 0.005	L 0.005
Nickel	Ni	L 0.005	L 0.005	L 0.005	L 0.005
Phosphorus	PO4	L 0.4	L 0.4	L 0.4	L 0.4
Potassium	K	1.79	1.38	4.95	0.98
Selenium	Se	L 0.001	L 0.001	L 0.001	L 0.001

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RESULTS OF TESTING: (CON'T)

SAMPLE #		5321-5	5321-6	5321-7	5321-8
CLIENT SAMPLE I.D.		Bragg	Metzler	Test Pit Seepage	Silveira
DISSOLVED METALS (mg/L) (CON'T)					
Silicon	SiO2	8.87	12.0	8.99	12.4
Silver	Ag	L 0.005	L 0.005	L 0.005	L 0.005
Sodium	Na	10.1	8.28	111.	12.4
Strontium	Sr	0.22	0.28	0.88	0.34
Tin	Sn	L 0.030	L 0.030	L 0.030	L 0.030
Titanium	Ti	L 0.006	L 0.006	L 0.006	L 0.006
Vanadium	V	L 0.010	L 0.010	L 0.010	L 0.010
Zinc	Zn	0.26	0.013	L 0.010	0.35
TOTAL METALS (mg/L)					
Aluminum	Al	0.12	0.099	1.11	0.098
Antimony	Sb	L 0.001	L 0.001	L 0.0012	L 0.001
Arsenic	As	L 0.001	L 0.001	0.002	L 0.001
Barium	Ba	0.11	0.23	0.22	0.093
Beryllium	Be	L 0.003	L 0.003	L 0.003	L 0.003
Bismuth	Bi	L 0.5	L 0.5	L 0.5	L 0.5
Boron	B	0.047	0.045	0.20	0.046
Cadmium	Cd	L 0.001	L 0.001	L 0.001	L 0.001
Calcium	Ca	37.4	75.1	34.6	65.5
Chromium	Cr	L 0.001	L 0.001	L 0.001	L 0.001
Cobalt	Co	L 0.005	L 0.005	L 0.005	L 0.005
Copper	Cu	0.010	0.11	0.003	0.006
Iron	Fe	0.038	L 0.030	0.75	1.02
Lead	Pb	L 0.001	L 0.001	L 0.001	L 0.001
Magnesium	Mg	10.2	12.6	17.1	14.0
Manganese	Mn	0.004	L 0.003	0.19	0.34
Mercury	Hg	L 0.00005	L 0.00005	L 0.00005	L 0.00005
Molybdenum	Mo	L 0.005	L 0.005	L 0.005	L 0.005
Nickel	Ni	L 0.005	L 0.005	L 0.005	L 0.005
Phosphorus	PO4	L 0.4	L 0.4	L 0.4	L 0.4
Selenium	Se	L 0.001	L 0.001	0.001	L 0.001
Silicon	SiO2	8.92	8.92	13.3	12.4
Silver	Ag	L 0.005	L 0.005	L 0.005	L 0.005
Sodium	Na	10.3	10.3	116.	12.5
Strontium	Sr	0.22	0.22	0.89	0.35
Tin	Sn	L 0.030	L 0.030	L 0.030	L 0.030
Titanium	Ti	L 0.006	L 0.006	0.049	L 0.006
Vanadium	V	L 0.010	L 0.010	L 0.010	L 0.010
Zinc	Zn	0.26	0.016	L 0.010	0.40
POLLUTANT TESTS (mg/L)					
Total Phosphate	P	L 0.02	L 0.02	0.090	L 0.02
Ammonia Nitrogen	N	L 0.01	L 0.01	0.40	0.050
Total Phenolics as Phenol		L 0.001	L 0.001	L 0.001	L 0.001
OTHERS (mg/L)					
Ferrous Iron	Fe	L 0.05	L 0.05	0.73	0.90
Dissolved Oxygen	O2	-	11.1	-	8.7

mg/L = milligrams per liter (= ppm, parts per million)
L = Less than = Not Detected

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RESULTS OF TESTING:

SAMPLE #		5321-9	5321-10	5321-11	5321-12
CLIENT SAMPLE I.D.		9.Rhodes	10.Visser	11.Dutov	12.Hoover
TEMPERATURE °C		10.5	10.5	9.0	8.5
SAMPLE DATE		09/14/84	09/14/84	09/14/84	09/14/84
PHYSICAL TESTS					
pH		7.95	7.15	7.95	8.20
Conductivity (micromhos/cm)		444.	119.	331.	281.
Color [Pt-Co Scale](Co)		L 5.	L 5.	L 5.	L 5.
Turbidity (NTU)		1.5	1.0	1.2	1.8
Hardness (mg/L)	CaCO3	237	56.	170.	147.
SOLIDS (mg/L)					
Total Suspended		1.5	L 0.5	0.8	2.5
Total Dissolved		437.	108.	297.	261.
DISSOLVED ANIONS (mg/L)					
Alkalinity: Bicarbonate	HCO3	318.	73.1	189.	179.
Alkalinity: Carbonate	CO3	Nil	Nil	Nil	Nil
Alkalinity: Hydroxide	OH	Nil	Nil	Nil	Nil
Chlorides	Cl	5.4	L 0.5	21.5	7.8
Sulfates	SO4	3.1	3.8	3.9	3.2
Nitrates	N	L 0.01	0.015	1.66	0.82
Nitrites	N	L 0.002	L 0.002	L 0.002	L 0.002
Total Dissolved Phosphates	P	L 0.001	L 0.001	0.003	0.002
ortho-Phosphates	P	L 0.001	L 0.001	L 0.001	L 0.001
Silica	SiO2	7.20	5.38	6.12	6.72
DISSOLVED METALS (mg/L)					
Aluminum	Al	0.10	0.020	0.012	0.026
Antimony	Sb	L 0.001	L 0.001	L 0.001	L 0.001
Arsenic	As	0.001	L 0.001	L 0.001	L 0.001
Barium	Ba	0.31	0.032	0.063	0.053
Beryllium	Be	L 0.003	L 0.003	L 0.003	L 0.003
Bismuth	Bi	L 0.5	L 0.5	L 0.5	L 0.5
Boron	B	0.026	0.025	0.042	0.025
Cadmium	Cd	L 0.001	L 0.001	L 0.001	L 0.001
Calcium	Ca	75.9	17.0	55.7	47.9
Chromium	Cr	L 0.001	L 0.001	L 0.001	L 0.001
Cobalt	Co	L 0.005	L 0.005	L 0.005	L 0.005
Copper	Cu	0.11	0.076	L 0.001	L 0.001
Iron	Fe	L 0.030	L 0.030	L 0.030	L 0.030
Lead	Pb	L 0.001	L 0.001	L 0.001	L 0.001
Magnesium	Mg	11.3	3.28	7.21	6.41
Manganese	Mn	0.59	L 0.003	0.005	L 0.003
Molybdenum	Mo	L 0.005	L 0.005	L 0.005	L 0.005
Nickel	Ni	L 0.005	L 0.005	L 0.005	L 0.005
Phosphorus	PO4	L 0.4	L 0.4	L 0.4	L 0.4
Potassium	K	1.18	0.43	0.74	0.59
Selenium	Se	L 0.001	L 0.001	L 0.001	L 0.001

ESULTS OF TESTING: (CON'T)

SAMPLE #		5321-9	5321-10	5321-11	5321-12
LIENT SAMPLE I.D.		Rhodes	Visser	Dutov	Hoover
ISSOLVED METALS (mg/L) (CON'T)					
Silicon	SiO2	14.0	7.97	11.8	11.4
Silver	Ag	L 0.005	L 0.005	L 0.005	L 0.005
Sodium	Na	6.01	2.08	3.08	3.06
trontium	Sr	0.29	0.070	0.16	0.14
Tin	Sn	L 0.030	L 0.030	L 0.030	L 0.030
Titanium	Ti	L 0.006	L 0.006	L 0.006	L 0.006
anadium	V	L 0.010	L 0.010	L 0.010	L 0.010
inc	Zn	1.17	0.31	0.028	0.054
OTAL METALS (mg/L)					
luminum	Al	0.15	0.12	0.080	0.12
Antimony	Sb	L 0.001	L 0.001	L 0.001	L 0.001
Arsenic	As	0.001	L 0.001	L 0.001	L 0.001
arium	Ba	0.31	0.033	0.064	0.054
eryllium	Be	L 0.003	L 0.003	L 0.003	L 0.003
Bismuth	Bi	L 0.5	L 0.5	L 0.5	L 0.5
oron	B	0.058	0.041	0.053	0.064
admium	Cd	L 0.001	L 0.001	L 0.001	L 0.001
Calcium	Ca	77.3	17.4	56.3	48.7
hromium	Cr	L 0.001	L 0.001	L 0.001	L 0.001
obalt	Co	L 0.005	L 0.005	L 0.005	L 0.005
Copper	Cu	0.13	0.081	0.006	0.006
Iron	Fe	0.22	0.037	0.097	0.081
ead	Pb	L 0.001	L 0.001	L 0.001	L 0.001
Magnesium	Mg	11.4	3.37	7.23	6.49
Manganese	Mn	⓪.60	0.004	0.009	L 0.003
ercury	Hg	L 0.00005	L 0.00005	L 0.00005	L 0.00005
olybdenum	Mo	L 0.005	L 0.005	L 0.005	L 0.005
Nickel	Ni	L 0.005	L 0.005	L 0.005	L 0.005
Phosphorus	PO4	L 0.4	L 0.4	L 0.4	L 0.4
elenium	Se	L 0.001	L 0.001	0.002	0.002
Silicon	SiO2	14.7	8.13	11.8	11.5
Silver	Ag	L 0.005	L 0.005	L 0.005	L 0.005
odium	Na	6.06	2.18	3.12	3.06
Strontium	Sr	0.30	0.073	0.16	0.14
Tin	Sn	L 0.030	L 0.030	L 0.030	L 0.030
tanium	Ti	L 0.006	0.007	L 0.006	L 0.006
nadium	V	L 0.010	L 0.010	L 0.010	L 0.010
Zinc	Zn	1.23	0.32	0.028	0.059
LLUTANT TESTS (mg/L)					
Total Phosphate	P	L 0.02	L 0.02	L 0.02	L 0.02
Ammonia Nitrogen	N	0.038	0.012	L 0.01	L 0.01
tal Phenolics as Phenol		L 0.001	L 0.001	L 0.001	L 0.001
OTHERS (mg/L)					
rrous Iron	Fe	0.16	L 0.05	0.077	0.079
ssolved Oxygen	O2	-	-	-	-

mg/L = milligrams per liter (= ppm, parts per million)

L = Less than = Not Detected

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RESULTS OF TESTING: (CON'T)

SAMPLE # CLIENT SAMPLE I.D.		5321-13 Van Der Horst	4321-14 Laird	5321-15 Paine	5321-16 Beamer
DISSOLVED METALS (mg/L) (CON'T)					
Silicon	SiO2	7.23	10.4	11.3	3.22
Silver	Ag	L 0.005	L 0.005	L 0.005	L 0.005
Sodium	Na	1.68	2.86	4.30	6.56
Strontium	Sr	0.057	0.12	0.15	0.11
Tin	Sn	L 0.030	L 0.030	L 0.030	L 0.030
Titanium	Ti	L 0.006	L 0.006	L 0.006	L 0.006
Vanadium	V	L 0.010	L 0.010	L 0.010	L 0.010
Zinc	Zn	0.12	0.016	0.037	0.018
TOTAL METALS (mg/L)					
Aluminum	Al	0.12	0.12	0.078	0.089
Antimony	Sb	L 0.001	L 0.001	L 0.001	0.002
Arsenic	As	L 0.001	L 0.001	L 0.001	L 0.001
Barium	Ba	0.028	0.040	0.059	0.067
Beryllium	Be	L 0.003	L 0.003	L 0.003	L 0.003
Bismuth	Bi	L 0.5	L 0.5	L 0.5	L 0.5
Boron	B	0.050	0.077	0.063	0.040
Cadmium	Cd	L 0.001	L 0.001	L 0.001	L 0.001
Calcium	Ca	13.7	45.0	53.9	39.0
Chromium	Cr	L 0.001	L 0.001	L 0.001	L 0.001
Cobalt	Co	L 0.005	L 0.005	L 0.005	L 0.005
Copper	Cu	0.072	0.002	0.005	0.002
Iron	Fe	(1.00)	L 0.030	0.12	(9.13)
Lead	Pb	L 0.001	L 0.001	L 0.001	L 0.001
Magnesium	Mg	2.31	5.30	7.02	9.43
Manganese	Mn	(0.13)	L 0.003	0.009	(0.99)
Mercury	Hg	L 0.00005	L 0.00005	L 0.00005	L 0.00005
Molybdenum	Mo	L 0.005	L 0.005	L 0.005	L 0.005
Nickel	Ni	L 0.005	L 0.005	L 0.005	L 0.005
Phosphorus	PO4	L 0.4	L 0.4	L 0.4	0.45
Selenium	Se	0.002	0.002	0.001	0.002
Silicon	SiO2	7.32	10.9	11.4	3.66
Silver	Ag	L 0.005	L 0.005	L 0.005	L 0.005
Sodium	Na	1.70	3.00	4.32	6.57
Strontium	Sr	0.057	0.12	0.15	0.11
Tin	Sn	L 0.030	L 0.030	L 0.030	L 0.030
Titanium	Ti	L 0.006	L 0.006	L 0.006	L 0.006
Vanadium	V	L 0.010	L 0.010	L 0.010	L 0.010
Zinc	Zn	0.13	0.026	0.037	0.033
POLLUTANT TESTS (mg/L)					
Total Phosphate	P	0.037	L 0.02	L 0.02	L 0.02
Ammonia Nitrogen	N	L 0.01	L 0.01	0.015	0.071
Total Phenolics as Phenol		L 0.001	L 0.001	L 0.001	L 0.001
OTHERS (mg/L)					
Ferrous Iron	Fe	(0.98)	L 0.05	0.12	(5.62)
Dissolved Oxygen	O2	-	-	-	-

mg/L = milligrams per liter (= ppm, parts per million)
L = Less than = Not Detected

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RESULTS OF TESTING:

SAMPLE #		5321-17	5321-18	5321-19	5321-20
CLIENT SAMPLE I.D.		17. Cebuliak	18. Campbell	19. Penner	20. Parks
TEMPERATURE °C		-	7.5	-	-
SAMPLE DATE		09/13/84	09/16/84	09/14/84	09/13/84
PHYSICAL TESTS					
pH		7.85	7.65	7.85	7.25
Conductivity (micromhos/cm)		319.	519.	313.	346.
Color [Pt-Co Scale](Co)		L 5.	L 5.	L 5.	L 5.
Turbidity (NTU)		0.60	0.32	0.47	4.5
Hardness (mg/L)	CaCO3	170.	290.	169.	178.
SOLIDS (mg/L)					
Total Suspended		L 0.5	2.0	1.0	3.0
Total Dissolved		302.	488.	298.	341.
DISSOLVED ANIONS (mg/L)					
Alkalinity: Bicarbonate	HCO3	228.	348.	215.	233.
Alkalinity: Carbonate	CO3	Nil	Nil	Nil	Nil
Alkalinity: Hydroxide	OH	Nil	Nil	Nil	Nil
Chlorides	Cl	0.90	7.9	0.55	1.0
Sulfates	SO4	3.7	4.8	3.3	11.0
Nitrates	N	0.59	2.39	0.33	0.072
Nitrites	N	L 0.002	L 0.002	0.086	L 0.002
Total Dissolved Phosphates	P	0.006	0.001	0.025	0.022
ortho-Phosphates	P	0.003	0.001	0.018	0.010
Silica	SiO2	5.78	7.80	7.02	7.20
DISSOLVED METALS (mg/L)					
Aluminum	Al	0.018	0.020	0.014	0.018
Antimony	Sb	L 0.001	L 0.001	L 0.001	L 0.001
Arsenic	As	L 0.001	L 0.001	L 0.001	L 0.001
Barium	Ba	0.063	0.31	0.061	0.038
Beryllium	Be	L 0.003	L 0.003	L 0.003	L 0.003
Bismuth	Bi	L 0.5	L 0.5	L 0.5	L 0.5
Boron	B	0.012	0.013	0.017	0.015
Cadmium	Cd	L 0.001	L 0.001	L 0.001	L 0.001
Calcium	Ca	54.5	95.0	54.8	43.0
Chromium	Cr	L 0.001	L 0.001	L 0.001	L 0.001
Cobalt	Co	L 0.005	L 0.005	L 0.005	L 0.005
Copper	Cu	0.003	L 0.001	L 0.001	0.039
Iron	Fe	L 0.030	0.056	L 0.030	0.13
Lead	Pb	L 0.001	L 0.001	L 0.001	L 0.001
Magnesium	Mg	7.93	12.5	7.51	16.7
Manganese	Mn	L 0.003	0.009	L 0.003	1.07
Molybdenum	Mo	L 0.005	L 0.005	L 0.005	L 0.005
Nickel	Ni	L 0.005	L 0.005	L 0.005	L 0.005
Phosphorus	PO4	L 0.4	L 0.4	L 0.4	L 0.4
Potassium	K	1.34	0.97	1.41	3.06
Selenium	Se	L 0.001	L 0.001	L 0.001	L 0.001

RESULTS OF TESTING: (CON'T)

SAMPLE #		5321-17	5321-18	5321-19	5321-20
CLIENT SAMPLE I.D.		Cebuliak	Campbell	Penner	Parks
DISSOLVED METALS (mg/L) (CON'T)					
Silicon	SiO2	11.3	12.3	10.8	12.8
Silver	Ag	L 0.005	L 0.005	L 0.005	L 0.005
Sodium	Na	4.82	4.40	4.16	10.9
Strontium	Sr	0.15	0.22	0.14	0.23
Tin	Sn	L 0.030	L 0.030	L 0.030	L 0.030
Titanium	Ti	L 0.006	L 0.006	L 0.006	L 0.006
Vanadium	V	L 0.010	L 0.010	L 0.010	L 0.010
Zinc	Zn	0.033	0.015	0.13	0.79
TOTAL METALS (mg/L)					
Aluminum	Al	0.060	0.072	0.054	0.064
Antimony	Sb	L 0.001	L 0.001	L 0.001	L 0.001
Arsenic	As	L 0.001	L 0.001	L 0.001	L 0.001
Barium	Ba	0.064	0.31	0.061	0.042
Beryllium	Be	L 0.003	L 0.003	L 0.003	L 0.003
Bismuth	Bi	L 0.5	L 0.5	L 0.5	L 0.5
Boron	B	0.042	0.058	0.032	0.027
Cadmium	Cd	L 0.001	L 0.001	L 0.001	L 0.001
Calcium	Ca	54.8	95.6	55.5	43.7
Chromium	Cr	L 0.001	L 0.001	L 0.001	L 0.001
Cobalt	Co	L 0.005	L 0.005	L 0.005	L 0.005
Copper	Cu	0.015	0.007	0.006	0.071
Iron	Fe	0.041	0.12	0.032	4.48
Lead	Pb	L 0.001	L 0.001	L 0.001	L 0.001
Magnesium	Mg	7.99	12.5	7.71	16.8
Manganese	Mn	L 0.003	0.010	L 0.003	1.12
Mercury	Hg	L 0.00005	L 0.00005	L 0.00005	L 0.00005
Molybdenum	Mo	L 0.005	L 0.005	L 0.005	L 0.005
Nickel	Ni	L 0.005	L 0.005	L 0.005	L 0.005
Phosphorus	PO4	L 0.4	L 0.4	L 0.4	L 0.4
Selenium	Se	0.002	0.002	0.001	0.002
Silicon	SiO2	11.4	12.6	10.9	12.9
Silver	Ag	L 0.005	L 0.005	L 0.005	L 0.005
Sodium	Na	4.97	4.41	4.27	10.9
Strontium	Sr	0.15	0.22	0.15	0.23
Tin	Sn	L 0.030	L 0.030	L 0.030	L 0.030
Titanium	Ti	L 0.006	L 0.006	L 0.006	L 0.006
Vanadium	V	L 0.010	L 0.010	L 0.010	L 0.010
Zinc	Zn	0.034	0.036	0.15	0.89
POLLUTANT TESTS (mg/L)					
Total Phosphate	P	L 0.02	L 0.02	0.031	0.029
Ammonia Nitrogen	N	L 0.01	0.055	L 0.01	0.013
Total Phenolics as Phenol		L 0.001	L 0.001	L 0.001	L 0.001
OTHERS (mg/L)					
Ferrous Iron	Fe	L 0.05	0.11	L 0.05	3.28
Dissolved Oxygen	O2	-	-	-	-

mg/L = milligrams per liter (= ppm, parts per million)
L = Less than = Not Detected

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RESULTS OF TESTING:

SAMPLE #		5321-21	5321-22	5321-23	5321-24
CLIENT SAMPLE I.D.		21. Helps	21 B.Help's Barn	22. Kerr	23. DeHooq
TEMPERATURE °C		6.5	-	9.5	8.5
SAMPLE DATE		09/13/84	09/13/84	09/15/84	09/12/84
PHYSICAL TESTS					
pH		7.45	7.00	7.45	7.25
Conductivity (micromhos/cm)		205.	200.	723.	626.
Color [Pt-Co Scale](Co)		L 5.	50.	5.	L 5.
Turbidity (NTU)		0.54	9.4	1.7	1.4
Hardness (mg/L)	CaCO3	100.	103.	416.	290.
SOLIDS (mg/L)					
Total Suspended		2.5	6.5	3.5	L 0.5
Total Dissolved		188.	190.	720.	552.
DISSOLVED ANIONS (mg/L)					
Alkalinity: Bicarbonate	HCO3	126.	133.	536.	346.
Alkalinity: Carbonate	CO3	Nil	Nil	Nil	Nil
Alkalinity: Hydroxide	OH	Nil	Nil	Nil	Nil
Chlorides	Cl	2.1	L 0.5	8.6	48.6
Sulfates	SO4	5.8	2.9	10.0	6.8
Nitrates	N	0.44	0.040	0.69	1.34
Nitrites	N	L 0.002	L 0.002	L 0.002	L 0.002
Total Dissolved Phosphates	P	0.002	0.021	0.010	0.001
ortho-Phosphates	P	0.002	0.021	0.003	L 0.001
Silica	SiO2	6.60	5.92	6.00	8.67
DISSOLVED METALS (mg/L)					
Aluminum	Al	0.070	0.11	0.017	0.089
Antimony	Sb	L 0.001	L 0.001	L 0.001	L 0.001
Arsenic	As	L 0.001	L 0.001	L 0.001	L 0.001
Barium	Ba	0.031	0.032	0.21	0.18
Beryllium	Be	L 0.003	L 0.003	L 0.003	L 0.003
Bismuth	Bi	L 0.5	L 0.5	L 0.5	L 0.5
Boron	B	0.040	0.018	0.018	0.017
Cadmium	Cd	L 0.001	L 0.001	L 0.001	L 0.001
Calcium	Ca	25.5	24.2	113.	84.5
Chromium	Cr	L 0.001	L 0.001	L 0.005	L 0.001
Cobalt	Co	L 0.005	L 0.005	L 0.005	L 0.005
Copper	Cu	0.019	0.006	L 0.001	0.054
Iron	Fe	L 0.030	2.53	0.033	L 0.030
Lead	Pb	L 0.001	L 0.001	L 0.001	L 0.001
Magnesium	Mg	8.57	10.0	31.7	18.7
Manganese	Mn	0.011	0.080	0.011	0.36
Molybdenum	Mo	L 0.005	L 0.005	L 0.005	L 0.005
Nickel	Ni	L 0.005	L 0.005	L 0.005	L 0.005
Phosphorus	PO4	L 0.4	L 0.4	L 0.4	L 0.4
Potassium	K	2.43	1.24	0.79	1.00
Selenium	Se	L 0.001	L 0.001	L 0.001	L 0.001

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RESULTS OF TESTING: (CON'T)

SAMPLE #		5321-21	5321-22	5321-23	5321-24
CLIENT SAMPLE I.D.		Helps	Helps Barn	Kerr	De Hoog
DISSOLVED METALS (mg/L) (CON'T)					
Silicon	SiO2	11.0	9.26	14.3	14.2
Silver	Ag	L 0.005	L 0.005	L 0.005	L 0.005
Sodium	Na	5.61	5.91	15.0	28.5
Strontium	Sr	0.12	0.16	0.50	0.58
Tin	Sn	L 0.030	L 0.030	L 0.030	L 0.030
Titanium	Ti	L 0.006	L 0.006	L 0.006	L 0.006
Vanadium	V	L 0.010	L 0.010	L 0.010	L 0.010
Zinc	Zn	0.021	0.13	0.059	0.32
TOTAL METALS (mg/L)					
Aluminum	Al	0.11	0.20	0.20	0.12
Antimony	Sb	L 0.001	L 0.001	L 0.001	L 0.001
Arsenic	As	L 0.001	L 0.001	L 0.001	L 0.001
Barium	Ba	0.031	0.033	0.21	0.19
Beryllium	Be	L 0.003	L 0.003	L 0.003	L 0.003
Bismuth	Bi	L 0.5	L 0.5	L 0.5	L 0.5
Boron	B	0.062	0.080	0.032	0.23
Cadmium	Cd	L 0.001	L 0.001	L 0.001	L 0.001
Calcium	Ca	25.5	24.2	115.	87.8
Chromium	Cr	L 0.001	L 0.001	L 0.001	L 0.001
Cobalt	Co	L 0.005	L 0.005	L 0.005	L 0.005
Copper	Cu	0.024	0.042	0.003	0.060
Iron	Fe	0.078	3.79	1.83	0.42
Lead	Pb	L 0.001	L 0.001	L 0.001	L 0.001
Magnesium	Mg	8.57	10.0	32.5	19.7
Manganese	Mn	0.013	0.080	0.016	0.36
Mercury	Hg	L 0.00005	L 0.00005	L 0.00005	L 0.00005
Molybdenum	Mo	L 0.005	L 0.005	L 0.005	L 0.005
Nickel	Ni	L 0.005	L 0.005	L 0.005	L 0.005
Phosphorus	PO4	L 0.4	L 0.4	L 0.4	L 0.4
Selenium	Se	0.003	0.001	L 0.001	0.001
Silicon	SiO2	11.1	9.47	14.4	14.4
Silver	Ag	L 0.005	L 0.005	L 0.005	L 0.005
Sodium	Na	5.62	5.95	15.2	29.9
Strontium	Sr	0.12	0.16	0.51	0.62
Tin	Sn	L 0.030	L 0.030	L 0.030	L 0.030
Titanium	Ti	L 0.006	L 0.006	L 0.006	L 0.006
Vanadium	V	0.010	L 0.010	L 0.010	L 0.010
Zinc	Zn	0.029	0.14	0.099	0.32
POLLUTANT TESTS (mg/L)					
Total Phosphate	P	L 0.02	0.027	L 0.02	L 0.02
Ammonia Nitrogen	N	0.030	0.040	0.018	0.030
Total Phenolics as Phenol		L 0.001	L 0.001	L 0.001	L 0.001
OTHERS (mg/L)					
Ferrous Iron	Fe	0.054	2.95	0.81	0.37
Dissolved Oxygen	O2	-	-	-	-

mg/L = milligrams per liter (= ppm, parts per million)
L = Less than = Not Detected

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RESULTS OF TESTING:

SAMPLE #	5321-25
CLIENT SAMPLE I.D.	24. Bulkley Balley Collievies
TEMPERATURE °C	6.1
SAMPLE DATE	09/12/84

PHYSICAL TESTS

pH		7.20
Conductivity (micromhos/cm)		205.
Color [Pt-Co Scale](Co)		L 5.
Turbidity (NTU)		0.46
Hardness (mg/L)	$CaCO_3$	99.

SOLIDS (mg/L)

Total Suspended	L 0.5
Total Dissolved	161.

DISSOLVED ANIONS (mg/L)

Alkalinity: Bicarbonate	HCO_3	86.6
Alkalinity: Carbonate	CO_3	Nil
Alkalinity: Hydroxide	OH	Nil
Chlorides	Cl	L 0.5
Sulfates	SO_4	29.5
Nitrates	N	0.050
Nitrites	N	L 0.002
Total Dissolved Phosphates	P	0.008
ortho-Phosphates	P	0.002
Silica	SiO_2	3.51

DISSOLVED METALS (mg/L)

Aluminum	Al	0.065
Antimony	Sb	L 0.001
Arsenic	As	L 0.001
Barium	Ba	0.041
Beryllium	Be	L 0.003
Bismuth	Bi	L 0.5
Boron	B	0.014
Cadmium	Cd	L 0.001
Calcium	Ca	26.0
Chromium	Cr	L 0.001
Cobalt	Co	L 0.005
Copper	Cu	L 0.001
Iron	Fe	0.052
Lead	Pb	L 0.001
Magnesium	Mg	8.15
Manganese	Mn	0.004
Molybdenum	Mo	L 0.005
Nickel	Ni	L 0.005
Phosphorus	PO_4	L 0.4
Potassium	K	0.55
Selenium	Se	L 0.001

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RESULTS OF TESTING: (CON'T)

SAMPLE #		5321-25
CLIENT SAMPLE I.D.		Bulkley Valley Collievies
DISSOLVED METALS (mg/L) (CON'T)		
Silicon	SiO2	5.51
Silver	Ag	L 0.005
Sodium	Na	3.81
Strontium	Sr	0.12
Tin	Sn	L 0.030
Titanium	Ti	L 0.006
Vanadium	V	L 0.010
Zinc	Zn	0.038
TOTAL METALS (mg/L)		
Aluminum	Al	0.092
Antimony	Sb	L 0.001
Arsenic	As	L 0.001
Barium	Ba	0.042
Beryllium	Be	L 0.003
Bismuth	Bi	L 0.5
Boron	B	0.064
Cadmium	Cd	L 0.001
Calcium	Ca	26.9
Chromium	Cr	L 0.001
Cobalt	Co	L 0.005
Copper	Cu	0.002
Iron	Fe	0.076
Lead	Pb	L 0.001
Magnesium	Mg	8.58
Manganese	Mn	0.004
Mercury	Hg	L 0.00005
Molybdenum	Mo	L 0.005
Nickel	Ni	L 0.005
Phosphorus	PO4	L 0.4
Selenium	Se	L 0.001
Silicon	SiO2	5.75
Silver	Ag	L 0.005
Sodium	Na	3.90
Strontium	Sr	0.12
Tin	Sn	L 0.030
Titanium	Ti	L 0.006
Vanadium	V	L 0.010
Zinc	Zn	0.047
POLLUTANT TESTS (mg/L)		
Total Phosphate	P	L 0.02
Ammonia Nitrogen	N	0.019
Total Phenolics as Phenol		L 0.001
OTHERS (mg/L)		
Ferrous Iron	Fe	0.067
Dissolved Oxygen	O2	-

mg/L = milligrams per liter (= ppm, parts per million)

L = Less than = Not Detected

PIEZOMETER WATER SAMPLES

QUALITY ANALYSES

RESULTS OF TESTING:

SAMPLE #		13	14	15
CLIENT SAMPLE I.D.		255	257	258
PHYSICAL TESTS				
pH		8.00	8.55	11.20
Conductivity(micromhos/cm)		401.	668.	1150.
Turbidity(JTU)		4.5	11.	5.0
Hardness(mg/L)	CaCO3	85.0	56.0	6.0
SOLIDS(mg/L)				
Total Suspended		16.5	135.	10.
Total Dissolved		312.	668.	550.
DISSOLVED ANIONS(mg/L)				
Alkalinity: Bicarbonate	HCO3	95.2	440.	Nil
Alkalinity: Carbonate	CO3	Nil	10.6	92.4
Alkalinity: Hydroxide	OH	Nil	Nil	53.0
Chlorides	Cl	57.7	3.42	36.2
Sulfates	SO4	55.2	30.0	55.0
Nitrates	N	0.032	0.032	0.10
Nitrites	N	0.005	0.003	0.009
Total Phosphates	PO4	0.022	0.011	0.008
Ortho Phosphates	P	0.004	0.008	0.003
Silica	SiO2	11.0	12.0	14.4
DISSOLVED METALS(mg/L)				
Aluminum	Al	0.028	0.23	0.29
Antimony	Sb	< 0.15	< 0.15	< 0.15
Arsenic	As	0.001	0.002	0.001
Barium	Ba	0.035	0.081	0.051
Beryllium	Be	< 0.003	< 0.003	< 0.003
Bismuth	Bi	< 0.5	< 0.5	< 0.5
Boron	B	0.027	0.080	0.068
Cadmium	Cd	< 0.001	< 0.001	< 0.001
Calcium	Ca	25.2	15.3	2.28
Chromium	Cr	< 0.005	< 0.005	< 0.005
Cobalt	Co	< 0.005	< 0.005	< 0.005
Copper	Cu	0.016	0.016	0.042
Iron	Fe	0.12	0.045	0.032
Lead	Pb	0.024	0.004	0.030
Magnesium	Mg	5.16	3.65	0.021
Manganese	Mn	0.049	0.22	< 0.003
Molybdenum	Mo	< 0.040	0.076	< 0.040
Nickel	Ni	< 0.005	< 0.005	< 0.005
Phosphorus	PO4	< 0.4	< 0.4	< 0.4
Potassium	K	2.41	3.06	8.72
Selenium	Se	< 0.001	< 0.001	< 0.001
Silicon	SiO2	7.09	7.13	8.42
Silver	Ag	< 0.001	< 0.001	< 0.001
Sodium	Na	63.6	174.	167.
Strontium	Sr	0.11	0.14	0.29
Tin	Sn	< 0.030	< 0.030	< 0.030
Titanium	Ti	< 0.006	0.017	0.008
Vanadium	V	< 0.010	< 0.010	< 0.010
Zinc	Zn	0.093	0.062	0.062

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RESULTS OF TESTING:

SAMPLE #		13	14	15
CLIENT SAMPLE I.D.		255	257	258
TOTAL METALS (mg/L)				
Aluminum	Al	0.30	10.8	0.68
Antimony	Sb	< 0.15	< 0.15	< 0.15
Arsenic	As	0.001	0.004	0.003
Barium	Ba	0.038	0.13	0.059
Beryllium	Be	< 0.003	< 0.003	< 0.003
Bismuth	Bi	< 0.5	< 0.5	< 0.5
Boron	B	0.033	0.080	0.068
Cadmium	Cd	< 0.001	0.005	< 0.001
Calcium	Ca	25.2	15.3	3.17
Chromium	Cr	< 0.005	< 0.005	< 0.005
Cobalt	Co	< 0.005	< 0.005	< 0.005
Copper	Cu	0.092	0.17	0.46
Iron	Fe	0.55	3.42	0.32
Lead	Pb	0.033	0.040	0.096
Magnesium	Mg	5.24	4.27	0.099
Manganese	Mn	0.053	0.26	0.008
Mercury	Hg	0.00010	<.00005	0.00015
Molybdenum	Mo	< 0.040	0.076	< 0.040
Nickel	Ni	0.005	0.015	< 0.005
Phosphorus	PO4	< 0.4	< 0.4	< 0.4
Selenium	Se	< 0.001	< 0.001	< 0.001
Silicon	SiO2	9.82	39.0	11.3
Silver	Ag	< 0.001	< 0.001	< 0.001
Sodium	Na	63.6	174.	167.
Strontium	Sr	0.11	0.15	0.30
Tin	Sn	< 0.030	< 0.030	< 0.030
Titanium	Ti	0.038	0.43	0.048
Vanadium	V	< 0.010	< 0.010	< 0.010
Zinc	Zn	0.14	0.24	0.24
POLLUTANT TESTS (mg/L)				
Total Phosphate	PO4	0.16	0.10	0.051
mmonia Nitrogen	N	1.79	0.22	2.03
Total Phenolics as Phenol		< 0.001	< 0.001	< 0.001
THERS				
errous Iron (mg/L)	Fe	< 0.10	< 0.10	< 0.10
Temperature C		7.2	-	-

g/L = milligrams per liter
< = Less than = Not Detected

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RESULTS OF TESTING:

SAMPLE #		13	14	15
CLIENT SAMPLE I.D.		#255	#257	#258
DATE SAMPLE		09/18/83	09/16/83	09/18/83
PHYSICAL TESTS				
pH		8.00	8.65	10.20
Conductivity(micromhos/cm)		960.	1780.	1830.
Turbidity(JTU)		5.2	35.	66.
Hardness(mg/L)	CaCO3	100.	46.5	11.5
SOLIDS(mg/L)				
Total Suspended		25.5	54.5	98.5
Total Dissolved		606.	1700.	1040.
DISSOLVED ANIONS(mg/L)				
Alkalinity: Bicarbonate	HCO3	157.	1040.	137.
Alkalinity: Carbonate	CO3	-	159.	370.
Alkalinity: Hydroxide	OH	Nil	Nil	Nil
Chlorides	Cl	205.	2.20	81.0
Sulfates	SO4	55.0	40.0	84.0
Nitrates	N	0.011	< 0.010	0.016
Nitrites	N	< 0.002	< 0.002	0.012
Total Phosphates	P	0.069	0.11	0.17
Ortho Phosphates	P	< 0.001	< 0.001	< 0.001
Silica	SiO2	14.4	13.1	-
DISSOLVED METALS(mg/L)				
Aluminum	Al	0.022	0.11	0.31
Antimony	Sb	0.001	< 0.001	< 0.001
Arsenic	As	0.001	0.002	0.003
Barium	Ba	0.038	0.096	0.093
Beryllium	Be	< 0.003	< 0.003	< 0.003
Bismuth	Bi	< 0.50	< 0.50	< 0.50
Boron	B	0.031	0.18	0.19
Cadmium	Cd	0.066	< 0.001	< 0.001
Calcium	Ca	31.2	13.8	3.93
Chromium	Cr	< 0.001	0.007	< 0.001
Cobalt	Co	< 0.005	< 0.005	< 0.005
Copper	Cu	0.041	0.007	0.058
Iron	Fe	0.19	0.040	0.084
Lead	Pb	0.029	< 0.001	< 0.001
Magnesium	Mg	5.26	2.90	0.36
Manganese	Mn	0.054	0.17	0.005
Molybdenum	Mo	0.022	0.015	0.037
Nickel	Ni	< 0.005	< 0.005	< 0.005
Phosphorus	PO4	< 0.4	< 0.4	< 0.4
Potassium	K	3.94	5.35	11.5
Selenium	Se	< 0.001	< 0.001	< 0.001
Silicon	SiO2	6.92	9.41	12.3
Silver	Ag	< 0.005	< 0.005	< 0.005
Sodium	Na	141.	428.	338.
Strontium	Sr	0.12	0.20	0.34
Tin	Sn	< 0.030	< 0.030	< 0.030
Titanium	Ti	< 0.006	< 0.006	0.006
Vanadium	V	< 0.010	< 0.010	< 0.010
Zinc	Zn	0.38	0.056	0.024

CAN TEST LTD.

Crows Nest Resources
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RESULTS OF TESTING:

SAMPLE #		13	14	15
CLIENT SAMPLE I.D.		#255	#257	#258
DATE SAMPLE		09/18/83	09/16/83	09/18/83
TOTAL METALS (mg/L)				
Aluminum	Al	0.33	5.71	12.7
Antimony	Sb	0.001	< 0.001	< 0.001
Arsenic	As	0.001	0.003	0.004
Barium	Ba	0.038	0.13	0.15
Beryllium	Be	< 0.003	< 0.003	< 0.003
Bismuth	Bi	< 0.5	< 0.5	< 0.5
Boron	B	0.039	0.19	0.19
Cadmium	Cd	0.078	< 0.001	< 0.001
Calcium	Ca	31.4	14.1	4.86
Chromium	Cr	0.003	0.007	0.013
Cobalt	Co	< 0.005	< 0.005	< 0.005
Copper	Cu	0.26	0.17	0.20
Iron	Fe	0.52	2.23	3.10
Lead	Pb	0.032	0.010	0.008
Magnesium	Mg	5.28	3.35	1.86
Manganese	Mn	0.058	0.22	0.042
Mercury	Hg	0.00038	0.00013	0.00018
Molybdenum	Mo	0.027	0.017	0.037
Nickel	Ni	< 0.005	< 0.005	< 0.005
Phosphorus	PO4	< 0.4	< 0.4	< 0.4
Selenium	Se	< 0.001	< 0.001	< 0.001
Silicon	SiO2	7.69	31.9	55.8
Silver	Ag	< 0.005	< 0.005	< 0.005
Sodium	Na	147.	431.	344.
Strontium	Sr	0.12	0.20	0.38
Tin	Sn	< 0.030	< 0.030	< 0.030
Titanium	Ti	0.028	0.25	0.50
Vanadium	V	< 0.010	< 0.010	0.023
Zinc	Zn	0.62	0.20	0.13
POLLUTANT TESTS (mg/L)				
Total Phosphate	P	< 0.020	0.20	0.091
Ammonia Nitrogen	N	1.82	0.66	0.093
Total Phenolics as Phenol		3.04	0.003	0.003
OTHERS				
Ferrous Iron	Fe	0.31	1.30	1.93

mg/L = milligrams per liter
< = Less than = Not detected

ESTIMATE OF ANNUAL GROUNDWATER RECHARGE

COMPUTATIONS

ESTIMATE OF ANNUAL GROUNDWATER RECHARGE

estimation of annual groundwater recharge from precipitation.

- Annual precipitation = 510mm (Smithers Airport)
- Area of Catchment area A_2 (see Drawing) = 5.5 km^2

if infiltration rate = 1% total annual recharge =

$5.5 \times 1000000 \times .0051 = 28,050 \text{ m}^3$

ESTIMATE OF ANNUAL GROUNDWATER FLUX.

Average groundwater flow path starts in recharge area at elevation 720m and flows approximately 500m to discharge in Goathorn Creek at elevation 655m.

The average hydraulic gradient $= I = (720-655)/500$

$I = 0.13.$

Assume average hydraulic conductivity (K) for catchment $= 5 \times 10^{-8}$ m/s

Cross sectional area(A) of Catchment A_2 = 50m deep × 8000m long

$A = 400,000 \text{ m}^2.$

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692 ENG. JAL.
PROJECT TELKWA
LOCATION TELKWA B.C.
DETAILS ESTIMATE OF GROUNDWATER INF.
DATE SHEET 1 OF 2

COMPUTATIONS

From Darcy's Law, groundwater flux, $Q = KIA$ m^3/sec.

$\therefore Q = 0.13 \times 5 \times 10^{-8} \times 400{,}000$ m^3/sec

$= 2.6 \times 10^{-3}$ m^3/sec

$= 82000$ $m^3/year$.

$\therefore$ Annual groundwater flux $= \frac{82{,}000}{28{,}050} = \sim 3\%$ infiltration.

