TABLES

TABLE I

RESULTS OF STATISTICAL ANALYSIS[1]
OF GEOTECHNICAL CORE LOGGING DATA

<table>
<tr><th>ROCK UNIT</th><th>LENGTH DRILLED (m)</th><th>HARDNESS</th><th>AVERAGE DEGREE OF BREAKAGE (Range)</th><th>AVERAGE TRUE SPACING OF NATURAL BEDDING JOINTS (Range) (m)</th><th>AVERAGE NATURAL CROSS JOINT FREQUENCY (Range) (No./m)</th><th>AVERAGE RQD (Range)</th><th>AVERAGE RECOVERY (Range)</th><th>LITHOLOGY</th></tr>
<tr><td>Hanging Wall Above D Seam</td><td>143</td><td>R2-R4</td><td>D/D+
(D- to E-)</td><td>2.2
(0.1 to 7.2)</td><td>0.3</td><td>94</td><td>97</td><td>Fine sandstone, siltstone and conglomerate with minor claystone.
Minor carbonaceous zones and coal blebs.</td></tr>
<tr><td>Interseam Rocks D to K Seams Inclusive</td><td>573</td><td>R0-R3</td><td>D+
(C- to E-)</td><td>0.3
(0.1 to 3.9)</td><td>0.5
(0 - 1.5)</td><td>85
(49-99)</td><td>92
(74-100)</td><td>Interbedded coal, claystone, siltstone and fine sandstone with some conglomerate.
Commonly carbonaceous.</td></tr>
<tr><td>Immediate Footwall Rocks (Stratigraphic Depth below K Seam <5m)</td><td rowspan="2">140</td><td>R2-R3</td><td rowspan="2">D+/E-
C+ to E</td><td>0.35
(0.3 to 0.5)</td><td rowspan="2">0.6
(0 - 1.1)</td><td rowspan="2">95
(82/92)</td><td rowspan="2">97.5
(95-100)</td><td>Interbedded claystone, siltstone and fine sandstone.
Commonly carbonaceous with minor coal stringers.</td></tr>
<tr><td>Competent Footwall Rocks (Stratigraphic Depth below K Seam >5m)</td><td>R2-R4</td><td>4.2
(3.9-4.6)</td><td>Fine sandstone and siltstone with some claystone.
Minor carbonaceous zones.</td></tr>
</table>

NOTES: 1. Descriptions of geotechnical parameters, the core logging technique and statistical analysis technique (cumulative sums technique) are given in Appendix A. Core logs are included in Appendix A.

TABLE II

SUMMARY OF PIEZOMETER INSTALLATIONS

	COLLAR[1] ELEV.	PIEZO.[2] NUMBER	DEPTH TO CENTRE OF POCKET (m)	ELEV. OF CENTRE OF POCKET (m-asl)	STRATIGRAPHIC LOCATION	WATER LEVEL[3] DEPTH (m)	WATER LEVEL[3] ELEV. (m-asl)	HYDRAULIC[4] CONDUCTIVITY (m/s)
QBD8205	930	P1	287	643	K Footwall	77.4	852.6	2×10^{-7}
		P2	215.6	714	K Hanging Wall	77.3	852.7	2×10^{-8}
		S3	54.9	875	Standpipe ?	49.4	880.6	-
QBD8207	995.5	P1	193.7	802	K Footwall	134.3	861.2	3×10^{-10}
		P2	154.0	841.5	K Hanging Wall	131.9	863.6	8×10^{-9}
QBD8209	904	P1	59.7	844.3	J3 Footwall	56.1	847.9	3×10^{-8}
		P2	42.5	861.5	J3 Footwall	DRY	-	-
		S3	38.8	875.2	J1 Hanging Wall	28.5	875.5	-
QBD8210	889	P1	46.2	842.8	E Seam	28.3	875.7	1×10^{-7}
		P2	36.1	867.9	E Hanging Wall	27.1	876.9	1.5×10^{-7}
		P3	12.1	876.9	E Hanging Wall	10.7	893.3	6×10^{-10}
QBD8212	839	P1	56.7	782.3	J Footwall	9.6	829.4	4×10^{-8}
		P2	31.8	802.2	J Hanging Wall	1.8	837.2	7×10^{-9}
		P3	16.9	822.1	J Hanging Wall	.8	838.2	1×10^{-8}
QBR8207	887	P1	76	811.0	K Hanging Wall	25.0	862.0	
		P2	58	829.0	J Hanging Wall	13.6	873.4	2×10^{-12}
		P3	30.8	856.2	G Hanging Wall	9.1	877.9	7×10^{-12}
QBD84001	842	P1	143.5	698.5	K Footwall	6.9	835.1	very slow
		P2	95.5	746.5	G Hanging Wall	8.9	833.1	3×10^{-11}
		P3	72	770.0	F Footwall	8.6	833.4	3×10^{-11}
QBR84004	872	P1	55.0	817.0	K Footwall	15.5	856.5	3×10^{-7}
		P2	44.8	827.2	J Hanging Wall	16.0	856.0	1×10^{-7}
QSR85001	968	P1	201.6	766.4	K Footwall	103.38	864.6	5×10^{-9}
		P2	150.8	817.2	G Hanging Wall	63.47	904.5	3×10^{-11}
		P3	94.0	874.0	D/E Seam	67.44	900.6	6×10^{-9}
		S4	61.0	907.0	D Hanging Wall	10.71	957.3	
QSR85503	870	P1	117.2	752.9	J Footwall	21.58	848.42	6×10^{-8}
		P2	69.5	800.5	G Footwall	20.93	849.07	4×10^{-9}
		P3	45.4	824.6	F Footwall	12.95	857.1	2×10^{-8}
		S4	6.0	864.0		11.04	859.0	

NOTES:
1. Elevation taken from topographic location plan.
2. P denotes sealed piezometer; S denotes standpipe; number from bottom of hole up.
3. All depth measurements made on March 12, 13, 1985
4. Hydraulic conductivity values calculated from falling head test data.

TABLE III
SUMMARY OF RECOMMENDED SLOPE DESIGNS

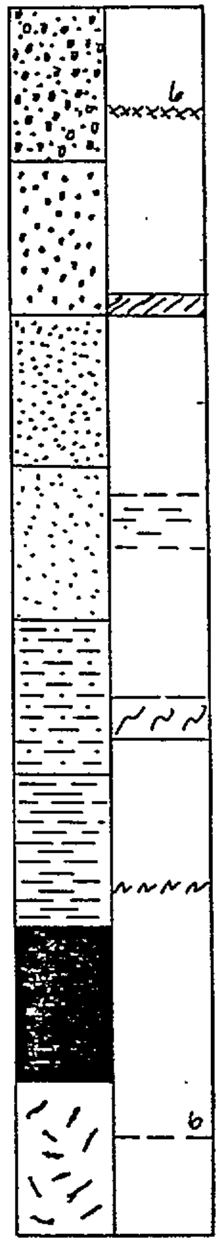
DESIGN SECTOR	WALL TYPE	FAILURE MODE CONSIDERED MOST PROBABLE TO CONTROL BENCH STABILITY	MAXIMUM BEDDING DIP OR RANGE OF BEDDING DIPS (°)	MAXIMUM SLOPE HEIGHT BETWEEN BERMS (m)	DESIGN BENCH FACE ANGLE (°)	DESIGN BERM WIDTH (m)	ANTICIPATED BREAK BACK AT CREST (m)	EFFECTIVE BERM WIDTH (m)	EFFECTIVE BENCH FACE ANGLE (°)	MAXIMUM INTERMEDIATE SLOPE ANGLE (°)	COMMENTS
VII VIII IX	FOOTWALLS (Immediate Footwall Rocks)	Plane failure on bedding	20	15	70	8	0	8	70	48	-Designs apply to the first 5m stratigraphically beneath the base of K Seam -Design assumes bedding is undercut -Plane failures may require local remedial measures
		Bilinear Slab Failure	35	Unbenched Slopes	Parallel to Bedding	-	-	-	-	35 (Parallel to Bedding)	-Designs apply to the first 5m stratigraphically beneath the base of K Seam -Do not undercut bedding -Maximum slope heights between berms based on slab failure assessment
			40	75	Parallel to Bedding	8	0	8	Parallel to Bedding	38	
			45	45	Parallel to Bedding	8	0	8	Parallel to Bedding	40	
			65	30	Parallel to Bedding	10	0	10	Parallel to Bedding	51	
			80	15	Parallel to Bedding	8	0	8	Parallel to Bedding	55	
			90	15	90	8	0-2	6-8	>80	-	
	FOOTWALLS (Competent Footwall Rocks)	Plane failure on bedding	30	15	70	8	0	8	70	48	-Design applies to rock more than 5m stratigraphically beneath the base of K Seam -Design assumes bedding is undercut -Plane failures may require local remedial measures
		Bilinear Slab Failure	45	Unbenched Slopes	Parallel to Bedding	-	-	-	-	45	-Designs apply to rock more than 5m stratigraphically beneath the base of K Seam -Do no undercut bedding -Maximum slope heights between berms based on slab failure assessment
			55	45	Parallel to Bedding	8	0	8	Parallel to Bedding	49	
			70	30	Parallel to Bedding	10	0	10	Parallel to Bedding	55	
			80	15	Parallel to Bedding	8	0	8	Parallel to Bedding	55	
			90	15	90	8	0-2	6-8	>80	-	
I	OBLIQUE ENDWALL	Stepped Wedge Failure or Stepped Plane Failure	N/A	30 (Double Benches)	70	14.2	0 - 3.9	10.3-14.2	64-70	50	-Design Sector I may be subject to plane failures on bedding where it abuts the southwestern most Footwall slope. Remedial measures may be required in this area.
IIA	ENDWALL										
IIB	ENDWALL										
III	HANGING WALL	Stepped Wedge Failure or Stepped Plane Failure	N/A	30 (Double Benches)	90	29.0	15.0-18.4	10.5-14.0	58-63	46	
IVA	ENDWALL	Stepped Plane Failure									
IVB	ENDWALL	Stepped Plane Failure	N/A	30 (Double Benches)	80	20.7	7.1- 9.9	10.8-13.6	63-66	49	
V	OBLIQUE HANGING WALL	Stepped Wedge Failure or Stepped Plane Failure									
VI	HANGING WALL										

NOTES:
1. Footwall slopes are assumed excavated parallel to the strike of bedding.
2. The occurrence of rolls and/or folds in bedding, high groundwater pressures or discrete unfavourably oriented faults or shears may require modifications to the designs shown. An ongoing program of geotechnical and piezometric monitoring should be conducted to ascertain the location of any such occurrences so that the slope designs may be altered, and/or remedial measures applied, if required.
3. It is assumed that coal next to final footwalls will be excavated by ripping or other non-explosive technique, and that controlled blasting will be utilized in the excavation of all other final walls.
4. Trial slopes and trial blasts should be utilized to evaluate and update the slope designs, as required.
5. Recommended slope designs are based on results of kinematic assessments, operational considerations and observed behaviour of existing slopes excavated in similar rock masses in the McConkey Mine and elsewhere.
6. Design sectors are shown in Fig. 4.
7. Slope depressurization may be required in some areas as described in Section 4.

APPENDIX A

GEOTECHNICAL LOGS FOR DIAMOND DRILLHOLES AND DESCRIPTION OF CORE LOGGING AND CUMULATIVE SUMS TECHNIQUES

LITHOLOGY	STRUCTURE
PEBBLE CONGLOMERATE	CRUSHED ZONE (THICKNESS INDICATED IN cm.)
COARSE SANDSTONE	BROKEN ZONE (LIMITS INDICATED)
MEDIUM SANDSTONE	
FINE SANDSTONE	THIN CRUSHED OR BROKEN LAYERS
SILTSTONE	INTENSE CALCITE VEINING
CLAYSTONE AND CARBONACEOUS CLAYSTONE	FAULT
COAL	
COALY OR CARBONACEOUS STRINGERS	CLAY OR SILT INFILLED JOINT (THICKNESS OF INFILLING INDICATED IN cm.)



QUINTETTE COAL LIMITED
DENISON MINES LIMITED
SHIKANO DEVELOPMENT

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

GRAPHIC LOG - SYMBOLS

BY:	DATE:
PMH	APR 85
APPROVED:	DWG:
	339-X4-AO

GEOTECHNICAL / HYDROGEOLOGICAL LOG

QSD 85001

LOCATION

NORTHING:

EASTING:

COLLAR ELEV.:

AZIMUTH:

INCLINATION: -90°

DEPTH:

DATE DRILLED: February '85

SUMMARY OF CUSUMS ANALYSIS							DEPTH 1:500 SCALE		GRAPHIC LOG			HYDROGEOLOGIC DATA	
HARDNESS (R)	DEGREE OF BREAKAGE	BEDDING JOINT TRUE SPACING (m)	JOINTS / m	RQD (%)	RECOVERY (%)	BEDDING DIP (°)	FEET	METRES	LITHOLOGY	STRUCTURE	DESCRIPTIVE LOG	INSTALLATION DETAILS	COMMENTS
	D-	0.6 / 0.2	3.3 / 1.3	79	95	53	50, 100	10, 20, 30		5, 9, 6, 15, 3, 3	Fine SANDSTONE with minor carb. mat'l and carb. claystone		
	C-	<0.1 ?	>6 ?	21	48					24, 49, 46, ?	COAL (Seam D/E)		
	D+	0.4	0.8	96	98	47	150	40, 50			Fine to Medium SANDSTONE with minor carb mat'l.		
											Carb. CLAYSTONE		
	C	0.1	2.4	50	75		200	60		6	COAL (Seam F)		
	D	0.3	1.2	89	97		250	70, 80		18	Carb SILTSTONE		
						60.5					Fine SANDSTONE with minor carb mat'l.		
	C-	0.1	4.7	48	45		300	90			Interbedded Carb. CLAYSTONE, COAL, Fine SANDSTONE and SILTSTONE	Seam G	
	D+	0.3	0.9	93	97	53.5	350	100, 110			Carb. SILTSTONE		
											Fine SANDSTONE with minor carb mat'l.		
							400	120			Interbedded Carb CLAYSTONE, COAL and SILTSTONE		
	B+	<0.1 ?	>6 ?	24	49						COAL (Seam J)		
	D			69	78	67.5		130		6	Carb CLAYSTONE and SILTSTONE		
							450	140		46, 9, 30	Interbedded COAL, Carb. CLAYSTONE, SILTSTONE and Fine SANDSTONE	K1, K2	
	D+	0.3	0.6	95	98	47	500	150			Interbedded Carb SILTSTONE, Fine SANDSTONE and CLAYSTONE		
						60		160			Fine SANDSTONE with minor carb mat'l		
						53	550, 600	170, 180			Carb SILTSTONE		

NOTE: Geotechnical logging carried out following geological logging.

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GEOTECHNICAL STUDY

PITEAU & ASSOCIATES
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VANCOUVER CALGARY

GEOTECHNICAL/HYDROGEOLOGICAL LOG OF DRILLHOLE QSD 85001

BY	DATE	APPROVED	DWG.
PMH	Mar. 85	MA	339-X4-A1

GEOTECHNICAL / HYDROGEOLOGICAL LOG

QSD 85003

LOCATION

NORTHING: ______

EASTING: ______

COLLAR ELEV.: ______

AZIMUTH: ______

INCLINATION: -90°

DEPTH: 81.1 m

DATE DRILLED: February/85

SUMMARY OF CUSUMS ANALYSIS: HARDNESS (R)	DEGREE OF BREAKAGE	BEDDING JOINT TRUE SPACING (m)	JOINTS/m	R Q D (%)	RECOVERY (%)	BEDDING DIP (°)	DEPTH 1:500 SCALE: FEET	METRES	GRAPHIC LOG: LITHOLOGY	STRUCTURE	DESCRIPTIVE LOG	HYDROGEOLOGIC DATA: INSTALLATION DETAILS	COMMENTS
		0.1											
	D+	1.0	1.1 0.5	99.1	100.0	46 37.5	50 100	10 20 30			carbonaceous, fine SANDSTONE with some interbedded carbonaceous SILTSTONE and carbonaceous CLAYSTONE		
	C+	0.2	4.4	48.0	92.4	46		40			COAL with carbonaceous siltstone split, thin broken/crushed zones	Seam J	
	D+	0.5	1.0	82.2	100.0	55.5	150	50			interbedded carbonaceous fine SANDSTONE and SILTSTONE		
											COAL, broken zones	Seam K	
	C+										intense calcite veining		
	E-	4.6	0.0	96.6	96.8	41.5	200 250	60 70 80			interbedded, carbonaceous fine SANDSTONE, fine SANDSTONE and carbonaceous SILTSTONE		

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GEOTECHNICAL/HYDROGEOLOGICAL LOG OF DRILLHOLE QSD 85003

BY	DATE
RAP	Mar/85
APPROVED	DWG.
[illegible]	339-X4-A2

GEOTECHNICAL / HYDROGEOLOGICAL LOG
QSD 85005

LOCATION
NORTHING: ______
EASTING: ______
COLLAR ELEV.: ______
AZIMUTH: —
INCLINATION: −90°
DEPTH: 167.9 m.
DATE DRILLED: February/85

SUMMARY OF CUSUMS ANALYSIS (values top to bottom)

- HARDNESS (R): —
- DEGREE OF BREAKAGE: D⁻/D; E⁻; C⁺/D⁻; E⁻; D⁺; E⁻/E; D⁻; E⁻
- BEDDING JOINT TRUE SPACING (m): 0.3; 5.1; 0.2; 3.9; 0.5; 4.5
- JOINTS/m: 0.9; 0.07; 1.2; 0.03; 0.8; 0.2
- RQD (%): 81; 98; 67; 97; 84; 89
- RECOVERY (%): 98; 92; 99; 84; 98
- BEDDING DIP (°): 27; 36; 30; 34; 27; 29; 24; 36; 27; 31; 26

DEPTH 1:500 SCALE
- FEET: 50, 100, 150, 200, 250, 300, 350, 400, 450, 500
- METRES: 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160

GRAPHIC LOG (LITHOLOGY, STRUCTURE)
Structure numbers (top to bottom): 3, 6, 1, 6, 15, 3, 3, 24, 3, 15, 21, 40

DESCRIPTIVE LOG	HYDROGEOLOGIC DATA – COMMENTS
carbonaceous, fine SANDSTONE; minor carbonaceous CLAYSTONE	
interbedded, medium to fine SANDSTONE and pebble CONGLOMERATE	
interbedded COAL and carbonaceous CLAYSTONE; minor SILTSTONE	(Seams D/E)
carbonaceous fine to medium SANDSTONE interbedded with some carbonaceous CLAYSTONE; becomes carbonaceous SILTSTONE + CLAYSTONE	
COAL and carbonaceous CLAYSTONE	(Seam F)
carbonaceous SILTSTONE with some interbedded carbonaceous SANDSTONE	
COAL; minor carbonaceous CLAYSTONE	(Seam G)
interbedded carbonaceous, fine SANDSTONE and SILTSTONE	
carbonaceous CLAYSTONE and some COAL	Seam J; Seam K
carbonaceous, fine SANDSTONE and minor carbonaceous SILTSTONE	
fine SANDSTONE and SILTSTONE with minor carbonaceous SILT/CLAYSTONE	

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GEOTECHNICAL/HYDROGEOLOGICAL LOG OF DRILLHOLE QSD 85005

BY: RP DATE: Apr/85
APPROVED: MH DWG: 339-X4-A3

GEOTECHNICAL / HYDROGEOLOGICAL LOG
QSD 85006

LOCATION

NORTHING:

EASTING:

COLLAR ELEV.:

AZIMUTH: —

INCLINATION: -90°

DEPTH: 139.0 m.

DATE DRILLED: February/85

SUMMARY OF CUSUMS ANALYSIS (listed top to bottom)

HARDNESS (R)	DEGREE OF BREAKAGE / BEDDING JOINT TRUE SPACING (m)	JOINTS / m	R Q D (%)	RECOVERY (%)	BEDDING DIP (°)
D+	5.7	0.0	100	100	16
D-	0.4	1.5	78	90	21
D+	0.9	0.2	95	99	27
C	0.3	1.6	80	86	22
D+	2.2	0.2	94	99	18
D	0.3	0.7	70	95	15
E-	2.6	0.0	98	99	23
	0.4		85		
	1.4		98		

DEPTH 1:500 SCALE

FEET: 50, 100, 150, 200, 250, 300, 350, 400, 450

METRES: 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130

GRAPHIC LOG: LITHOLOGY, STRUCTURE

Structure annotations (top to bottom): 3, 15, 3, 15, 15, Coal Vein, 6, 3, 6, 3, 6, 6, 9, 3, 9

DESCRIPTIVE LOG

- coarse SANDSTONE + pebble CONGLOMERATE; minor fine-medium SANDSTONE and carbonaceous fine SANDSTONE
- COAL and carbonaceous CLAYSTONE Seams D/E
- carbonaceous fine to medium SANDSTONE becoming carbonaceous SILTSTONE and CLAYSTONE with depth
- COAL Seam F
- carbonaceous, fine SANDSTONE interbedded with carbonaceous SILTSTONE and CLAYSTONE
- COAL + carb. CLAYSTONE Seam G
- carbonaceous, fine SANDSTONE with some interbedded carbonaceous SILTSTONE and CLAYSTONE
- interbedded COAL, carbonaceous CLAYSTONE and SILTSTONE Seams J/K
- interbedded carbonaceous fine SANDSTONE CLAYSTONE + SILTSTONE over fine SANDSTONE SILTSTONE and CLAYSTONE

HYDROGEOLOGIC DATA: INSTALLATION DETAILS | COMMENTS

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GEOTECHNICAL STUDY

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

GEOTECHNICAL/HYDROGEOLOGICAL LOG OF DRILLHOLE QSD 85006

BY	DATE	APPROVED	DWG.
RP	Apr/85		339-X4-A4

GEOTECHNICAL / HYDROGEOLOGICAL LOG

QSD 85007

LOCATION

NORTHING: ______

EASTING: ______

COLLAR ELEV.: ______

AZIMUTH: ______

INCLINATION: -90°

DEPTH: 175.3 m

DATE DRILLED: February/85

SUMMARY OF CUSUMS ANALYSIS

Columns: HARDNESS (R) | DEGREE OF BREAKAGE | BEDDING JOINT TRUE SPACING (m) | JOINTS / m | R Q D (%) | RECOVERY (%) | BEDDING DIP (°)