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. Pa 1692 ENG. JAn
PROJECT Telkwa
LOCATION Telkwa B.C.
DETAILS ESTIMATE OF GROUNDWATER INFILTRATION
DATE SHEET 2 OF 2

APPENDIX III

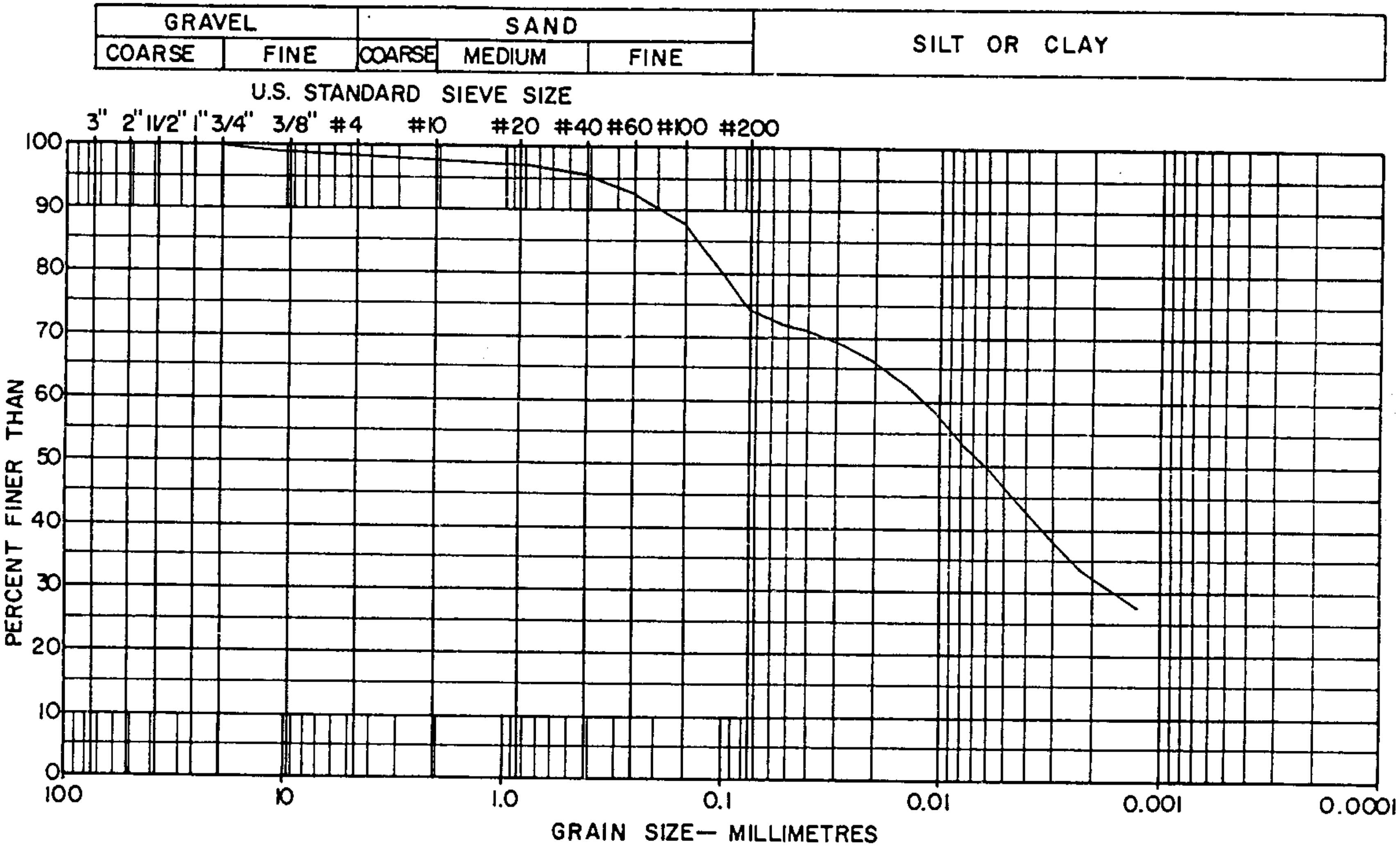
LABORATORY TEST RESULTS

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

JOB No. PA 1692.02.01
PROJECT CROWSNEST RESOURCES LTD.
LOCATION TELKWA, B.C.
HOLE No. 255 DEPTH 0.5 m
DATE October 18, 1982

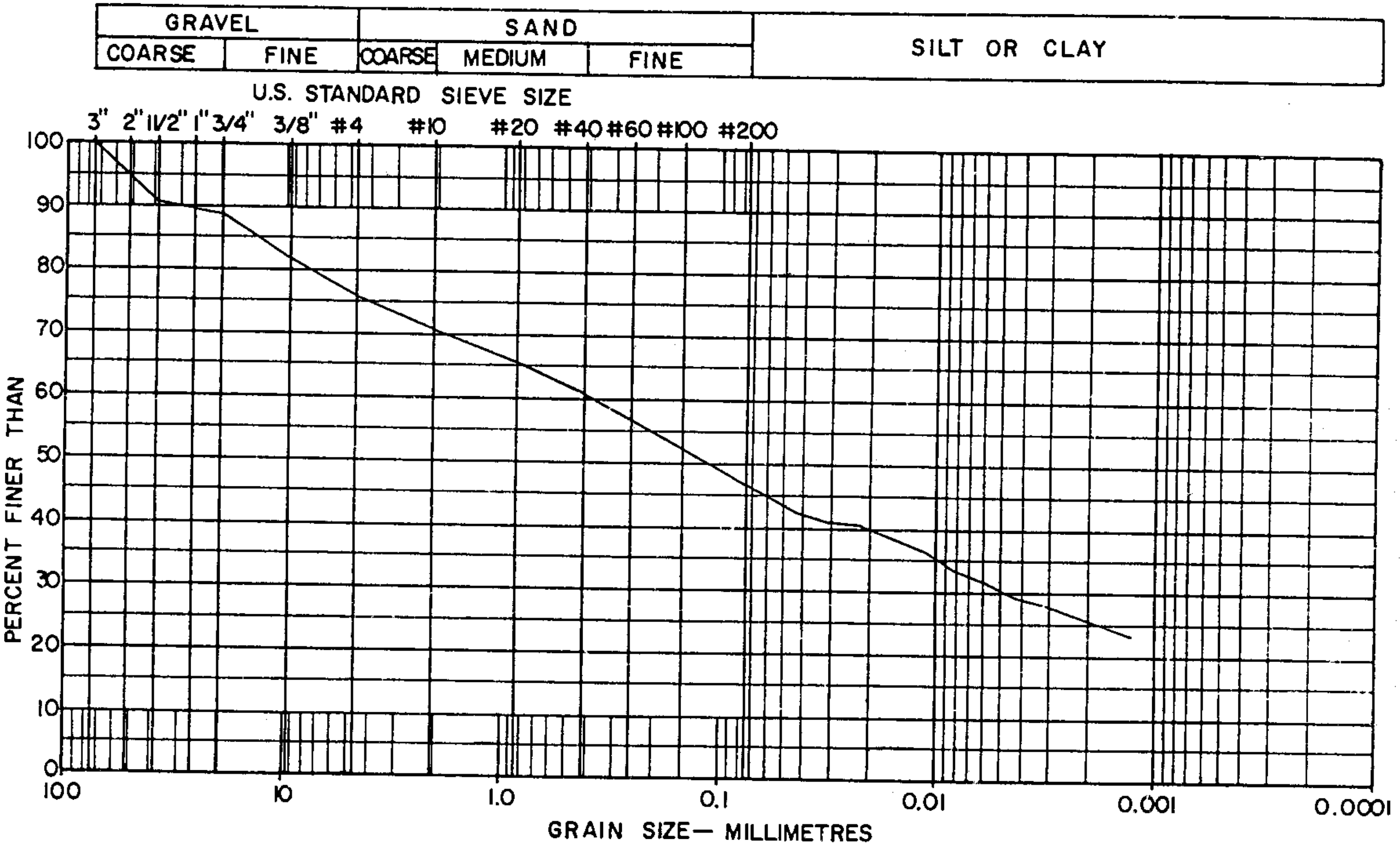
GRAIN SIZE CURVE



REMARKS:

KLOHN LEONOFF
CONSULTING ENGINEERS

GRAIN SIZE CURVE



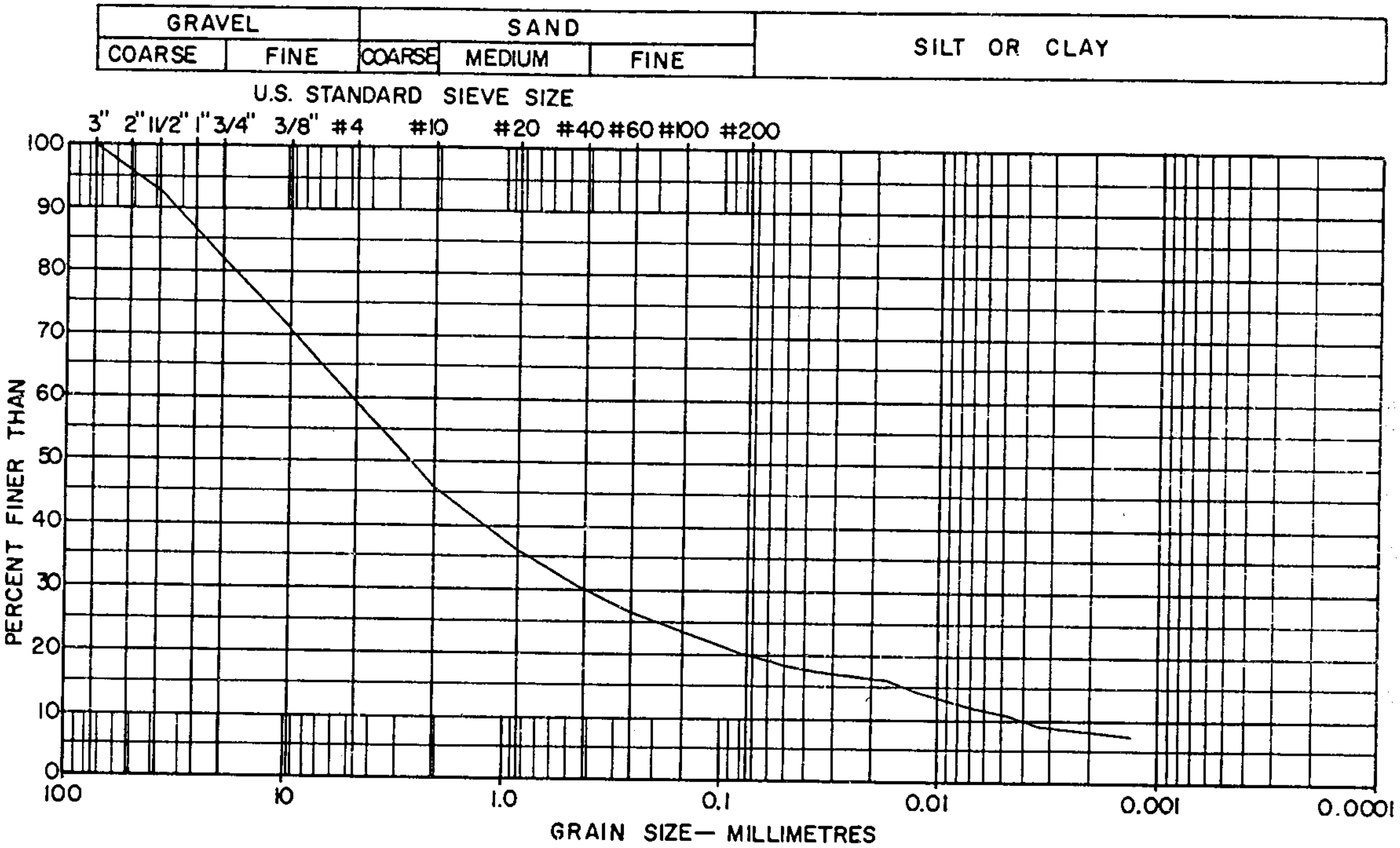
REMARKS: ____________________

JOB No. PA 1692.02.01
PROJECT CROWSNEST RESOURCES LTD.
LOCATION TELKWA, B.C.
HOLE No. 256 DEPTH 0.5 m
DATE October 19, 1982

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

GRAIN SIZE CURVE



REMARKS: ____________________

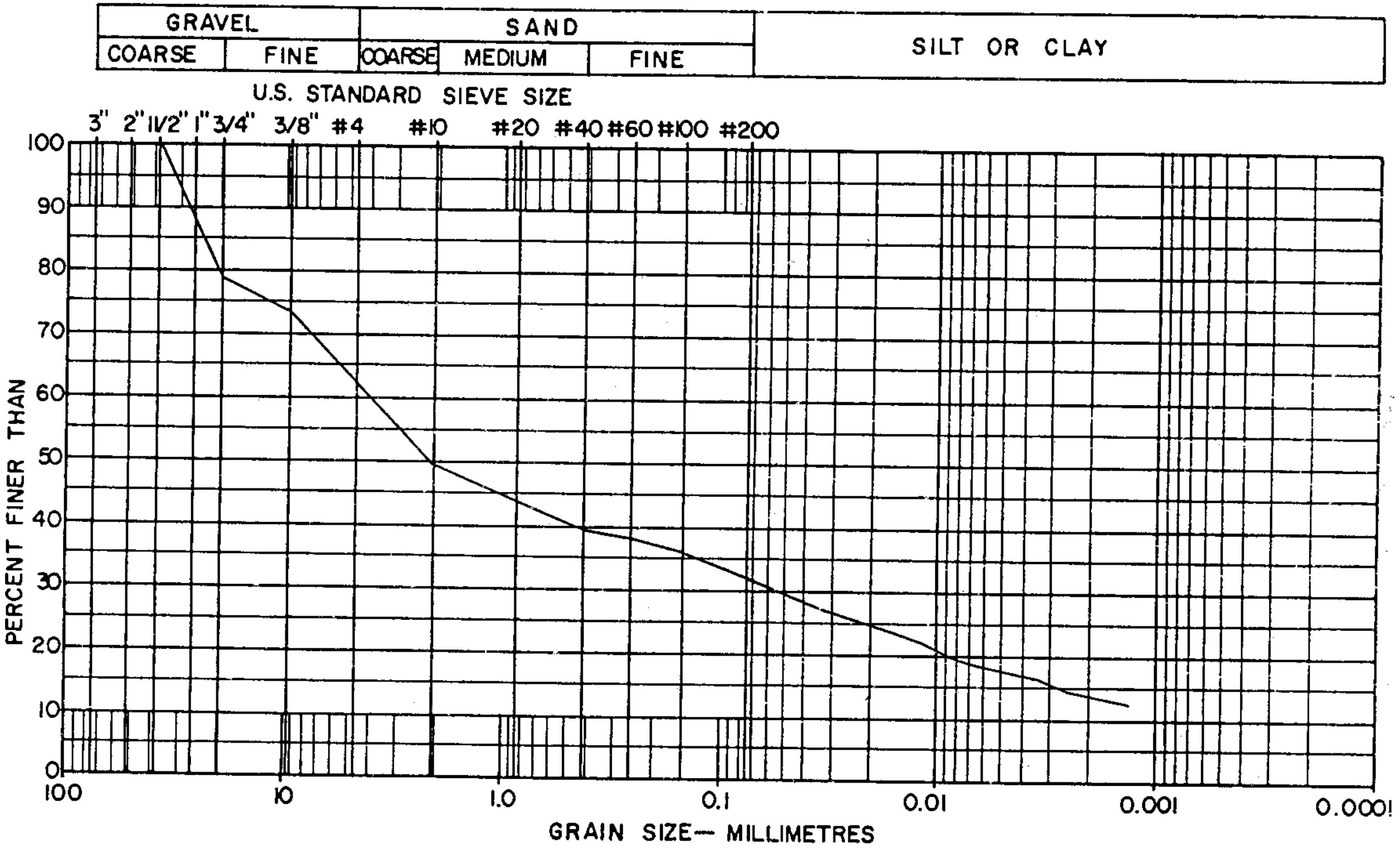
JOB No. PA 1692.02.01
PROJECT CROWSNEST RESOURCES LTD.
LOCATION TELKWA, B.C.
HOLE No. 256 DEPTH 2.0 m
DATE October 19, 1982

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

JOB No. PA 1692.02.01
PROJECT CROWSNEST RESOURCES LTD.
LOCATION TELKWA, B.C.
HOLE No. 256 DEPTH 3.0 m
DATE October 19, 1982

GRAIN SIZE CURVE



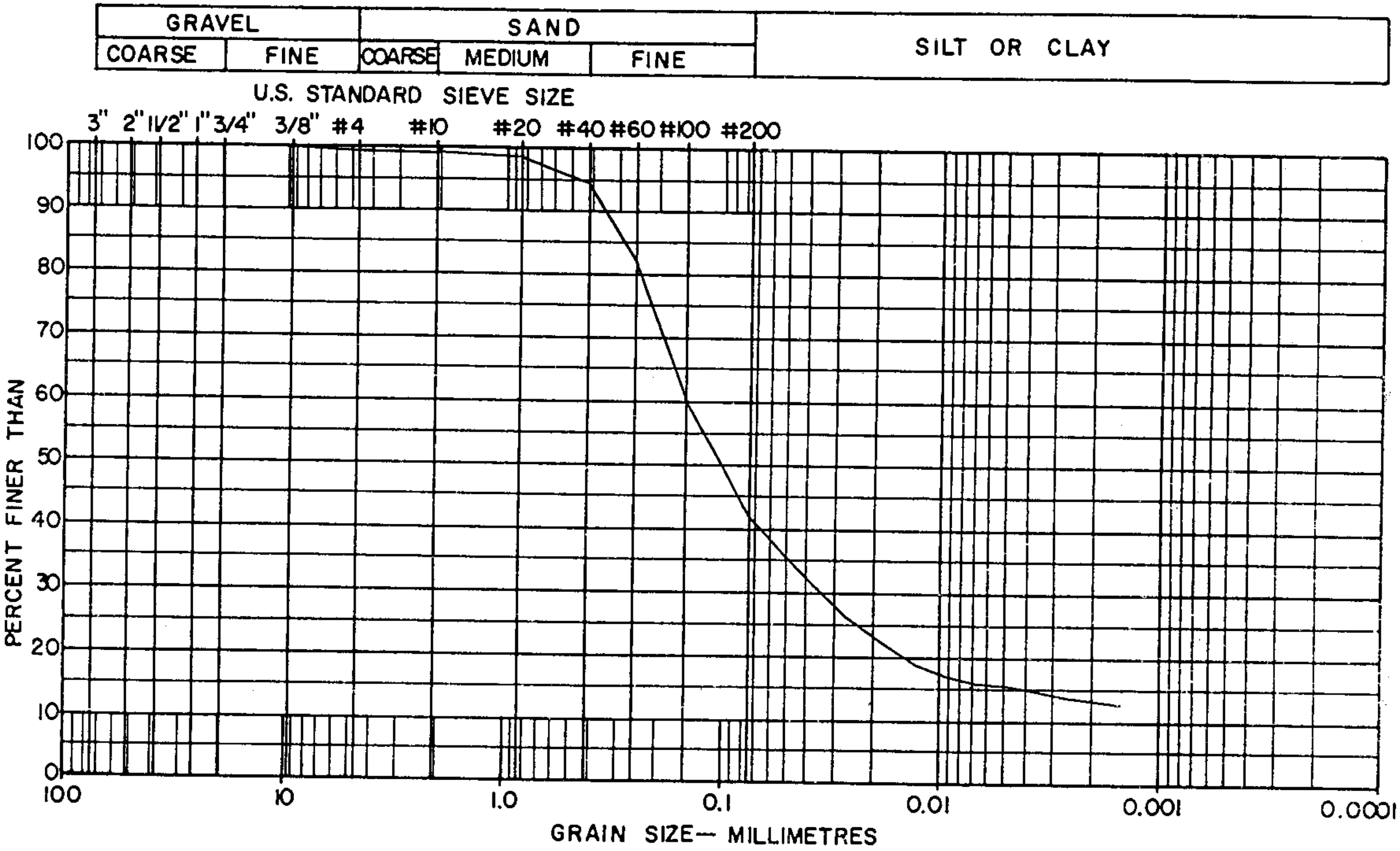
REMARKS: ____________________

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

JOB No. PA 1692.02.01
PROJECT CROWSNEST RESOURCES LTD.
LOCATION TELKWA, B.C.
HOLE No. 257 DEPTH 0.5 m
DATE October 19, 1982

GRAIN SIZE CURVE

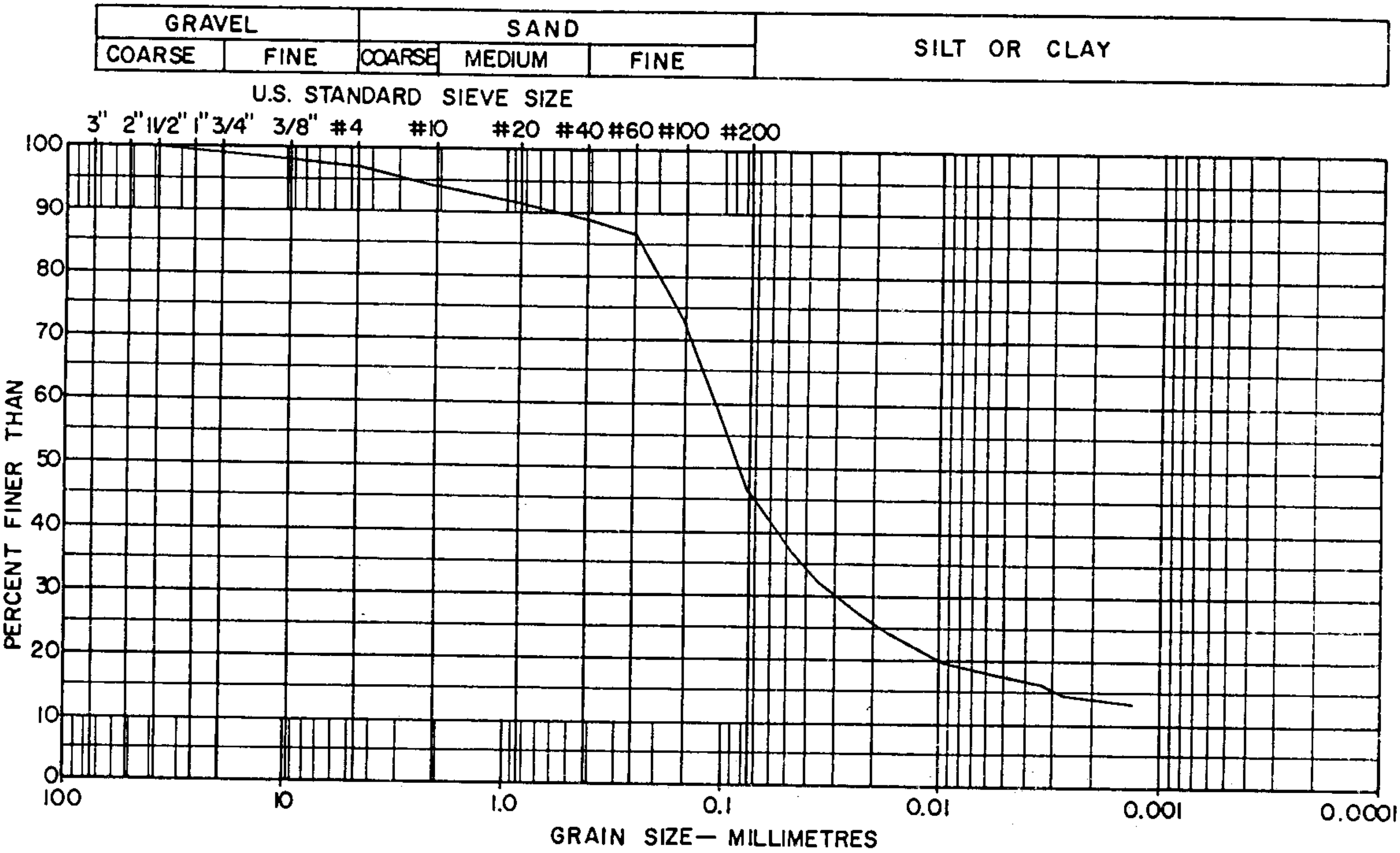


REMARKS:

GRAIN SIZE CURVE

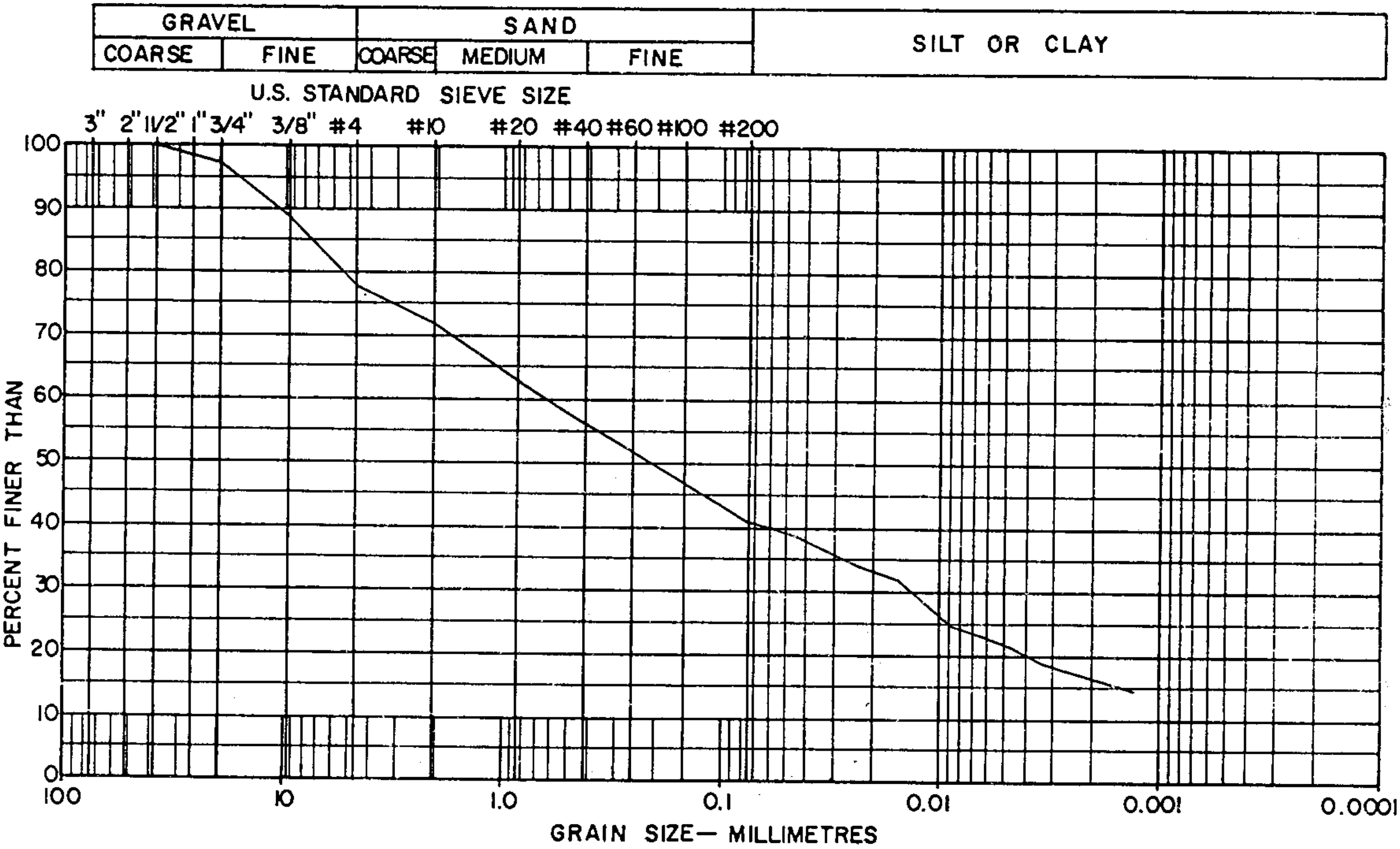
KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692.02.01
PROJECT CROWSNEST RESOURCES LTD.
LOCATION TELKWA, B.C.
HOLE No. 257 DEPTH 1.5 m
DATE October 19, 1982



REMARKS:

GRAIN SIZE CURVE



REMARKS: ____________________

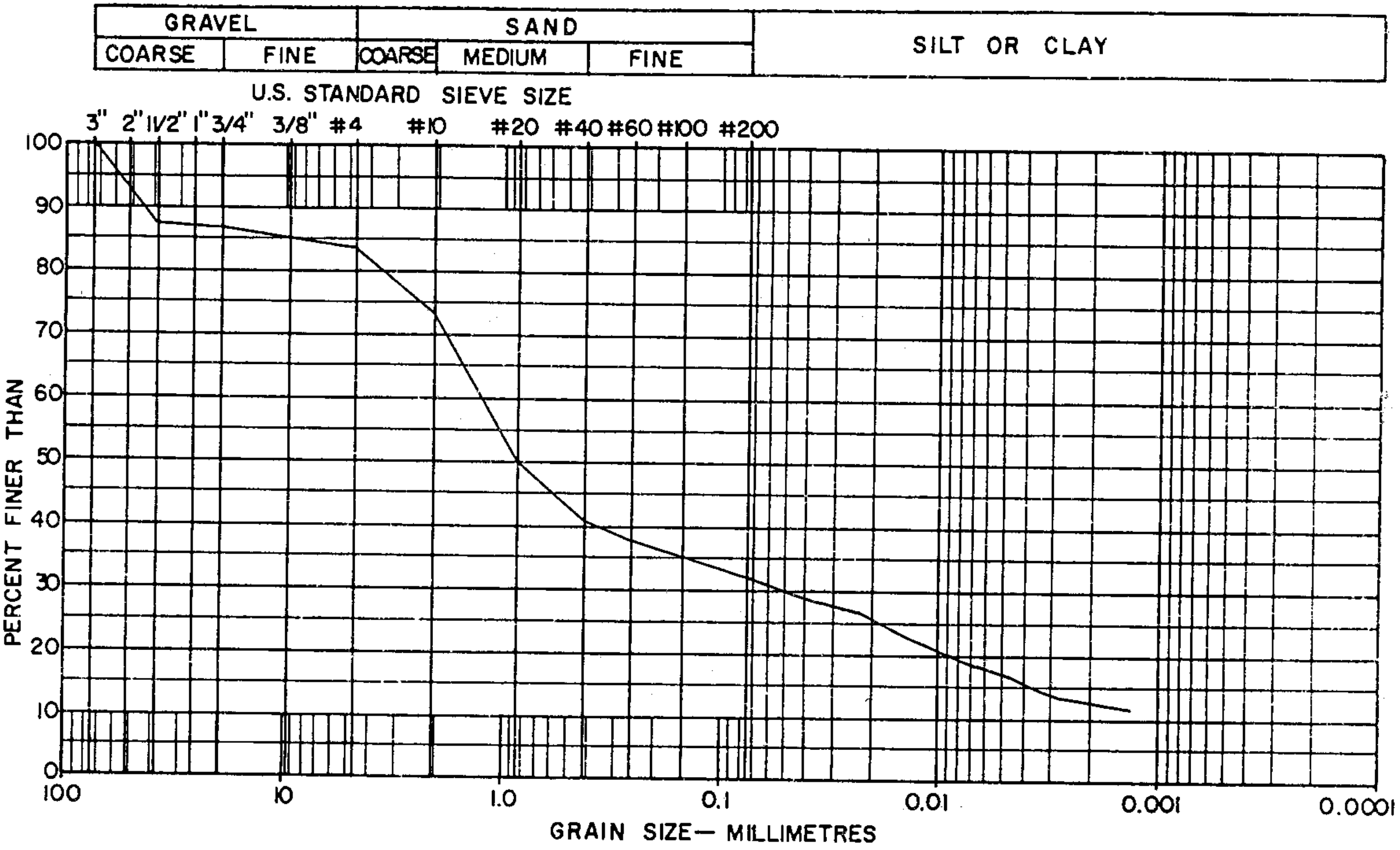
KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

JOB No. PA 1692.02.01
PROJECT CROWSNEST RESOURCES LTD.
LOCATION TELKWA, B.C.
HOLE No. 257 DEPTH 3.0 m
DATE October 19, 1982

KLOHN LEONOFF
CONSULTING ENGINEERS

GRAIN SIZE CURVE



REMARKS:

JOB No. PA 1692.02.01

PROJECT CROWSNEST RESOURCES LTD.

LOCATION TELKWA, B.C.

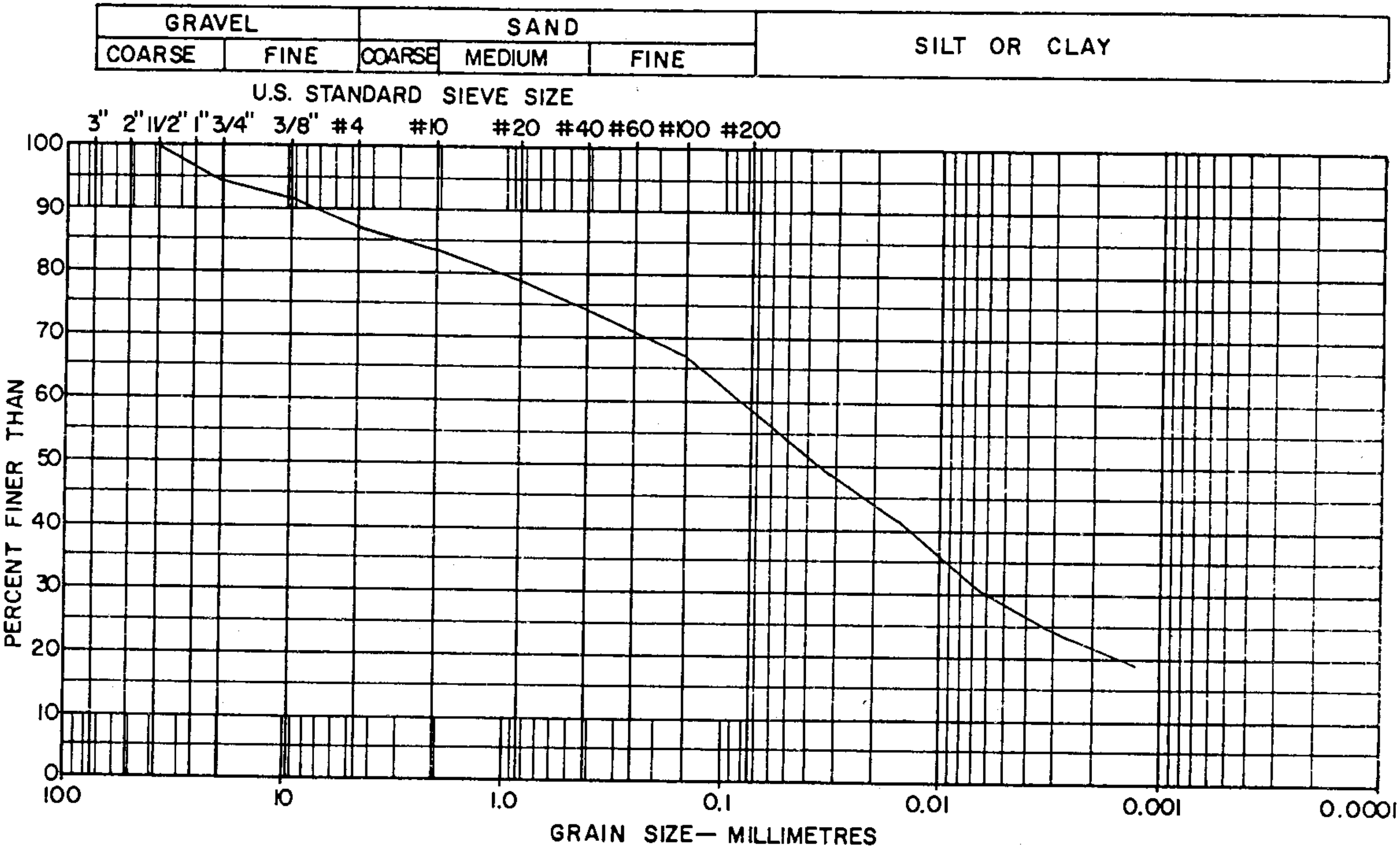
HOLE No. 257 DEPTH 5.0 m

DATE October 19, 1982

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

GRAIN SIZE CURVE



REMARKS: ______________________________

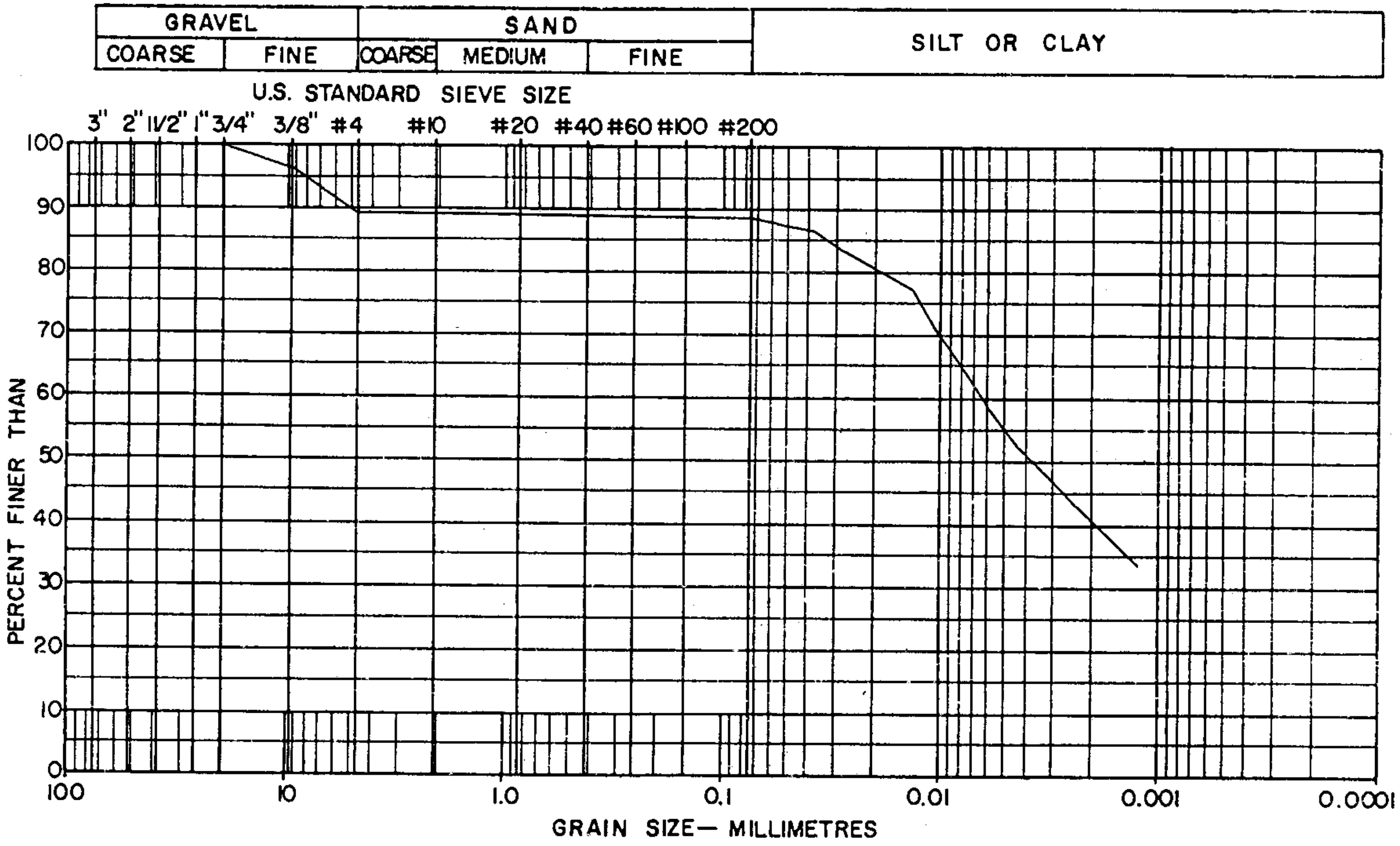
JOB No. PA 1692.02.01
PROJECT CROWSNEST RESOURCES LTD.
LOCATION TELKWA, B.C.
HOLE No. 259 DEPTH 0.5 m
DATE October 18, 1982

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

JOB No. PA 1692.02.01
PROJECT CROWSNEST RESOURCES LTD.
LOCATION TELKWA, B.C.
HOLE No. 259 DEPTH 2.0 m
DATE October 18, 1982

GRAIN SIZE CURVE



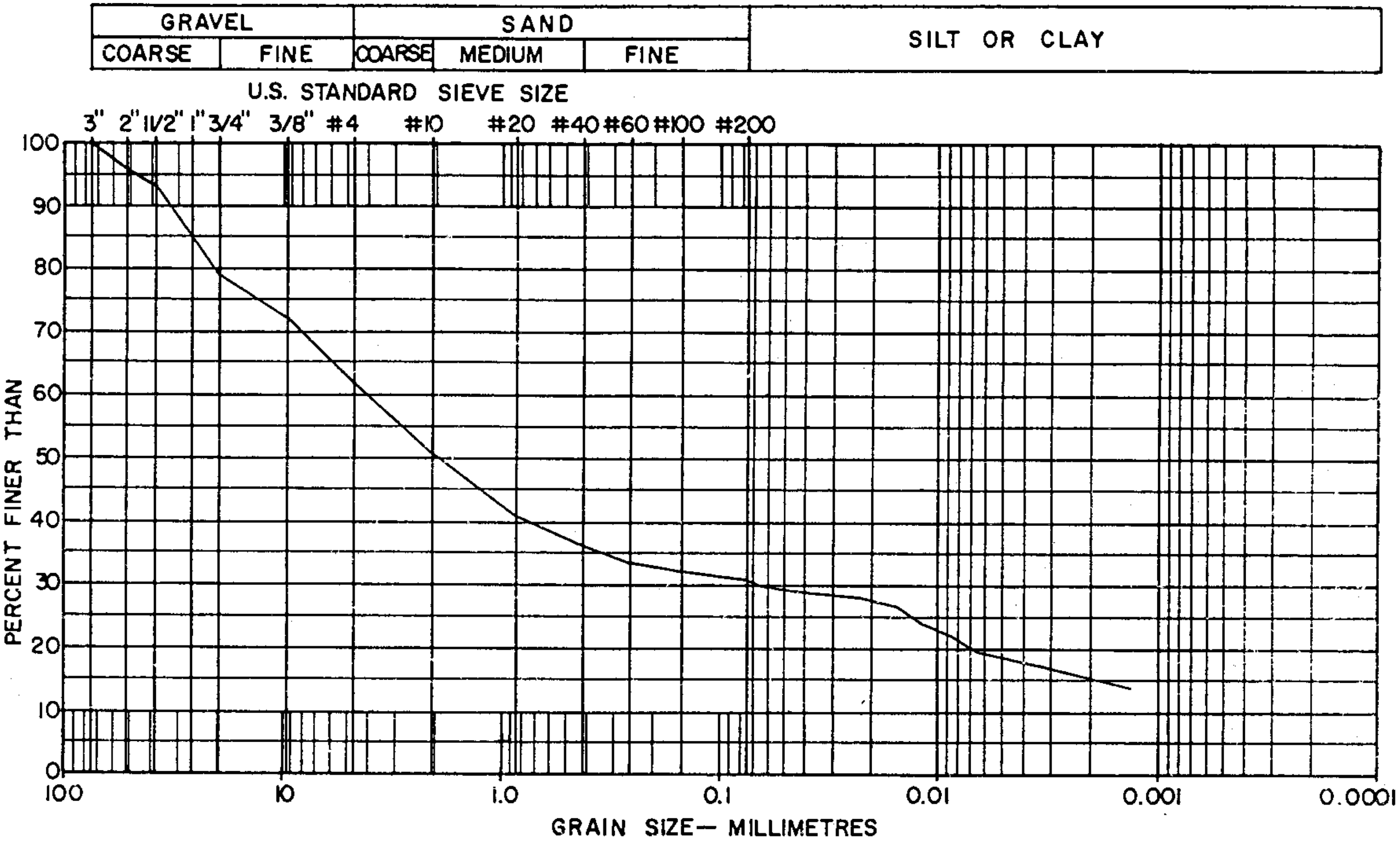
REMARKS: ______________________________

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

JOB No. PA 1692.02.01
PROJECT CROWSNEST RESOURCES LTD.
LOCATION TELKWA, B.C.
HOLE No. 259 DEPTH 3.0 m
DATE October 18, 1982