Intervals of each column, from top to bottom (the columns have independent interval boundaries):

Column	Values (top to bottom)
HARDNESS (R)	
DEGREE OF BREAKAGE	D; D+; D; E−; D; D+; C+; D+; D−; D+; C; E−
BEDDING JOINT TRUE SPACING (m)	0.4; 3.2; 0.5; 7.2; 0.5; 1.5; 0.3; 4.8; 0.4; 1.9; 0.3; 3.9
JOINTS / m	1.4; 0.3; 1.5; 0.2; 2.0; 0.2; 1.1; 0.1
R Q D (%)	83; 95; 83; 99; 65; 98
RECOVERY (%)	97; 99; 96; 85; 99; 88; 100
BEDDING DIP (°)	13; 24; 14; 22; 14; 24; 15; 21; 15; 21; 31; 25; 18

DEPTH (1:500 SCALE)

FEET: 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550

METRES: 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170

GRAPHIC LOG (LITHOLOGY, STRUCTURE)

Structure annotations (top to bottom): 6/9; 3/3; 6; 39; 6; 3; 9; 15; 6; 18; K2/6

DESCRIPTIVE LOG

Descriptive Log
carbonaceous, fine SANDSTONE interbedded with carbonaceous claystone
coarse grained SANDSTONE with some carb. SILTSTONE and CLAYSTONE
coarse SANDSTONE and pebble CONGLOMERATE
carbonaceous, coarse SANDSTONE
COAL with some carbonaceous CLAYSTONE (Seams D/E)
carbonaceous, fine SANDSTONE with minor carbonaceous CLAYSTONE, SILTSTONE and medium sandstone
COAL (Seam F)
carbonaceous, fine SANDSTONE
carbonaceous SILTSTONE + CLAYSTONE
COAL (Seam G)
carbonaceous, fine SANDSTONE with interbedded carbonaceous SILTSTONE and CLAYSTONE
COAL with a carbonaceous CLAYSTONE split (Seams J/K1)
interbedded carbonaceous CLAYSTONE, SILTSTONE and fine SANDSTONE with minor COAL; becomes less carbonaceous w/depth

HYDROGEOLOGIC DATA

INSTALLATION DETAILS | COMMENTS

QUINTETTE COAL LIMITED
SHIKANO PROJECT
GEOTECHNICAL STUDY

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

GEOTECHNICAL/HYDROGEOLOGICAL LOG OF DRILLHOLE QSD 85007

BY: R.P. DATE: Apr/85
APPROVED: [illegible] DWG: 339-X4-A5

GEOTECHNICAL / HYDROGEOLOGICAL LOG
QSD 85008

LOCATION
NORTHING:
EASTING:
COLLAR ELEV.:

AZIMUTH: —
INCLINATION: -90°
DEPTH: 148.1 m.
DATE DRILLED: February /85

SUMMARY OF CUSUMS ANALYSIS: HARDNESS (R)	DEGREE OF BREAKAGE	BEDDING JOINT TRUE SPACING (m)	JOINTS/m	R.Q.D. (%)	RECOVERY (%)	BEDDING DIP (°)	DEPTH 1:500 SCALE: FEET	METRES	GRAPHIC LOG: LITHOLOGY	STRUCTURE	DESCRIPTIVE LOG	HYDROGEOLOGIC DATA: INSTALLATION DETAILS	COMMENTS
							50	10, 20					
	D+	0.7	1.3	93	97	28	100	30		36	carbonaceous, fine to medium SANDSTONE; some CONGLOMERATE and fine SANDSTONE		
	C+	0.3		51	78	33		40		9	COAL and carbonaceous CLAYSTONE (Seam D/E)		
							150	50		6, 6	carbonaceous CLAYSTONE and fine SANDSTONE		
	D+	1.7	0.5	96	97	24, 35	200	60			interbedded carbonaceous fine SANDSTONE and SILTSTONE; minor carbonaceous CLAYSTONE		
	D-	0.3						70		39, 18	COAL Seam F		
		2.5	2.7	80, 99	89	24	250, 300	80, 90			interbedded carbonaceous medium to coarse SANDSTONE and pebble CONGLOMERATE; minor carbonaceous CLAYSTONE and SILTSTONE		
	D+	0.3	0.3	82				100		6, 15	COAL + carb. CLAYSTONE	Seam G	
		6.4		98	98	32	350, 400	110, 120		24	interbedded carbonaceous SILTSTONE, CLAYSTONE and fine SANDSTONE; sequence becomes coarser with depth		
	D-	0.3	1.1	65		30		130		12, 6, 6, 18	interbedded COAL, carbonaceous CLAYSTONE and some SILTSTONE	J	
				91			450	140		12, 30	carbonaceous CLAYSTONE and fine SANDSTONE	K	

QUINTETTE COAL LIMITED
SHIKANO PROJECT
GEOTECHNICAL STUDY

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

GEOTECHNICAL/HYDROGEOLOGICAL LOG OF DRILLHOLE QSD85008

BY: RP DATE: Apr/85
APPROVED: [illegible] DWG: 339-X4-A6

DESCRIPTION OF CORE LOGGING TECHNIQUE

The basic parameters measured from the rock core are as follows:

1. Core recovery
2. Rock hardness
3. Degree of fracturing (breakage)
4. Degree of weathering
5. Core size

It is noteworthy that the best data on core competency can be collected by the drill inspector at the drill site before the core becomes broken or data lost from excessive handling, splitting, or drying out.

The data on the various parameters may be tabulated on appropriate recording forms and presented graphically for specific boreholes on geological sections or plans.

A detailed description of each of the parameters recorded is given in the following:

1. CORE RECOVERY AND RQD

Core recovery is expressed as a percentage of the total length drilled for each core run which is marked by wooden blocks in the core boxes. Recovery gives an indication of the quality of the ground being drilled and the general competency of the rock. Low recovery may also be indicative of faults.

2. RQD (ROCK QUALITY DESIGNATION)

The RQD is defined as the percentage of core in each run in which the spacing between natural fractures is greater that four (4) inches (10 cm).

3. HARDNESS

A simple scheme for classifying soil or rock according to its consistency or hardness is given below. Using this scheme, a reasonble first estimate of the unconfined compressive strength (q_u) of the material may be made. Classifications are based on simple mechanical tests which can be easily performed in the field. By the use of fingers, a pocket knife and geologic pick and with a minimum amount of experience, the complete range of classifications can be established in the field.

QUALITATIVE & QUANTITATIVE EXPRESSIONS
FOR CONSISTENCY OF COHESIVE SOIL AND ROCK*

HARDNESS	CONSISTENCY	FIELD IDENTIFICATION	APPROXIMATE RANGE OF UNCONFINED COMPRESSIVE STRENGTH	
			Kg/cm^2 (Approx Tons/ft^2)	p.s.i.
S1	very soft	Easily penetrated several inches by fist.	<0.25	<3.5
S2	soft	Easily penetrated several inches by thumb.	0.25 - 0.5	3.5 - 7
S3	firm	Can be penetrated several inches by thumb with moderate effort.	0.5 - 1.0	7 - 14
S4	stiff	Readily indented by thumb but penetrated only with great effort.	1.0 - 2.0	14 - 28
S5	very stiff	Readily indented ty thumbnail.	2.0 - 4.0	28 - 56
S6	hard	Indented with difficulty by thumbnail.	>4.0	>56
R0	extremely soft	Indented by thumbnail.	2.0 - 7.0	28 - 100
R1	very soft rock	Crumbles under firm blows with point of geological pick; can be peeled by a pocket knife.	7.0 - 70	100 - 1,000
R2	soft rock	Can be peeled by a pocket knife with difficulty; shallow indentations made by firm blow of geological pick.	70 - 280	1,000 - 4,000
R3	average rock	Cannot be scraped or peeled with a pocket knife; specimen can be fractured with single firm blow of hammer end of geological pick.	280 - 560	4,000 - 8,000
R4	hard rock	Specimen requires more than one blow with hammer end of geological pick to fracture it.	560 - 1,120	8,000 - 16,000
R5	very hard rock	Specimen requires many blows of hammer end of geological pick to fracture it.	1,120 - 2,240	16,000 - 32,000
R6	extremely hard rock	Specimen can only be chipped with geologic pick.	>2,240	>32,000

* Modified Rock Hardness Classification

S1 to S6 Modified after Terzaghi, K. and Peck, R.B., 1967. "Soil Mechanics in Engineering Practice, 2nd Edition, John Wiley and Sons Inc., New York. p.30.

R1 to R5 Modified after Piteau, D.R., 1970. "Geological Factors Significant to the Stability of Slopes Cut in Rock" in Planning Open Pit Mines, Van Rensburg Ed. Aug. 29-Sept. 4, 1970. Balkema. p.51 and 68.

4. DEGREE OF BREAKAGE

Degree of Breakage is a visual and thus somewhat subjective estimation of the quality of the rock in terms of the number of fractures or breaks. General categories, numerical equivalents and qualifying descriptions are given below.

CATEGORY	NUMERICAL EQUIVALENT	MEAN SPACING OF BREAKS OR DIAMETER OF FRAGMENTS (in.)	QUALITY DESCRIPTIONS
A-	1		Mostly fault gouge with/without minor rock fragments
A	2	<½	Gouge and crushed rock
A+	3		Crushed rock with/without minor gouge
B-	4	½ to 2	Crushed rock - no gouge
B	5		Crushed rock - diameter of pieces <2 in.
B+	6		Broken rock - fracture spacing <2 in.
C-	7		Mean spacing 2 to 3 in.
C	8	2 - 4	Mean spacing 3 in.
C+	9		Mean spacing 3 to 4 in.
D-	10		Mean spacing 4 to 6 in.
D	11	4 - 8	Mean spacing 6 in.
D+	12		Mean spacing 6 to 8 in.
E-	13		Mean spacing 8 to 12 in.
E	14	>8	Mean spacing 12 to 14 in.
E+	15		Mean spacing >24 in.

NOTE: Care should be taken to identify all fault/shear zones (Category A). However, for other Degrees of Breakage, the category should be averaged over a length of three (3) metres.

5. DEGREE OF WEATHERING

The degree of weathering or oxidation of the rock core is used to define the upper boundary of unweathered bedrock and to delineate faults and other zones of intense weathering. The degree of weathering is estimated visually to give a qualitative feel for this parameter. The classification for degree of weathering is as follows:

A - intensely oxidized or weathered.
B - moderately oxidized or weathered.
C - mildly oxidized or weathered (on joints only).
D - fresh and unweathered.

6. CORE SIZE

Core size has a direct effect on the quality of core recovered. It is generally recognized that larger diameter core will give better core recovery and a better sample of the geological structures. Accordingly, a record of the core size is kept in conjunction with the core competency study to consider these aspects.

7. JOINT FREQUENCY

The number of natural joints or fractures in each core run is used to calculate the joint frequency. In sedimentary rocks, the number of bedding joints/m and number of cross joints/m are recorded separately.

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Thirteenth Symposium on Rock Mechanics
ASCE/ Urbana, Illinois/ August 30-September 1, 1971

CUMULATIVE SUMS TECHNIQUE: A NEW APPROACH TO ANALYZING JOINTS IN ROCK

By Douglas R. Piteau* and Lindsay Russell**

SYNOPSIS

The cumulative sums technique for analyzing joints in rock was developed as part of an extensive slope stability study of Nchanga pit. It was used successfully to determine the joint orientation trends, the pattern of their behavior and whether the joint information could be extrapolated to other areas in which slopes are proposed. This technique is illustrated with reference to the Nchanga study.

INTRODUCTION

The cumulative sums technique for analyzing joints in rock was developed as part of an extensive slope stability analysis of the hanging-wall of the Nchanga open pit in Zambia. This technique was used successfully to define the characteristic features of the joints, most particularly to determine the pattern of their behavior from one part of the Nchanga syncline, where the pit is situated, to the other. A description of cumulative sums technique is

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given with particular reference to the joint analysis of the Nchanga pit.

Basically, the cumulative sums technique was developed to analyze the joint trends in a more definitive manner. This technique led to a better understanding of the genetic relationship of the joints occurring within the overall synclinal structure. Ultimately, predictions were made as to whether the joint data acquired from the existing hanging-wall pit face could be extrapolated (a) to an area some 300 ft behind the existing hanging-wall face, where the final slope is to be located and (b) to areas east of the existing face, where the pit is to be extended another mile.

The Nchanga syncline is approximately one and one quarter miles wide and seven miles long. The Nchanga open pit is located in the southern half of the western limits of the syncline, which consists of a clearly defined sequence of mainly sedimentary rocks (i.e. argillite, siltstones, shale, sandstone, etc). The sediments strike roughly east-west. The south limb dips between 20° N to 35° N, and the north limb dips steeply to the south, forming an asymmetrical synclinal structure with an axial plane dipping steeply north. The syncline plunges between 5° and 15° to the west.

The overall approach to the structural analysis of the hanging-wall slopes was basically straightforward /Piteau (6)/. Discontinuities in the rock were systematically measured along over three miles of benches, using the continuous detail line survey method as described by Piteau (5). The joint data were statistically analyzed, initially using rectangular, histogram, cumulative sums and other analysis methods to determine their nature and distribution. For purposes of this discussion "joint" is meant to include any naturally-occurring structural discontinuity in the rock mass.

CONSIDERATION OF THE ROCK MASS JOINT MODEL

An objective of the joint analyses is to obtain a schematized concept or model of the joints in the rock mass and to establish certain criteria which indicate where this model changes. Also, one seeks to establish confidence limits in areas where the model is considered to apply, regardless of whether it is in areas of extensive, limited or no sampling.

When designing open pit slopes on a rational basis, an *important, if not the most important, consideration in most* geological environments is the determination of the attitude, geometry and spatial distribution of the joints in the boundary of the proposed excavation. Thus, for purposes of rationally analyzing a rock slope, such a study must be dependent upon assessing three main factors, namely (1) the nature and structural arrangement of the joints; (2) the strength parameters of the joints; and (3) their relationships to possible failure surfaces. Based on this approach, the geological factors and certain geological premises are given by Piteau (4) and (5), methods of structural interpretation by Robertson (8) and mathematical theories for stability calculations by Jennings (3). This discussion deals exclusively with assessment of factor (1).

Of the three factors listed above, the first is the most important, as the two others are of little consequence if the structural interpretation, and hence the jointing model of the rock mass, does not represent the actual situation in a statistical sense. The first requirement of the model, whether it is of a physical, graphical or mathematical nature, is that it be true, and that a statistical sampling of any property will give a representative picture of the whole situation. The second is that any calculations made for a representative portion or section of the model apply to the model as a whole.

Thus, on the basis of the jointing model, and with due consideration of the strength parameters and kinematically possible failure modes for that particular structural situation, the stability of the slope can be theoretically determined [Jennings (3)].

CONSIDERATIONS AT NCHANGA LEADING TO THE DEVELOPMENT OF THE CUMULATIVE SUMS TECHNIQUE

The present dimensions of the pit are 9,600 ft along strike, but will extend, eventually, along strike for three miles, after the extension of the pit eastwards is completed. It is presently approximately 2,500 ft wide at its present depth of 750 ft. However, it is planned to go to 1,000 ft, and possibly even to 1,200 ft depth, the result being a final width of about 3,000 ft.

The structural mapping was conducted on the hanging-wall face of the pit. The problem involved trying to determine whether the same or a different structural situation can be expected to exist in the hanging-wall slope when the final depth of 1,000 ft is achieved. The final hanging-wall slope will be at least 300 ft farther in from the existing face as the pit is advanced northwards. The existing and approximate final locations of the hanging-wall, along with some salient geological features, are shown in Fig. 1.

A print-out of the raw joint data representing greater than 3,000 joints from the hanging-wall is shown in a rectangular plot in Fig. 2. Horizontal rows indicate similar angle of dip, whereas vertical rows on the upper half and lower half of the plot indicate joints with similar direc-

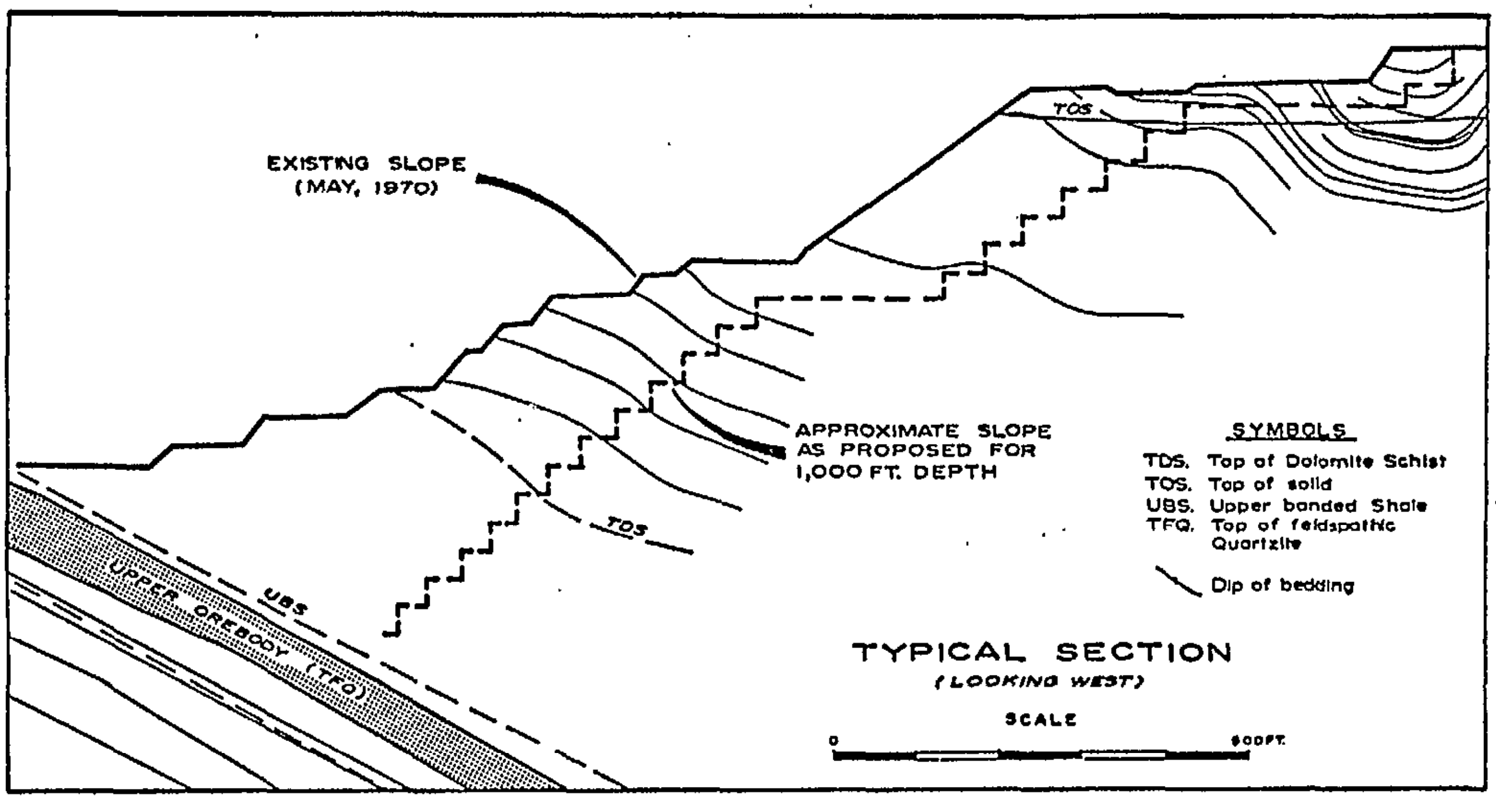

Fig. 1 Typical geological section (looking west), showing the existing and approximate final location of the Nchanga pit hanging-wall.

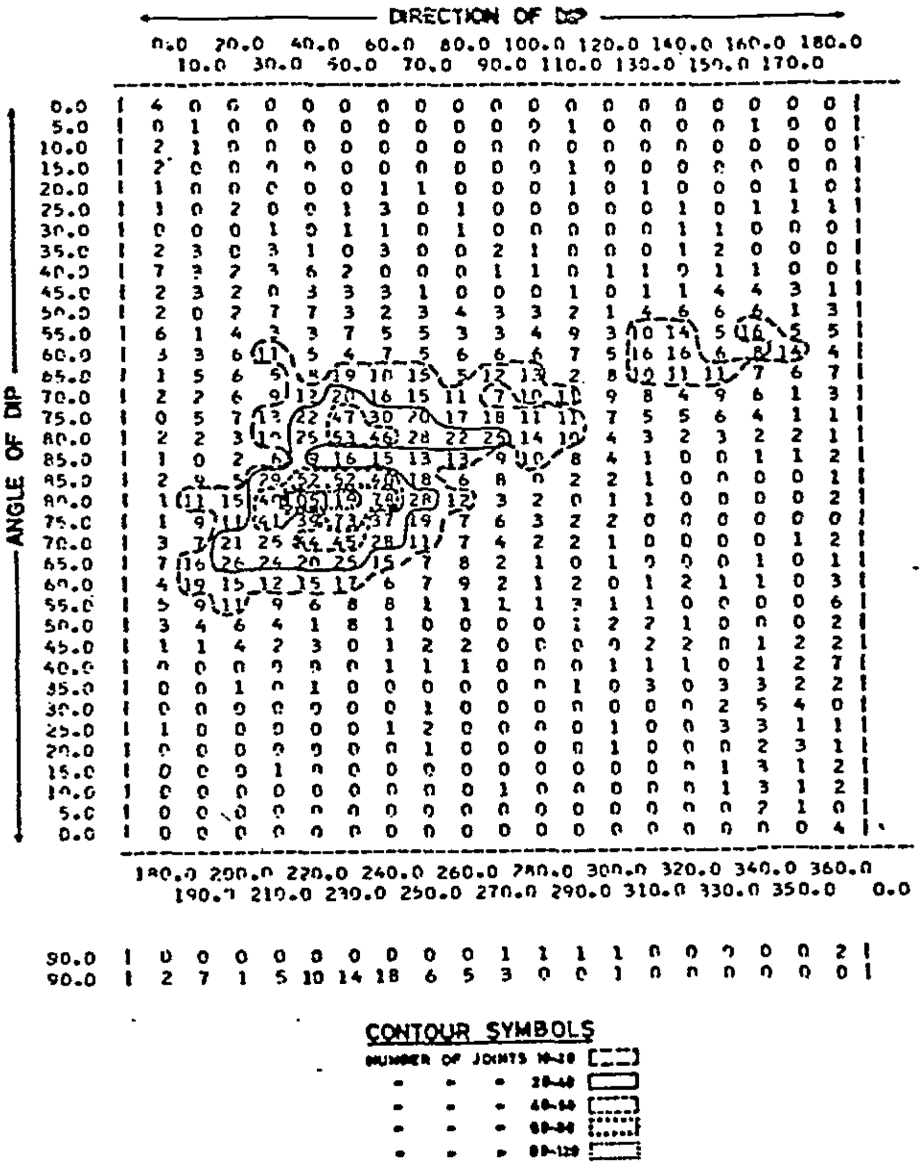

Fig. 2 Rectangular plot showing the distribution of raw joint data from Nchanga north face

tion of dip* /Robertson (8)/. It can be seen that about 70 percent of the joints are highly concentrated, occurring within a direction of dip interval of 50° (i.e. between 20° and 70°, and 200° and 250° in the upper and lower halves, respectively), and within an angle of dip interval of 55° (i.e. between 70° and 90°, and 65° and 90° in the upper and lower halves, respectively). That is, the peak concentration of these joints is centred about a strike of approximately 310°, and they dip steeply both to the northeast and southwest.