GRAIN SIZE CURVE

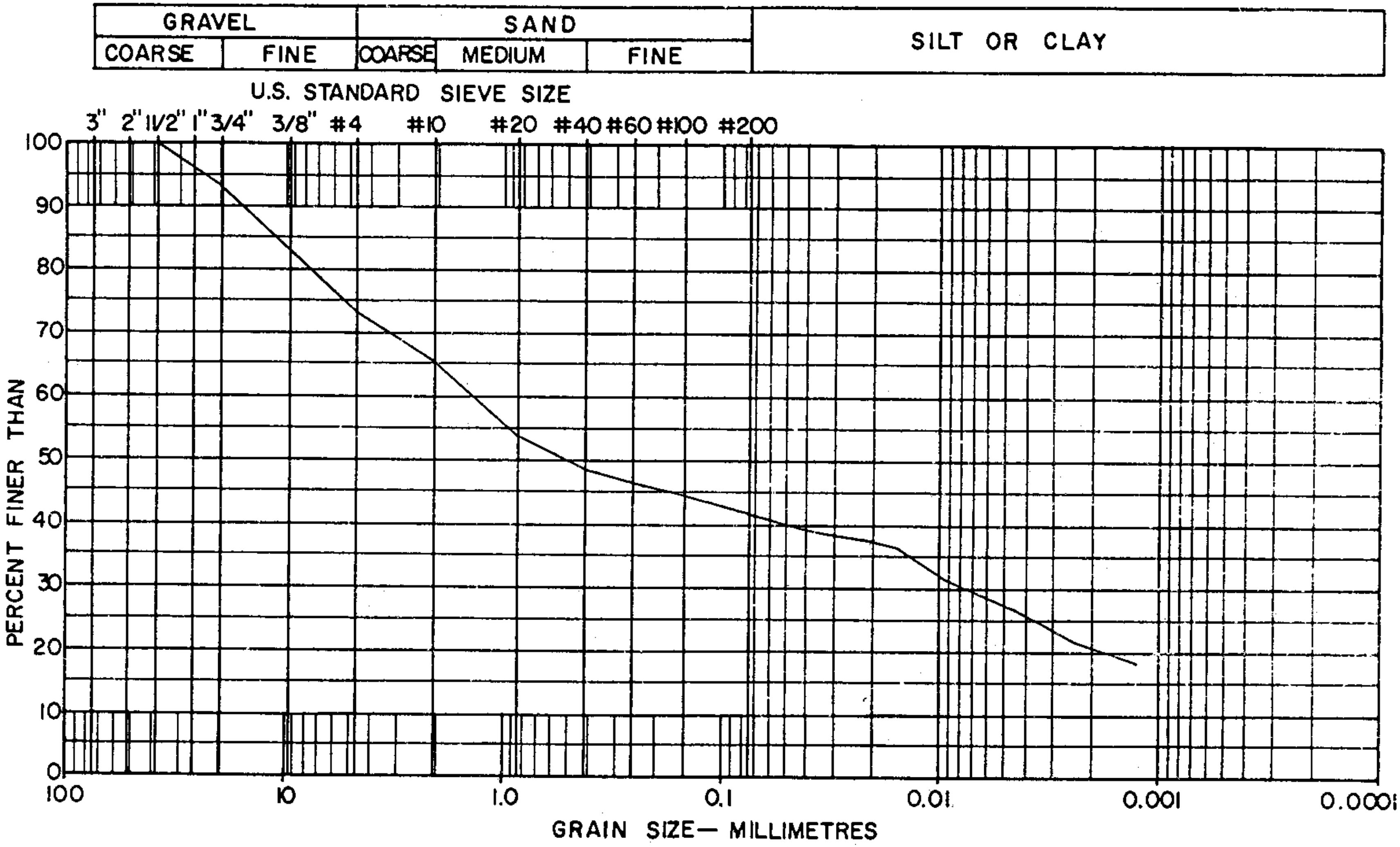


REMARKS: ____________________

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

GRAIN SIZE CURVE



REMARKS: ____________________

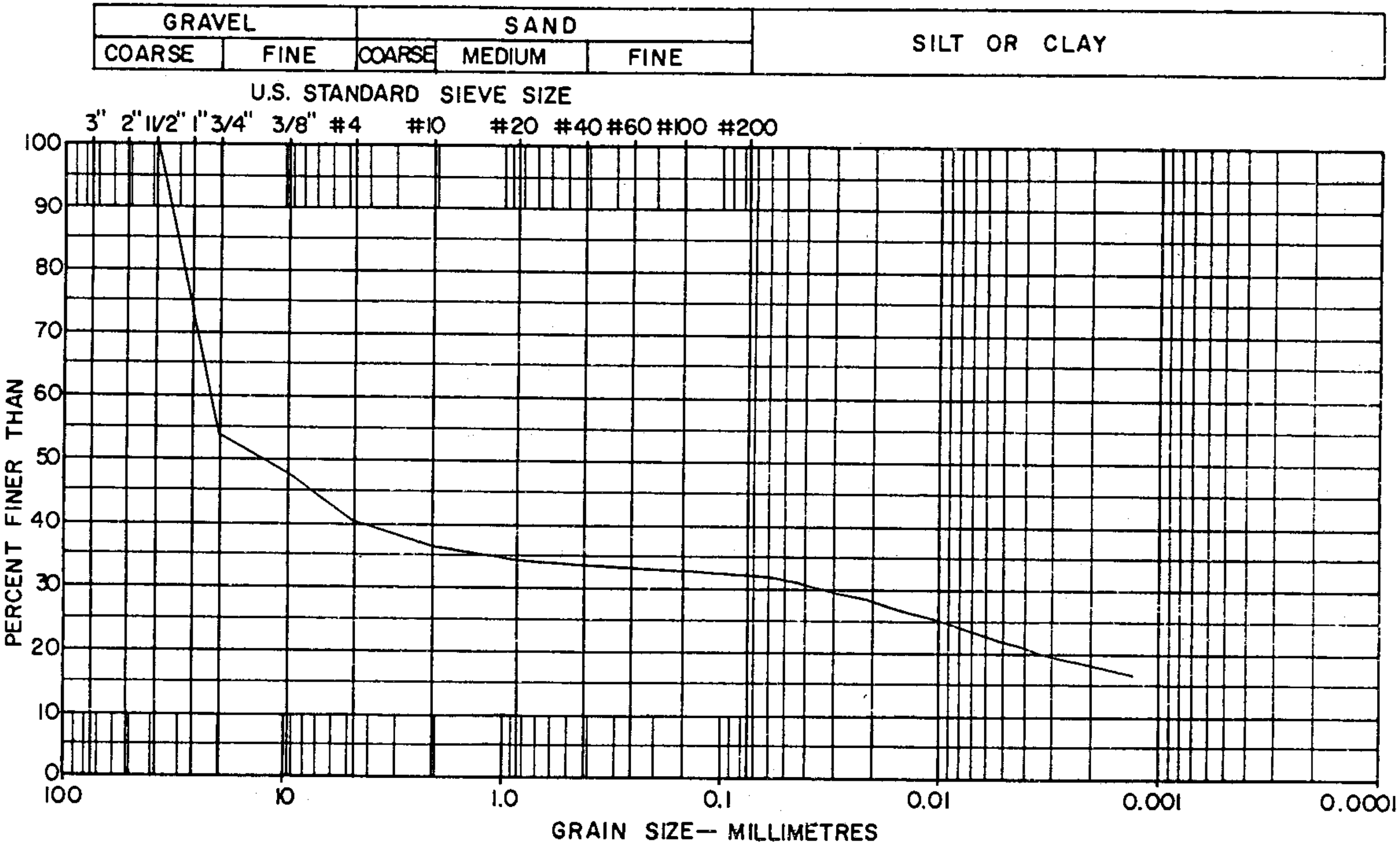
JOB No. PA 1692.02.01
PROJECT CROWSNEST RESOURCES LTD.
LOCATION TELKWA, B.C.
HOLE No. 259 DEPTH 5.0 m
DATE October 18, 1982

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

GRAIN SIZE CURVE

JOB No. PA 1692.02.01
PROJECT CROWSNEST RESOURCES LTD.
LOCATION TELKWA, B.C.
HOLE No. 259 DEPTH 11.0 m
DATE October 19, 1982

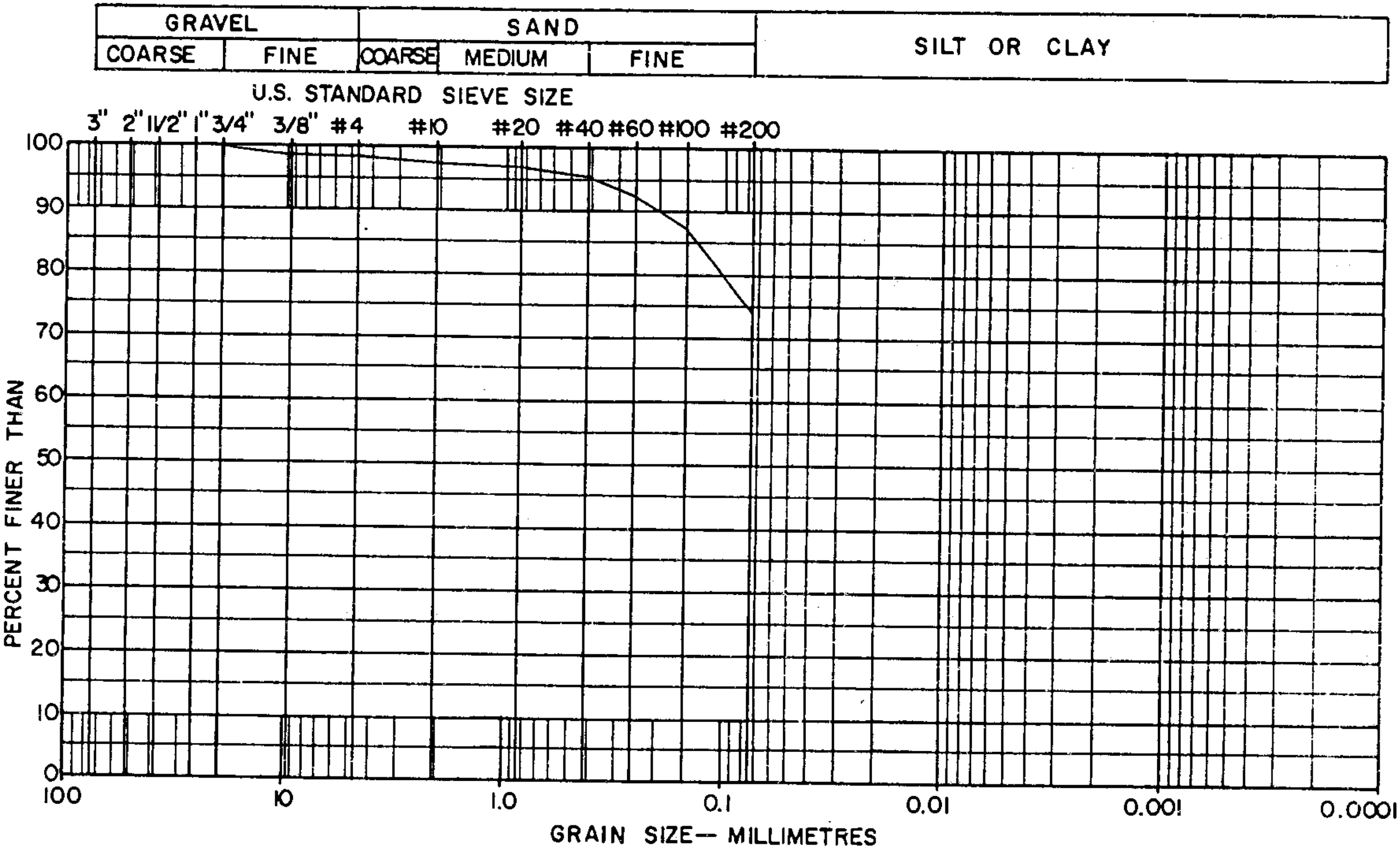


REMARKS:

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

GRAIN SIZE CURVE

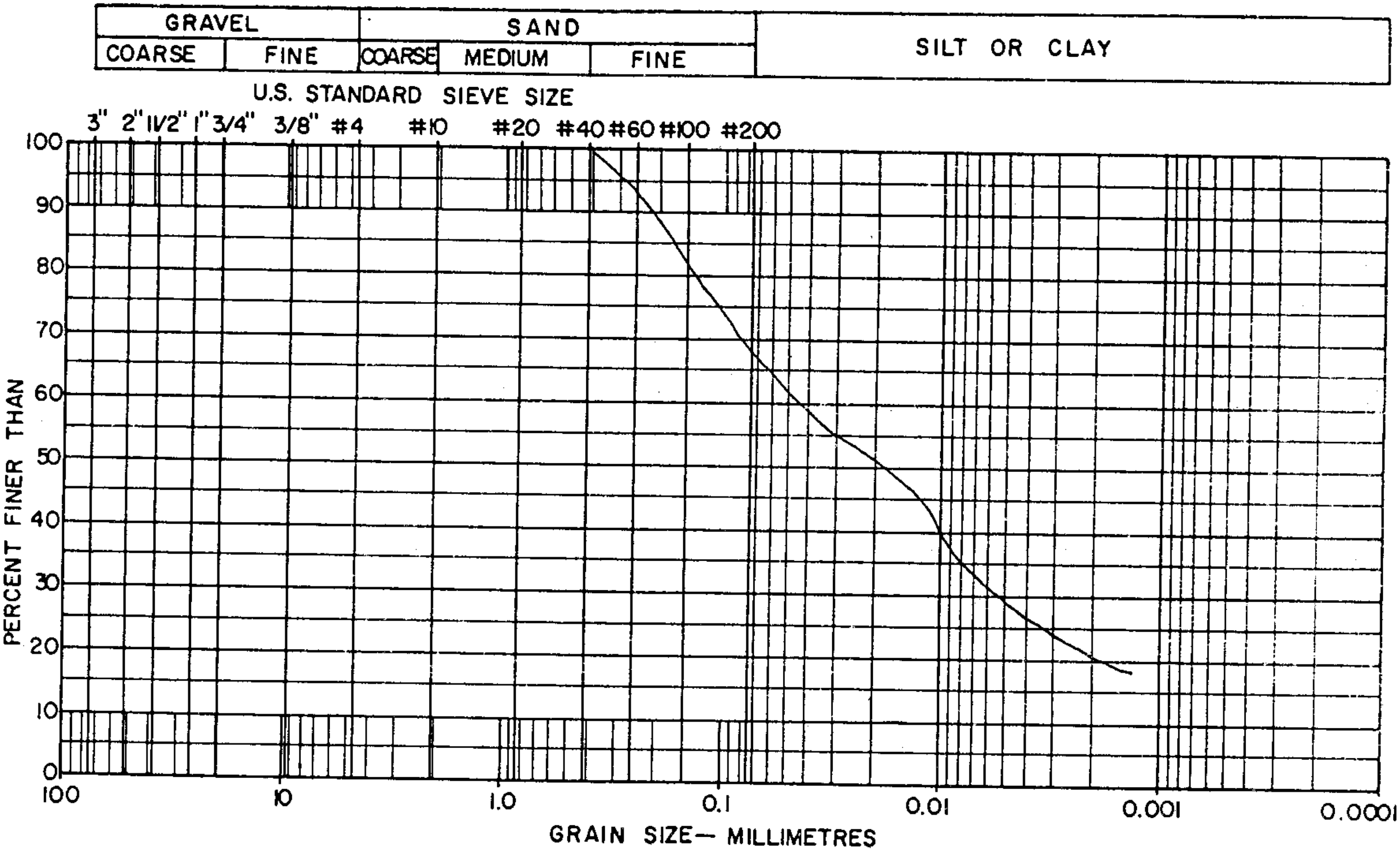


JOB No. PA 1692.02.01
PROJECT CROWSNEST RESOURCES LTD.
LOCATION TELKWA, B.C.
HOLE No. DH 255 DEPTH 0.5 m
DATE OCTOBER 6/82

REMARKS:

KLOHN LEONOFF
CONSULTING ENGINEERS

GRAIN SIZE CURVE



REMARKS: Dark grey moderately strong massive micaceous siltstone

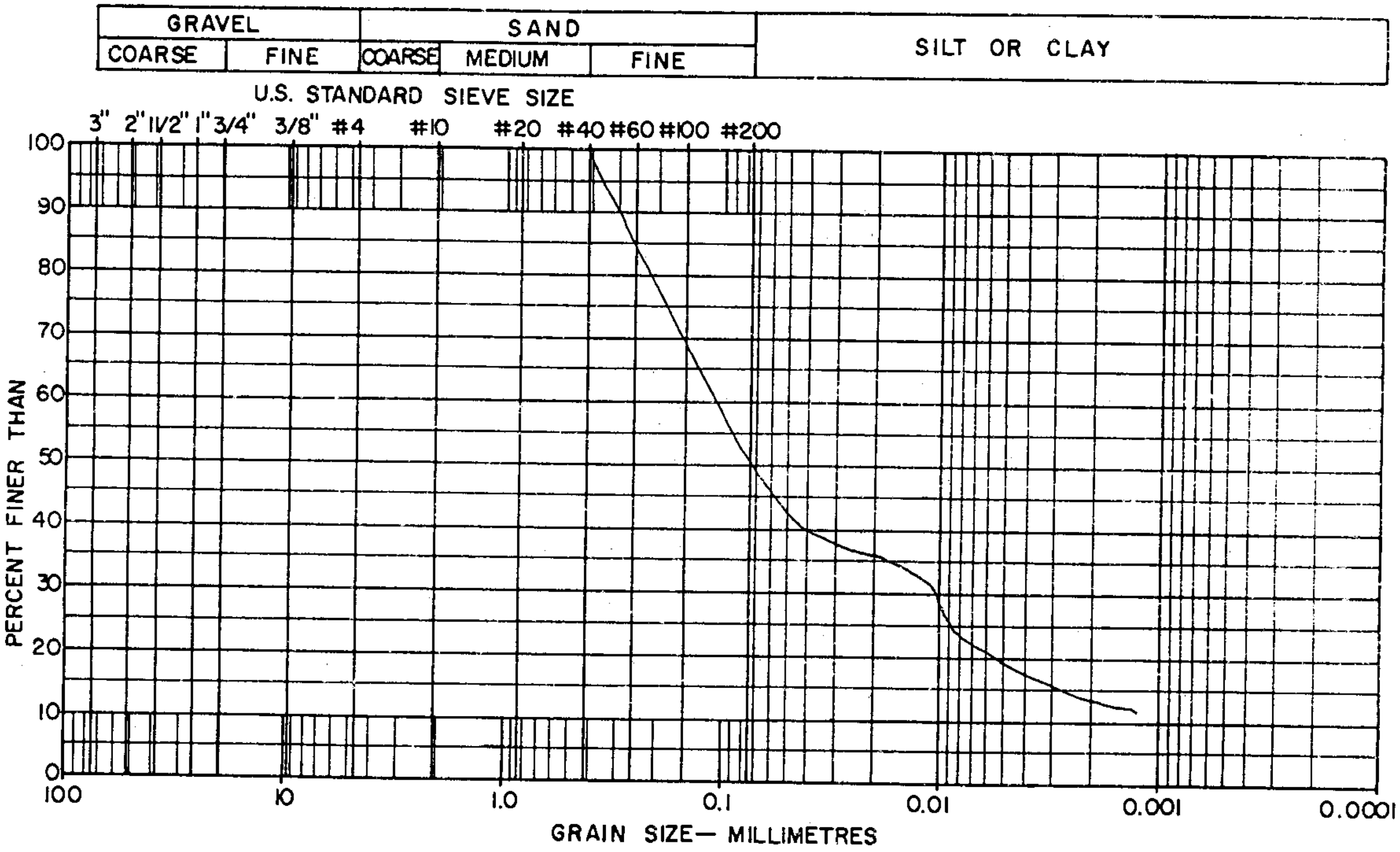
JOB No. PA 1692.03.01
PROJECT CROWS NEST RESOURCES
LOCATION TELKWA, B.C.
HOLE No. TW82-0267 DEPTH 66.2-66.3 m
DATE February 10, 1983

KLOHN LEONOFF
CONSULTING ENGINEERS

KLOHN LEONOFF

JOB No. PA 1692.03.01
PROJECT CROWS NEST RESOURCES
LOCATION TELKWA, B.C.
HOLE No. TW82-268 DEPTH 130.8 m
DATE February 10, 1983

GRAIN SIZE CURVE



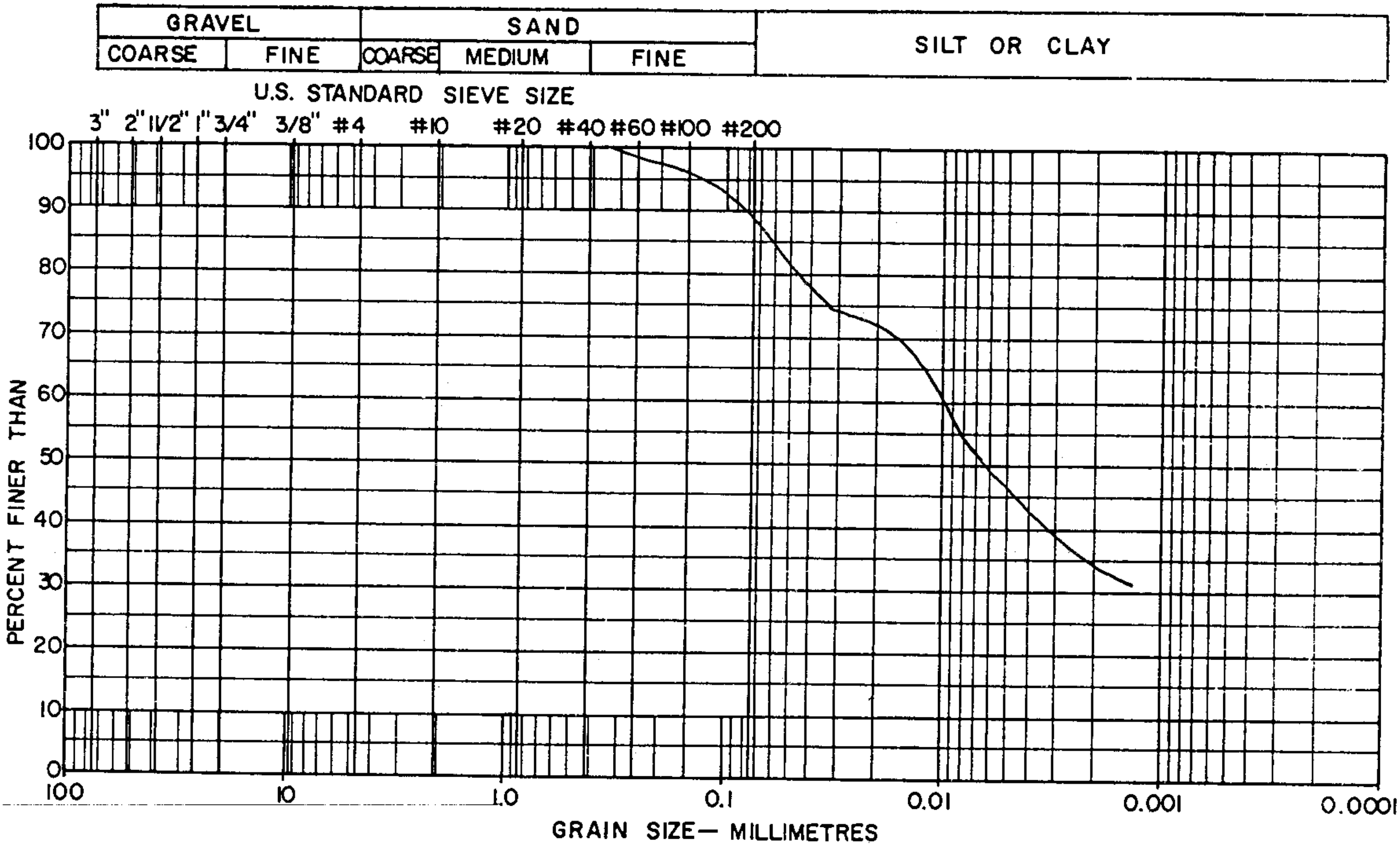
REMARKS: Massive siltstone

KLOHN LEONOFF
CONSULTING ENGINEERS

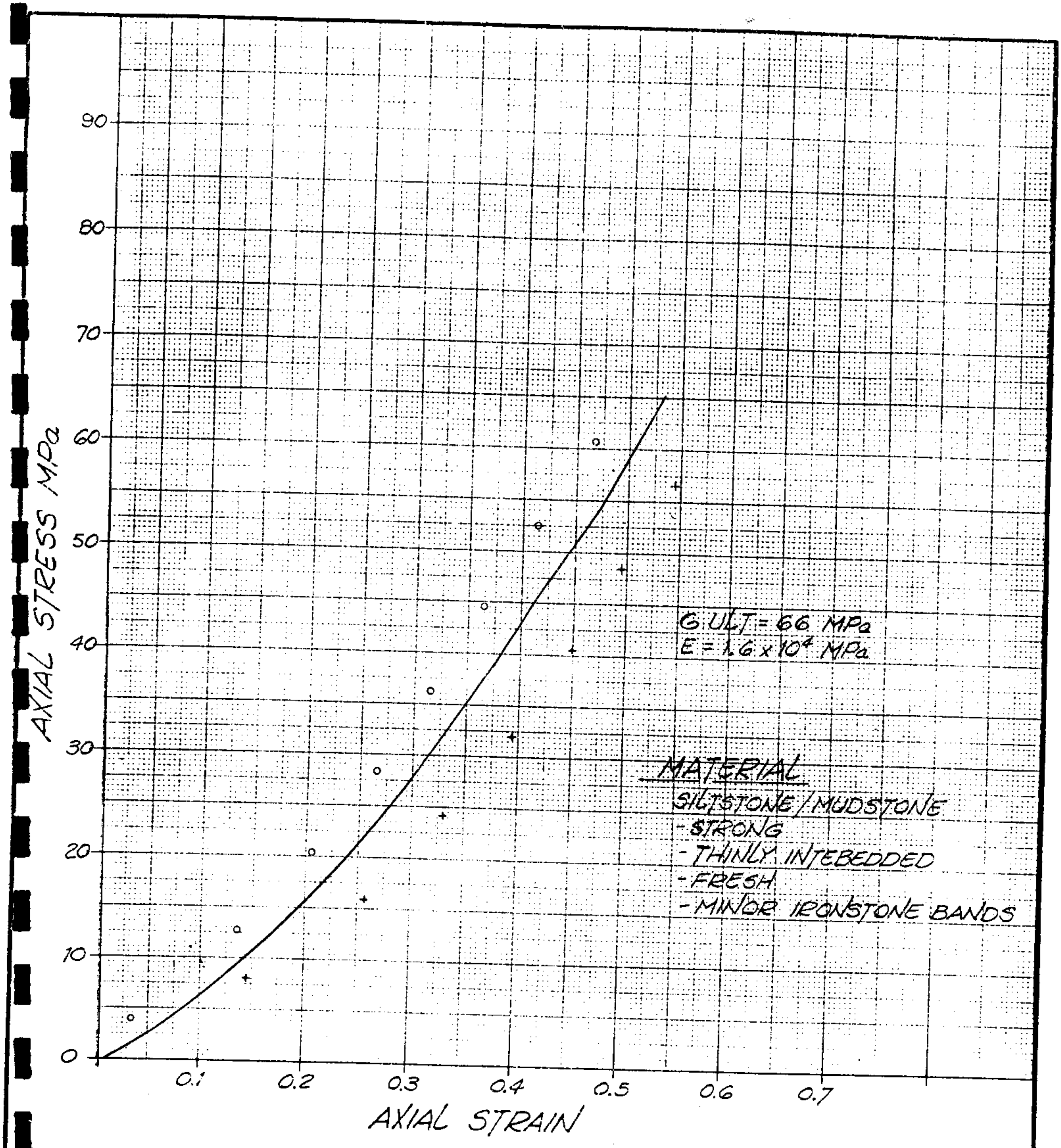
KLOHN LEONOFF

JOB No. PA 1692.03.01
PROJECT CROWS NEST RESOURCES
LOCATION TELKWA, B.C.
HOLE No. TW82-268 DEPTH 157.7 m
DATE February 10, 1983

GRAIN SIZE CURVE



REMARKS: Dark grey thinly bedded slickensided mudstone



σ ULT = 66 MPa
E = 1.6 x 10^4 MPa

MATERIAL

SILTSTONE / MUDSTONE
- STRONG
- THINLY INTEBEDDED
- FRESH
- MINOR IRONSTONE BANDS

DEPTH : 29.25 m

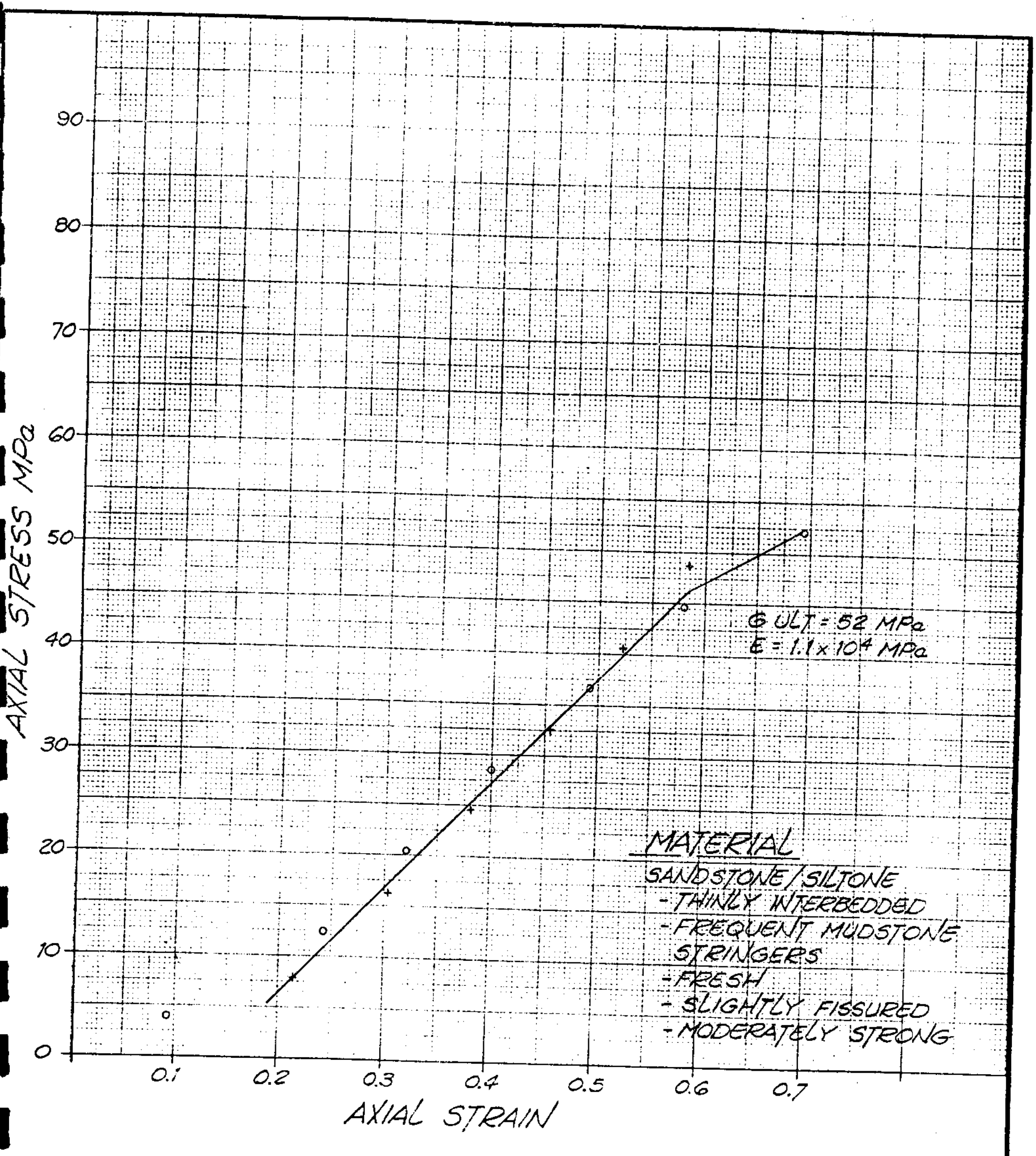
KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: CROWS NEST RESOURCES LTD.

PROJECT: TELKWA COAL PROJECT

TITLE: UNIAXIAL COMPRESSION TEST
TESTHOLE NO. 335

DATE OF ISSUE	PROJECT No.	DWG. No.
APPROVED KLOHN LEONOFF	1692	



DEPTH : 45.0 m

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT:
CROWS NEST RESOURCES LTD.

PROJECT
TELKWA COAL PROJECT

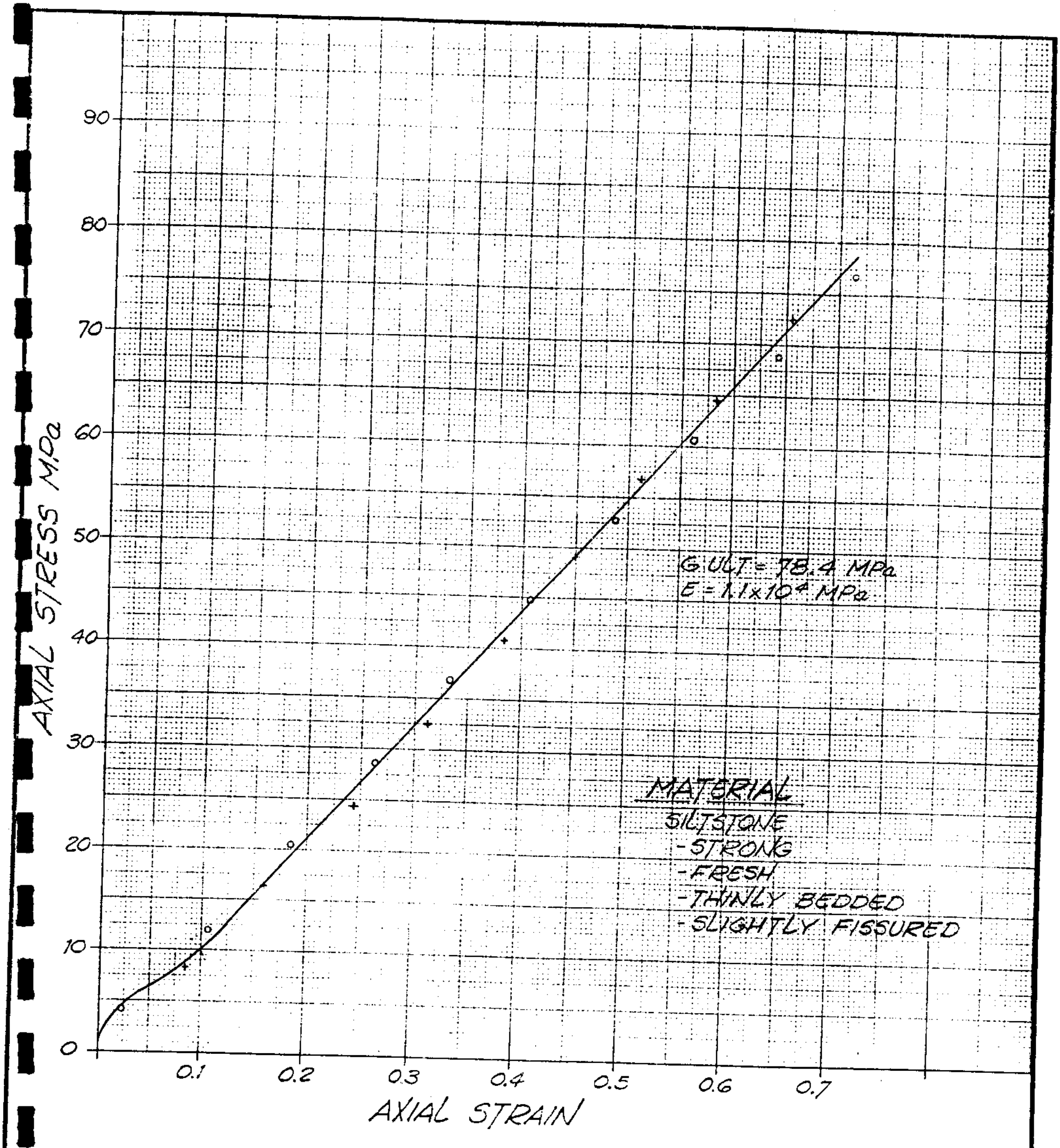
TITLE
UNIAXIAL COMPRESSION TEST
TESTHOLE No. 335

DATE OF ISSUE

APPROVED
KLOHN LEONOFF

PROJECT No.
1692

DWG. No.



σ ULT = 78.4 MPa
E = 1.1x10^4 MPa

MATERIAL
SILTSTONE
- STRONG
- FRESH
- THINLY BEDDED
- SLIGHTLY FISSURED

DEPTH : 72.75 m

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT
TELKWA COAL PROJECT

TITLE
UNIAXIAL COMPRESSION TEST
TESTHOLE NO. 336

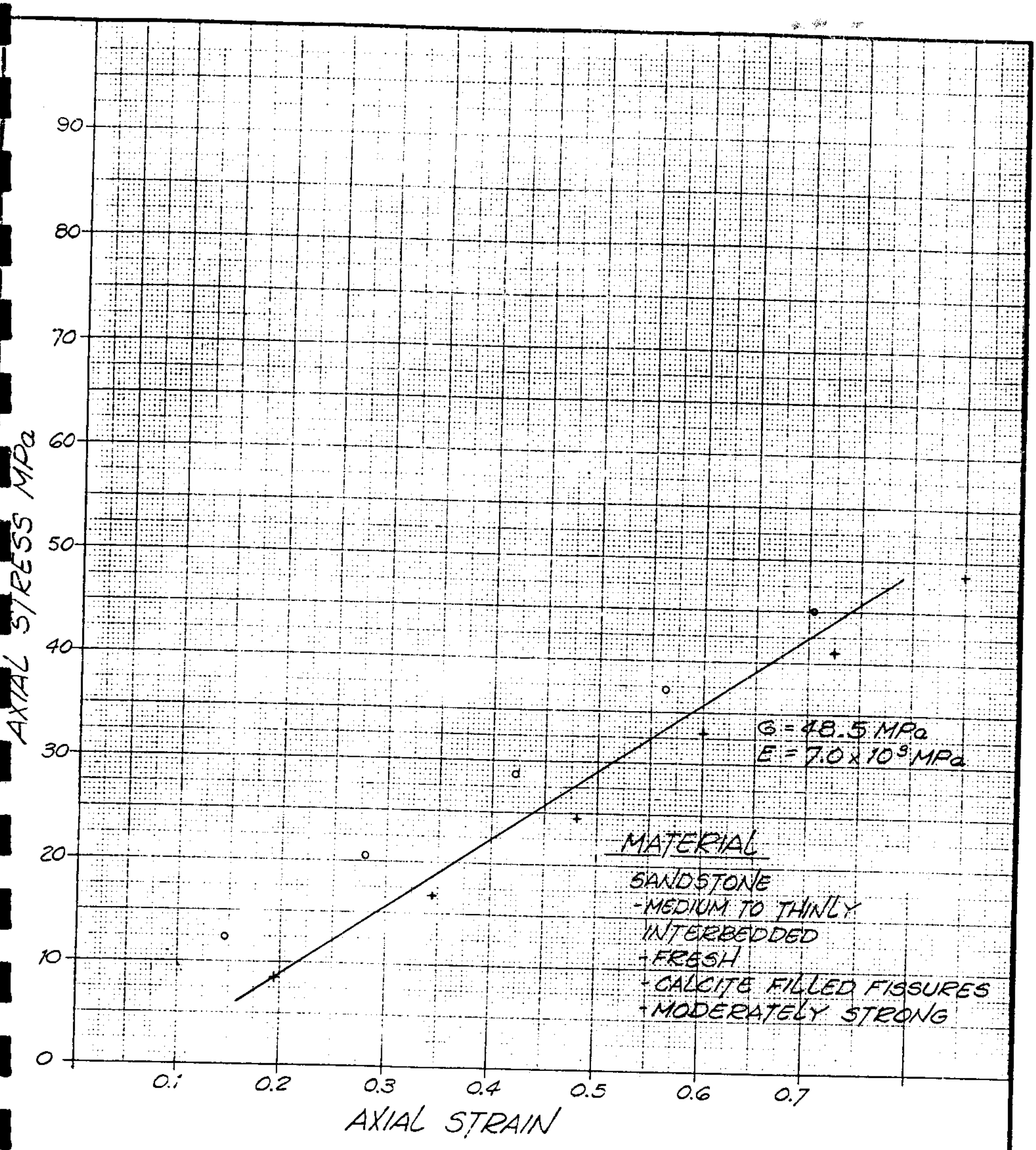
CLIENT:
CROWS NEST RESOURCES LTD.

DATE OF ISSUE

PROJECT No.
1692

DWG. No.

APPROVED
KLOHN LEONOFF



DEPTH: 80.5m.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: CROWS NEST RESOURCES LTD.

PROJECT: TELKWA COAL PROJECT

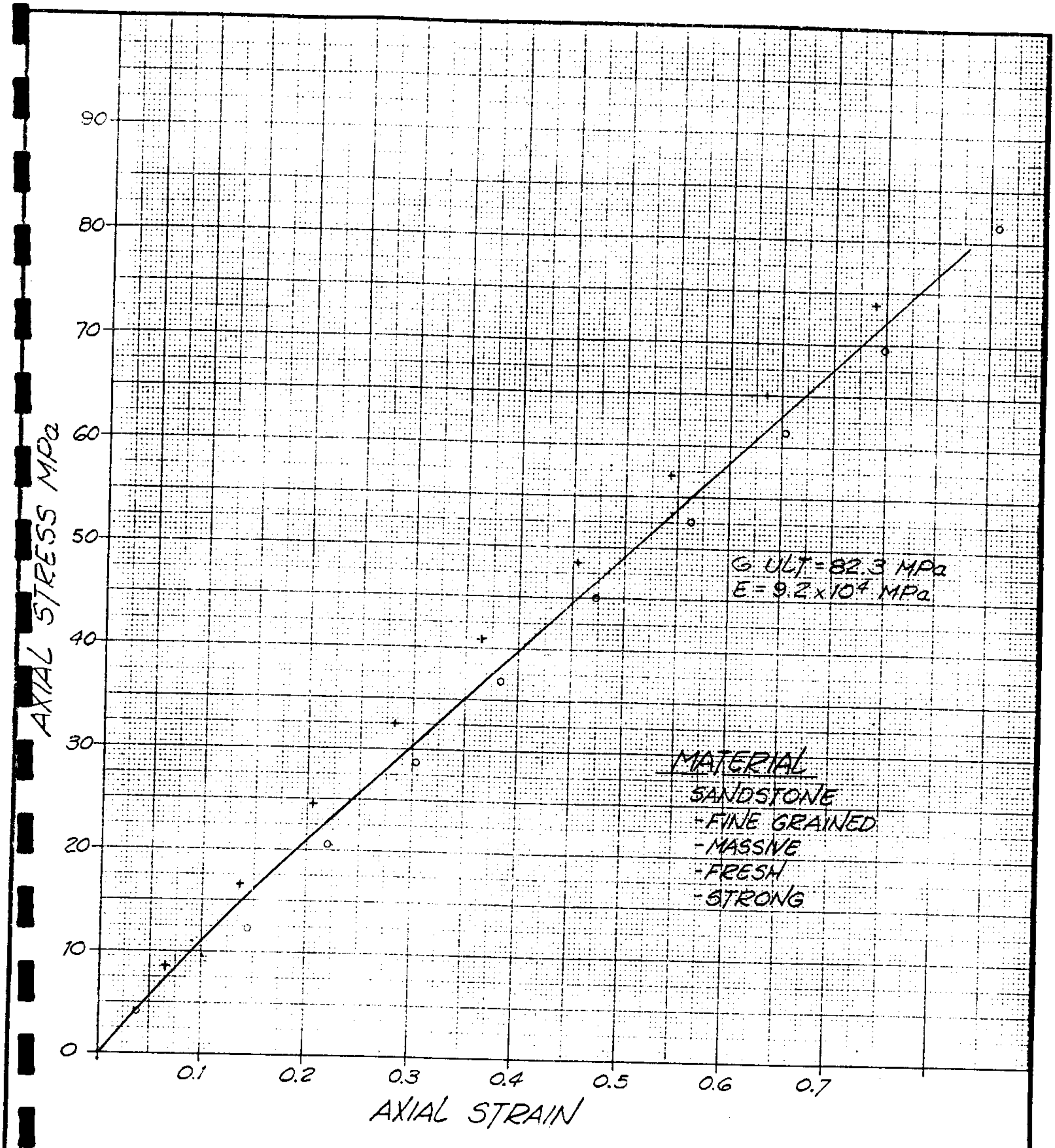
TITLE: UNIAXIAL COMPRESSION TEST
TESTHOLE NO. 335

DATE OF ISSUE:

PROJECT No. 1692

DWG. No.