Detailed examinations of drag, monoclinal and major recumbent folds, both locally and at other points around the syncline, revealed that their axial planes were in fact striking about 300° to 310°, and not east-west, as might be expected from the approximately east-west orientation of the Nchanga syncline proper. From the results in Fig. 2 it can be seen that the peak concentration of the joints approximately parallel this tectonic fold axis.

Further study indicated that the topography of underlying basement granite dome structures to a large extent controlled the overall synclinal shape and did not control the tectonic fold process proper. For purposes of extrapolation and, ultimately, for assessing the significance of the joints with respect to slopes developed at different locations in the syncline, a more definitive knowledge of the joint behavior in regards to both dip and strike trends was required.

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* Direction of dip of a joint is the strike plus or minus 90°, depending upon whether the joint dips in a clockwise or counter-clockwise direction.

THE CUMULATIVE SUMS TECHNIQUE

GENERAL FEATURES

Cumulative sums, or "cusums" as they are also called, have been used extensively in industrial quality control [Woodward and Goldsmith (9)]. They have also been used for studying long-term trends in natural phenomena, such as river volume flows and silt deposition [Hurst et al (2)]. As far as is known, these techniques have been applied only to series of events equally spaced in time. In the analysis of joints, however, we have used these methods to study events occurring, not in time, but in an irregular sequence in space. This analysis is sequential in that the dip or strike values of the joints are considered in the order in which they are derived along the survey line.

The cumulative sums technique provides a rapid and a precise method of determining major trends above or below a particular reference value which is selected, and for ascertaining both the magnitude and location of these variations. The main uses of such an analysis method can be summarized briefly as follows:

(a) To detect general changes in joint orientation above and below the mean level of the joint orientation data;

(b) To determine where changes in joint orientation take place in the rock mass;

(c) To determine a reliable estimate of the mean orientation of the joints at any point along the surveyed pit face;

(d) To predict the average orientation of a particular joint set, or group of joints, in other parts of the mass where information is not available.

METHOD OF COMPUTATION

Basically, the approach is simple, consisting merely of subtracting a constant quantity, which at Nchanga was taken to be the mean value of either the strike or dip, from each value of strike or dip in the series, and accumulating the differences as each additional value is introduced. Successive accumulated differences are designated the "cumulative sums" of the original sequence of joint orientation values. The resulting graph of these sums is designated the "cumulative sum joint orientation plot".

When large numbers of joints are to be analysed, it is convenient to create cusum plots by computer methods, methods to which the analysis is ideally suited. Plots on the line printer, using a width of 100 characters, have proven to be an excellent medium for this method of analysis. In order to make the plots comparable, however, it is necessary to use the same cusum range and mean for all plots.

Let us suppose that we have a series of joint strike values acquired from a continuous detail joint survey. We will denote these values by $X_1, X_2, \ldots X_r$, recorded in that order along the pit face. From each X we subtract a reference value K, the mean strike of the joints. We then add these deviations to form a series of partial sums:

$$S_1 = X_1 - K$$

$$S_2 = (X_1 - K) + (X_2 - K) = S_1 + (X_2 - K)$$

$$S_3 = S_2 + (X_3 - K)$$

The general equation for the cumulative sums can thus be written as follows:

$$S_r = S_{r-1} + (X_r - K) = X_1 + X_2 + \ldots\ldots X_r - rK$$

$S_1, S_2, S_3, \ldots S_r$ is the cumulative sum series (or cusum) of the joint strike series. The plot of S against position in the sequence (S_r vs r) is the cumulative sum joint orientation plot.

The random spacing of the joints presents no problem, so long as the position, not the distance, in the sequence is used. It does not matter if the interval between observations changes. In this computation, strike or direction of dip data must be converted so that only values from either the 0° to 180° or the 180° to 360° intervals are calculated in the same analysis.

METHOD OF INTERPRETATION

If there is no trend in the strike of the joints, some of the difference terms (X_r - K) will be positive and others negative, with the result being that the cusum will be basically co~stant. But, if the current or local mean strike value is ~lightly greater than K (the overall mean), more of the differences will be positive, and the cusum will then be a straight line or curve sloping upwards. The reverse will occur if the current mean is less than K.

The actual distance of the plotted cusum curve from the horizontal is irrelevant; the interpretation is based exclusively on the average slope of the curve. The steeper the curve, the further the mean strike of the joints within any particular location is from the mean value K. The slope of the line (and hence the amount of deviation of the current mean strike from the overall mean value) can be easily calculated. The slope of the plotted line joining, let us say, the mth point and an nth point further along in the series indicates the average difference from the reference value of all the results from X_{m+1} to X_n inclusive. The mean strike ($\bar{X}$) over any interval of the cumulative sum joint orientation plot is given by

$$\bar{X} = K + \frac{\text{change in cumulative sum}}{\text{change in n}}$$

When conducting this type of analysis considerable care should be taken in selecting a suitable reference value. (K). One important feature of this analysis method is that relatively small changes, say in the current mean value of the joint strike, will appear as clearly different slopes. However, changes from one positive value to another in the slope of the cusum plot are not nearly so discernable as a reversal of the sign of the slope, i.e. a change from a situation in which the mean strike of the joints is above the reference value, to one in which it is below. The reference value K should be chosen as a reasonable target from which the results are expected to vary. Also, erratic variations or "noise" in the data are smoothed out. This is a significant factor when looking for trends and patterns, particularly when analyzing data from natural phenomena such as joints.

This technique is best used to determine long-term trends. Interpretation becomes difficult if attempts are made to include short-duration effects.

COMPARISON WITH TIME TREND ANALYSES

Several techniques, adapted from time series analysis, have been used extensively to analyze sets of geological data which are arranged as a series in space /Harbough and Merriam (1)7. They include moving average methods, harmonic analysis, spectral analysis and auto-correlation. All but the first of these are concerned with acquiring information from rapid fluctuations present in all data.

The moving average techniques (including polynomial trend analysis) tackle a problem similar to that discussed here. However, they assume that the underlying variations sought are continuous functions and will smooth out any sudden breaks. The analyst is presented with a plethora of results which are difficult to interpret.

In contrast, cusums are best used to highlight step changes in the underlying function, and are excellent for displaying slow cyclic variations. A comparison of cusums with other techniques used to detect slow variations is given by Hurst et al (2). It is interesting to note that the cusum of a series of equally spaced events is a convenient aid in calculating the simple moving average, particularly when a number of base lengths are to be examined.

APPLICATION OF THE CUMULATIVE SUMS ANALYSIS AT NCHANGA

METHOD OF APPROACH

All joints occurring within 30° of either side of the tectonic fold axis (which for analysis purposes was taken to be 300°) were considered in the analysis (i.e. joints with a direction of dip of 0° to 60° and 180° to 240°). In order that the joint data be representative of different parts of the pit slope, the hanging-wall was sub-divided into 14 arbitrary areas of approximately similar size going from west to east.

Analysis Using One Mean

One cusums technique consisted of analyzing the direction of dip data of all joints within the limits defined. Those joints with direction of dip of 0° to 60° were converted to 180° to 240° by adding 180° to their respective values. Thus, all joints could be analyzed together in the 180° to 240° range.

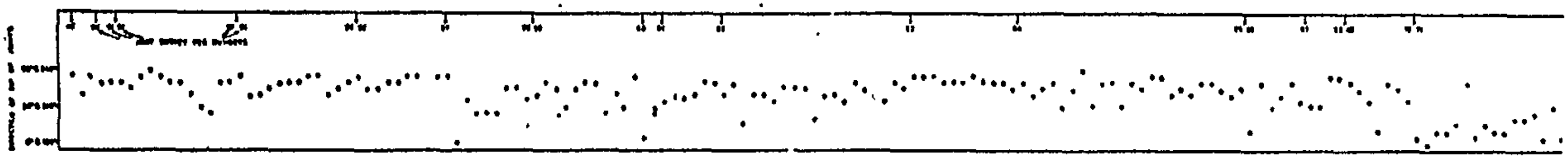
An example of the method of interpretation of the cumulative sums is shown in Fig. 3. The actual direction of dip orientations, as calculated from strike measurements in the field, are shown in Fig. 3(a). The resulting cumulative sums joint orientation plot of the raw data in Fig. 3(a) is shown in Fig. 3(b). Fig. 3(c) shows a Manhattan diagram, depicting the degree of deviation of the current mean strike above or below the overall mean strike K, according to the curves plotted in Fig. 3(b). See Fig. 4 for details of Fig. 3.

In Fig. 5, Manhattan diagrams of the cumulative sums of the analyses of the entire hanging-wall area that was surveyed, are shown. The various bench levels and subdivided areas of the hanging-wall (i.e. 1 to 14) are denoted accordingly. The bottom Manhattan diagram in Fig. 5 gives, for each of the 14 areas, the current mean deviation of the strike* of the joints about the mean. This is determined by calculating the mean deviation for all the benches occurring in a particular area.

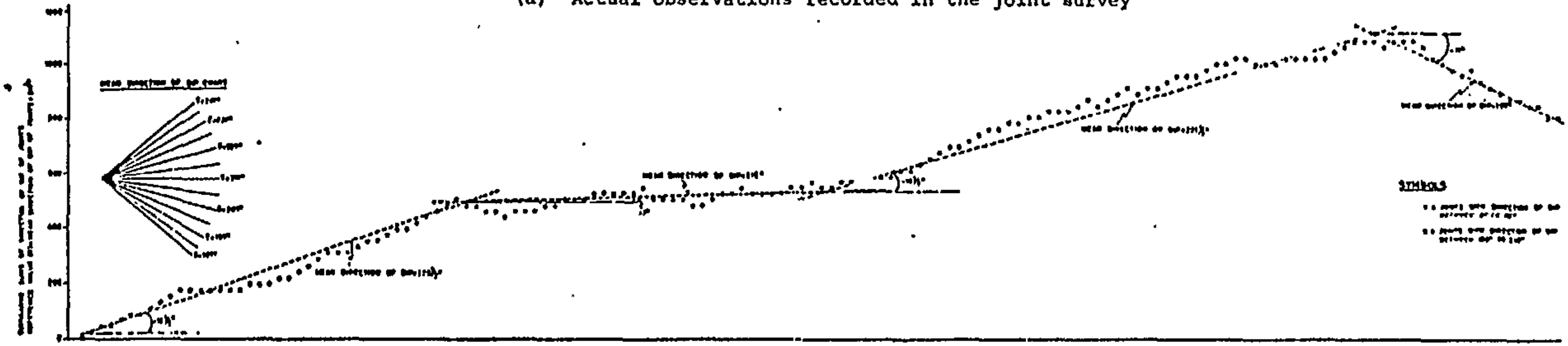
Analysis Using Four Means

This analysis technique consisted of determining the cusums of both the direction of dip and angle of dip of the joints dipping to the northeast and of those dipping to the southwest. The respective mean direction of dip and mean angle of dip for each group were used. Hence, four K values are required, giving four cusum plots. The four K values applying to the Nchanga data are as follows:

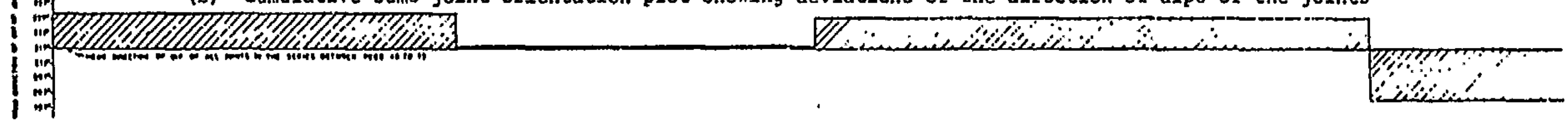
* The cumulative sums plots in Fig. 3, of direction of dip data, is converted to actual strike values in Fig. 5 for purposes of clarity.



(a) Actual observations recorded in the joint survey



(b) Cumulative sums joint orientation plot showing deviations of the direction of dips of the joints



(c) Manhattan diagram showing the current mean direction of dip of the joints at progressive positions along the survey line

Fig 3 Illustration of cumulative sums technique for analysing joint direction of dip trends

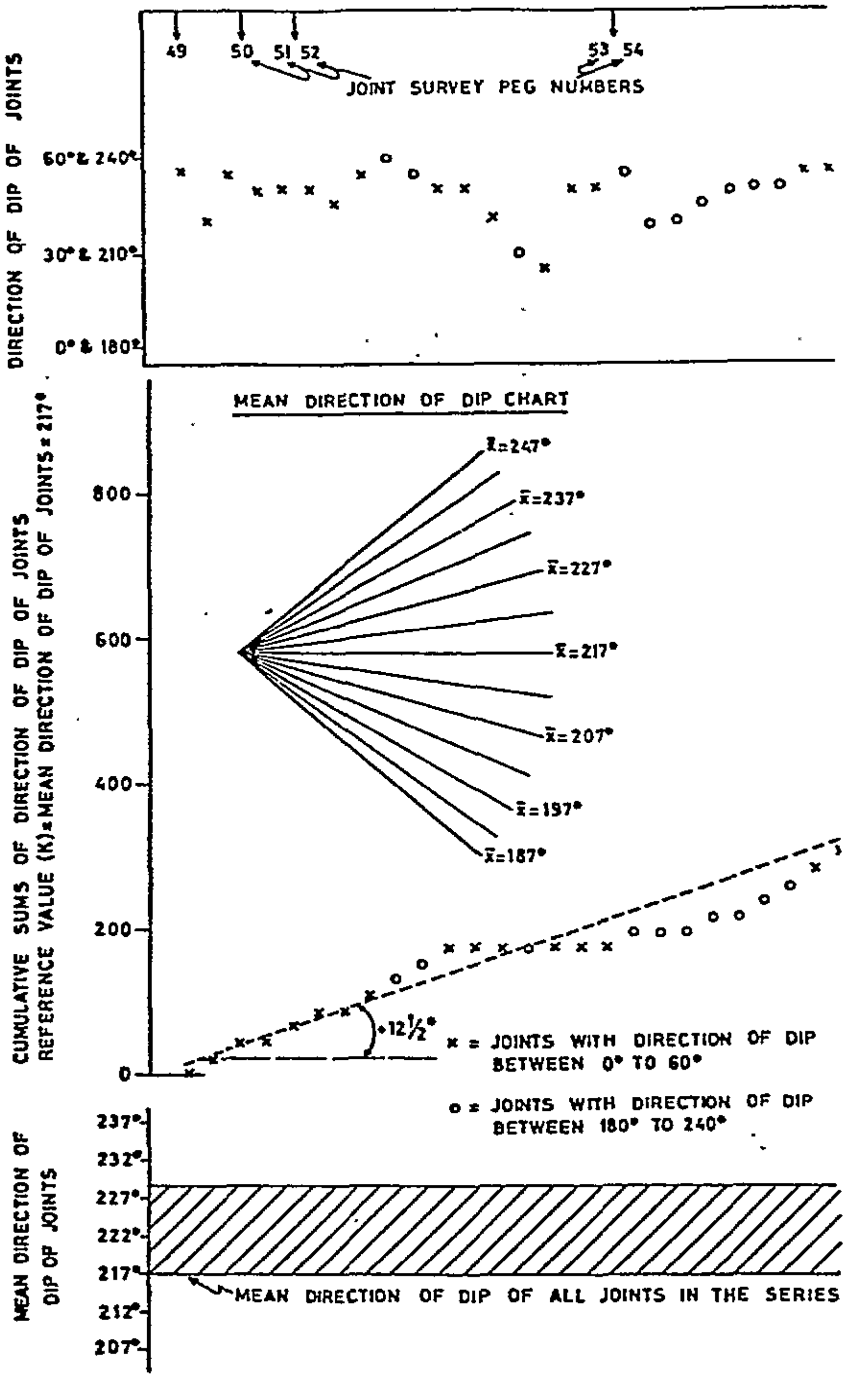


Fig. 4 Enlarged portion of the left side of Fig. 3 showing detail clearer

Joints Considered	Orientation Data	K Value
Direction of Dip $0^\circ - 60^\circ$	Strike	310°
" " " $0^\circ - 60^\circ$	Angle of Dip	74°
" " " $180^\circ - 240^\circ$	Strike	306°
" " " $180^\circ - 240^\circ$	Angle of Dip	78°

The general results are similar to those illustrated in Fig. 3, except that four cusum joint orientation plots are produced. Two plots apply to strike and two to angle of dip, although only one strike chart and one angle of dip chart are required. Four Manhattan diagrams must be considered in the same manner. The Manhattan diagrams of this analysis are given in Fig. 6. See Fig. 7 for some details of Fig. 6.

Applying this general form of cumulative sums analysis, boundaries to structural regions (i.e. areas of similar jointing characteristics in a statistical sense) were also determined. Cusum techniques used for this purpose will be published elsewhere.

DISCUSSION OF THE RESULTS

Counter-clockwise Rotation

In Fig. 5 it can be seen that the mean strike of all the joints is 307°. There is, however, a counter-clockwise rotation in the current mean strike, going from west to the east side of the hanging-wall. It rotates from about 317° in areas 1 and 2 to about 297° in areas 9 to 14. Around areas 5 and 6 the current mean strike is about the same as K.

Effects of Major Fault

As shown in Fig. 5, the rate of change of this rotation is greatest in areas 3 to 7. In Fig. 6, where the northeast and southwest dipping joints are analyzed separately, it can be seen that this phenomenon is due largely to the rotation

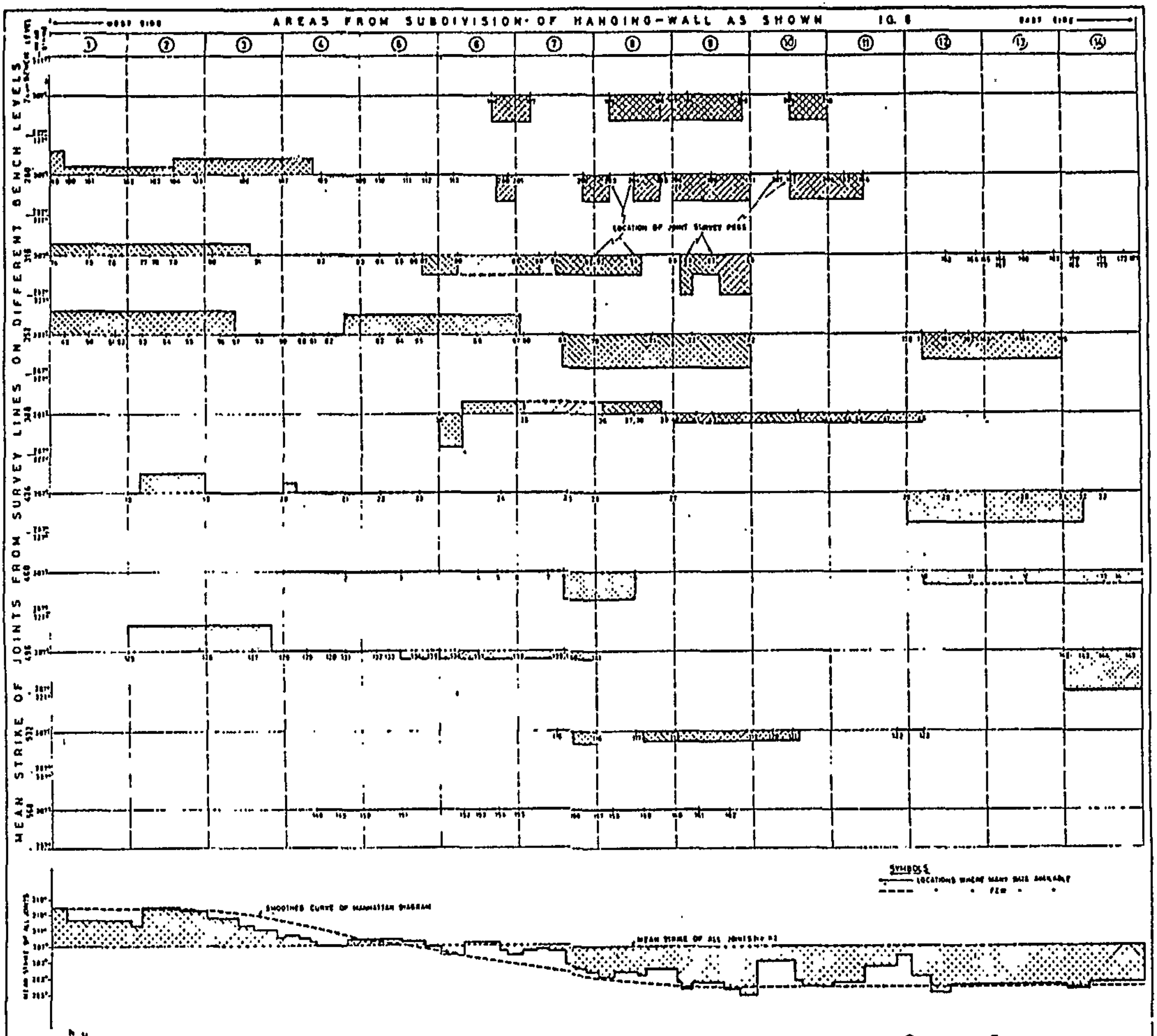


Fig. 5 Manhattan diagrams of strike trends of joints occurring within $\pm$ 30° of 300°