APPROVED
KLOHN LEONOFF



DEPTH : 115 m

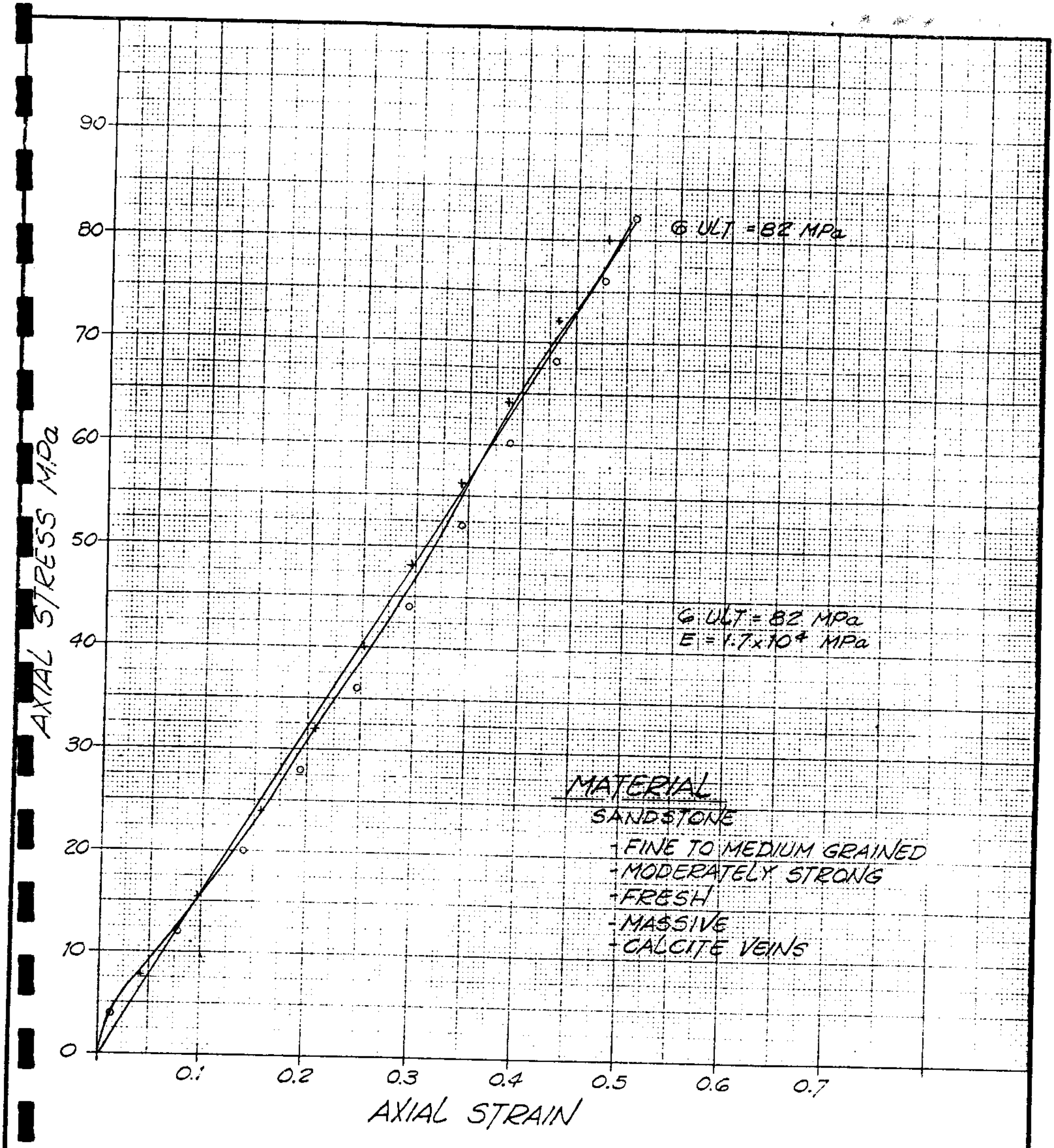
KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT:
CROWS NEST RESOURCES LTD.

PROJECT
TELKWA COAL PROJECT

TITLE
UNIAXIAL COMPRESSION TEST
TESTHOLE NO. 335

DATE OF ISSUE	PROJECT No.	DWG. No.
APPROVED KLOHN LEONOFF	1692	



DEPTH : 44.5 m.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

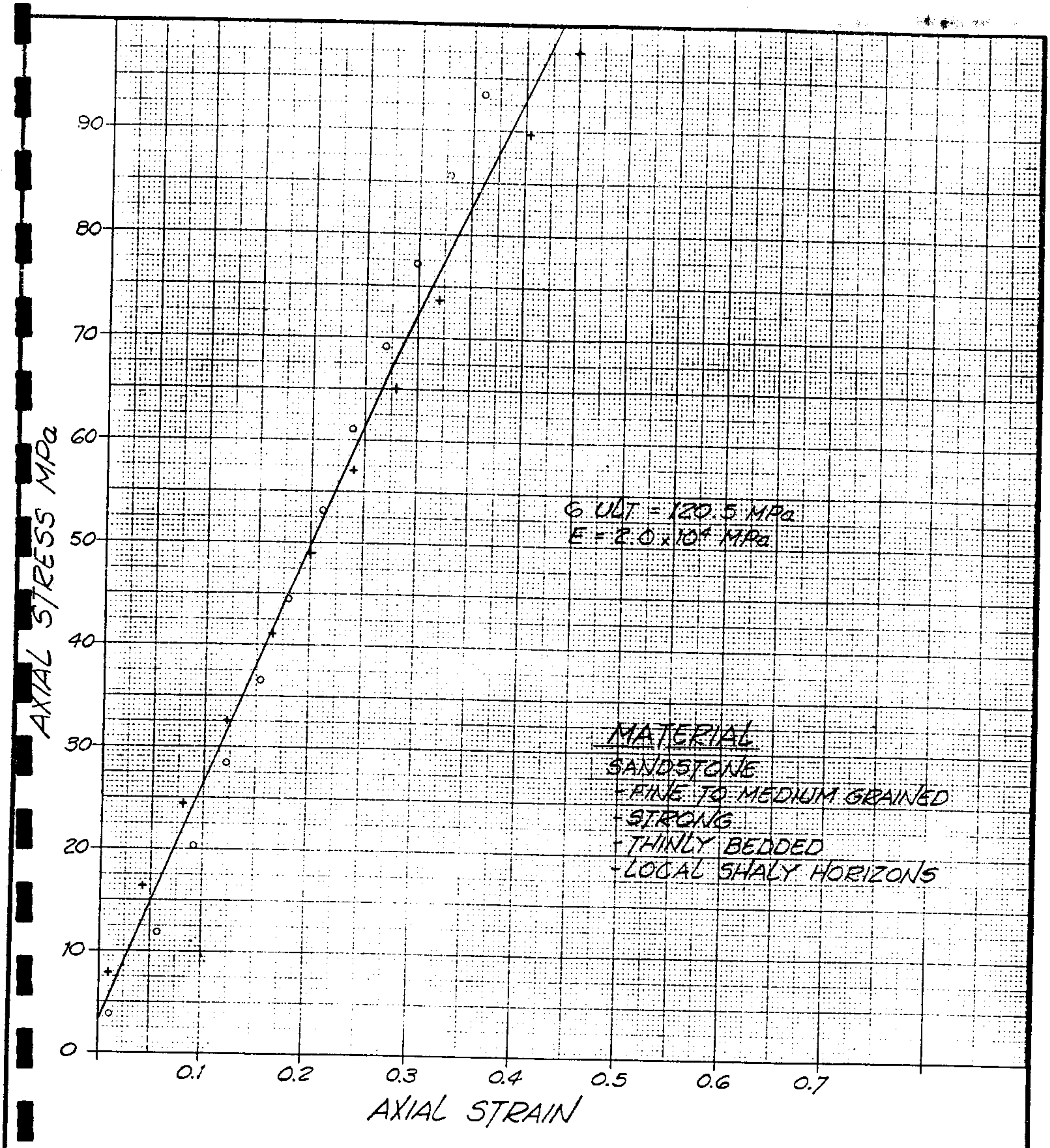
CLIENT: CROWS NEST RESOURCES LTD.

PROJECT: TELKWA COAL PROJECT

TITLE: UNIAXIAL COMPRESSION TEST
TESTHOLE NO. 336

DATE OF ISSUE	PROJECT No.	DWG. No.
APPROVED	1692	

KLOHN LEONOFF



σ ULT = 120.5 MPa

$E = 2.0 \times 10^4$ MPa

MATERIAL

SANDSTONE
- FINE TO MEDIUM GRAINED
- STRONG
- THINLY BEDDED
- LOCAL SHALY HORIZONS

DEPTH: 92.4 m.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: CROWS NEST RESOURCES LTD.

PROJECT: TELKWA COAL PROJECT

TITLE: UNIAXIAL COMPRESSION TEST
TESTHOLE NO. 336

DATE OF ISSUE	PROJECT No.	DWG. No.
APPROVED	1692	

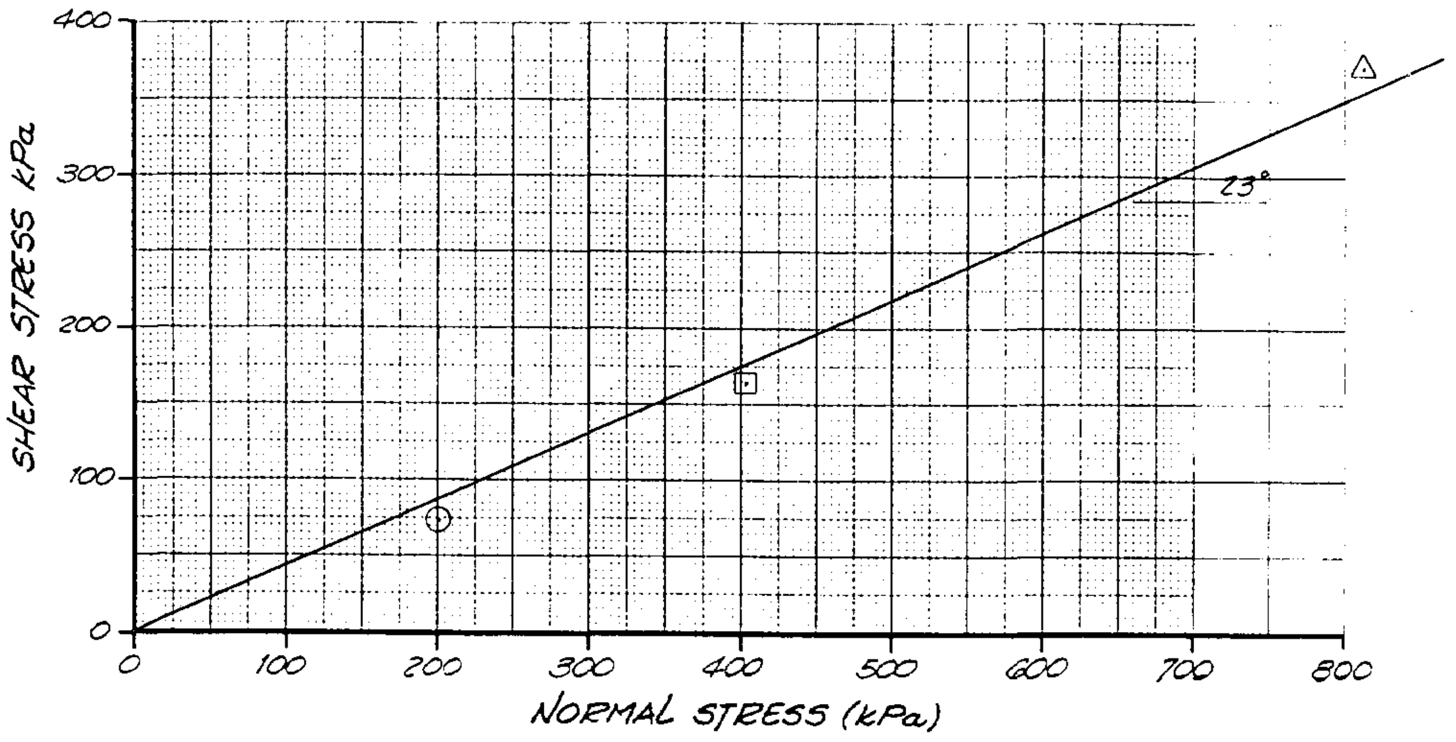
KLOHN LEONOFF

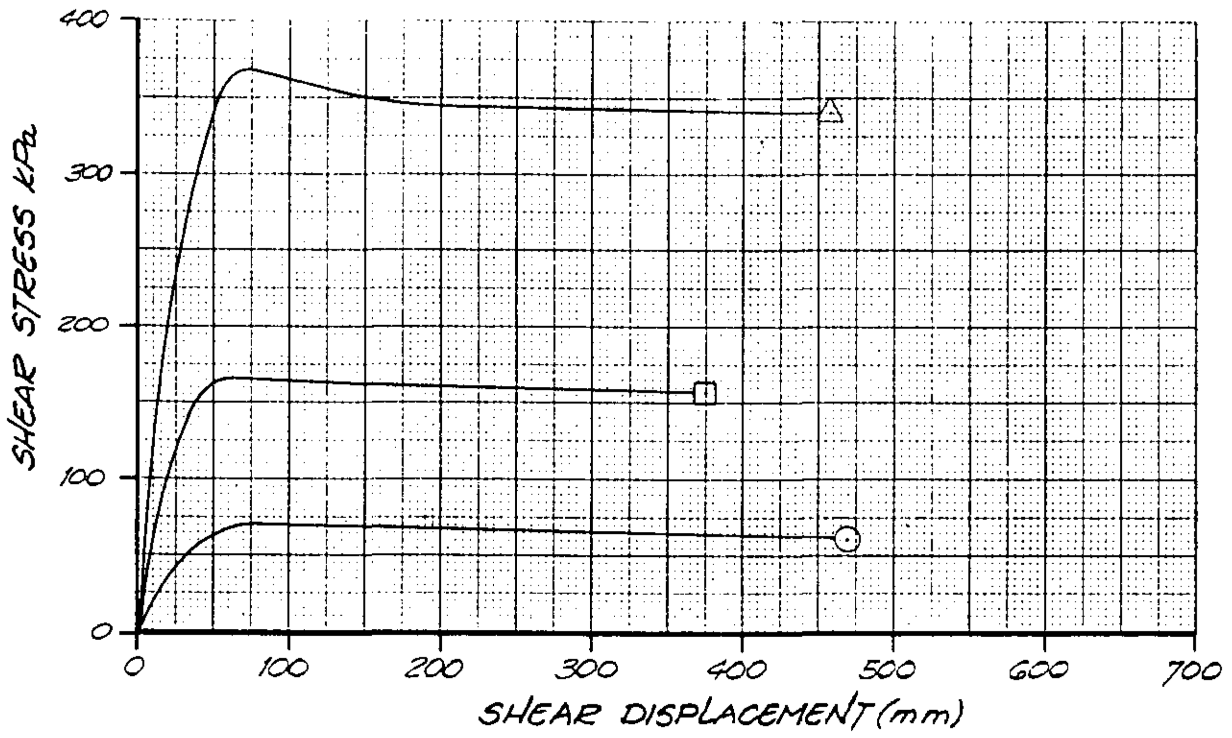
Summary of Slake Durability Tests

T.H.	Depth	Material	Slake Durability Test 1	Test 2
267	57.3- 66.2	Mudstone with coal	89.1%	77.6%
267	81.1- 83.1	Mudstone with coal	81.0%	63.7%
271	20.4	Interbedded sandstone & siltstone	97.6%	95.1%
271	59.8	Siltstone	99.5%	99.3%
272	45.7- 51.2	Interbedded siltstone & sandstone	98.1%	94.9%

SUMMARY OF SULPHATE SOUNDNESS TESTS

T.H.	Depth	Material	Sulphate Soundness Correct % Loss
268	81.4	Sandstone	100
271	35.1	Sandstone	83
272	40.2	Sandstone	78
272	82.5	Sandstone	92





SAMPLE DESCRIPTION: CARBONACEOUS SILTSTONE									TEST CONDITION
TEST NO.	SYMBOL	TEST HOLE NO.	DEPTH (m)	NATURAL MC %	γd (Ma/m³)	L.L. (%)	P.L. (%)	P.I. (%)	NORMAL STRESS σ'_n(kPa)
1	⊙	267	61.5			23	14	9	200
2	⊡	267	61.5			23	14	9	400
3	△	267	61.5			23	14	9	800

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT
TELKWA COAL PROJECT

TITLE
DIRECT SHEAR TEST RESULTS (MULTISTAGE)

CLIENT:
CROWS NEST RESOURCES LTD.

DATE OF ISSUE

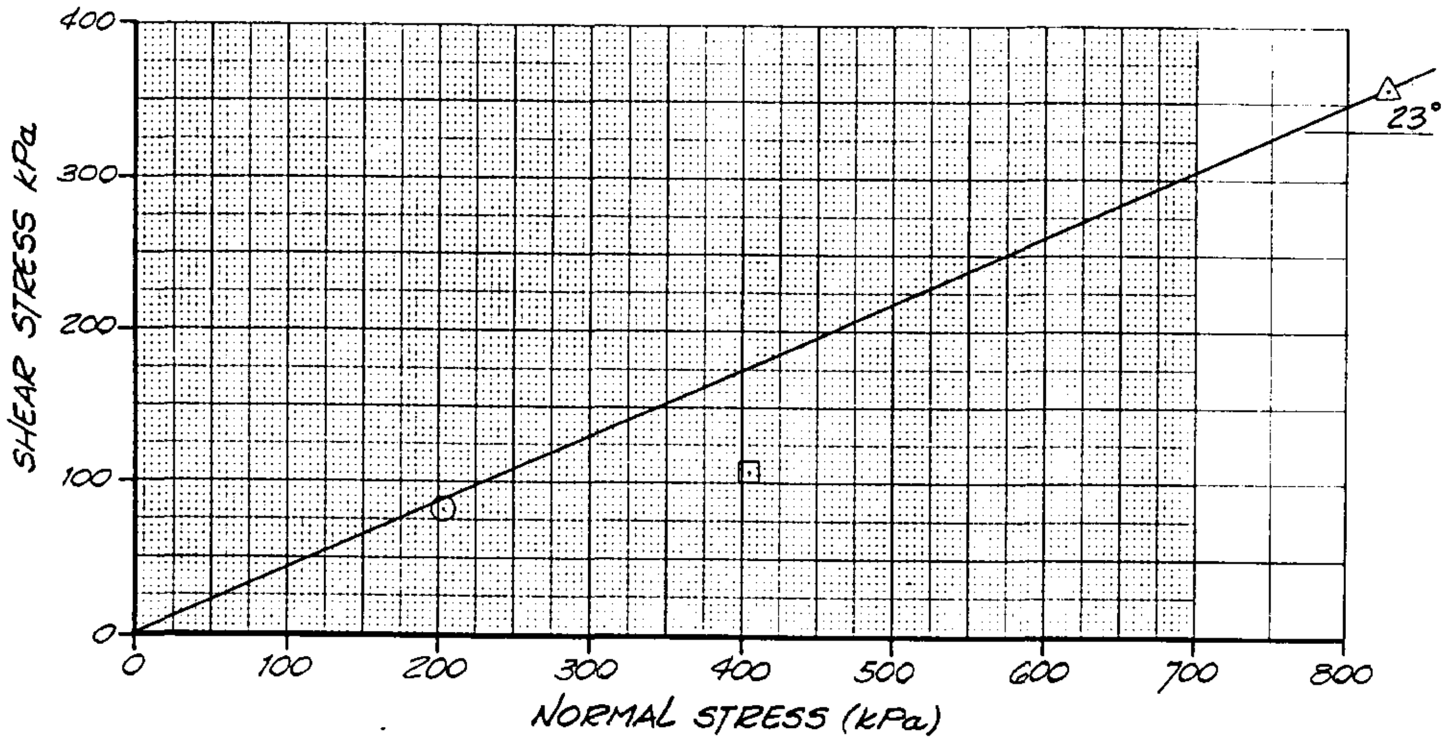
APPROVED

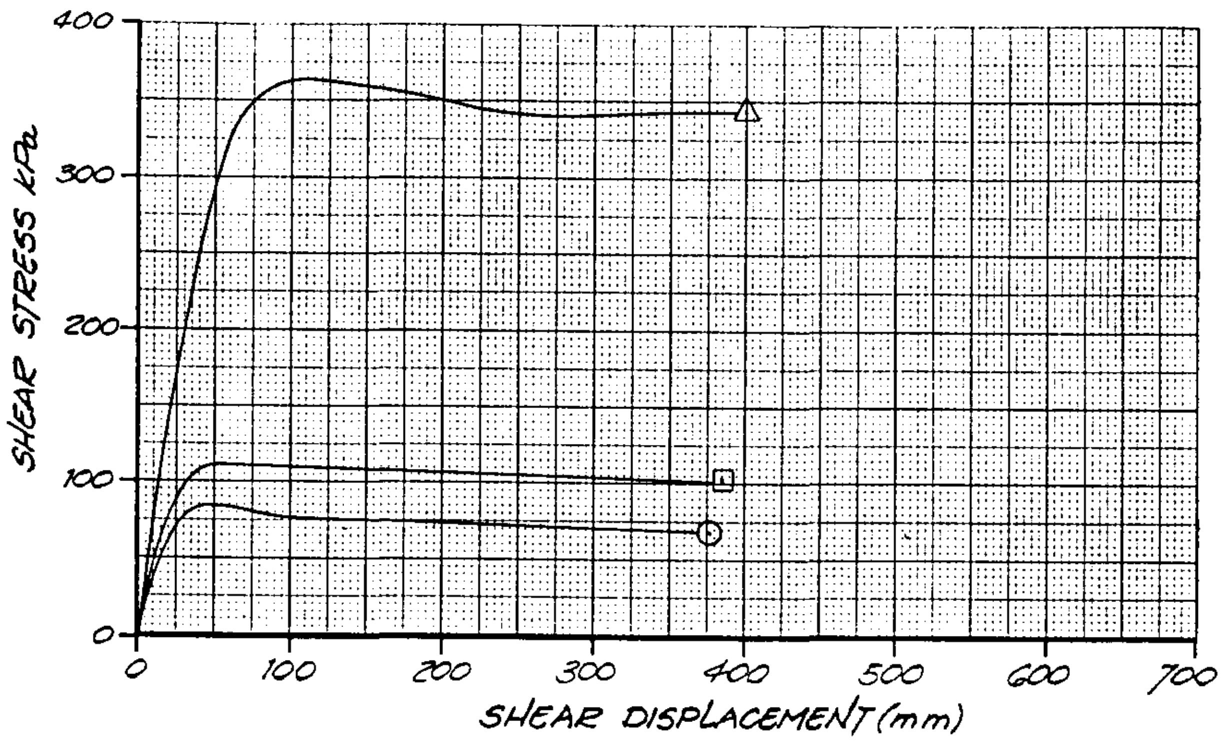
PROJECT No.
PN 1692

DWG. No.
1692-III-01

REV.

NC1-456-K.L





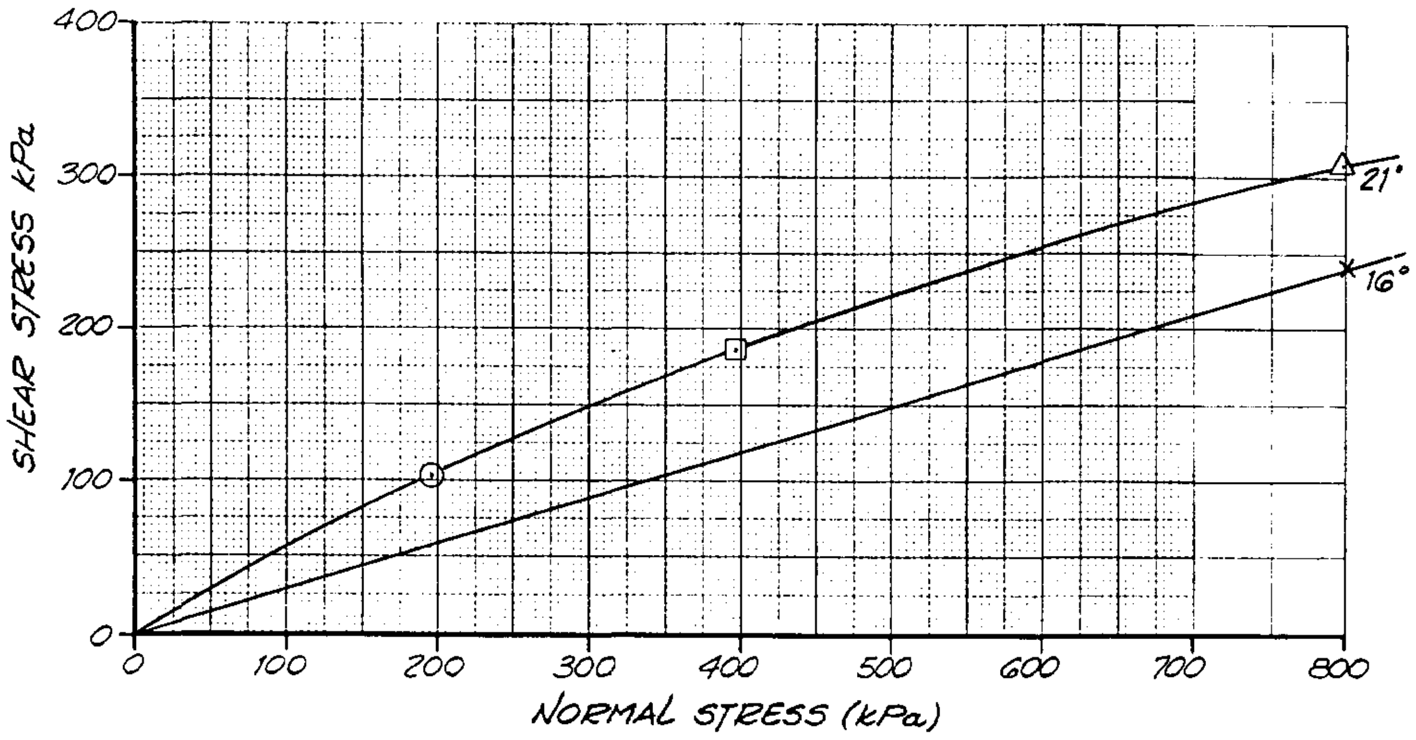
SAMPLE DESCRIPTION									TEST CONDITION
TEST NO.	SYMBOL	TEST HOLE NO.	DEPTH (m)	NATURAL MC %	γd (Ma/m^3)	L.L. (%)	P.L. (%)	P.I. (%)	NORMAL STRESS σ'_n(kPa)
1	⊙	267	116.4			20	15	5	200
2	⊡	267	116.4			20	15	5	400
3	△	267	116.4			20	15	5	800

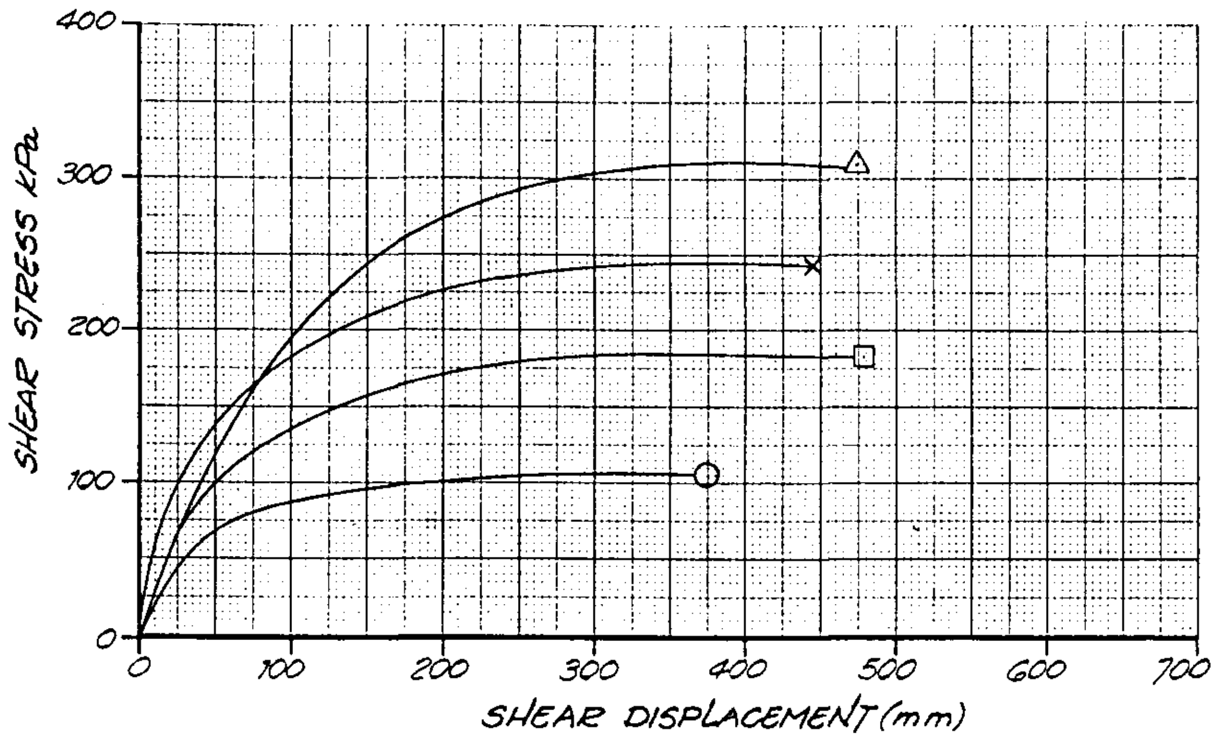
pg. 210

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: TELKWA COAL PROJECT
TITLE: DIRECT SHEAR TEST RESULTS (MULTISTAGE)
CLIENT: CROWS NEST RESOURCES LTD.
DATE OF ISSUE:
APPROVED:
PROJECT No.: PA 1692
DWG. No.: 1692-III-02
REV.:

NCI-456-KL





SAMPLE DESCRIPTION: MUDSTONE UNDERCLAY									TEST CONDITION
TEST No.	SYMBOL	TEST HOLE No.	DEPTH (m)	NATURAL MC %	γd (Mg/m³)	L.L. (%)	P.L. (%)	P.I. (%)	NORMAL STRESS σ'_n (kPa)
1	⊙	268	139.40	16.9 *		40	20	20	200
2	⊡	268	139.40	19.6**		40	20	20	400
3	△	268	139.40			40	20	20	800
4	×	268	139.40			40	20	20	800

* BEFORE TEST
** AFTER TEST

SAMPLE PREPARATION

TEST 1 - RECOMPACTED MUDSTONE PASSING THROUGH #40 SIEVE
TEST 2 - " " " " " "
TEST 3 - " " " " " "
TEST 4 - RECOMPACTED SHEARED SURFACE POLISHED PRIOR TO SHEARING
} MULTI STAGE

Pg. 211

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: TELKWA COAL PROJECT
TITLE: DIRECT SHEAR RESULTS (MULTISTAGE)
CLIENT: CROWS NEST RESOURCES LTD.
DATE OF ISSUE:
APPROVED:
PROJECT No.: PA 1692
DWG. No.: 1692-III-03
REV.:

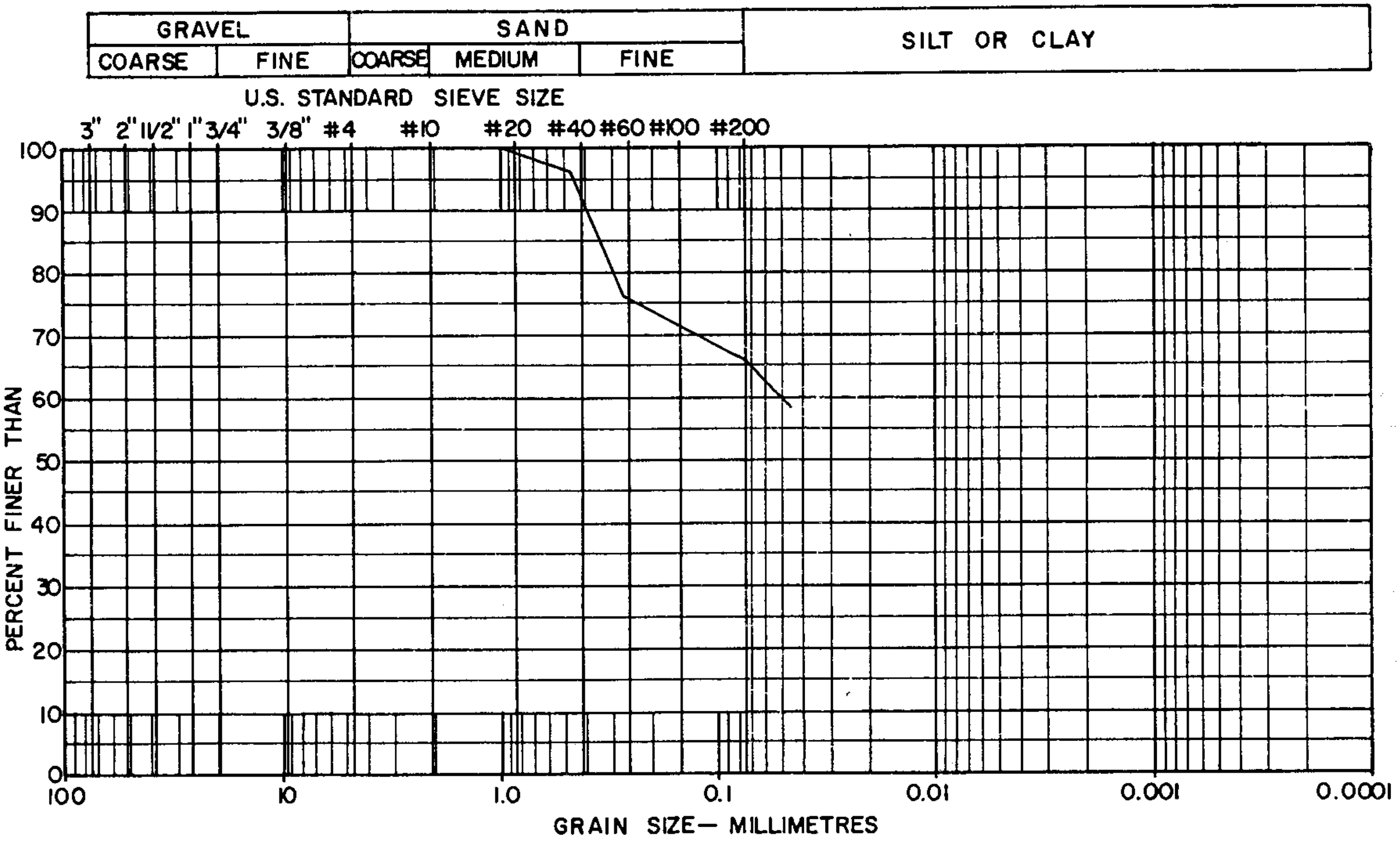
NCI-456-KL

APPENDIX IV

GRAIN SIZE CURVES FOR FINE TAILINGS

GRAIN SIZE CURVE

KLOHN LEONOFF
CONSULTING ENGINEERS



REMARKS: *TELKWA FINE REJECT TAILINGS*

JOB No. *PA 1692*

PROJECT *TELKWA COAL PROJECT*

LOCATION *SMITHERS, B.C.*

HOLE No.

DEPTH

DATE *OCT, 1984*

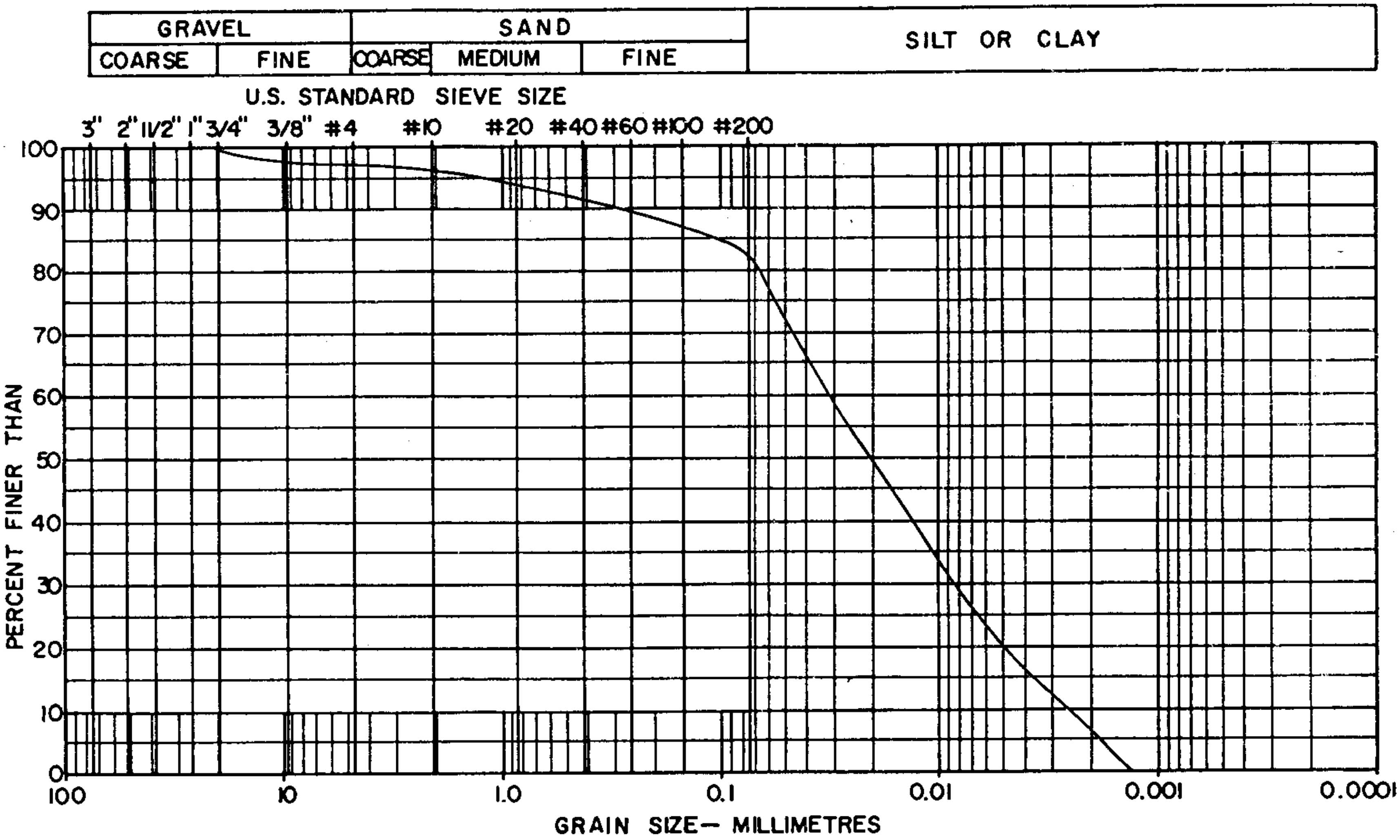
PLATE 1

KLOHN LEONOFF

KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692-OF-03
PROJECT TELKWA COAL PROJECT
LOCATION SITE 369
HOLE No. DEPTH
DATE

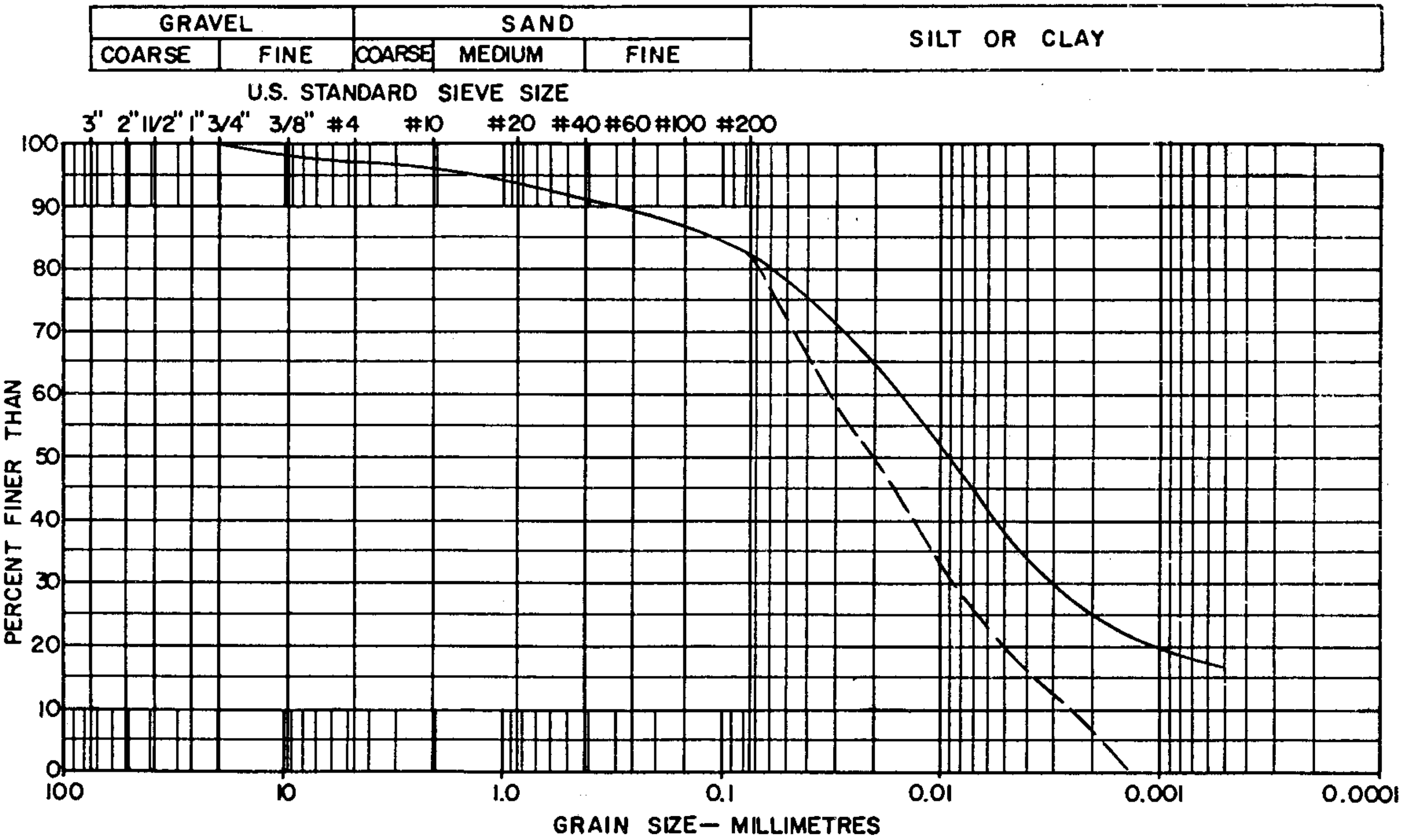
GRAIN SIZE CURVE



REMARKS: SA # 1-WITHOUT DEFLOCCULANT

KLOHN LEONOFF
CONSULTING ENGINEERS

GRAIN SIZE CURVE

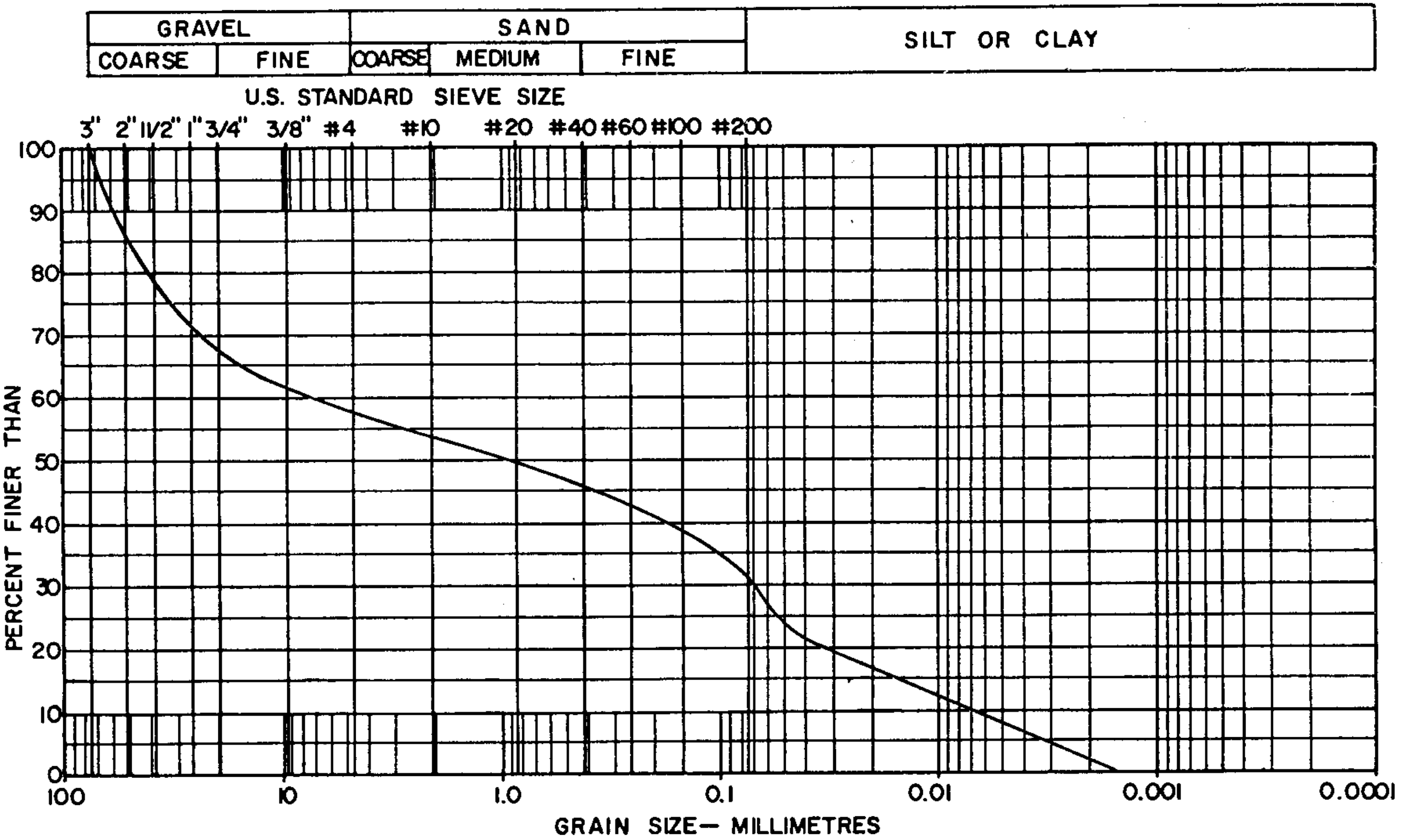


REMARKS: —— SA#1 - WITH SODIUM HEXAMETAPHOSPHATE
— — SA#1-WITHOUT SODIUM HEXAMETAPHOSPHATE

JOB No. PA 1692-OF-03
PROJECT TELKWA COAL PROJECT
LOCATION SITE 369
HOLE No. DEPTH
DATE

KLOHN LEONOFF
CONSULTING ENGINEERS

GRAIN SIZE CURVE



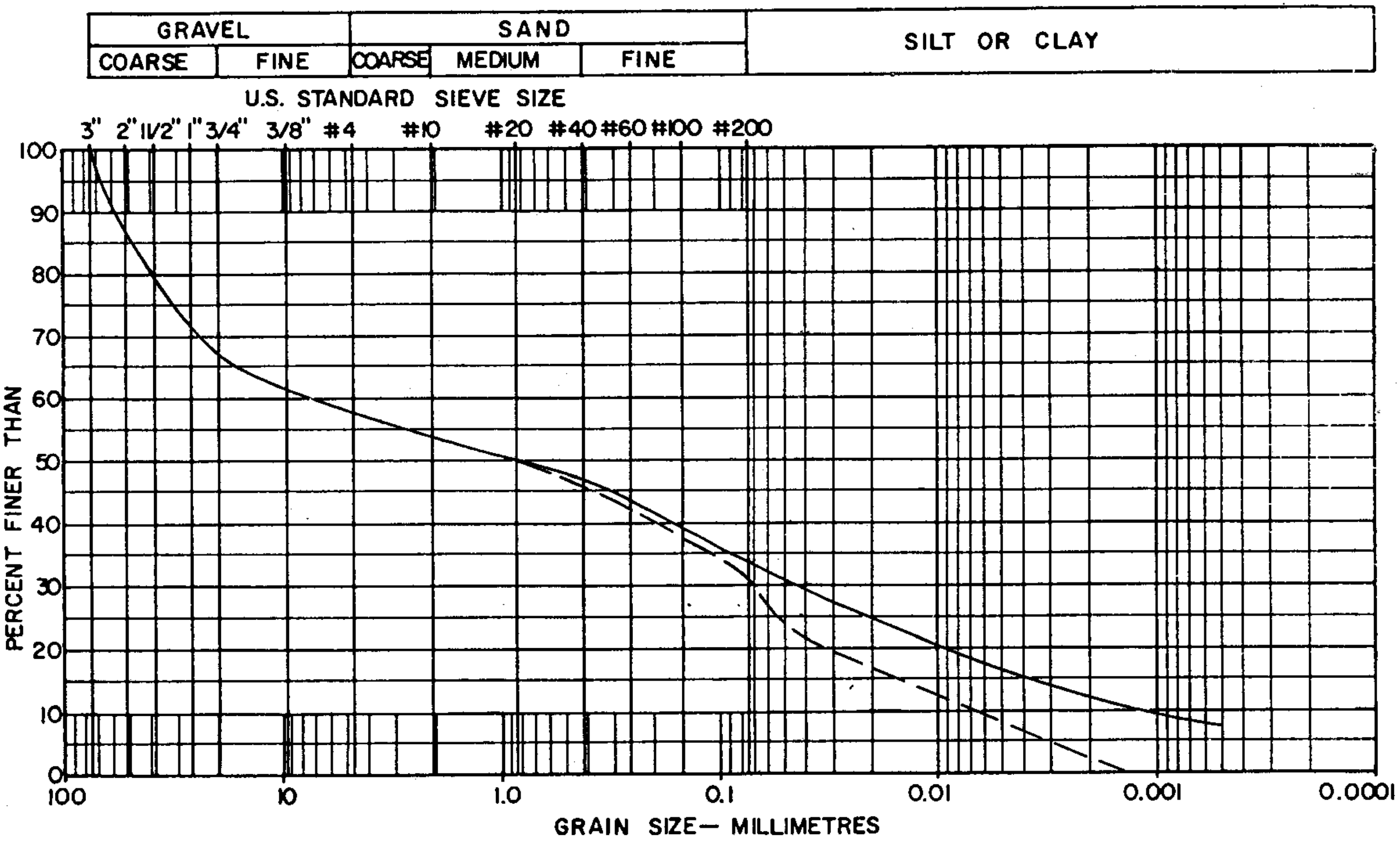
REMARKS: SA #2 - WITHOUT DEFLOCCULANT

JOB No. PA 1692-OF-03
PROJECT TELKWA COAL PROJECT
LOCATION SITE 369
HOLE No.
DEPTH
DATE

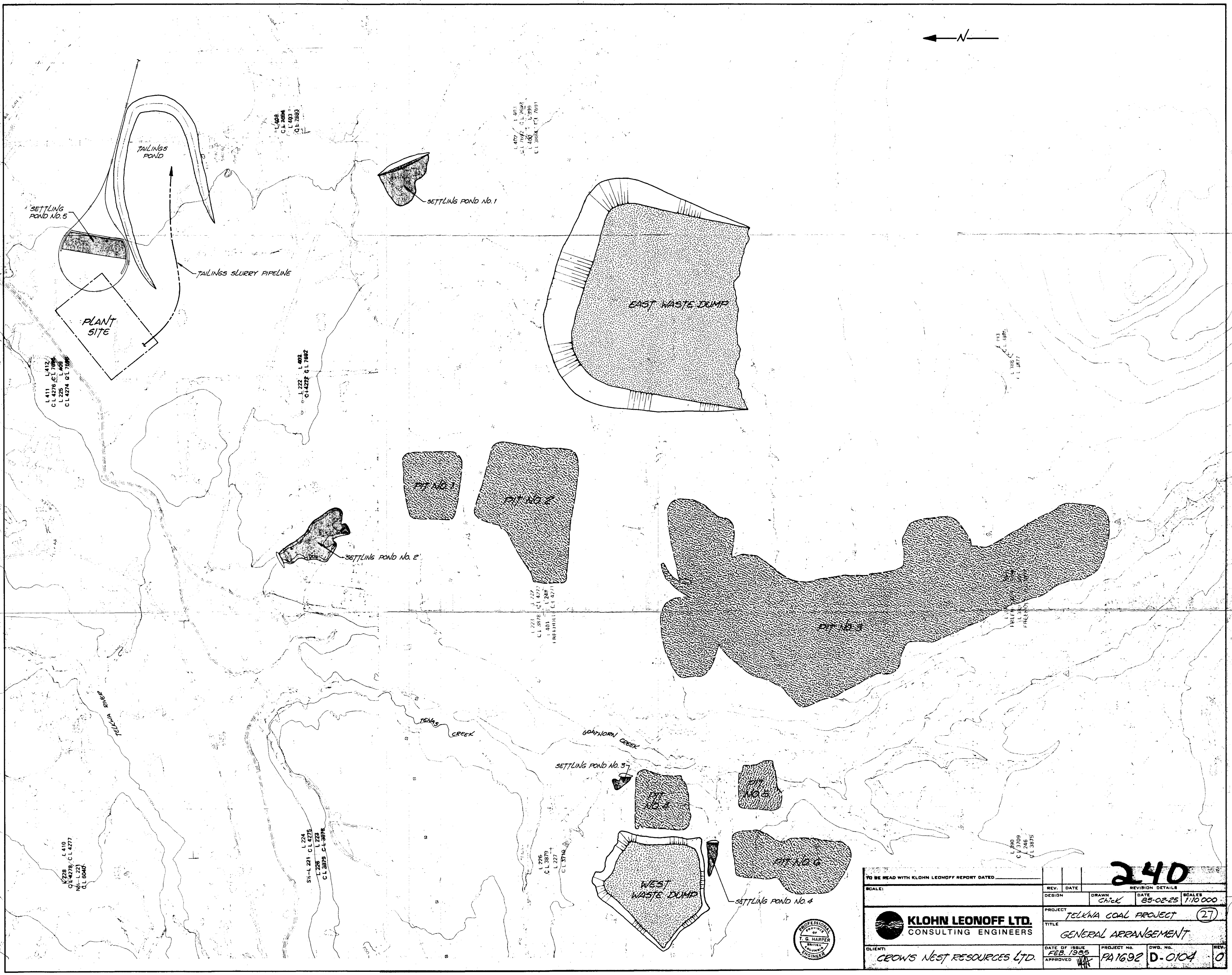
KLOHN LEONOFF
CONSULTING ENGINEERS

JOB No. PA 1692-OF-03
PROJECT TELKWA COAL PROJECT
LOCATION SITE 369
HOLE No.
DEPTH
DATE

GRAIN SIZE CURVE



REMARKS: —— SA#2 - WITH SODIUM HEXAMETAPHOSPHATE
— — SA#2 - WITHOUT SODIUM HEXAMETAPHOSPHATE



240

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SCALE:

REV.	DATE	REVISION DETAILS

DESIGN	DRAWN	DATE	SCALES
	Chick	85-02-25	1:10 000

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CONSULTING ENGINEERS

PROJECT TELKWA COAL PROJECT (27)

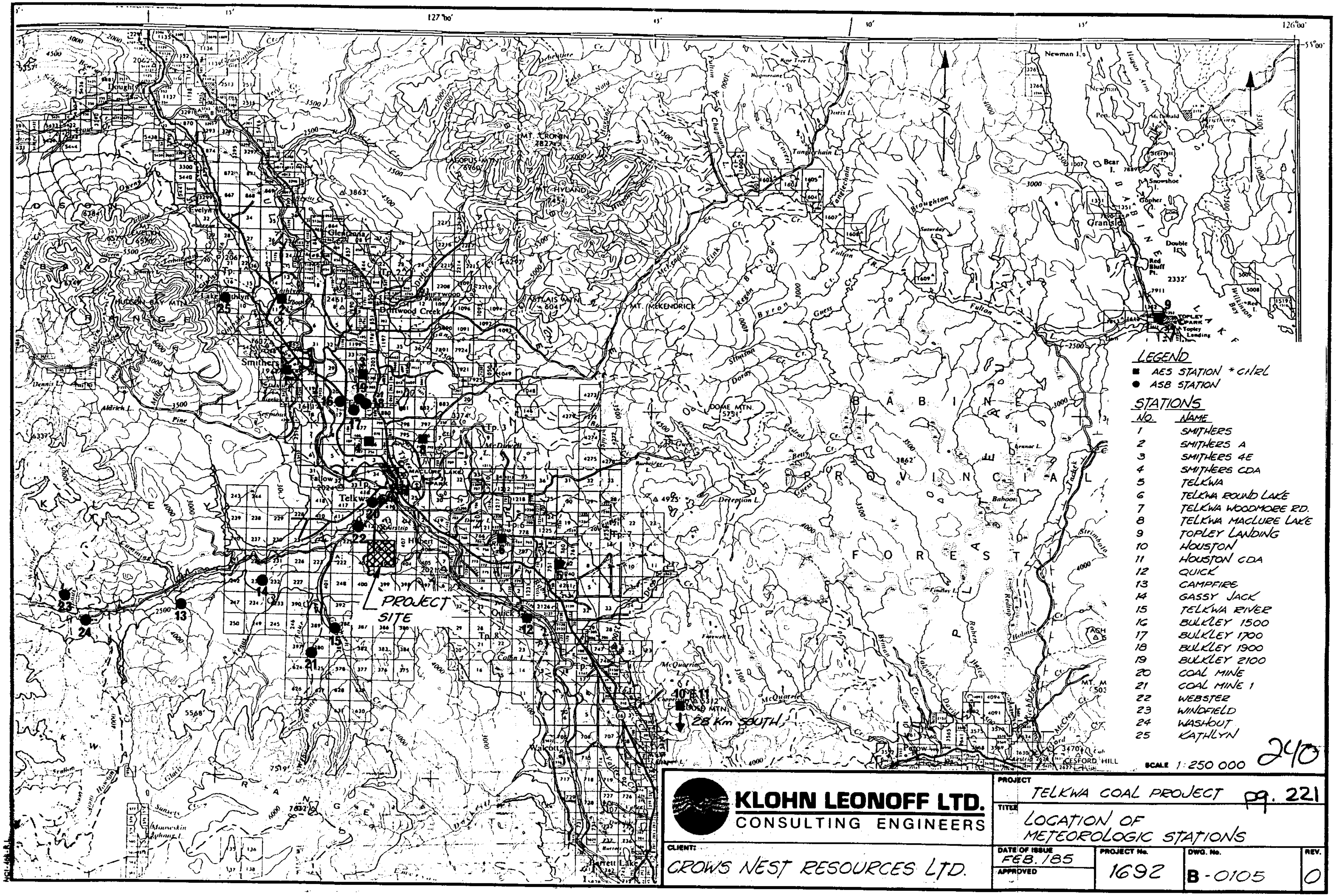
TITLE GENERAL ARRANGEMENT

T. G. HARPER

CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB. 1985	PA1692	D-0104	0

APPROVED



LEGEND

■ AES STATION *CH/RL

● ASB STATION

STATIONS

NO.	NAME
1	SMITHERS
2	SMITHERS A
3	SMITHERS 4E
4	SMITHERS CDA
5	TELKWA
6	TELKWA ROUND LAKE
7	TELKWA WOODMORE RD.
8	TELKWA MACLURE LAKE
9	TOPLEY LANDING
10	HOUSTON
11	HOUSTON CDA
12	QUICK
13	CAMPFIRE
14	GASSY JACK
15	TELKWA RIVER
16	BULKLEY 1500
17	BULKLEY 1700
18	BULKLEY 1900
19	BULKLEY 2100
20	COAL MINE
21	COAL MINE 1
22	WEBSTER
23	WINDFIELD
24	WASHOUT
25	KATHLYN

SCALE 1:250 000

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: TELKWA COAL PROJECT

TITLE: LOCATION OF METEOROLOGIC STATIONS

CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB./85	1692	B-0105	0
APPROVED			

CLIENT:
CROWS NEST RESOURCES LTD.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT
TELKWA COAL PROJECT

TITLE
INTENSITY DURATION FREQUENCY
CURVES - SMITHERS AIRPORT

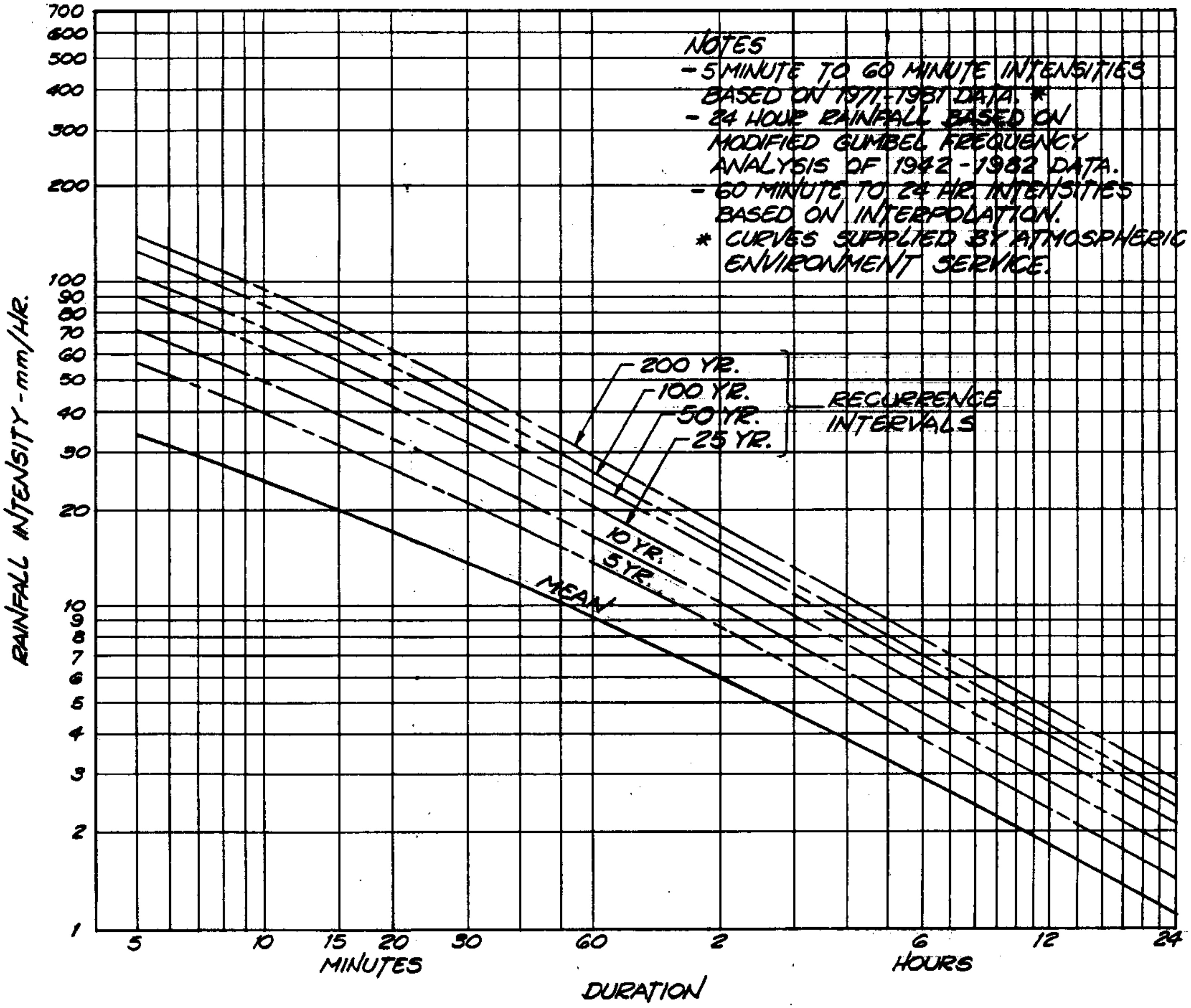
DATE OF ISSUE
FEB./85

APPROVED

PROJECT No.
1692

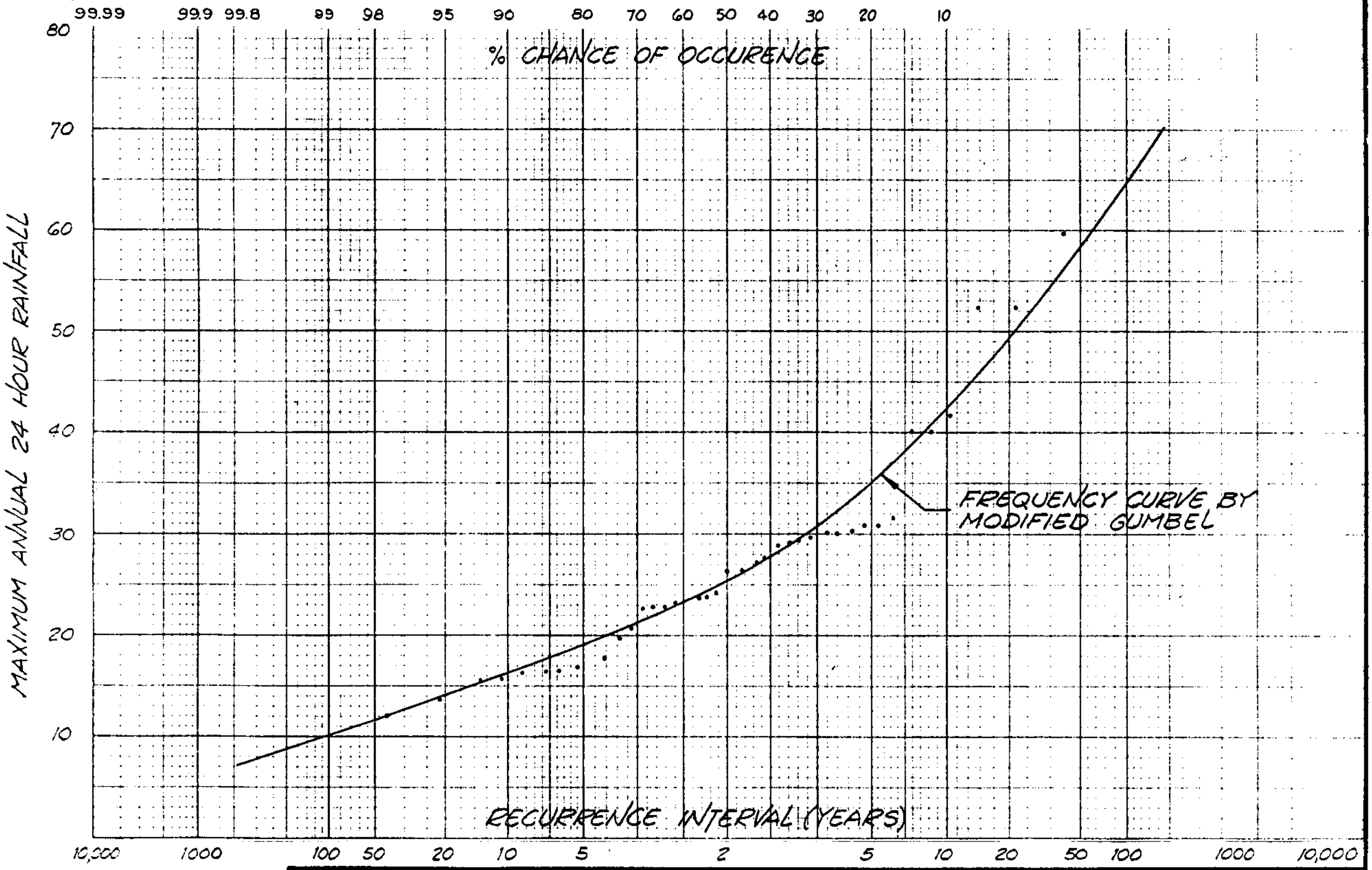
DWG. No.
A-0108

REV.
0



NOTES
- 5 MINUTE TO 60 MINUTE INTENSITIES BASED ON 1971-1981 DATA. *
- 24 HOUR RAINFALL BASED ON MODIFIED GUMBEL FREQUENCY ANALYSIS OF 1942 - 1982 DATA.
- 60 MINUTE TO 24 HR. INTENSITIES BASED ON INTERPOLATION.

* CURVES SUPPLIED BY ATMOSPHERIC ENVIRONMENT SERVICE.



KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

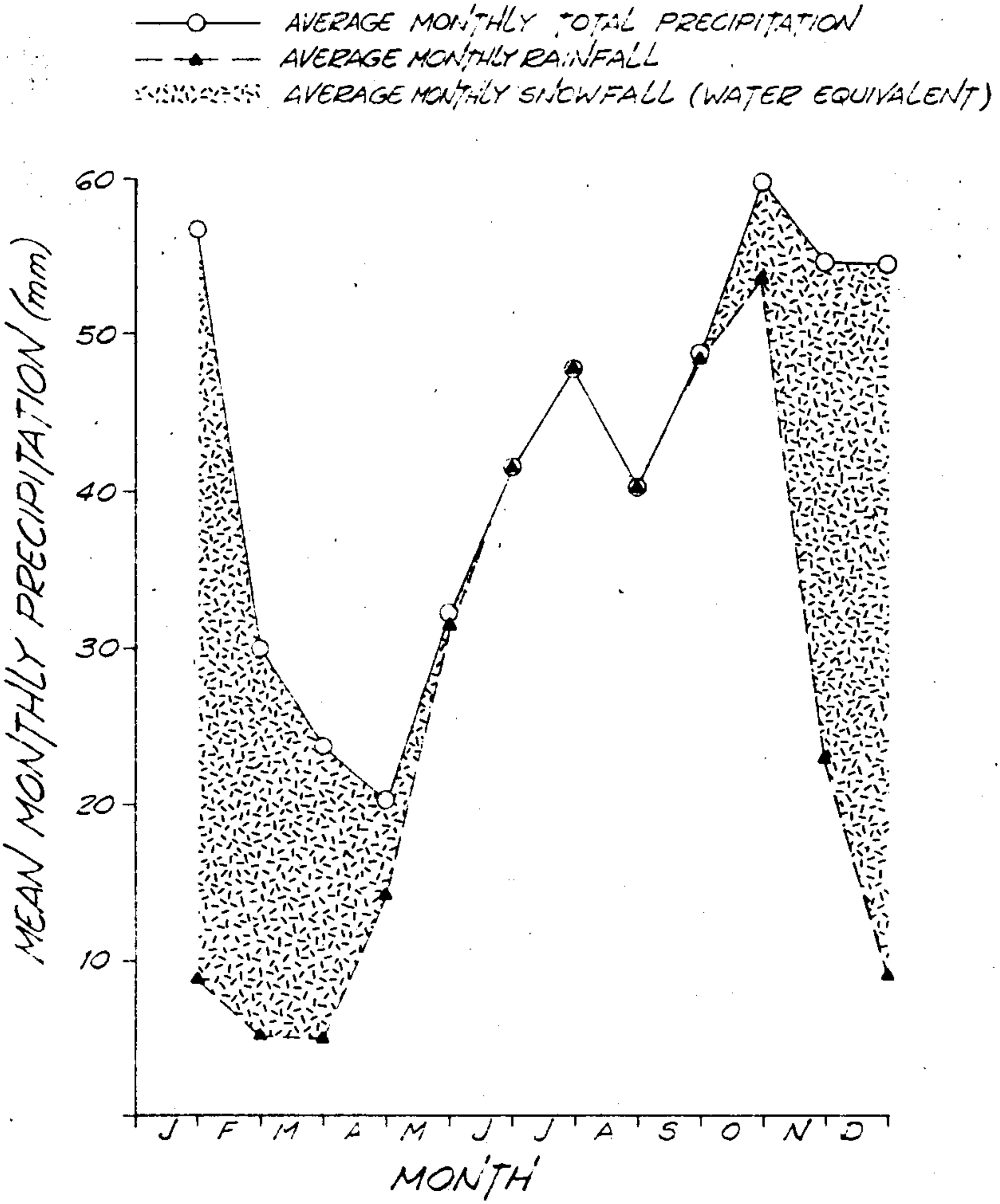
PROJECT TELKWA COAL PROJECT

TITLE FREQUENCY OF MAXIMUM ANNUAL
24 HOUR RAINFALL
- SMITHERS AIRPORT

CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB./85	1692	A-0107	0

APPROVED



SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT
TELKWA COAL PROJECT

TITLE
MEAN MONTHLY PRECIPITATION AT
SMITHERS AIRPORT - 1942 TO 1983

CLIENT:
CROWS NEST RESOURCES LTD.

DATE OF ISSUE
FEB./85

APPROVED

PROJECT No.
1692

DWG. No.
A-0106

REV.
0

REGIONAL DRAINAGE BASINS
SCALE - 1:500 000 (CONTOURS IN FEET)

LOCAL DRAINAGE BASINS
SCALE - 1:50 000 (CONTOURS IN FEET)

T. G. HARPER

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.

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REV.	DATE	REVISION DETAILS

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DRAWN KTC
DATE 84-11-20
SCALES AS SHOWN

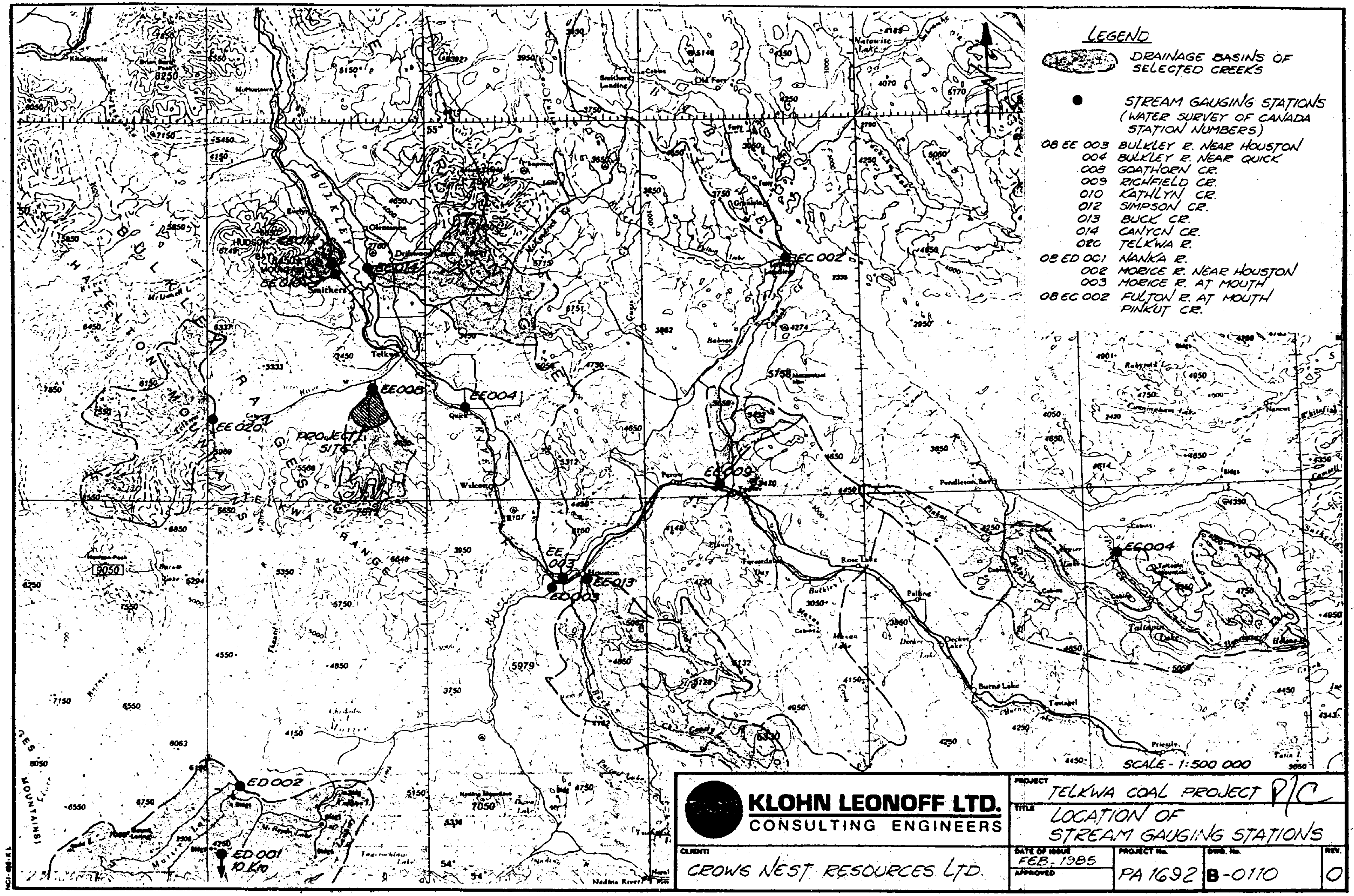
KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT TELKWA COAL PROJECT

TITLE REGIONAL & LOCAL DRAINAGE BASINS (28)

CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE FEB. 1985
APPROVED
PROJECT No. PA1692
DWG. No. D-0109
REV. 0



LEGEND

▨ DRAINAGE BASINS OF SELECTED CREEKS

● STREAM GAUGING STATIONS (WATER SURVEY OF CANADA STATION NUMBERS)

08 EE 003	BULKLEY R. NEAR HOUSTON
004	BULKLEY R. NEAR QUICK
008	GOATHORN CR.
009	RICHFIELD CR.
010	KATHLYN CR.
012	SIMPSON CR.
013	BUCK CR.
014	CANYON CR.
020	TELKWA R.
08 ED 001	NANKA R.
002	MORICE R. NEAR HOUSTON
003	MORICE R. AT MOUTH
08 EC 002	FULTON R. AT MOUTH
	PINKUT CR.

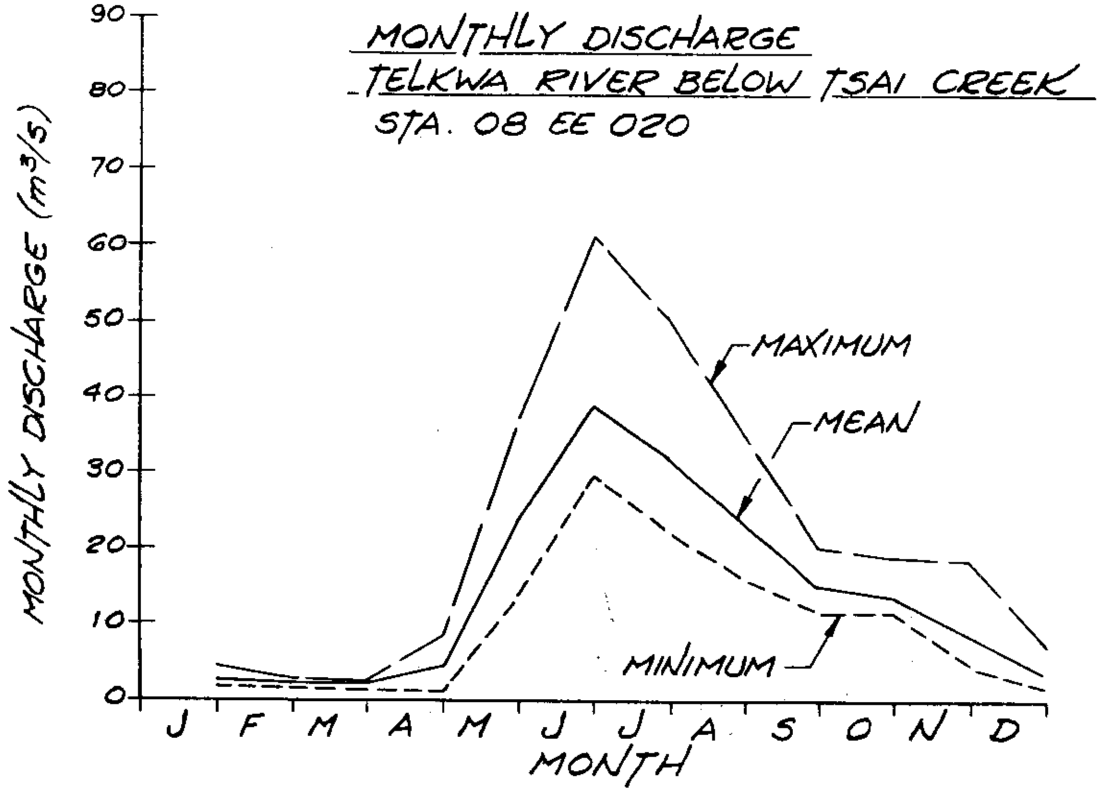
KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT TELKWA COAL PROJECT P/C

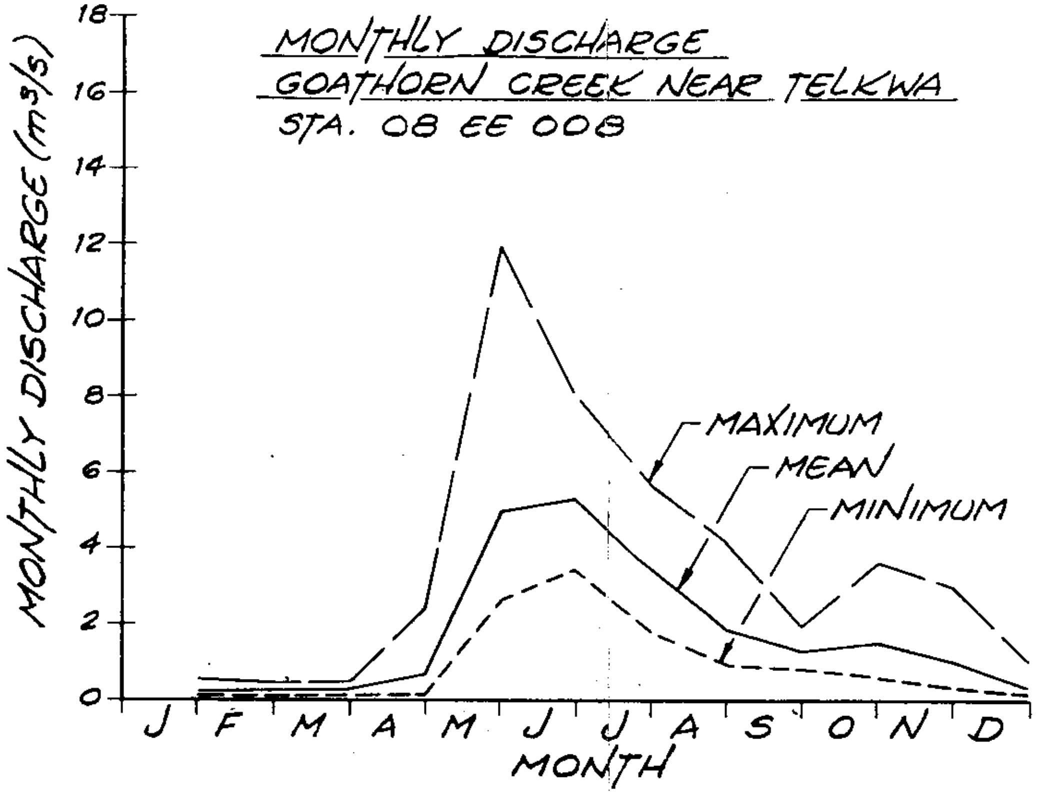
TITLE LOCATION OF STREAM GAUGING STATIONS

CLIENT: CROWS NEST RESOURCES LTD.

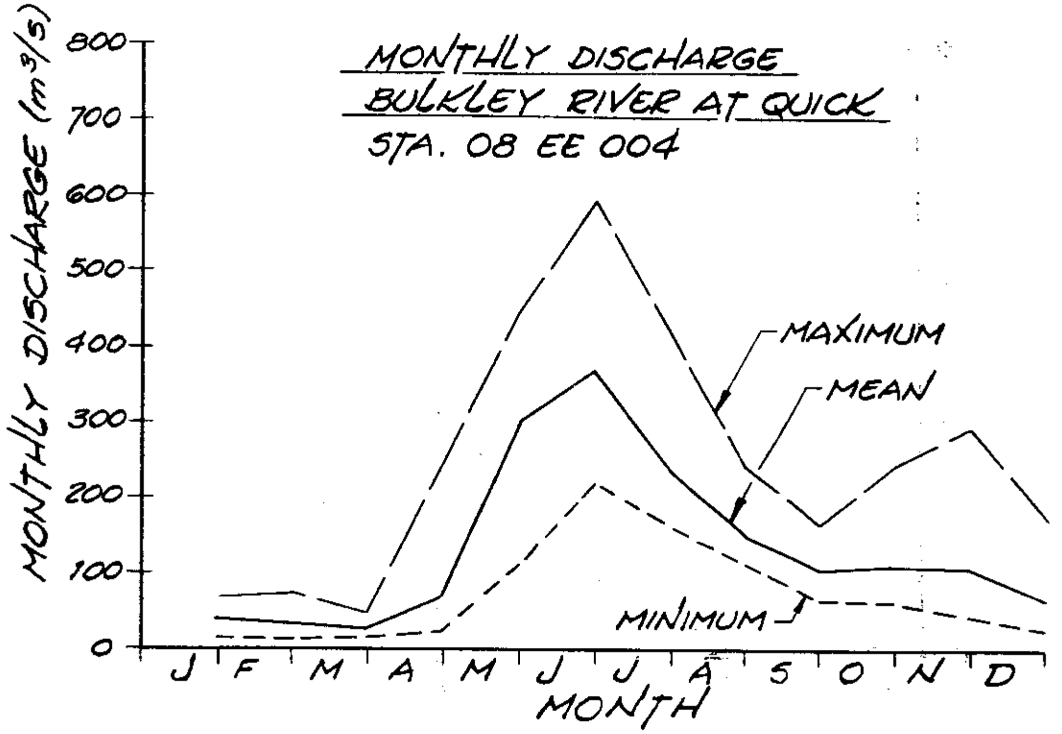
DATE OF ISSUE FEB. 1985
APPROVED
PROJECT No. PA 1692
DWG. No. B-0110
REV. 0



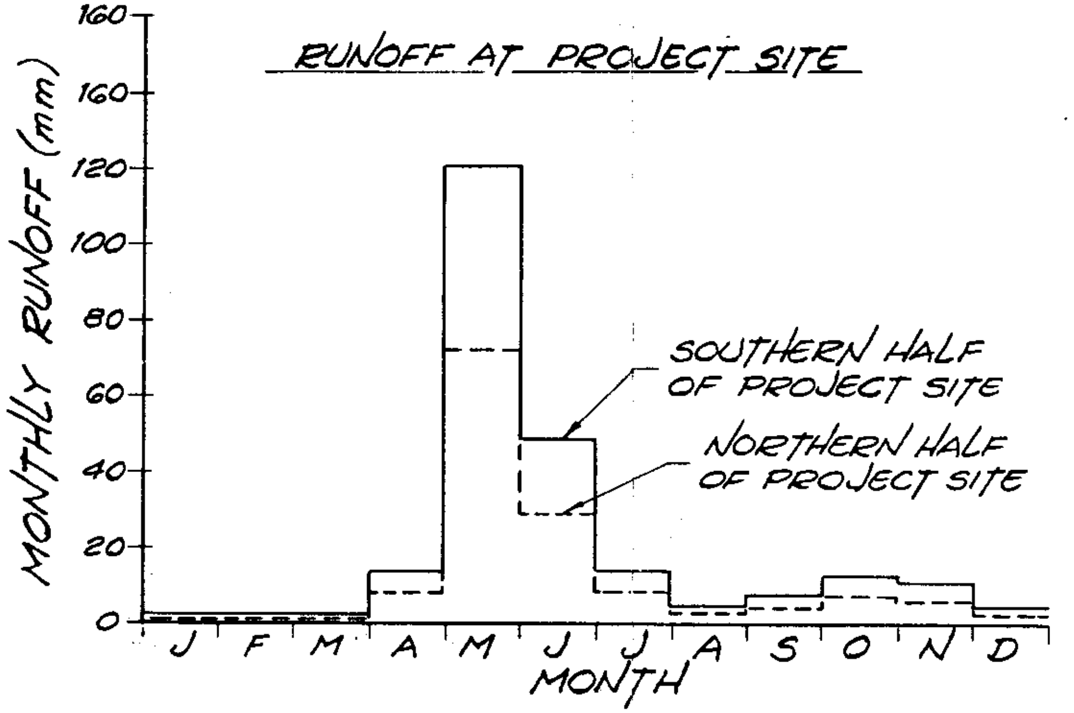
MONTHLY DISCHARGE
TELKWA RIVER BELOW TSAI CREEK
STA. 08 EE 020



MONTHLY DISCHARGE
GOATHORN CREEK NEAR TELKWA
STA. 08 EE 008



MONTHLY DISCHARGE
BULKLEY RIVER AT QUICK
STA. 08 EE 004



RUNOFF AT PROJECT SITE

TO BE READ WITH KLOHN LEONOFF REPORT DATED ____________

SCALE 240

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

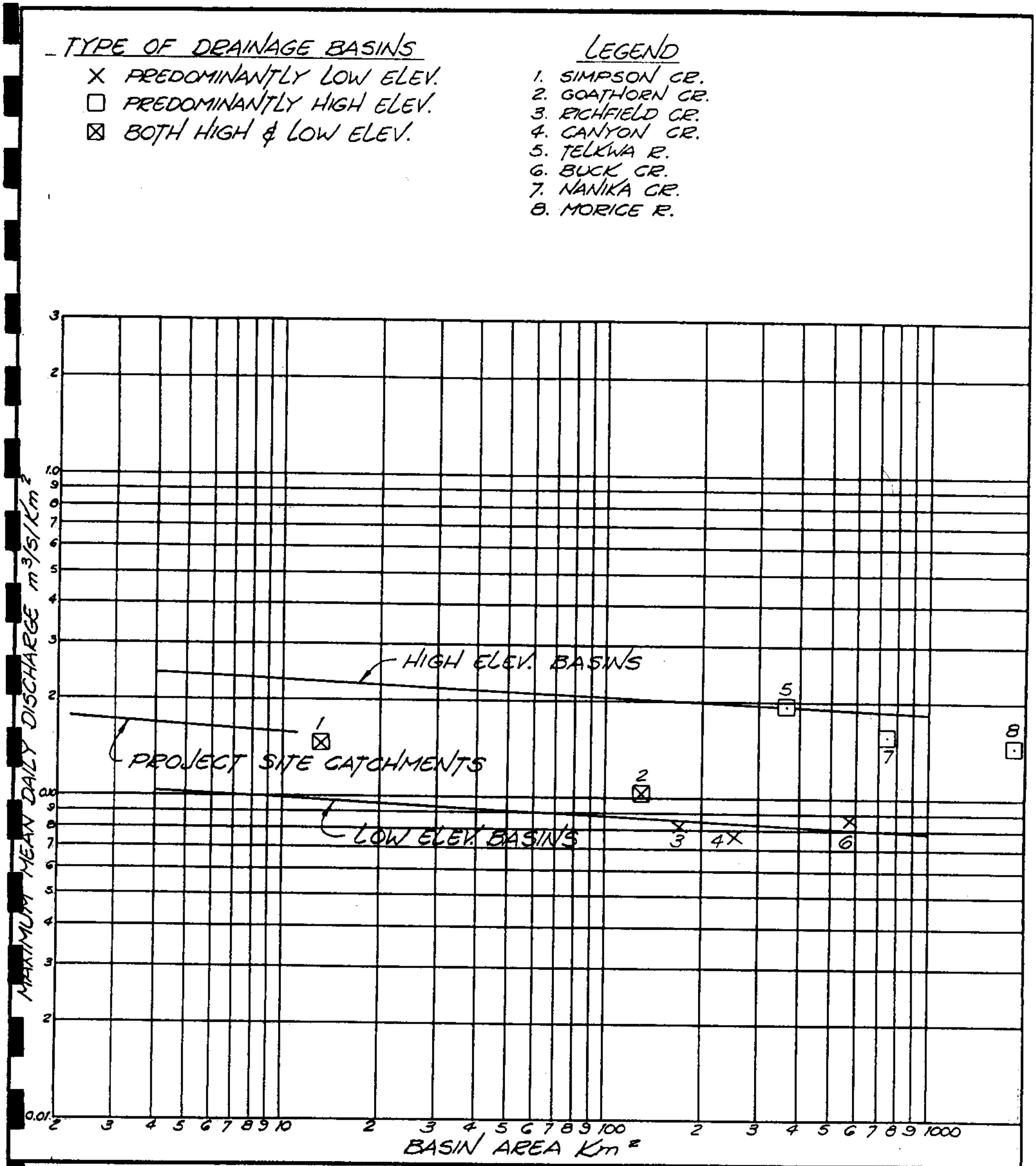
CLIENT: CROWS NEST RESOURCES LTD.