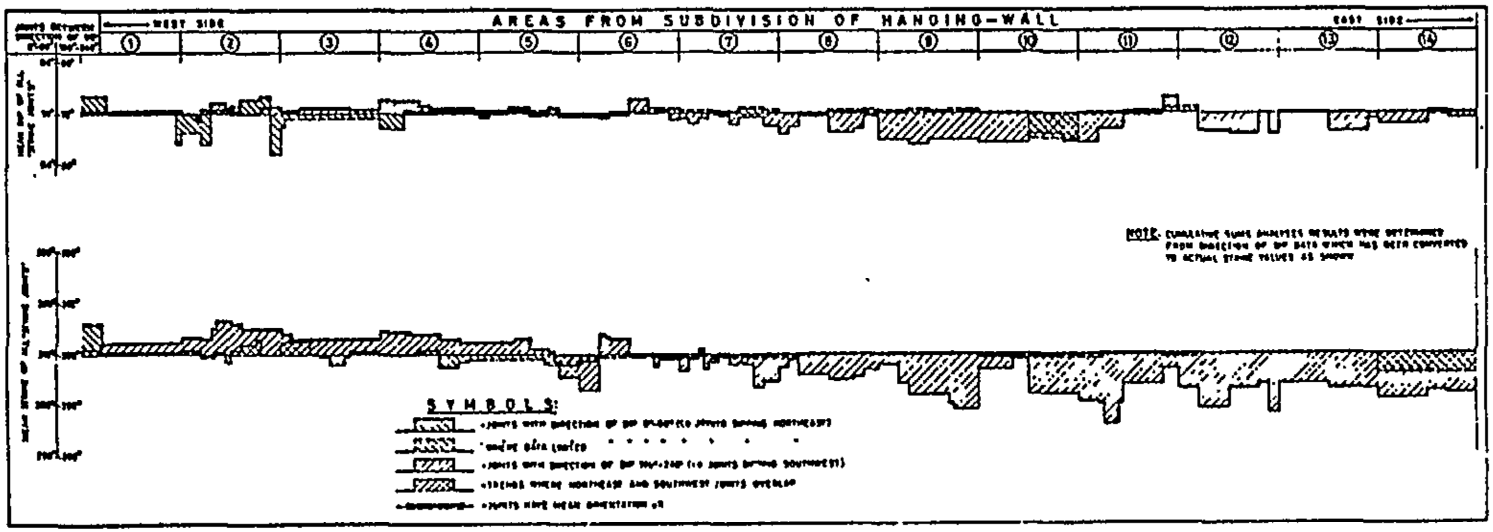


Fig. 6 Manhattan diagrams of the mean values of the cumulative sums analysis of strike and dip trends of "strike joints" dipping northeast and southwest of the estimated regional tectonic structural axis (300°) at Nchanga

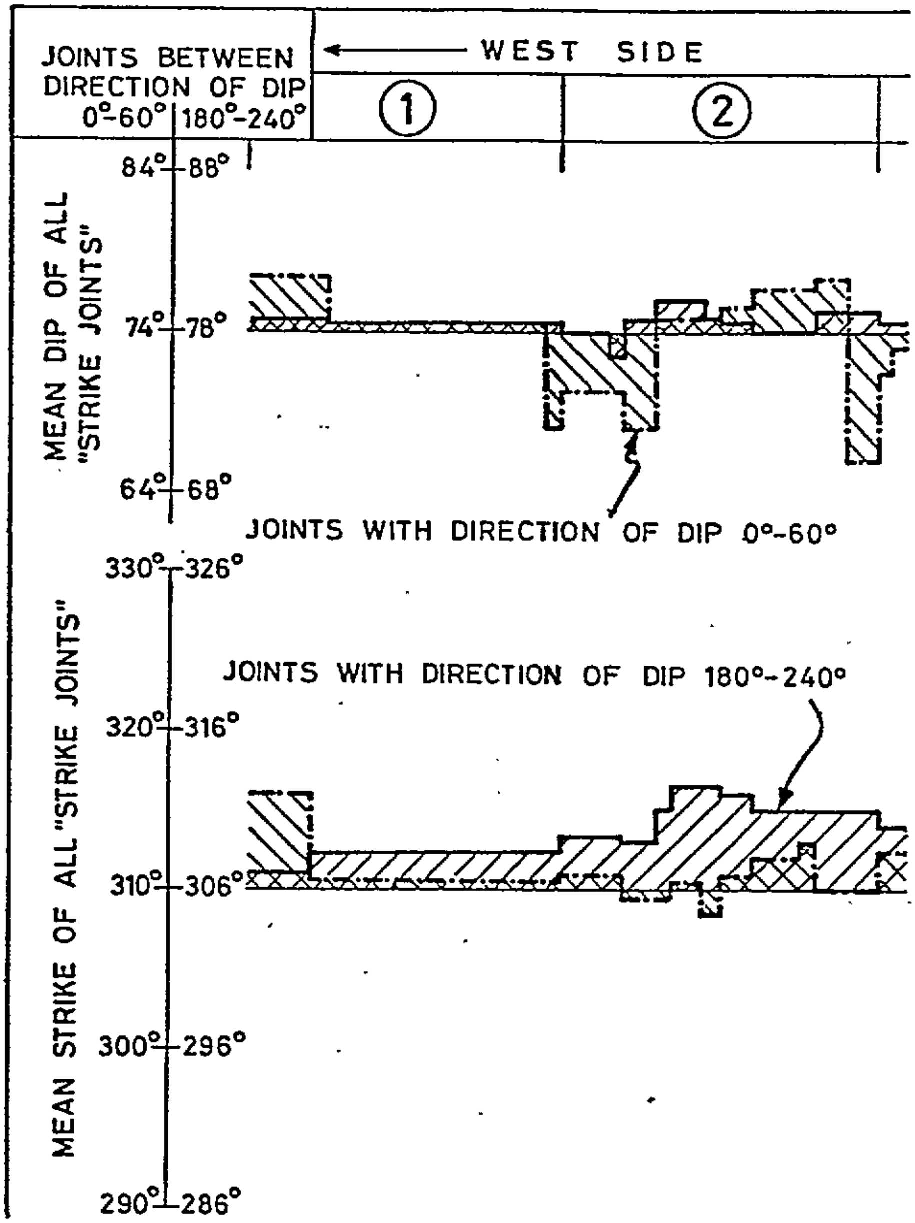


Fig. 7 Enlarged portion of the left side of Fig. 6 showing detail clearer

of the southwest dipping joints. This rotation is due to a major fault, the only major fault occurring in the area considered. This fault strikes 320° and dips 80° to 85° SW. The vertical component of net slip is about 80 ft, the downthrow being to the southwest.

In Fig. 6 the northeast dipping joints, with respect to both strike and dip, vary only slightly about the mean. Also, they decrease in frequency going eastwards, becoming negligible beyond area 7. This indicates, along with their angular relationship to the fault, that these joints are probably feather fractures which have developed sympathetic to the fault.

The southwest dipping joints, on the other hand, are significantly above the mean on the west side of the pit. Here, sympathetic fracturing parallel to the fault has swung the current mean strike slightly towards that of the fault. Further east, however, the southwest dipping joints rotate counter-clockwise past the mean. Beyond area 9, where the influence of the fault is negligible, and where only tectonic forces appear to have been significant in causing the existing joints, they maintain a remarkably consistent current mean strike of about 295°.

Plots in Fig. 8 of both (1) the percentage and (2) the number of joints per foot (i,e, joint intensity) of northeast and southwest dipping joints occurring in each of the areas 1 to 14, provide convincing additional evidence of the conclusions above. Fig. 8(a) indicates that the percentage of northeast dipping joints is considerably greater on the west side of the pit and decreases rapidly, becoming negligible east of area 7. The opposite is true for the southwest dipping joints. Area 4 is the changing point where one or the other dominates. In Fig. 8(b) the influence of the fault can be seen clearly. The intensity of the northeast dipping joints is excessively high in areas 1 to 4,

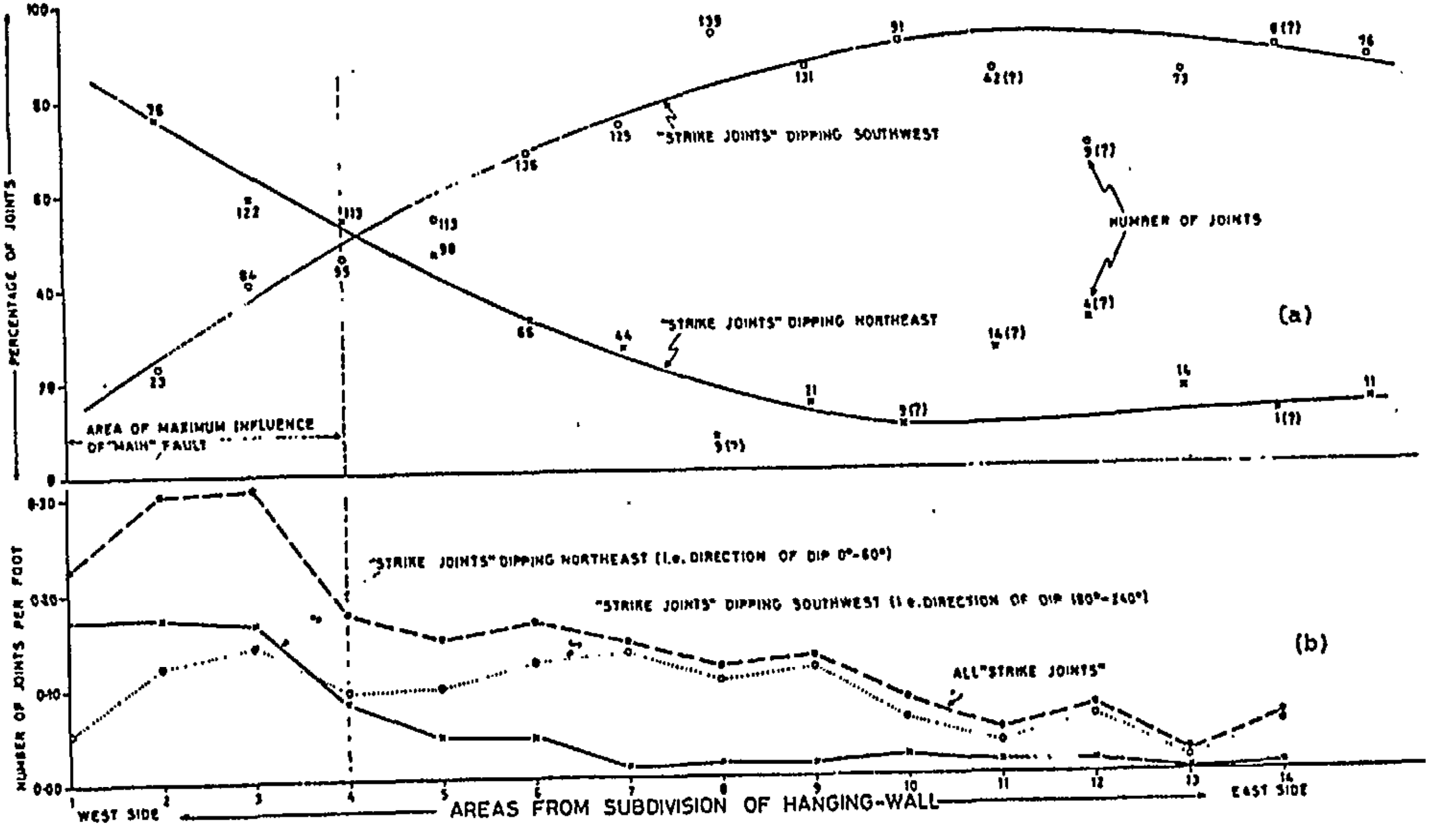


Fig. 8 Plot of the percentage (a) and frequency (b) of "strike joints" dipping southwest and northeast of the synclinal axis for different areas across the hanging-wall

but negligible beyond area 7. The southwest dipping joints, however, increase in frequency only slightly across the fault-affected area and maintain a fairly constant, though slightly decreasing, frequency going from west to east beyond this area.