PROJECT: TELKWA COAL PROJECT

TITLE: SEASONAL VARIATION IN RUNOFF

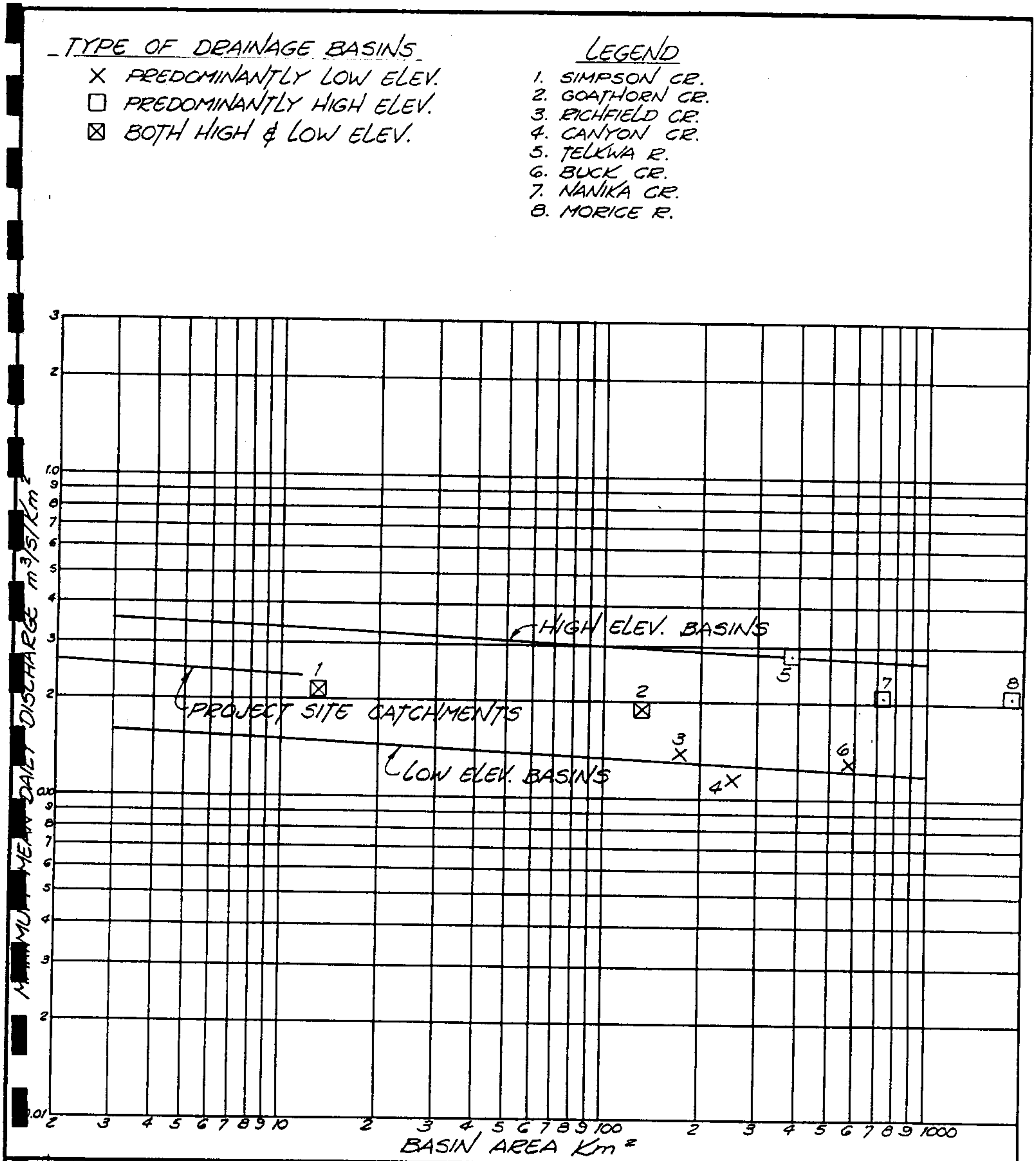
DATE OF ISSUE: FEB. 1985
APPROVED:
PROJECT No. PA 1692
DWG. No. B-0111
REV. 0

NCI-486-K.L.



KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT	TELKWA COAL PROJECT
TITLE	AVERAGE ANNUAL MAXIMUM DAILY SNOWMELT DISCHARGE VERSUS BASIN AREA
CLIENT:	CROWS NEST RESOURCES LTD.
DATE OF ISSUE	FEB. 1985
APPROVED	
PROJECT No.	PA 1692
DWG. No.	A-0112
REV.	0

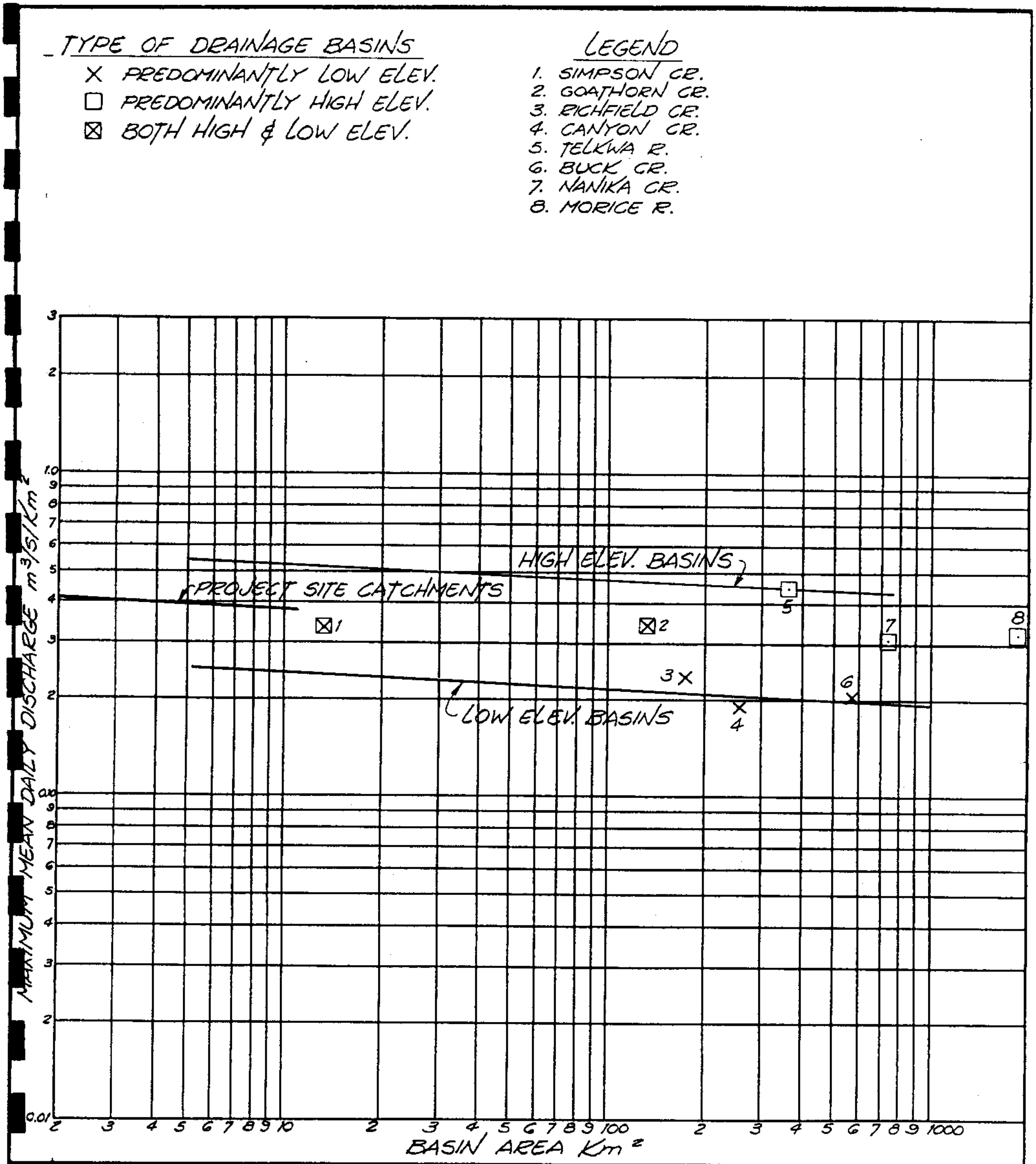


KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT	TELKWA COAL PROJECT
TITLE	10 YEAR ANNUAL MAXIMUM DAILY SNOWMELT DISCHARGE VERSUS BASIN AREA

CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB. 1985	PA 1692	A-0113	0
APPROVED			



KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

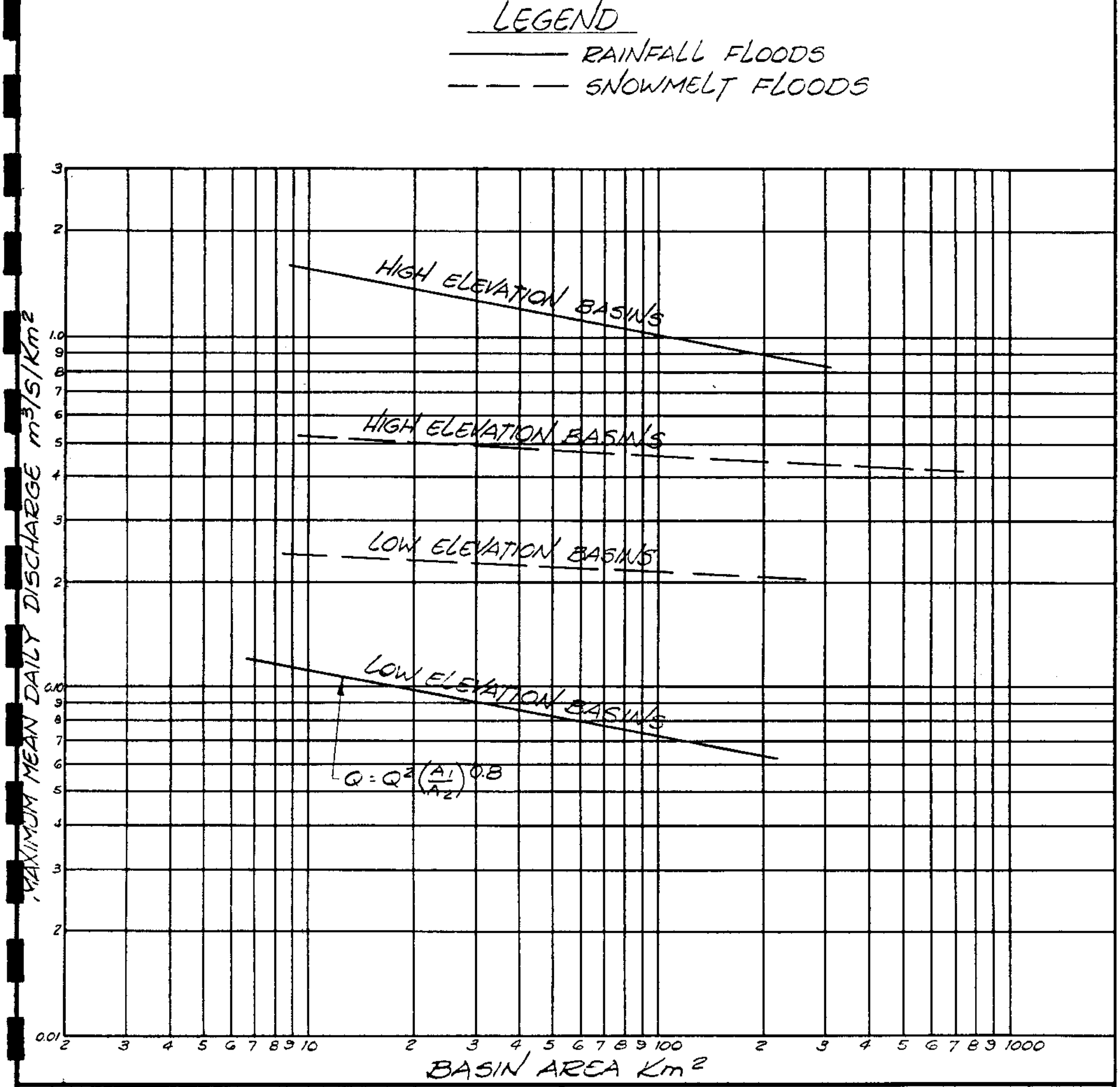
PROJECT: TELKWA COAL PROJECT

TITLE: 200 YEAR ANNUAL MAXIMUM DAILY SNOWMELT DISCHARGE VERSUS BASIN AREA

CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB. 1985	PA 1692	A-0114	0

APPROVED



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CONSULTING ENGINEERS

PROJECT: TELKWA COAL PROJECT

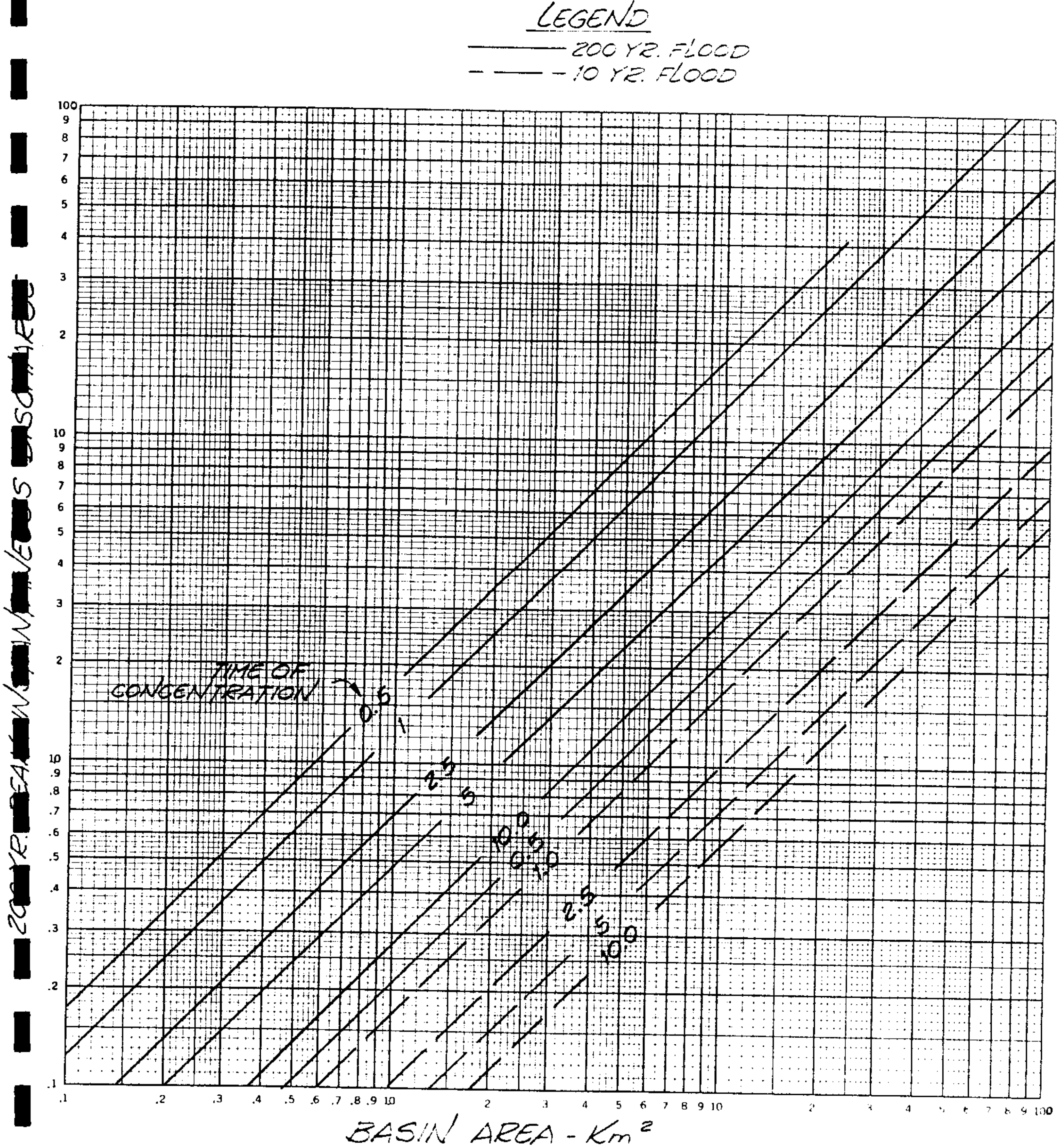
TITLE: 200 YEAR ANNUAL MAXIMUM DAILY RAINFALL RUNOFF VERSUS BASIN AREA

CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB. 1985	PA 1692	A-0015	0

APPROVED:

NCL 455-K



KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: TELKWA COAL PROJECT

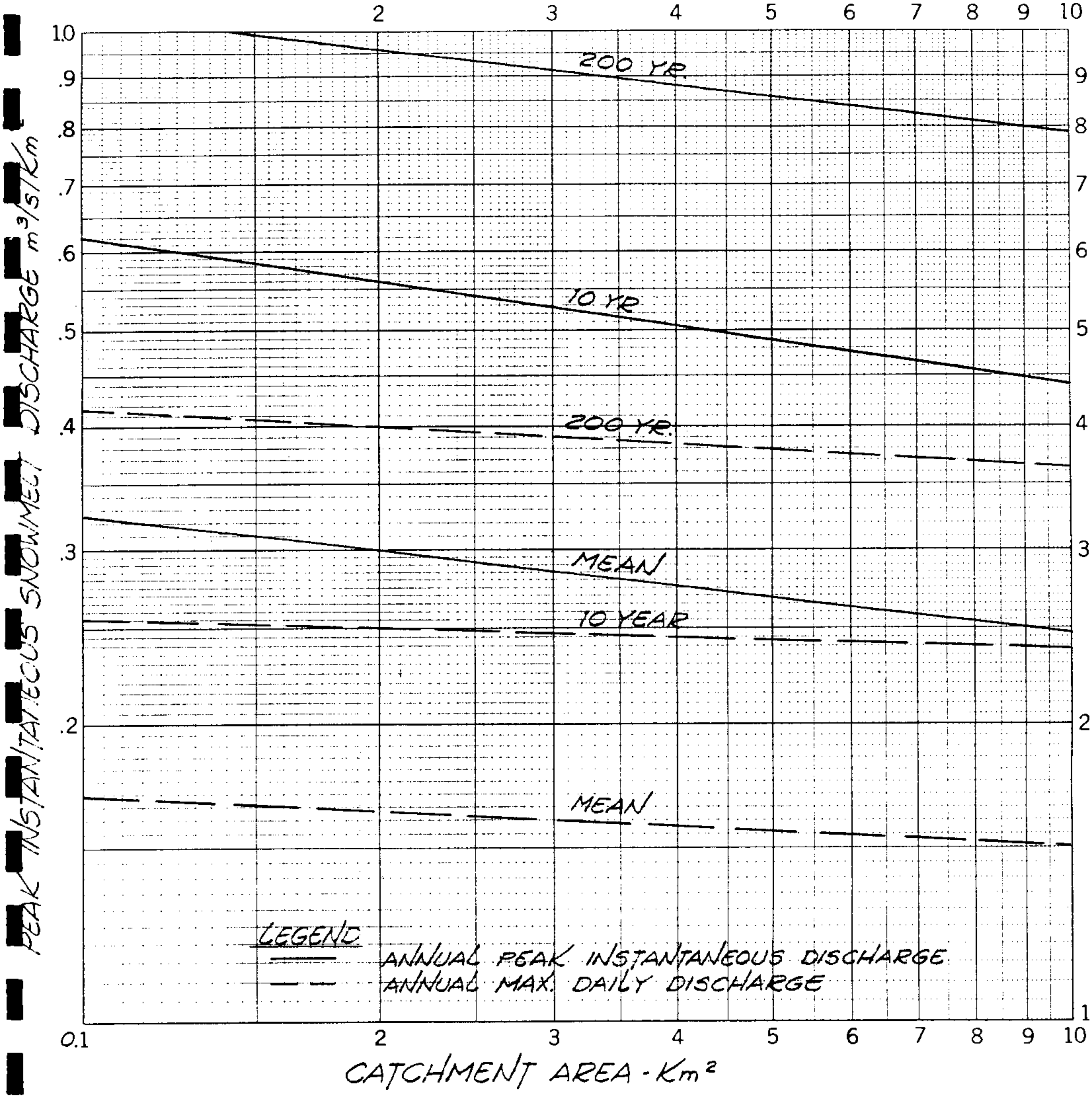
TITLE: PEAK INSTANTANEOUS DISCHARGE - RAINFALL FLOODS

CLIENT: CROWS NEST RESOURCES LTD

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB. 1985	PA 1693	A - 0116	0

APPROVED:

NCI-455-K L



KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT
TELKWA COAL PROJECT

TITLE
PEAK INSTANTANEOUS DISCHARGE
-SNOWMELT FLOODS

CLIENT:
CROW'S NEST RESOURCES LTD.

DATE OF ISSUE
FEB. 1985
APPROVED

PROJECT No.
PA 1692

DWG. No.
A-0117

REV.
0

NCI-455-KL

240

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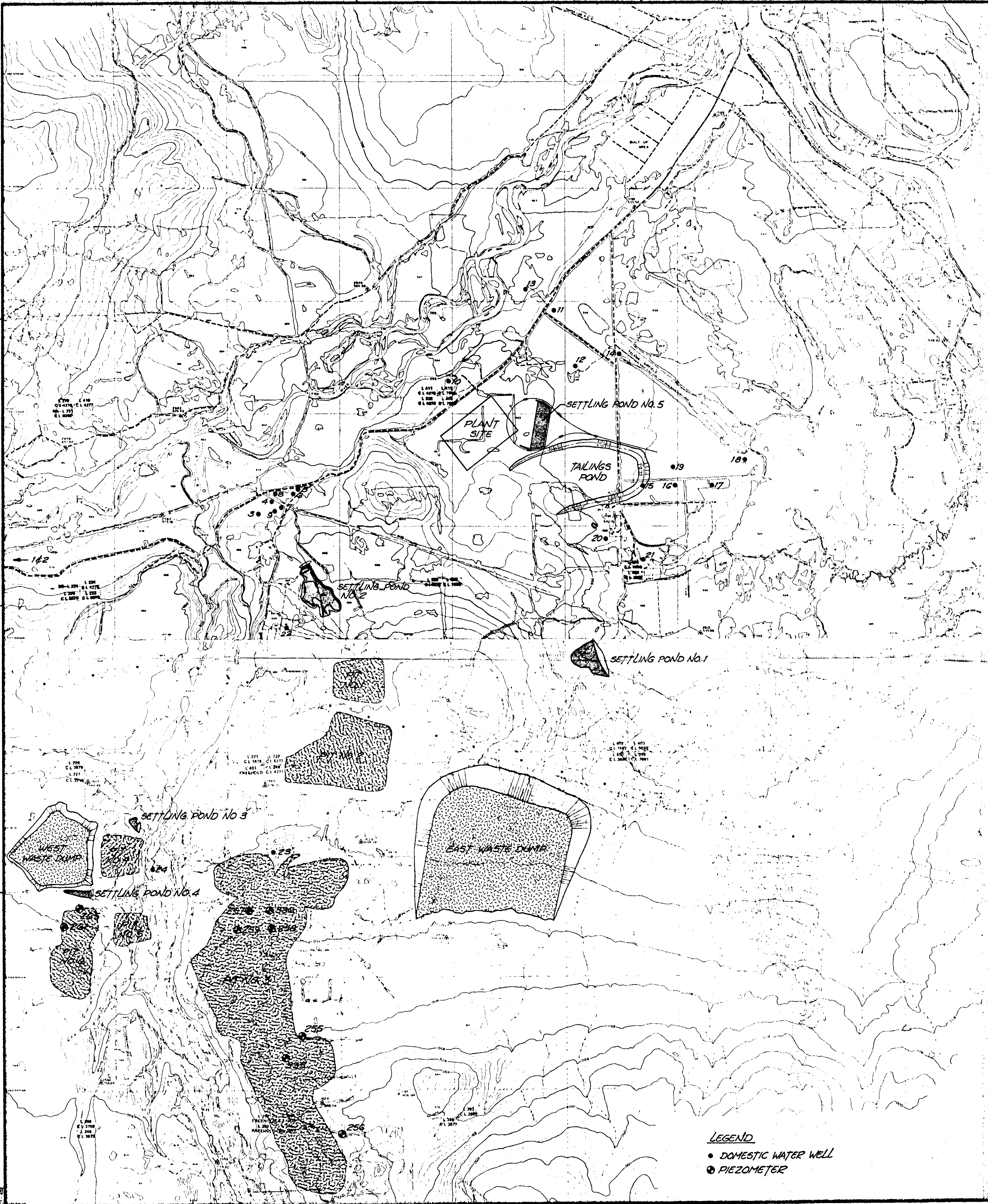
CLIENT: CROWS NEST RESOURCES LTD.			
DESIGN JAL	DRAWN KC	DATE JAN./85	SCALES 1:10 000
PROJECT TELKWA COAL PROJECT (29)			
TITLE TEST HOLE LOCATIONS & MAJOR STRUCTURAL FEATURES			
DATE OF ISSUE FEB. 1985 APPROVED	PROJECT No. PA1692	DWG. No. D-0118	REV. 0

T. G. HARPER



Sample Number	Resident	Property Description	Sampling Date	Point Sampling	Well Location	Well Construction	Field Parameters			Water Source Notes
							pH	T(°C)	Dissolved Oxygen (ppm)	
5321-1	L. Hart	Block A Lot 3, except plan 10224 DL 221 Rge 5 CD Plan 8713	12/9/84	Kitchen hand pump	Approximately 10 m from house in depression beside garden	Dug well, 4.3 m deep with 25 cm diameter galvanized corregated steel casing	6.0	-	-	Well reported to have about 1/2 m of water and to provide limited water supply. Top of well casing is packed with fibreglass insulation. No well housing.
5321-2	L. Cosman	Lot 3, except Plan 10224 DL 221, Rge 5, C.D., Plan 8713	12/9/84	Wellhead portable pump	Approx. 10 m from house and 75 m from Telkwa River on flood plain gravel deposit	Dug well, 2.3 m deep with 90 cm diameter galvanized corrugated steel casing No grouting	6.0	5.3	-	Flood plain gravel aquifer provides abundant supply. Well construction surface runoff to enter well allows outside of casing. Water contains high content of suspended material and lacks clarity.
5321-3	A. Mortenson	Block B, D.L. 224, Rge. 5 C.D. Plan 6417	13/9/84	Garden hose connected to pressure tank	Well site remote from house and about 15 m from Goathorn Creek	Dug well, 3.7 m deep with 90 cm diameter galvanized corrugated steel casing	6.5	13.0	11.6	Well water level about 1 m below ground level. Sufficient supply fed in part by seepage from Goathorn Creek. Heated pump house over wellhead, also houses pressure tank. High water temperature probably reflects pressure tank temperature, not groundwater temperature.
5321-4	L. Langhaug	Block D, D.L. 224, Rge 5, C.D. Plan 6417	13/9/84	House tap	Approximately 12 m from house & 3 m from road	Drilled well 44 m deep with 15 cm diameter steel casing	6.0	7.0	12.0	Well water level about 40 m below ground level. Drilled through 12 m surficial gravel, 18 m of clay and into pea gravel. Wellhead and pressure tank below ground and covered by large diameter corrugated steel culvert.
5321-5	H. Bragg	Block F, D.L. 225, Rge. 5, C.D.	12/9/84	Wellhead tap	Approximately 15 m from road	Drilled well with 15 cm steel casing Well installed in 1979	6.0	-	-	Water supply not large and resident must be careful with use. Well head constructed with concrete pad and housing with metal siding.
5321-6	F. Metzler	Block E, D.L. 225, Rge 5, C.D.	13/9/84	Garden hose	Approximately 5 m from trailer	Drilled well 13 m deep	6.0	7.0	11.1	Well serves two trailer homes. Located on gravelly terrain.
5321-7	-	Mine pit area	14/9/84	Test Pit seepage	-	-	7.0	10.5		Seepage area on lower slope of reclaimed area. Seepage is diffuse and covers area some 60 by 15 m.
5321-8	G. Silveira	Lot 1, Block C, D.L. 225, Rge. 5, C.D.	13/9/84	Kitchen tap	Approximately 6 m south of house	Drilled well 43 m deep	6.0	8.0	8.7	Wellhead below ground and sealed. No shortage of water.
5321-9	R. Rhodes	Block D, D.L. 225, Rge 5, C.D.	14/9/84	Kitchen tap	Approximately at toe of slope	Dug well with 90 cm diameter galvanized corrugated casing.	6.0	10.5	-	Less than 3 meters of water in well which is dug in gravel.
5321-10	M. Visser	Lot A, Block B, except Plan 10444, D.L. 412, Rge. 5, C.D.	14/9/84	Garden hose	Approximately 200 m north of house at base of steep slope	Dug well	6.0	10.5	-	Well in alluvial sand and gravel deposit. 3 to 4 m of water in well.
5321-11	N. Dutov	Block D, D.L. 412, Rge. 5, C.D.	14/9/84	Garden hose	Few metres east of house	Drilled well 21 m deep with 15 cm	6.0	9.0	-	Well drilled in outwash sand and gravel which is exposed in gravel pit some 50 m from house.
5321-12	D. Hoover	Block E, D.L. 412, Rge. 5, C.D.	14/9/84	Garden hose	Adjacent to house	Drilled well 21 m deep with 15 cm diameter steel casing	6.0	8.5	-	Well drilled in outwash sand and gravel aquifer. Water level reported to be 15 m below ground level.
5321-13	Van Der Horst	Block C, D.L. 412, Rge. 5, C.D.	15/9/84	House tap	Near house in depression	Dug well 2 m deep with 90 cm diameter galvanized, corrugated casing.	6.0	8.5	-	Well dug into sand and gravel near a slough and river.
5321-14	Laird	Lot 8, D.L. 413, Plan 9490, Rge: 5 C.D.	15/9/84	House tap		Drilled well 15 m deep with 15 cm diameter steel casing	6.0	8.5	-	Sand and gravel aquifer with good supply of water (20/gpm).
5321-15	R. Paine	Lot 15, D.L. 408, Rge. 5 C.D., Plan 10149	13/9/84	Garden hose at well head	30 m south of house	Drilled well 12 m deep with 15 cm diameter steel casing.	6.0	6.5	-	Well in outwash sand and gravel. Good water supply. Pump and pressure tanks at wellhead enclosed in pumphouse.
5321-16	R. Beamer	Lot 12, D.L. 408, Rge. 5, C.D., Plan 10149	13/9/84	Hand pump at well head	Adjacent to house under construction	Newly drilled well 18 m deep with 15 cm diameter steel casing	6.0	6.5	-	Well drilled through outwash sand and gravel to full depth. Water level estimated 6 m below ground level.
5321-17	T. Cebuliak	Lot 10, D.L. 408, Rge. 5 C.D. Plan 10149	13/9/84		Adjacent to trailer house	Dug well, 6 m deep with 15 cm diameter steel casing. Casing slotted for 2 m.	6.0	-	-	Water level 4.3 m and varies only small amount with seasons. Well dug in outwash sand and gravel.
5321-18	Campbell	Block C, D.L. 225, Rge. 5, C.D.	16/9/84			Drilled - 12 m well with 15 cm steel casing	6.0	8.5	-	New well providing good water supply.
5321-19	Penner									
5321-20	L. Parks	S.E. 1/4, D.L. 409, Rge. 5, C.D.	19/9/84	Kitchen tap	200 m south of house in topographic depression	Dug well 6 m deep with large diameter corrugated steel casing	6.0	15.0	-	Heated pumphouse with concrete floor. Shortage of water. Water turbid.
5321-21	O. Helps	Block A, except Plan 10149, D.L. 408, C.D.	13/9/84	Garden hose at wellhead	30 m northeast of house in pumphouse	Drilled (?) well with 20 cm diameter steel casing	6.0	6.5	-	Well drained flat outwash plain. Well serves two houses.
5321-22	D. Helps	as above	13/9/84	Wellhead	Adjacent to livestock barn	Drilled (?) well with 20 cm diameter casing.	6.0	10.0	-	Water turbid with sediment. Wellhead below ground with pressure tank.
5321-23	Kerr	D.L. 222, except Block A and B, Rge. 5, C.D.		Pumped directly from well	Down slope from house	Dug well 2.5 m deep with 90 cm diameter corrugated steel casing.	7.0	9.5	-	Well pumped 20 minutes before collecting sample. Well not in good condition and had not been in use.
5321-24	J. Dehoog	D.L. 248, Rge. 5, C.D.	12/9/84	Garden hose	30 m north of house and adjacent to small lake	Dug well with 90 cm diameter galvanized corrugated casing.	6.0	8.3	-	Water level estimated 2 m below ground level. Water shortage in dry periods and dependant on seepage from small lake.
5321-25	Bulkley Valley Collieries (L. Gething)	D.L. 401, Rge. 5, C.D.	12/9/84	Small reservoir in house	Estimated 8 m from house and 15 m from Goathorn Creek	Dug will installed in 1956 and cased with three 45 gal. drums.	6.0	6.1	-	Wellhead covered by several feet of soil and overgrown by grass and weeds. Located in small corral.

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TO BE READ WITH KLOHN LEONOFF REPORT DATED

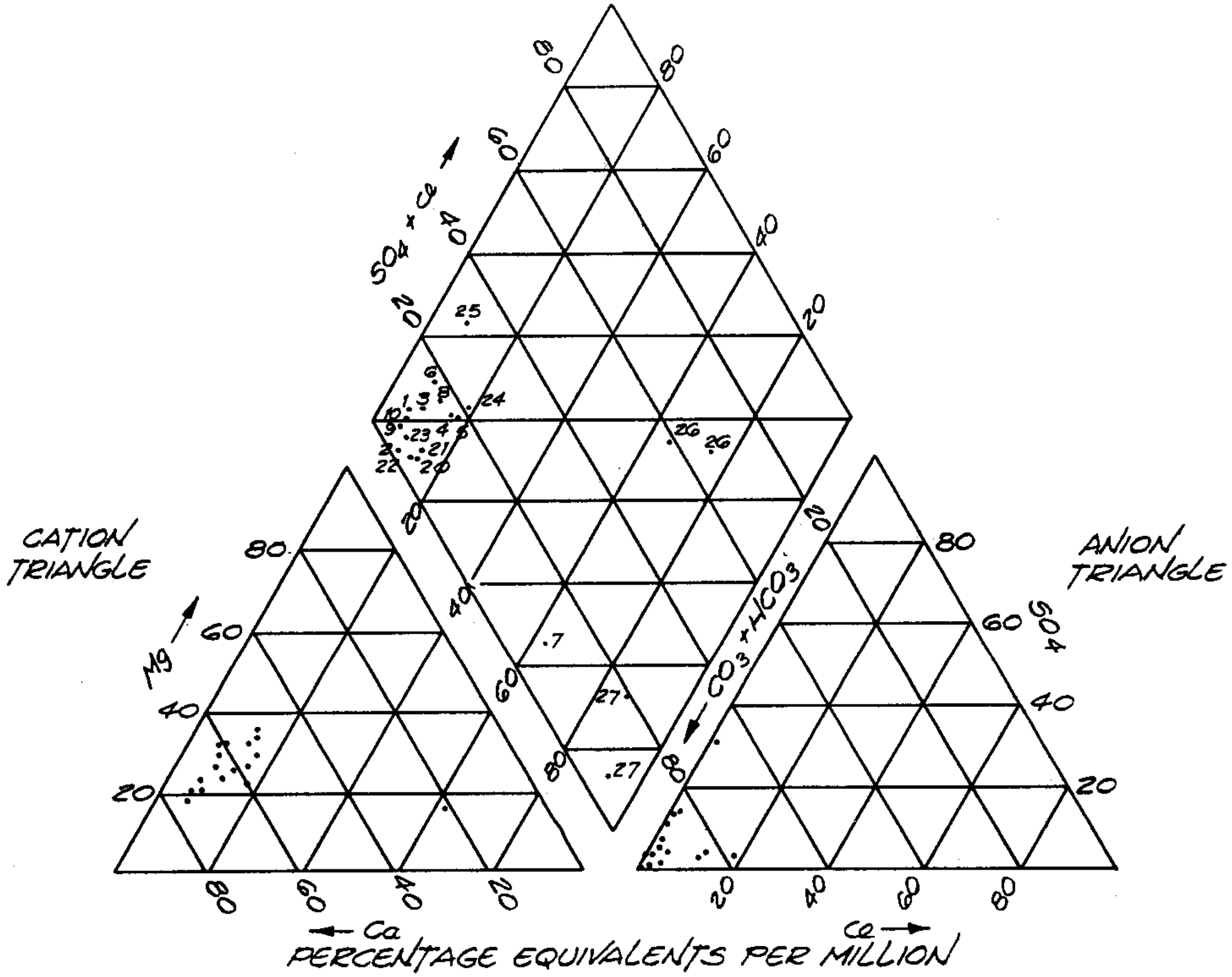
SCALE:

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: CROWS NEST RESOURCES LTD.

REV.	DATE	REVISION DETAILS

DESIGN J.A.L.
DRAWN Chick
DATE 85-02-25
SCALES 1:20 000
PROJECT TELKWA COAL PROJECT (30)
TITLE GROUNDWATER QUALITY SAMPLING SITES
DATE OF ISSUE FEB. 1985
APPROVED
PROJECT No. PA1692
DWG. No. D-0119
REV. 0



•22 - SAMPLE NUMBER (SEE TABLE AND APPENDIX)

NOTES

1. SAMPLES PLOTTED (EXCEPT NUMBER 7) ARE REPRESENTATIVE OF RURAL DOMESTIC WATER SUPPLIES IN VICINITY OF THE MINESITE.
2. NUMBER 7 IS SEEPAGE WATER FROM RECLAIMED TEST PIT.
3. NUMBERS 26 & 27 RESPECTIVELY ARE FROM TESTHOLES 255 AND 257.

SCALE

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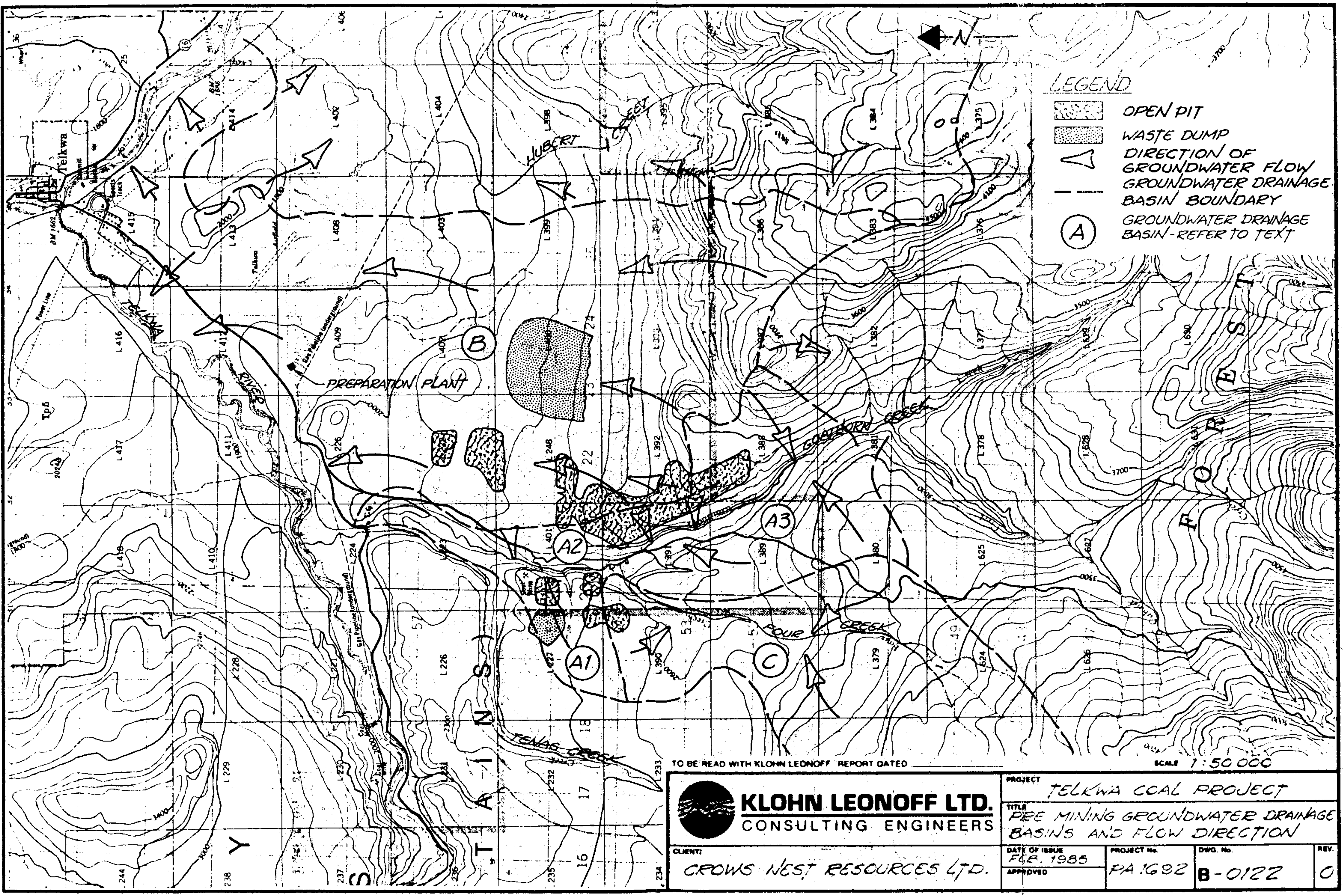
PROJECT: TELKWA COAL PROJECT

TITLE: GROUNDWATER CHEMISTRY DOMESTIC WATER SUPPLIES

CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB. 1985	PA 1692	A - 0120	0
APPROVED			



TO BE READ WITH KLOHN LEONOFF REPORT DATED

SCALE 1:50 000

KLOHN LEONOFF LTD.
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PROJECT TELKWA COAL PROJECT

TITLE PRE MINING GROUNDWATER DRAINAGE BASINS AND FLOW DIRECTION

CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB. 1985	PA 1692	B-0122	0
APPROVED			

240

TO BE READ WITH KLOHN LEONOFF REPORT DATED ________

SCALE:

REV.	DATE	REVISION DETAILS

DESIGN L.F.S.
DRAWN Chick
DATE 84-12-05
SCALES 1:20 000

KLOHN LEONOFF LTD.
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PROJECT TELKWA COAL PROJECT (31)

TITLE CHANGE IN LOCAL DRAINAGE BOUNDARIES

CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE FEB. 1985
APPROVED
PROJECT No. PA1692
DWG. No. D-0123
REV. 0

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DESIGN DISCHARGES AND VELOCITIES

Location	Drainage Area km²	10 Year Flood Peak		200 Year Flood Peak	
		Discharge m³/s	Velocity m/s	Discharge m³/s	Velocity m/s
1	1.1	0.7	1.2	1.1	1.5
2	0.2	0.1	0.6	0.3	0.7
3	3.3	1.7	1.2	3.0	1.4
4	4 9	2.4	2.7	4.2	3.2
5	5 1	2.5	1.9	3.4	2.3
6	9.7	4.3	3.0	7.6	3.6
7	3.2	1.7	2.0	2.9	2.4
8	1.2	0.7	1.3	1.2	1.6
9	1.1	0.7	1.4	1.2	1.8
10	4.1	2.1	2.2	3.6	2.6
11	0.6	0.4	0.8	0.7	1.1
12	5.6	2.7	3.1	4.7	3.9
13	0.6	0.4	0.9	1.0	1.3
14	6.9	3.2	1.9	5.7	2.2
15	0.2	0.1	1.1	0.3	1.2
16	0.6	0.4	0.6	0.8	0.8
17	0.4	0.3	0.9	0.5	1.0
18	1.5	0.9	1.8	1.5	2.2
19	1.0	0.6	1.0	1.1	1.2
20	1.4	0.8	0.9	1.4	1.1
21	0.3	0.2	0.6	0.4	0.7
22	0.2	0.2	0.5	0.3	0.7

NOTE: THE DRAINAGE SYSTEM SHOWN HAS BEEN DESIGNED BASED ON 1:5000 TOPOGRAPHY WITH 5m CONTOUR INTERVALS. SEE DRAWINGS BY CROWS NEST RESOURCES LIMITED.

T. G. HARPER

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SCALE:

REV. | DATE | REVISION DETAILS

DESIGN L.F.S. | DRAWN Chick | DATE 84-11-30 | SCALES 1:10 000

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

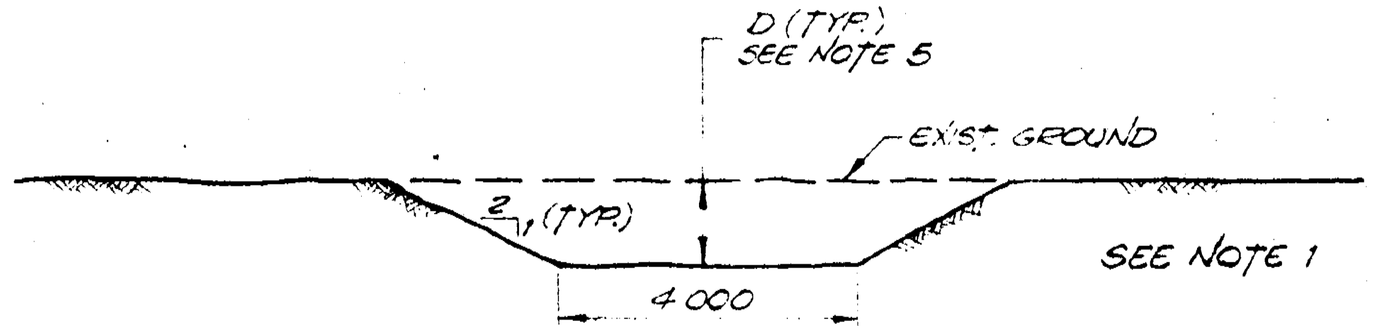
PROJECT TELKWA COAL PROJECT ㉜

TITLE LAYOUT OF DRAINAGE SYSTEM

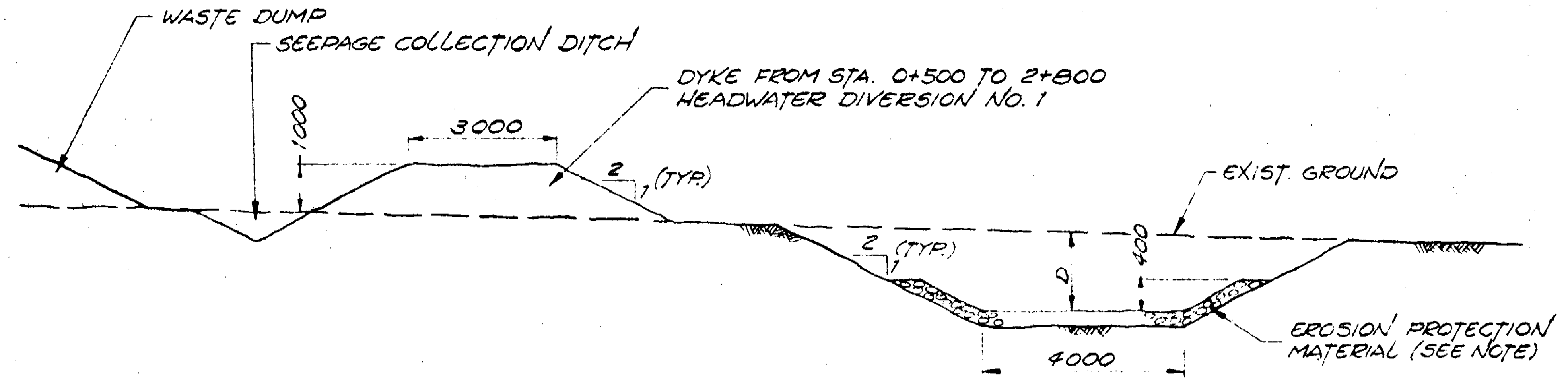
CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE 18-01-85 | PROJECT No PA 1692 | DWG. No. D-0124 | REV. 0

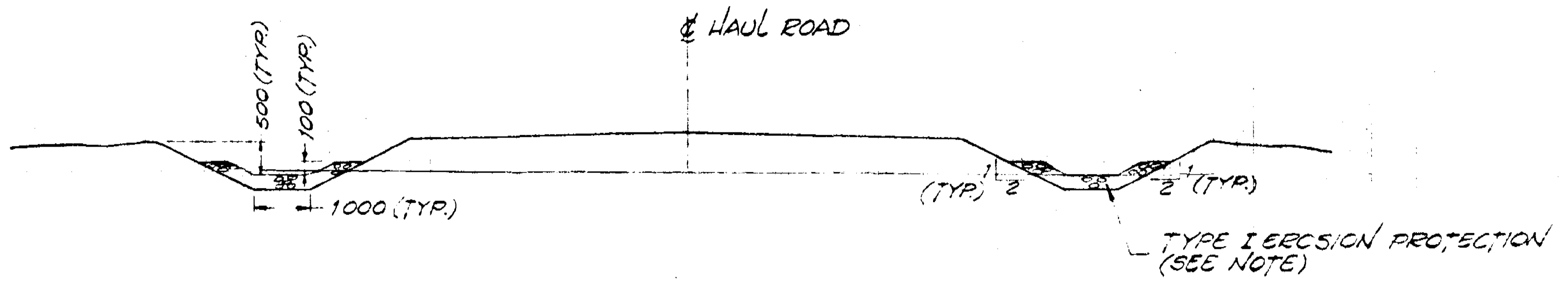
APPROVED



SECTION (A) N.T.S. 0124



SECTION (B) N.T.S. 0124



SECTION (D) N.T.S. 0124

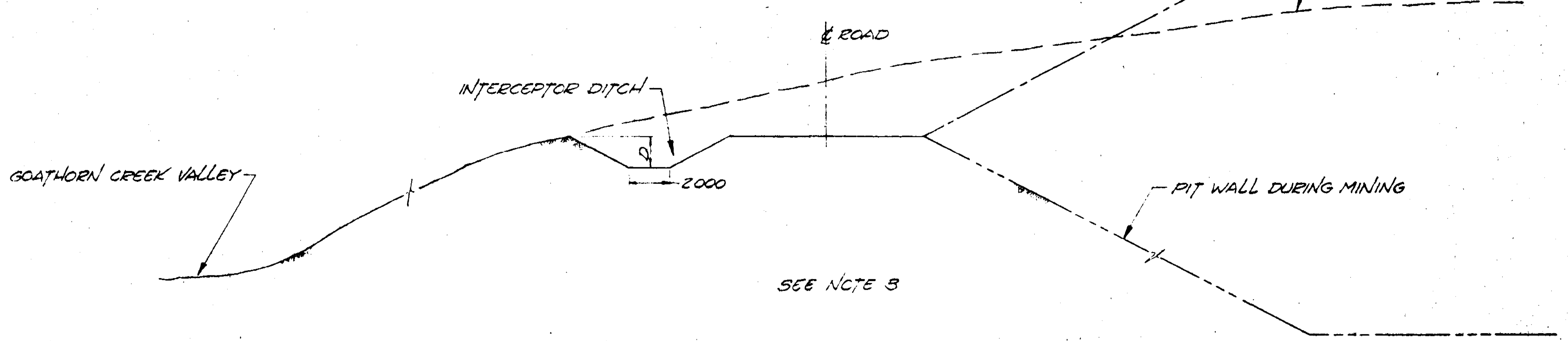
SEE NOTE 4

EROSION PROTECTION

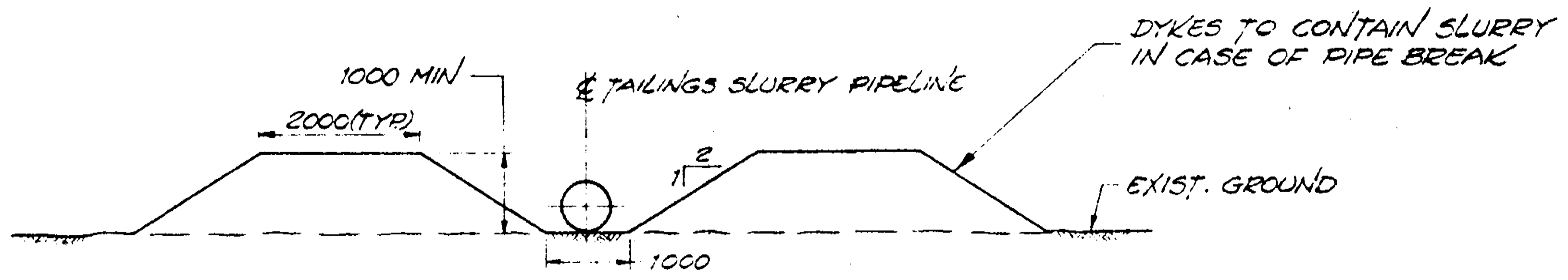
EROSION PROTECTION IS REQ'D. ON HEADWATER DIVERSION NO. 1 FROM STA. 0+000 TO 3+000, SPILLWAY CHANNELS OF SETTLING PONDS NO. 1 & 2 AND ROADSIDE DITCHES WITHIN GOATHORN CREEK VALLEY.
TYPE I IS REQ'D. WHERE CHANNEL GRADIENTS ARE LESS THAN 6%.
TYPE II IS REQ'D WHERE CHANNEL GRADIENTS EXCEED 6%.
GEOTEXTILE FILTER FABRIC TO BE PROVIDED BENEATH TYPE I & II EROSION PROTECTION MATERIAL.

	TYPE I	TYPE II
THICKNESS	200	300
D 100	200	300
D 50	100	200
D 25	25	50

NOTE: INTERCEPTOR DITCH TO BE EXCAVATED BEFORE CLEARING AND STRIPPING PIT AREA. CONSTRUCTION TO PROCEED FROM DOWNSTREAM END TO ENSURE THAT ALL SURFACE RUNOFF FROM CONSTRUCTION AREA IS ROUTED THROUGH SETTLING PONDS.



SECTION (C) N.T.S. 0124



SECTION (E) N.T.S. 0124

NOTES

1. SECTION A IS TYPICAL OF:
   - INTERCEPTOR DITCH NO. 1 FROM OUTLET TO POINT OF ENTRY INTO PIT NO. 3.
   - INTERCEPTOR DITCHES NO. 2, 3, 4, 5, 6, 7, 8, 9 & 10.
   - HEADWATER DIVERSION NO. 1, STA. 3+000 - 5+850.
   - OUTLET DITCH FOR EMERGENCY SPILLWAY OF TAILINGS POND.
2. SECTION B IS TYPICAL OF
   - HEADWATER DIVERSION NO. 1, STA. 0+000 - 3+000.
   - SPILLWAY CHANNELS FOR SETTLING PONDS NO. 1 & 2.
3. SECTION C IS TYPICAL OF INTERCEPTOR DITCH NO. 1 WITHIN LIMITS OF PIT NO. 3.
4. ROADSIDE DITCHES TO BE CONSTRUCTED IN GOATHORN CREEK VALLEY AS SHOWN IN SECTION D.
5. MINIMUM DEPTHS OF HEADWATER DIVERSION & INTERCEPTOR DITCHES ARE AS FOLLOWS:

CHANNEL	STATION	'D'
HEADWATER DIVERSION NO. 1	0+000 - 4+400	1.0m.
" " " 1	4+400 - END	0.6m.
" " " 2	FULL LENGTH	0.6m.
INTERCEPTOR DITCHES NO. 1-8	FULL LENGTH	0.6m.
" " " 9 & 10	FULL LENGTH	0.8m.
SPILLWAY CHANNEL NO. 1	FULL LENGTH	1.0m

PROFESSIONAL ENGINEER
T. G. HARPER

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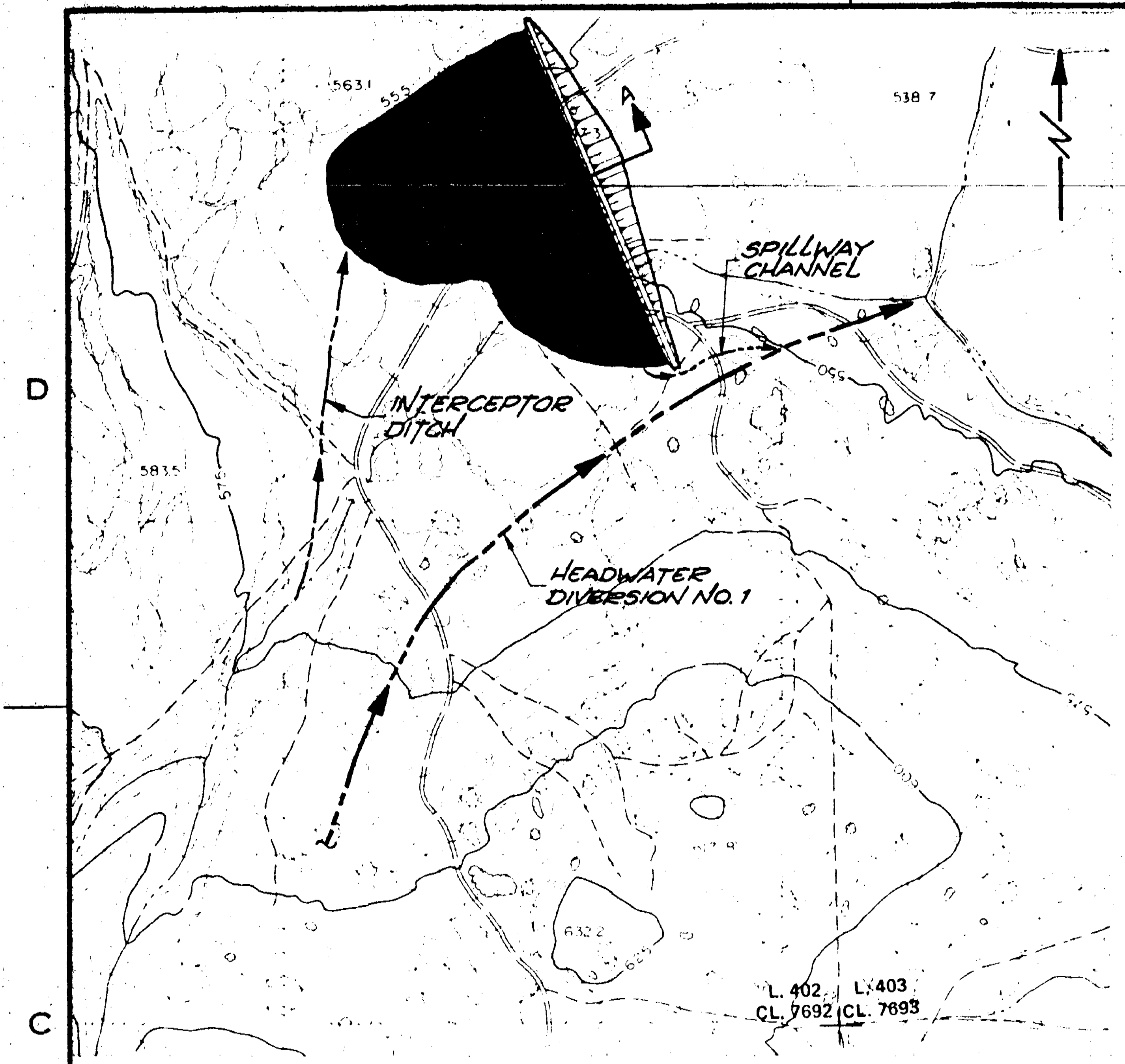
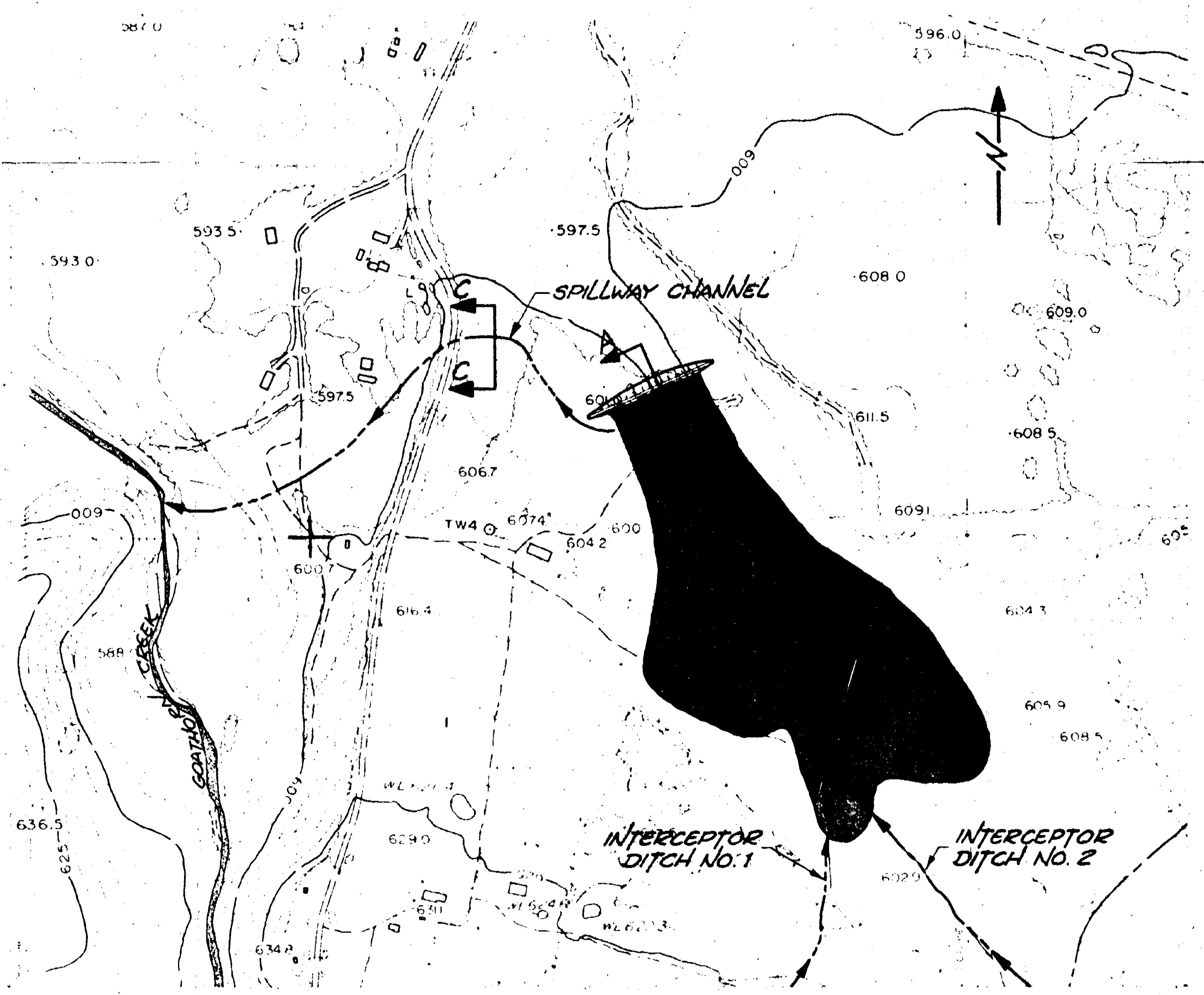
SCALE:
REV. | DATE | REVISION DETAILS
DESIGN L.F.S. | DRAWN Chick | DATE DEC. '84 | SCALES N.T.S.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

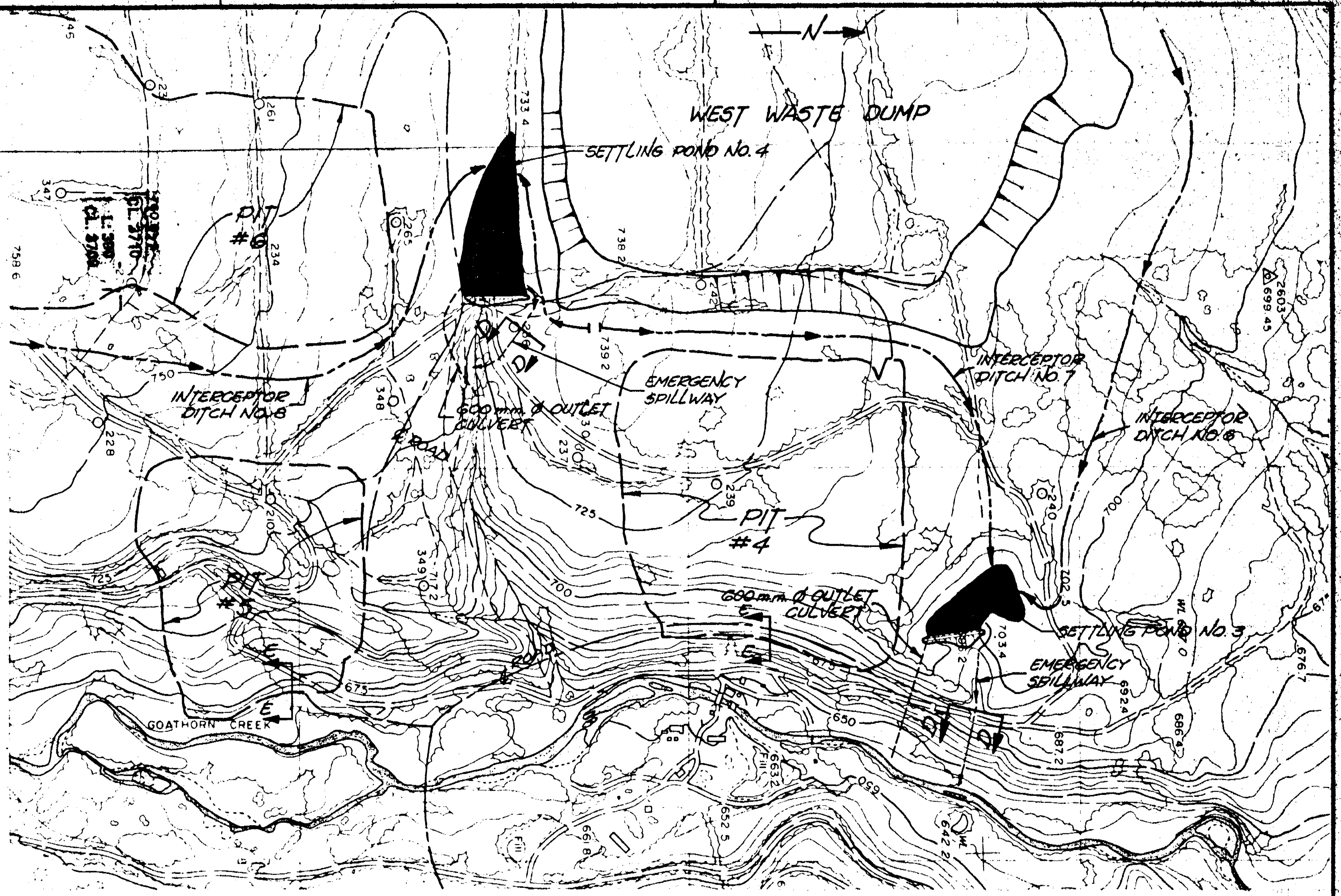
PROJECT TELKWA COAL PROJECT (33)
TITLE DIVERSIONS, DITCHES & SPILLWAY CHANNELS SECTIONS & DETAILS
CLIENT: CROWS NEST RESOURCES LTD.
DATE OF ISSUE 18-01-85
APPROVED
PROJECT No. PA1692
DWG. No. D-0125
REV. 0



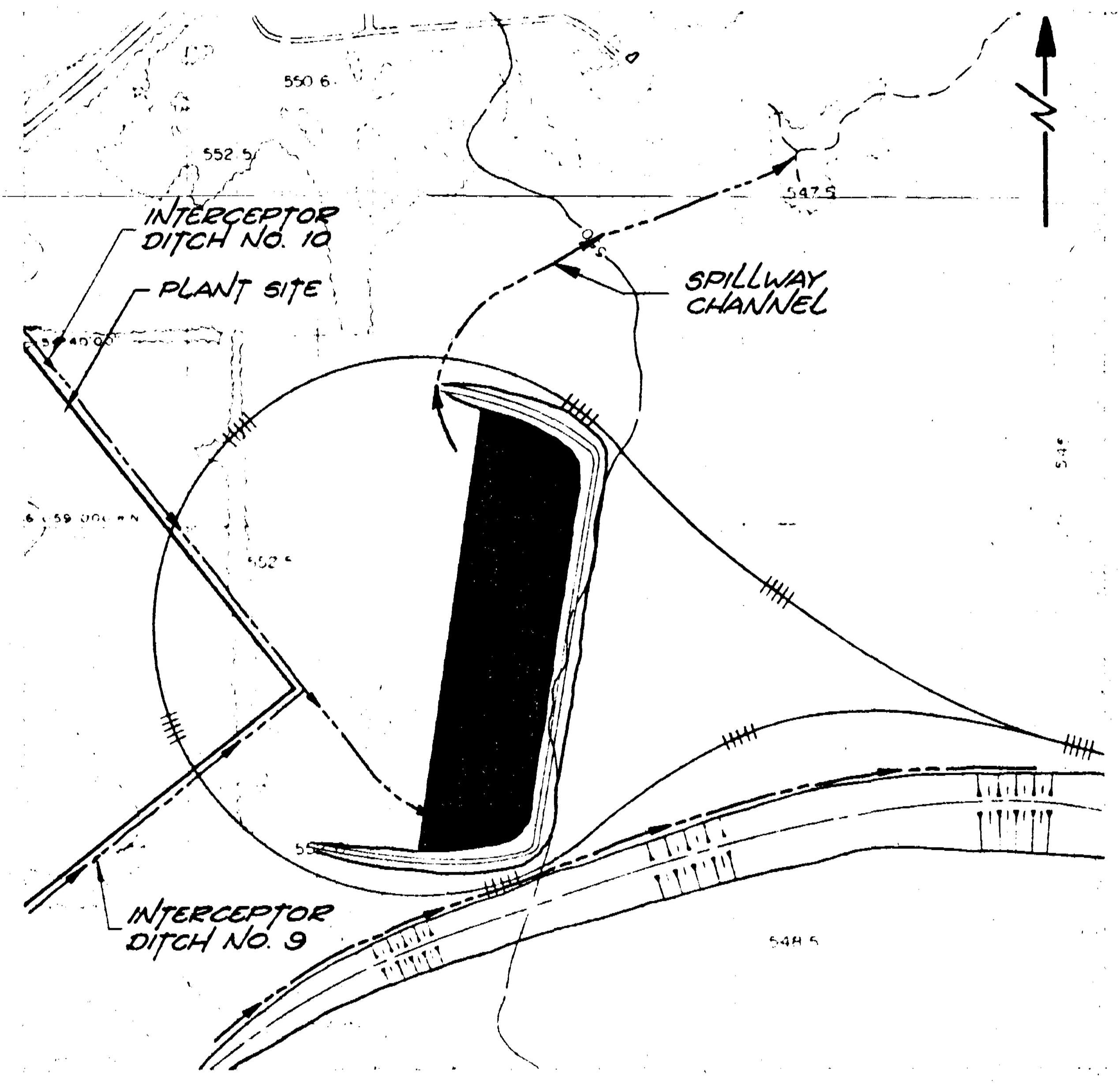
PLAN - SETTLING POND NO. 1
SCALE - 1:5000



PLAN - SETTLING POND NO. 2
SCALE - 1:5000

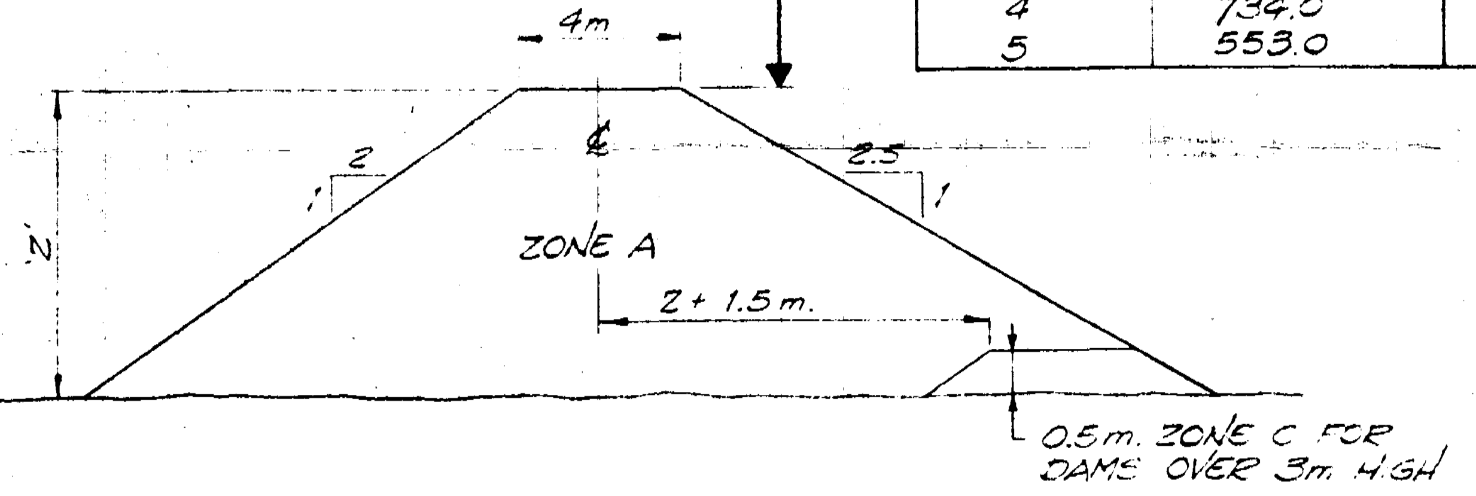


PLAN - SETTLING PONDS NO. 3 & NO. 4
SCALE - 1:5000

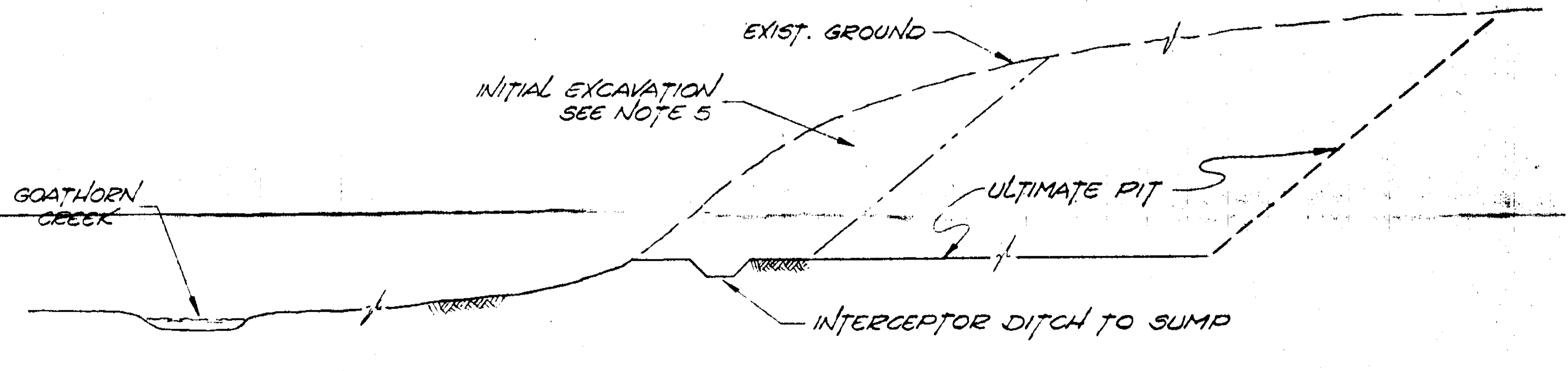


PLAN - SETTLING POND NO. 5
SCALE - 1:5000

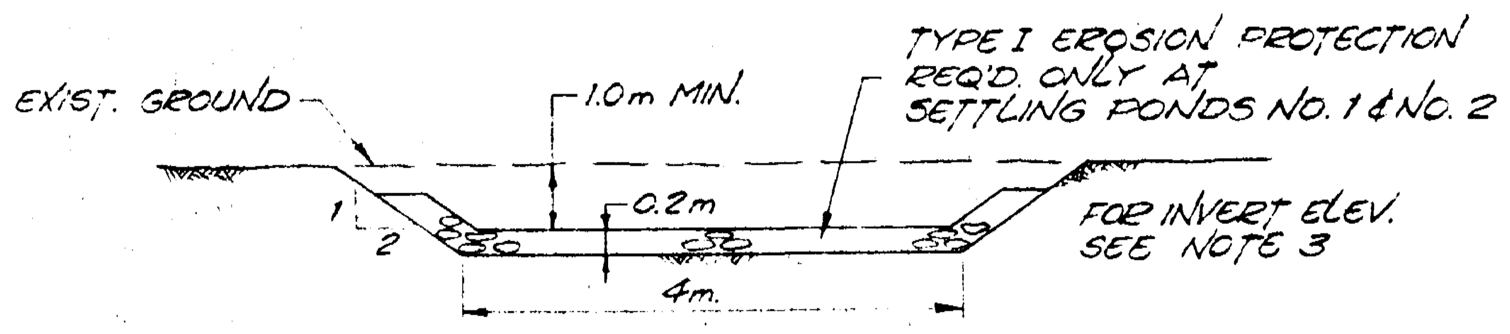
SETTLING POND NO.	DAM CREST ELEVATION	APPROX. DAM HEIGHT 'Z'
1	555.1	2.9m.
2	602.2	2 m.
3	702.6	3m.
4	734.0	4m
5	553.0	3m.



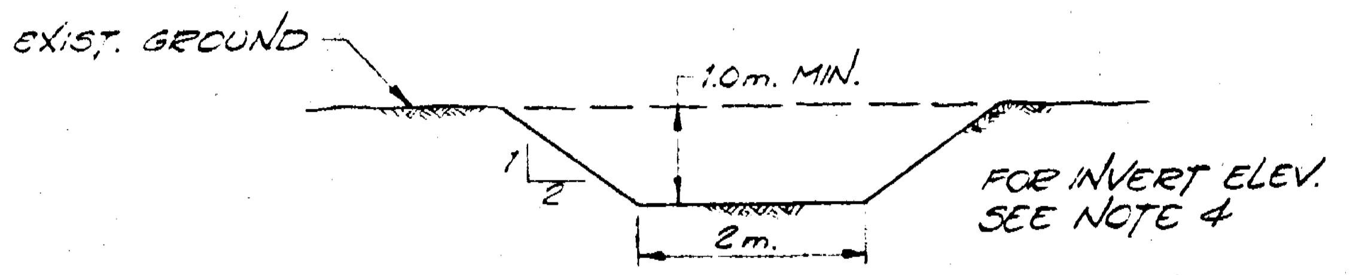
SECTION A-A - TYPICAL DAM
N.T.S.



SECTION E-E
N.T.S.



SECTION C-C - SPILLWAY CHANNEL
N.T.S.



SECTION D-D - EMERGENCY SPILLWAY
N.T.S.

NOTES

1. SECTION A-A IS TYPICAL FOR ALL DAMS.
2. FOR ZONE DEFINITIONS SEE TEXT.
3. INVERT OF SPILLWAY CHANNELS AND OUTLET CULVERTS AS FOLLOWS:

SETTLING PONDS	INV. AT POND OUTLET	MIN. GRADIENT
1	554.0	2%
2	601.0	1%
3	701.0	10%
4	732.5	10%
5	522.0	1%

4. INVERT OF EMERGENCY SPILLWAYS AS FOLLOWS:

SETTLING PONDS	INV. AT POND OUTLET	MIN. GRADIENT
3	701.6	3%
4	733.0	3%

5. TRENCH TO BE OPENED BEFORE GENERAL CLEARING AND STRIPPING, TO CATCH ALL RUNOFF FROM THE PIT AREA. SURFACE RUNOFF TO BE PUMPED TO SETTLING POND NO. 4 FOR CLARIFICATION. AN IN-PIT SETTLING POND WITH AN ARMOURED CHANNEL OUTLET TO GOATHORN CREEK IS TO BE BUILT AFTER MINING.

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TO BE READ WITH KLOHN LEONOFF REPORT DATED ______
SCALE:

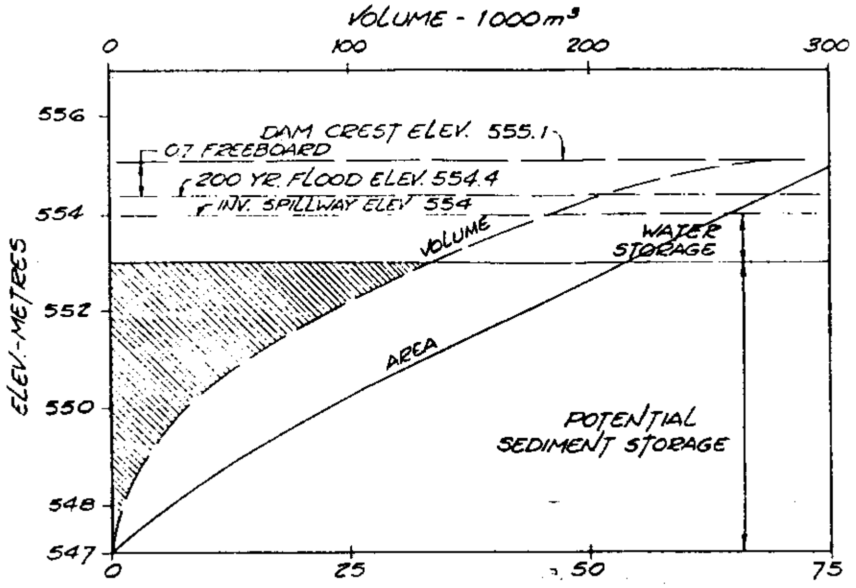
KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

CLIENT: CROWS NEST RESOURCES LTD.

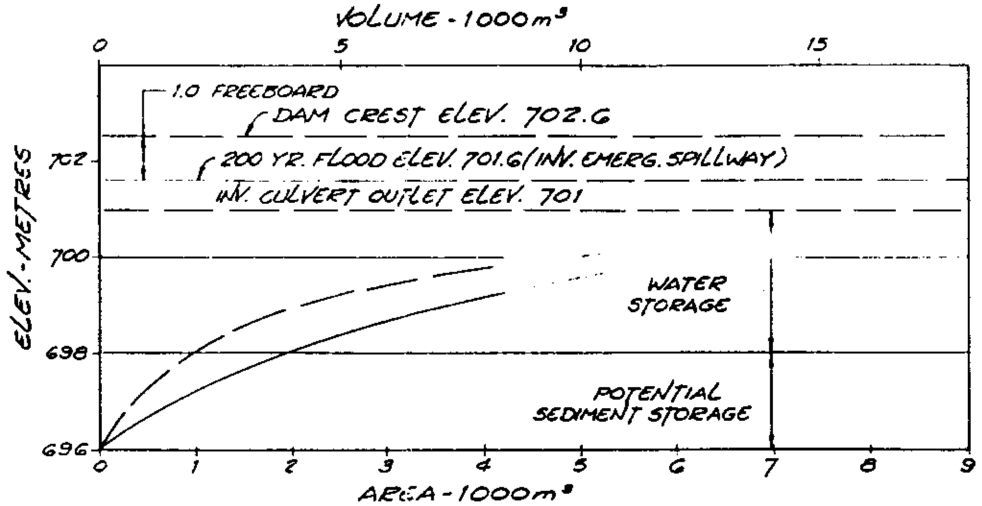
REV.	DATE	REVISION DETAILS	
DESIGN L.F.S.	DRAWN Chick	DATE 84-11-29	SCALES AS SHOWN

PROJECT: TELKWA COAL PROJECT
TITLE: SETTLING PONDS PLANS & SECTIONS (34)

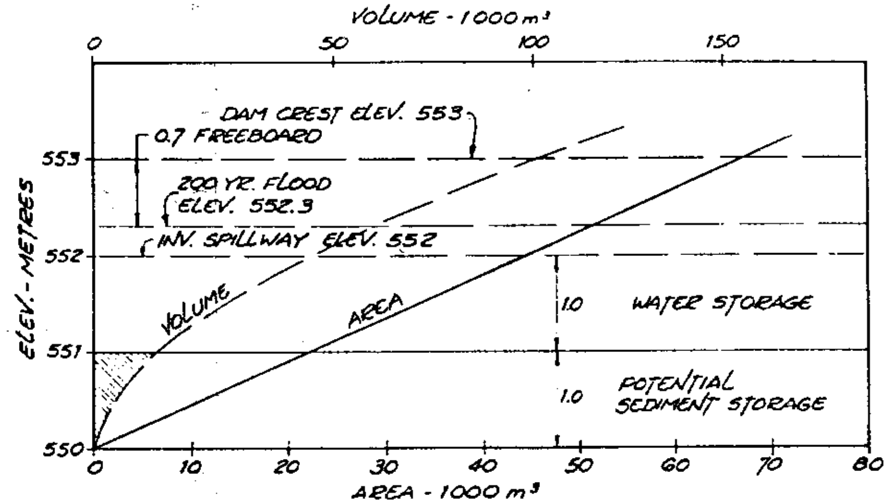
DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB. 1985 APPROVED	PA1692	D-0126	0



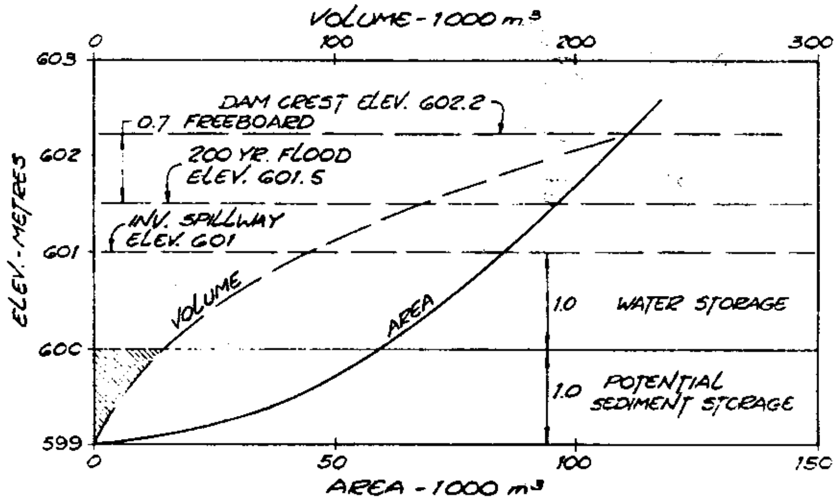
SETTLING POND NO. 1



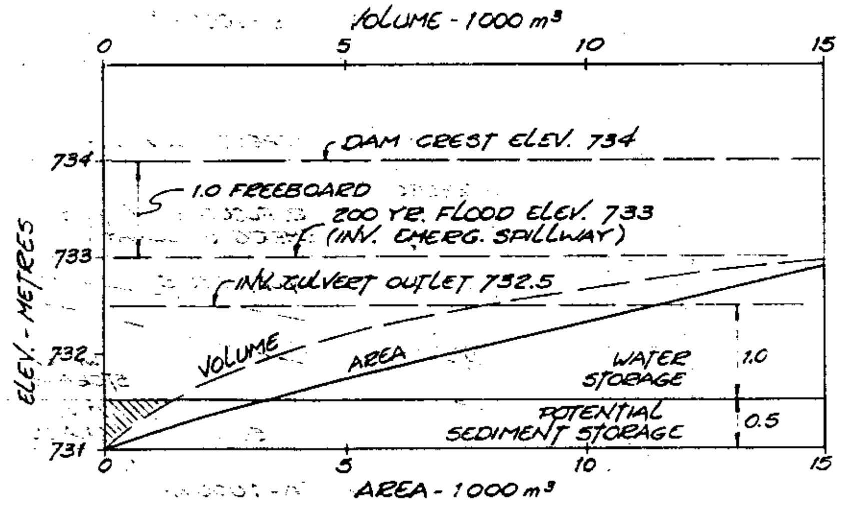
SETTLING POND NO. 3



SETTLING POND NO. 5



SETTLING POND NO. 2



SETTLING POND NO. 4

TO BE READ WITH KLOHN LEONOFF REPORT DATED ________

SCALE N.T.S. 240

KLOHN LEONOFF LTD.
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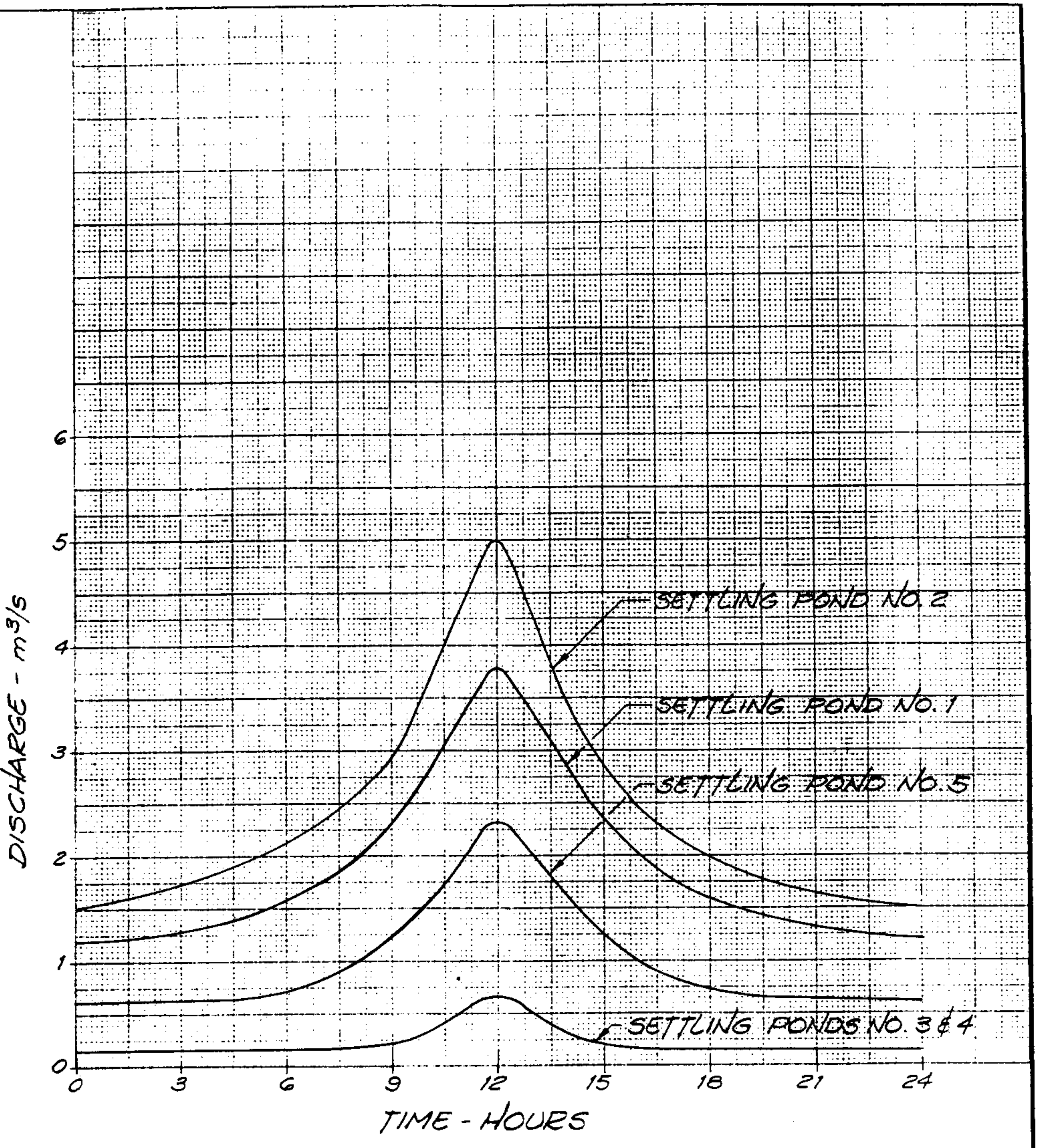
PROJECT TELKWA COAL PROJECT
TITLE SETTLING POND AREA AND CAPACITY CURVES
CLIENT: CROWS NEST RESOURCES LTD.
DATE OF ISSUE FEB. 1985
APPROVED
PROJECT No. PA1692
DWG. No. B-0127
REV. 0

NCI-486-K.L.



KLOHN LEONOFF LTD.
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PROJECT
TELKWA COAL PROJECT

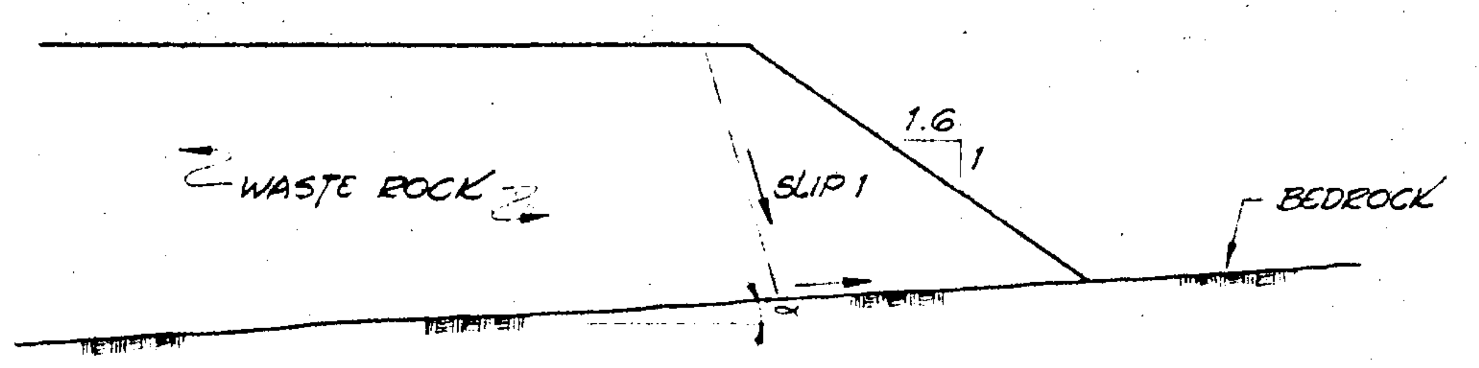
TITLE
SETTLING POND INFLOW
HYDROGRAPHS - 200 YR. FLOOD

CLIENT: CROWS NEST RESOURCES LTD.	DATE OF ISSUE APPROVED	PROJECT No. PA 1629	DWG. No. A - 0128

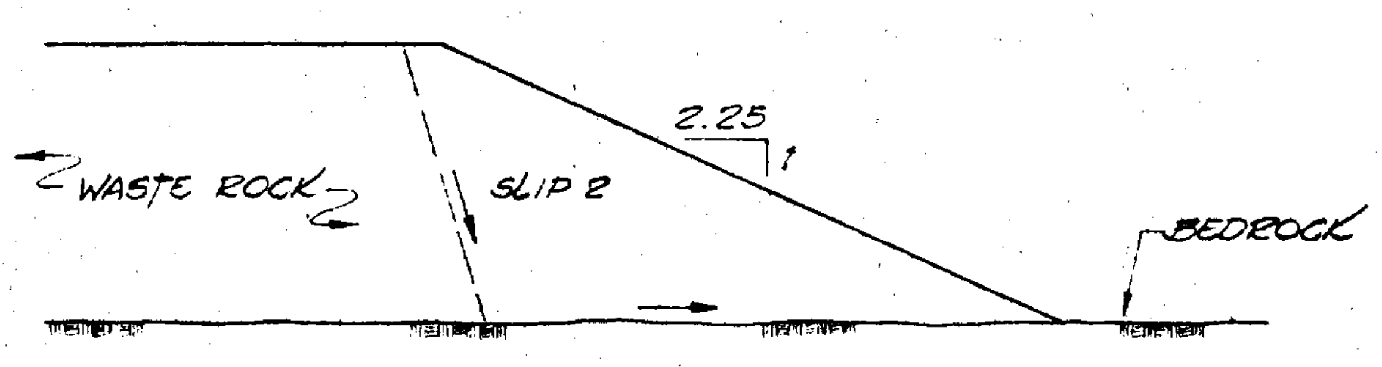
NCI-455-KL

SOIL PARAMETERS

SOIL TYPE	EFFECTIVE COHESION kPa	EFFECTIVE FRICTION ANGLE DEGREES	UNIT WEIGHT kN/m³
WASTE ROCK	0	32	18
BEDROCK	0	16	22



NORTH-SOUTH SLOPES WHERE α > 13°



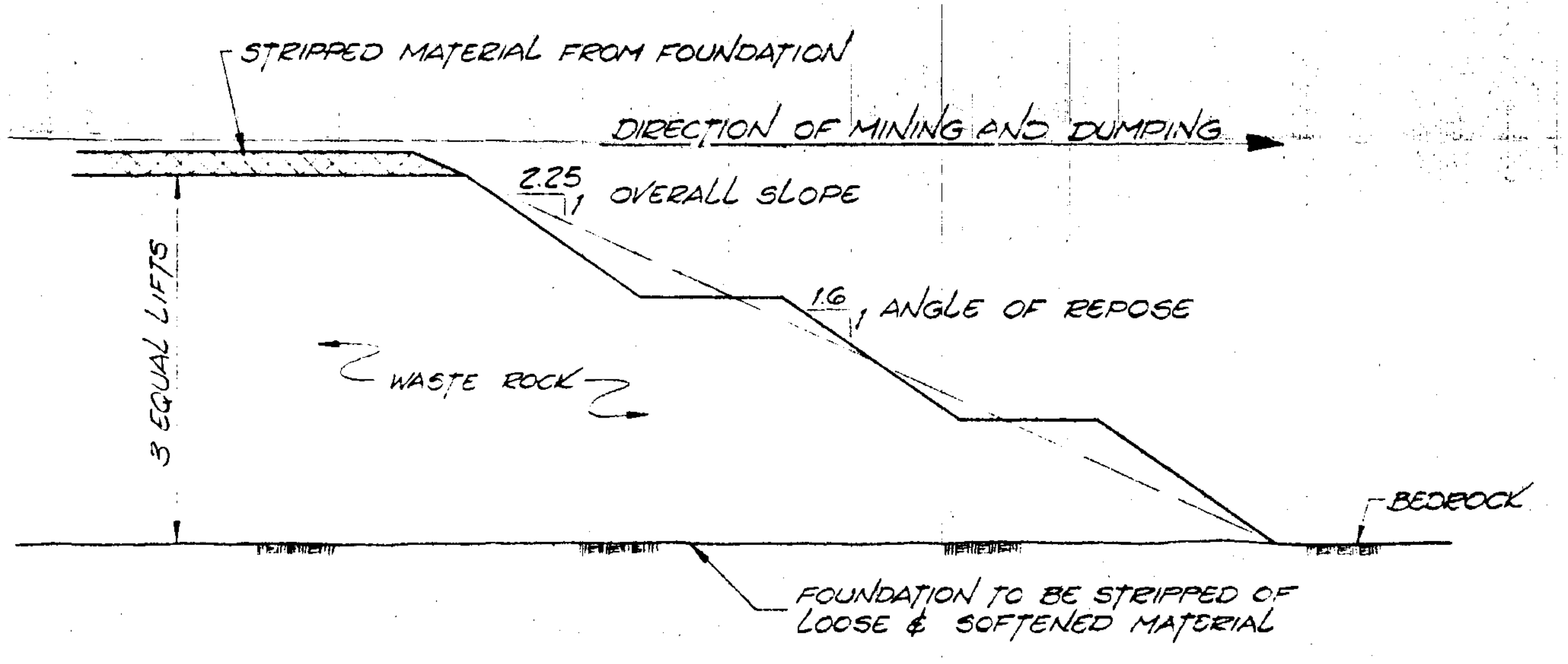
EAST-WEST SLOPES

IN PIT DUMPS - TYPICAL FAILURE MODES

SLIP	ru IN FOUNDATION	FACTOR OF SAFETY
1	0	1.3 FOR α = 13°
2	0	1.3
2	0.2	1.2

NOTE: FOR 1.6:1 H:V SLOPE, SURFACE SLIDE HAS FACTOR OF SAFETY OF 1.0
FOR 2.25:1 H:V SLOPE, SURFACE SLIDE HAS FACTOR OF SAFETY OF 1.4

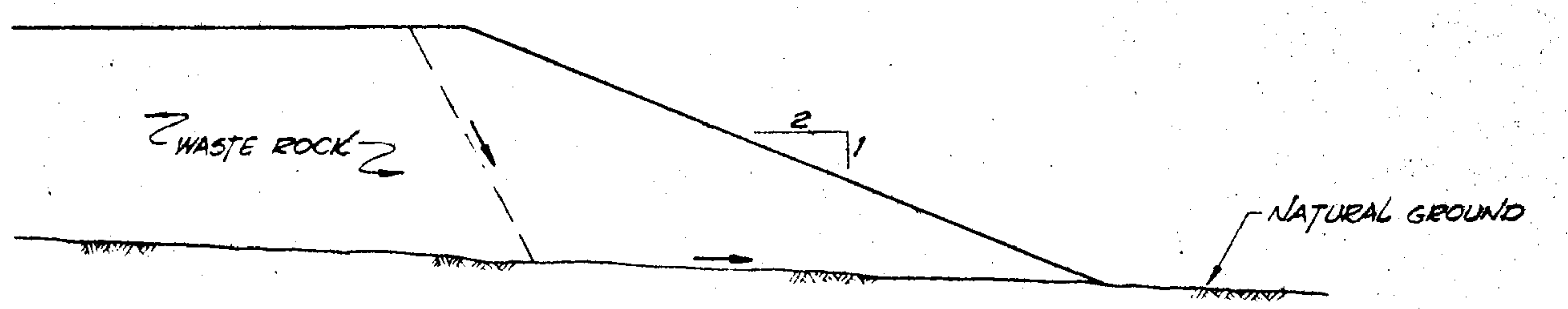
RESULTS OF STABILITY ANALYSES



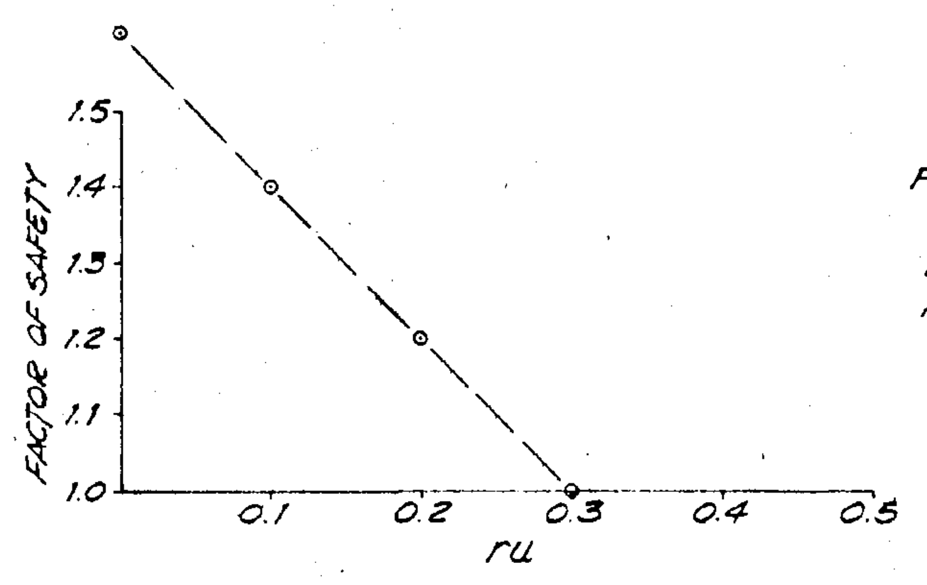
IN PIT DUMPS
RECOMMENDED CONSTRUCTION SCHEMATIC

SOIL PARAMETERS

SOIL TYPE	EFFECTIVE COHESION kPa	EFFECTIVE FRICTION ANGLE DEGREES	UNIT WEIGHT kN/m³
WASTE ROCK	0	32	18
NATURAL GROUND	0	30	20



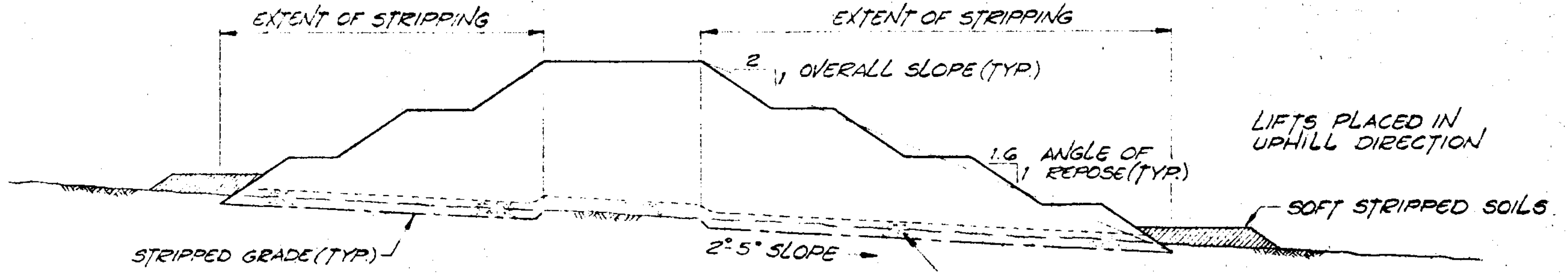
OUT OF PIT DUMPS - TYPICAL SECTION



FOR SLIP 1 FACTOR OF SAFETY FOR ru = 0.0 IS 2.15
ru = 0.2 IS 1.18

FOR EARTHQUAKE = 0.06 % g
FACTOR OF SAFETY REDUCES BY 2% TO 3%

FACTOR OF SAFETY vs. ru FOR SURFACE SLIP



NOTE: MAXIMUM BERM HEIGHT 15m.
ON ABANDONMENT MAXIMUM SLOPE BETWEEN BERMS IS 2:1. H:V.

OUT OF PIT DUMPS
RECOMMENDED CONSTRUCTION SCHEMATIC

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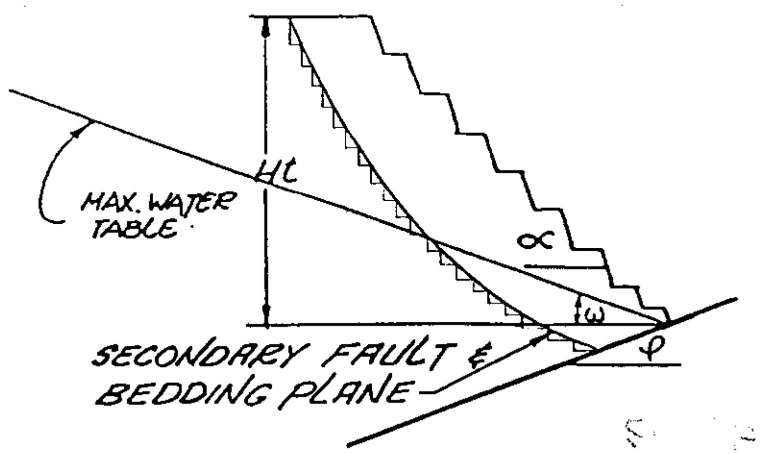
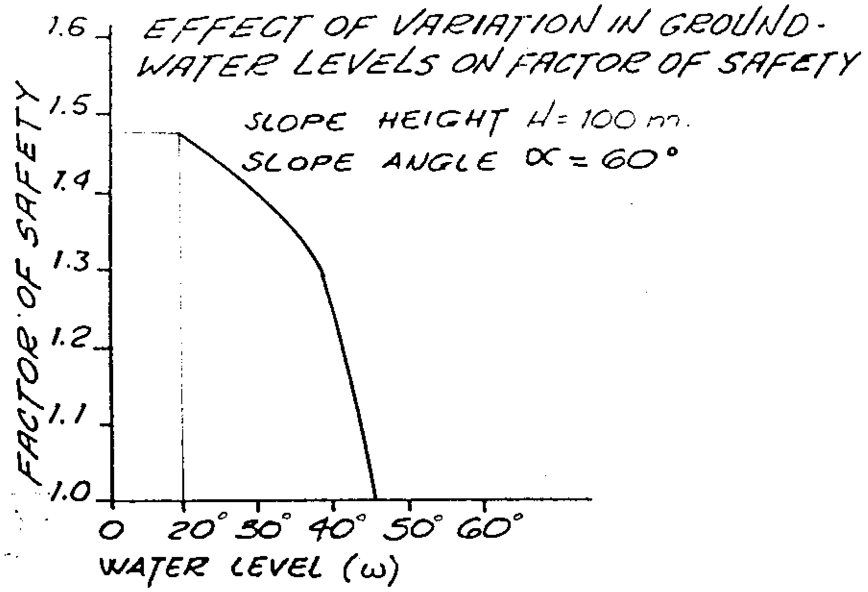
PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA T. G. HARPER

TO BE READ WITH KLOHN LEONOFF REPORT DATED ____________
SCALE:
KLOHN LEONOFF LTD.
CONSULTING ENGINEERS
CLIENT: CROWS NEST RESOURCES LTD.

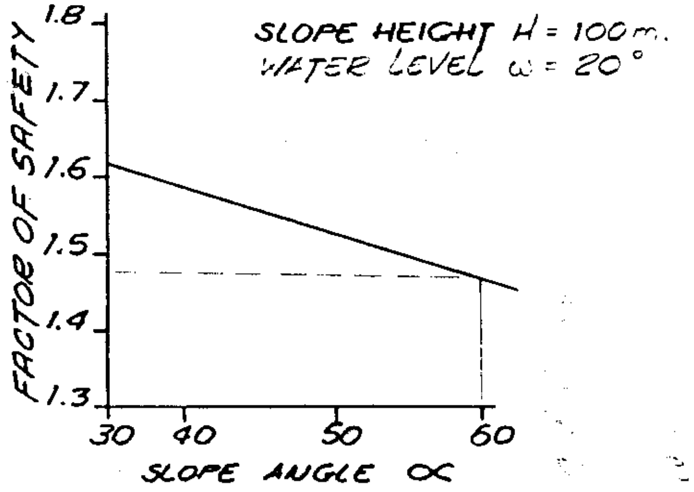
REV.	DATE	REVISION DETAILS

DESIGN L.M. MURRAY
DRAWN Chick
DATE 84-11-01
SCALES N.T.S.
PROJECT TELKWA COAL PROJECT (35)
TITLE WASTE DUMP CROSS SECTIONS & STABILITY ANALYSIS
DATE OF ISSUE FEB. 1985
APPROVED
PROJECT No. PA1692
DWG. No. D-0129
REV. 0

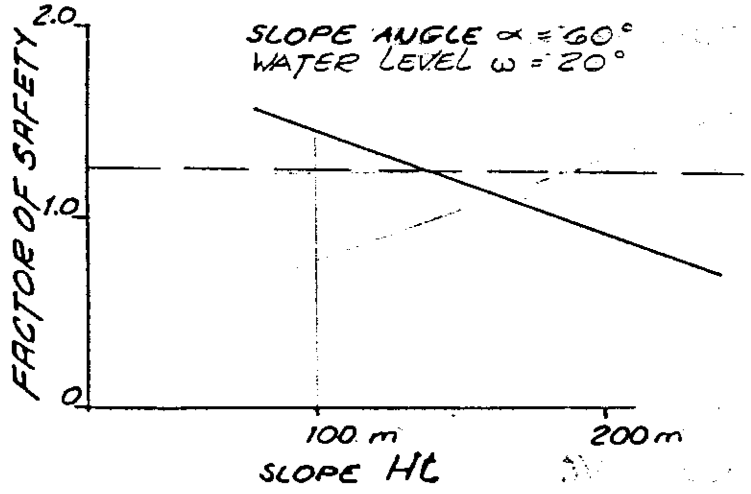



EFFECT OF VARIATION IN GROUNDWATER LEVELS ON FACTOR OF SAFETY

EFFECT OF SLOPE ANGLE ON FACTOR OF SAFETY



EFFECT OF SLOPE HEIGHT ON FACTOR OF SAFETY



SLOPE GEOMETRY

- HEIGHT H: 50m., 100m., 200m.
- SLOPE ANGLE α - 30°, 45°, 50°, 60°
- WATER LEVEL ω - 20°, 30°, 40° FROM TOE
- φ = 15°

MATERIAL PARAMETERS

- UNIT WEIGHT - 21 KN/m³
- SHEAR STRENGTH THROUGH ROCK {φ' = 30°, C' = 300 KPa}
- SHEAR STRENGTH THROUGH MUDSTONE AT BASE OF PIT {φ' = 17°, C' = 0 KPa}

DESCRIPTION OF SLOPE MODEL

1. FAILURE PLANE COMPRISES CURVED, STEPPED SURFACE CONSISTING OF SECONDARY FAULT PLANES & BEDDING PLANES WITH A SHORT SECTION OF THE FAILURE PLANE ALONG THE FOOT WALL MATERIAL.
2. FOOTWALL MATERIAL COMPRISES WEATHERED MUDSTONE

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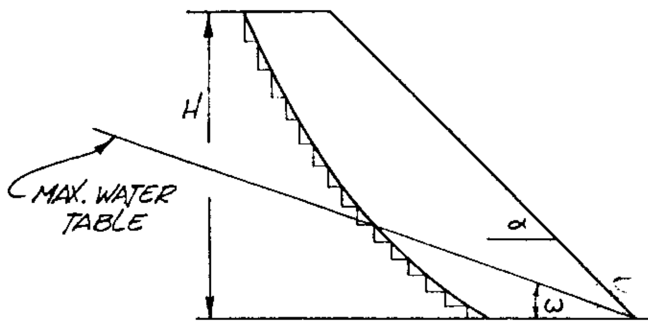
SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

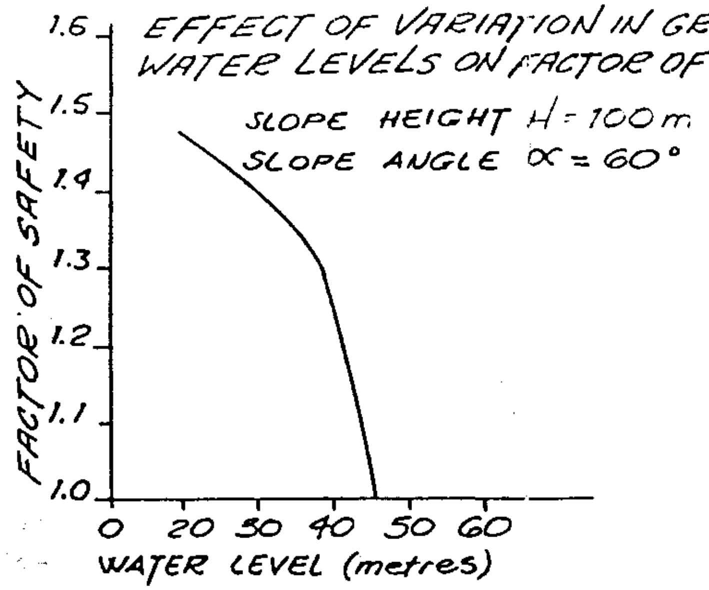
CLIENT: CROWS NEST RESOURCES LTD.

PROJECT: TELKWA PROJECT
TITLE: HIGHWALL SLOPE STABILITY - MODEL I
DATE OF ISSUE: FEB. 1985
APPROVED:
PROJECT No.: PA 1692
DWG. No.: B-0130
REV.: C

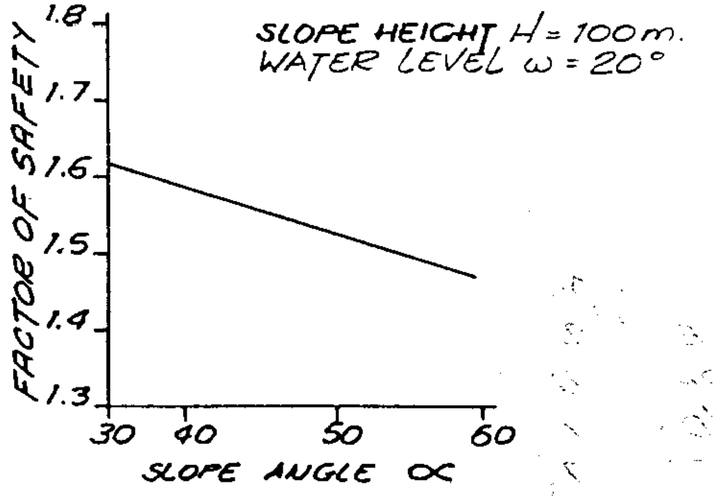
NCI-456-KL



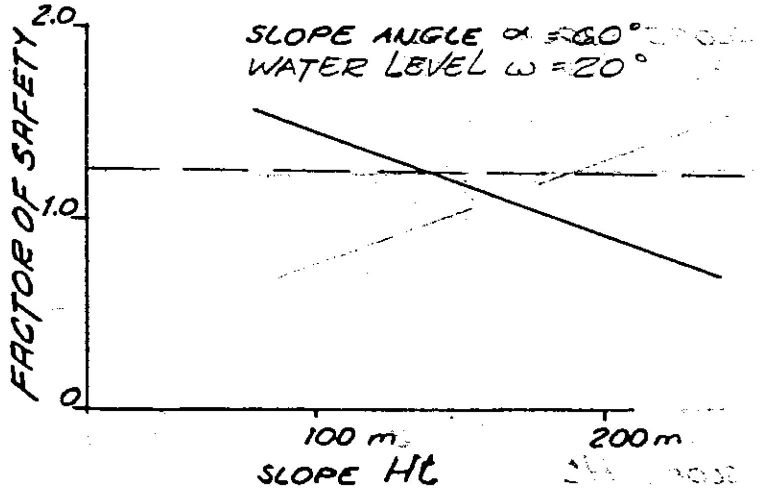
EFFECT OF VARIATION IN GROUNDWATER LEVELS ON FACTOR OF SAFETY



EFFECT OF SLOPE ANGLE ON FACTOR OF SAFETY



EFFECT OF SLOPE HEIGHT ON FACTOR OF SAFETY



SLOPE GEOMETRY

- HEIGHT H = 50m., 100m., 200m.
- SLOPE ANGLE α - 30°, 45°, 50°, 60°
- WATER LEVEL ω - 20°, 30°, 40° FROM TOE

MATERIAL PARAMETERS

- UNIT WEIGHT - 21 KN/m³
- SHEAR STRENGTH THROUGH ROCK {φ' = 30° c' = 300 KPa
- SHEAR STRENGTH THROUGH MUDSTONE AT BASE OF PIT {φ' = 17° c' = 0 KPa

DESCRIPTION OF SLOPE MODEL

1. FAILURE PLANE COMPRISES CURVED, STEPPED SURFACE CONSISTING OF SECONDARY FAULT PLANES & BEDDING PLANES WITH A SHORT SECTION OF THE FAILURE PLANE ALONG THE FOOT WALL MATERIAL.
2. FOOTWALL MATERIAL COMPRISES WEATHERED MUDSTONE

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CLIENT: CROWS NEST RESOURCES LTD.

SCALE

PROJECT: TELKWA PROJECT

TITLE: ENDWALL SLOPE STABILITY - MODEL I

DATE OF ISSUE: FEB. 1985
APPROVED
PROJECT No.: PA 1692
DWG. No.: B - 0132
REV.

NCI-455-KL

TO BE READ WITH KLOHN LEONOFF REPORT DATED

SCALE:

REV.	DATE	REVISION DETAILS

DESIGN L.M.M.
DRAWN K.T.C.
DATE 84-11-14
SCALES: 1:5000

PROJECT TELKWA COAL PROJECT

TITLE TAILINGS DAM PLAN & SECTIONS ㊱

KLOHN LEONOFF LTD.
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CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE 18-01-85
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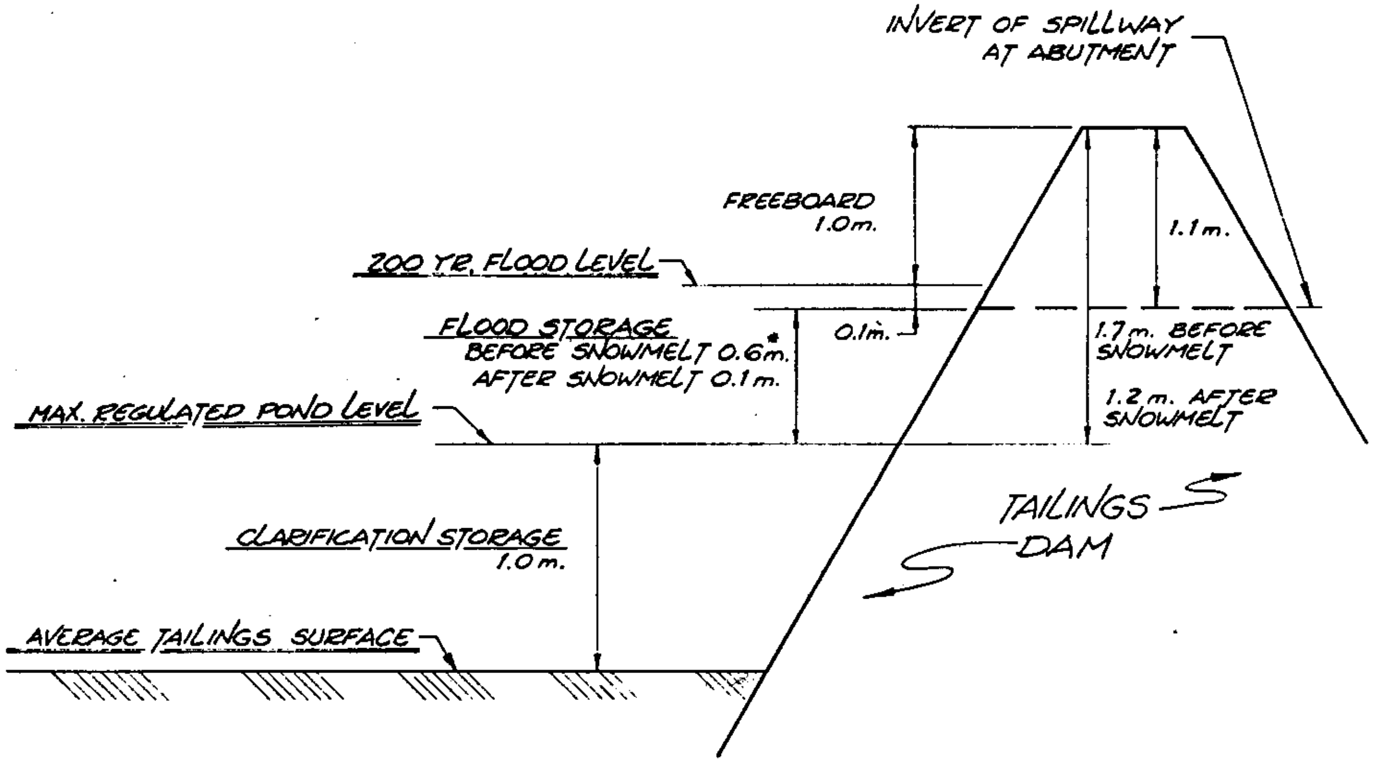

* INCLUDES 0.2m. ALLOWANCE FOR EXCESS WATER ACCUMULATION DURING 3 MONTH PERIOD OF NO RECLAIM.

SCALE N.T.S.

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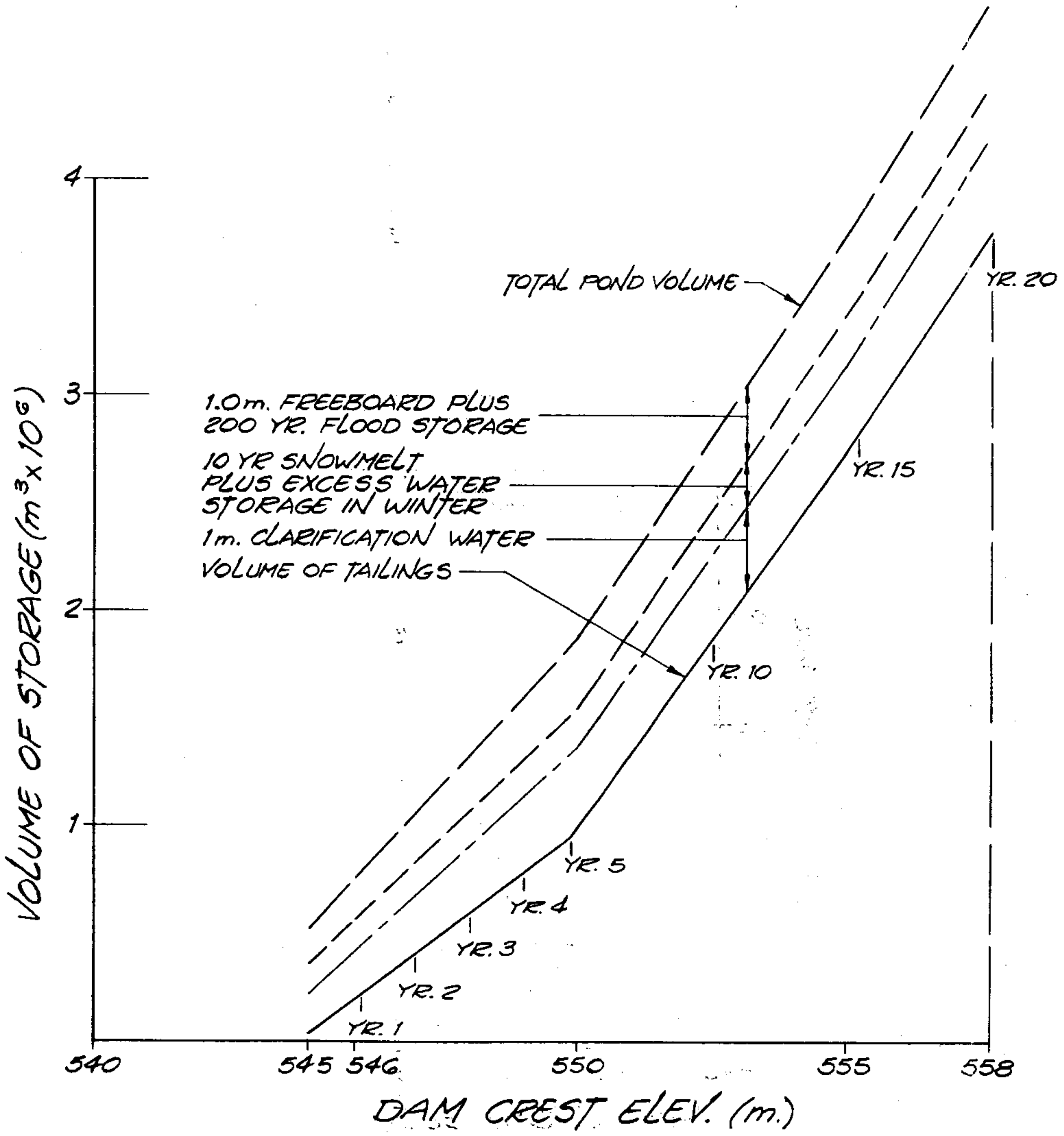
PROJECT TELKWA COAL PROJECT

TITLE TAILINGS POND STORAGE REQUIREMENTS ABOVE TAILINGS SURFACE

CLIENT: CROWS NEST RESOURCES LTD.

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
APPROVED	PA 1692	A-1692-102	0

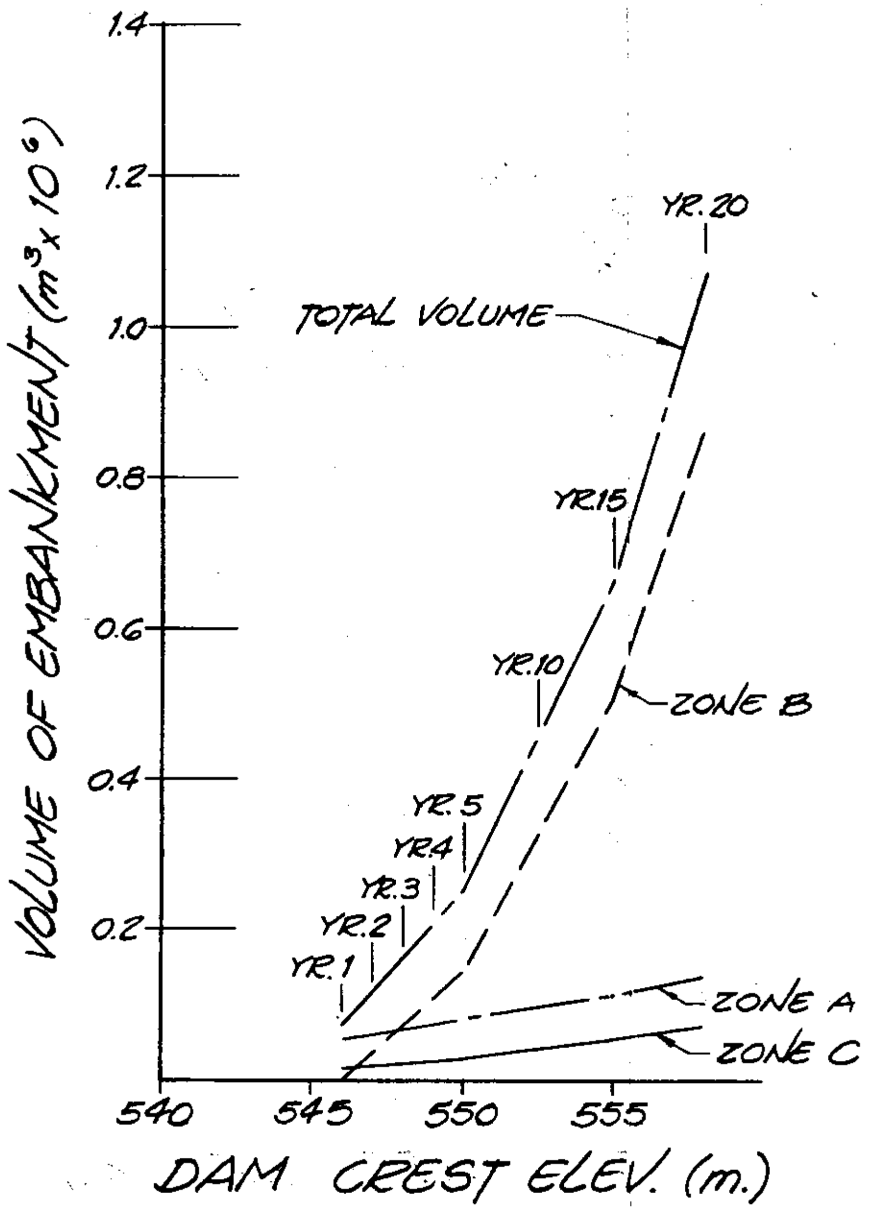
NCI-455-K.L



	ELEV. OF DAM (m.) 540	546	550	558
AREA OF STRIPPING (Ha)	2.6	4	4.75	5.2
AREA OF CLEARING (Ha)	19.5	40	45	50

ZONE DEFINITIONS

ZONE A - GLACIAL TILL
ZONE B - WASTE ROCK
ZONE C - DRAIN GRAVEL



TO BE READ WITH KLOHN LEONOFF REPORT DATED ____

SCALE

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: TELKWA COAL PROJECT
TITLE: TAILINGS POND VOLUME/ELEVATION CURVES
CLIENT: CROWS NEST RESOURCES LTD.
DATE OF ISSUE:
APPROVED:
PROJECT No.: PA 1692
DWG. No.: B-0103
REV.: 0

NCI-486-K.L