Regional Joint Pattern

East of area 7 additional joints of an anomalous nature, (i.e. joints other than those originating through regional tectonic processes) are not evident. Thus, it must be assumed that those remaining, namely the joints occurring outside of the limits of the fault influence, are of the regional joint pattern. These are exclusively the southwest dipping joints.

Not only are these joints part of the regional pattern, but they represent greater than 80 per cent of the regional pattern (see Fig. 2 and 8). Greater than 80 per cent of the regional joint pattern, therefore, can be defined, approximately, as having an average strike of 295° and an average dip of 72° SW to 76° SW.

Genesis of Jointing and the Tectonic Process at Nchanga

With the general joint distributions in Fig. 2 and other structural relationships, the genesis of this dominant regional set, and the conditions during which both folding and this jointing took place, can be postulated.

Since definite sets of either one or both conjugate shear joints are not evident, and the intermediate tension joint set is essentially absent, the sedimentary rocks in the area appear to have yielded, at least initially, by plastic deformation or flowage and recrystallization in contrast to brittle fracture. The first and major form of brittle fracture (i.e. southwest dipping joints) appears to have developed as a result of elastic rebound of the originally highly compressed materials after both the temperature and pressure subsided. The southwest dipping joints, therefore, appear to be tension joints, having developed due to elastic rebound after the principal tectonic force had terminated. The principal form of deformation was that of crustal shortening. The type of folding was related primarily to those of horizontal tectonics, i.e. to processes of deformation wherein the maximum principal stress (tectonic stress) acted horizontally.

EXTRAPOLATION OF JOINT DATA

For purposes of making slope stability evaluations for the pit faces advancing both northwards and eastwards at Nchanga, the question of the reliability of applying information acquired from the existing hanging-wall slope to other parts of the mass where information is not available and where the advancing and final pit faces are to be located, is an important consideration. If any degree of confidence is to be achieved in proposing slope designs based to a large extent on these results, it must be shown whether the joint characteristics can be expected to be the same or to differ, and in what way to differ, in other parts of the mass where information is not available. The question of the extrapolation of joint properties when designing engineering structures in rock, and basic considerations relating to this problem, are discussed by Piteau (7).

Results in Fig. 6 show that both the current mean strike and current mean angle of dip are, statistically speaking, remarkably consistent east of area 8. This is particularly so with respect to the current mean strike. In either case, the deviation about the overall mean strike and mean dip orientation in this area is plus or minus three degrees. The history of folding in the majority of the syncline, and at least within the confines of the proposed final pit limits, is expected to be reasonably similar. Since the joints in question are genetically related to this folding process (in that they are rebound features which developed normal to the principal tectonic stress), based on the results of the cumulative sums analysis described above (see Fig. 6), there is good reason to believe that southwest dipping joints with similar orientations will exist in the proposed eastern extension areas of the pit.

For comparative purposes it is fortunate that at Nchanga an extensive joint survey had been conducted on the hanging-wall of the pit in 1966. The pit face at the time was 250 ft to the south of its present location, but the joint survey was conducted at approximately the same elevation and same relative location as that of the present survey. Hence, an ideal situation exists for determining whether the joint patterns are similar between the two survey lines and, accordingly, whether extrapolation of such structures is reasonable over this same distance in the opposite direction.

The 1966 survey results were available on stereographic projections, hence the peak concentration of the southwest dipping joints was easily measured. This information was compared directly to the cusum results for the respective areas across the pit. Except for minor variations, in general a remarkable similarity was found between the two separate survey results. Since the history of deformation is expected to be similar within the final pit limits, this indicated that the results from the present analysis would probably apply also behind the existing face in areas where the advancing pit faces are to be eventually located. These results also confirmed the conviction that the joint trends will be maintained in areas further east of the pit in which the extension is proposed.

CONCLUSIONS

The cumulative sums technique, illustrated with particular reference to an extensive joint analysis of the Nchanga open pit hanging-wall, provides an efficient and definitive method of examining joint dip and/or joint strike data in the order in which the joints are derived along the survey line. Unlike most joint analysis methods, this technique smooths out "noise" effectively. Also, both step changes in the underlying function and slow cyclic variations are readily displayed.

Basically, it is used to determine:

(a) the current deviation of either the joint dip or strike above or below some level of the orientation data or reference value (K) (i.e. in the Nchanga analysis K was taken to be the mean of the orientation data used);

(b) where these particular changes take place along the pit face; and

(c) the current mean orientation or simple moving average at any point in the consecutive sequence of the joints.

The behavior of a particular group of joints can be ascertained with respect to such characteristics as imperceptible rotation, both in the horizontal (i.e. strike) and vertical (i.e. dip) planes. In that the plots depicting this behavior are statistically significant, they can assist in predicting whether the information from the exposed pit face can be extrapolated with confidence to other parts of the mass where information is limited, but where pit slopes are to be eventually located. In this respect a knowledge of the geological history and the genetic relationship of the joints to the regional structure is important.

ACKNOWLEDGEMENTS

The authors extend their thanks to Nchanga Consolidated Copper Mines Limited - Chingola Division, for the co-operation which was given throughout the course of this work. The authors particularly wish to express their appreciation to C. Kovacevic, cartographer, for drawing not only these figures but numerous others in the Nchanga report; to A. Carbray, for helping to process the data; to F. Chisela, for supervising the survey; and to J. Hellings, for his general co-operation. Finally, the authors acknowledge with grateful thanks J. E. Jennings, O. K. H. Steffen and A. MacG. Robertson, with whom the senior author worked closely in recent years and who, although not directly involved with the development of this new technique, contributed significantly to important earlier development work, of which the results in this paper are an outgrowth.

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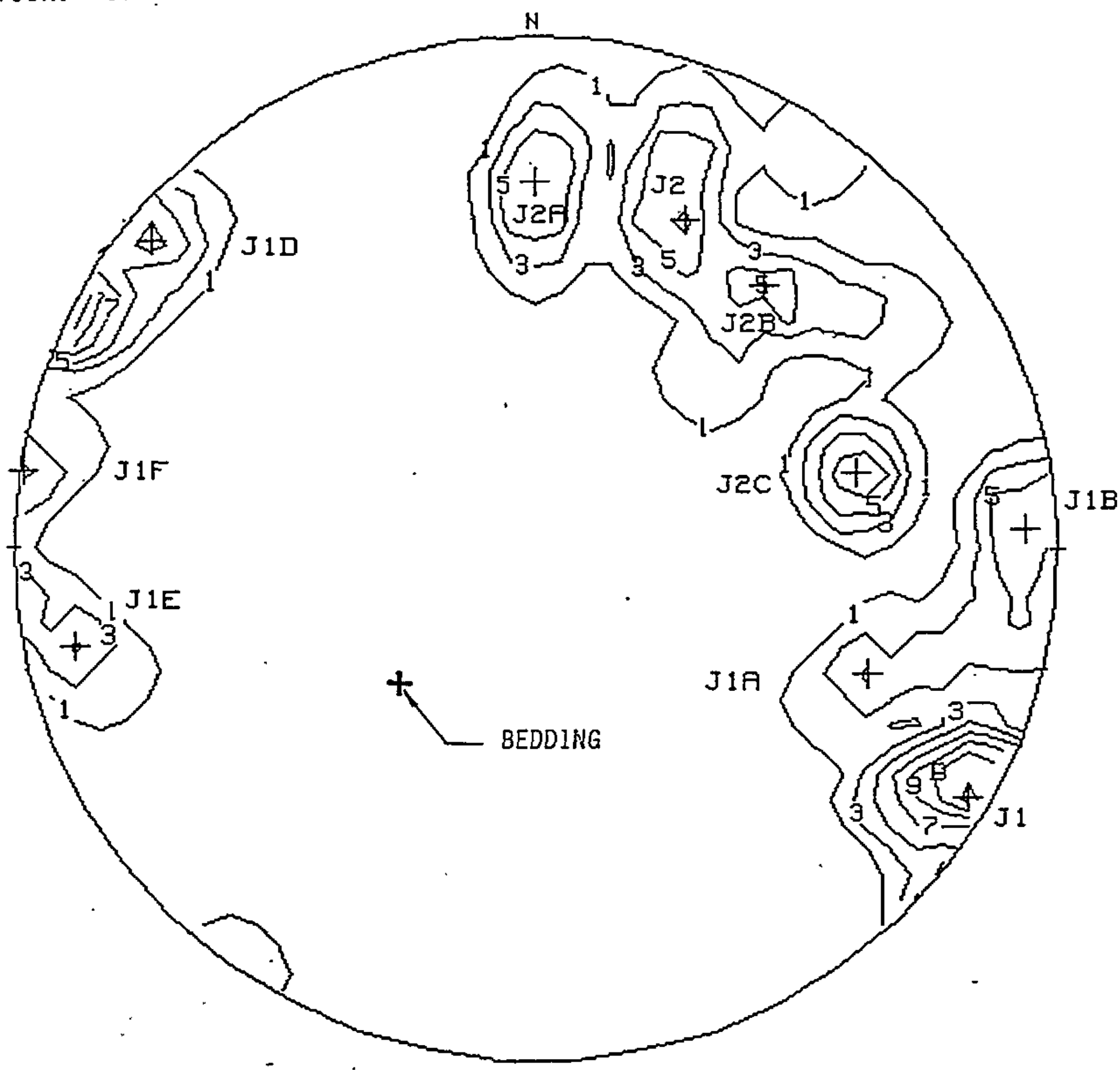
APPENDIX B

LOWER-HEMISPHERE, EQUAL-AREA PROJECTIONS OF POLES TO DISCONTINUITIES IN EACH STRUCTURAL DOMAIN

OBSERVATIONS: 37
POPULATION: 37

CONTOUR PLOT



LABEL	DIP DIRECTION	DIP	CONCENTRATION (%)
J1	300	85	14
J1A	291	58	5
J1B	268	83	5
J2	205	59	8
J2B	221	57	5
J2A	180	61	6
J2C	256	53	8
J1D	129	83	8
J1E	078	79	5
J1F	099	89	5

QUINTETTE COAL LIMITED
DENISON MINES LIMITED
SHIKANO DEVELOPMENT

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

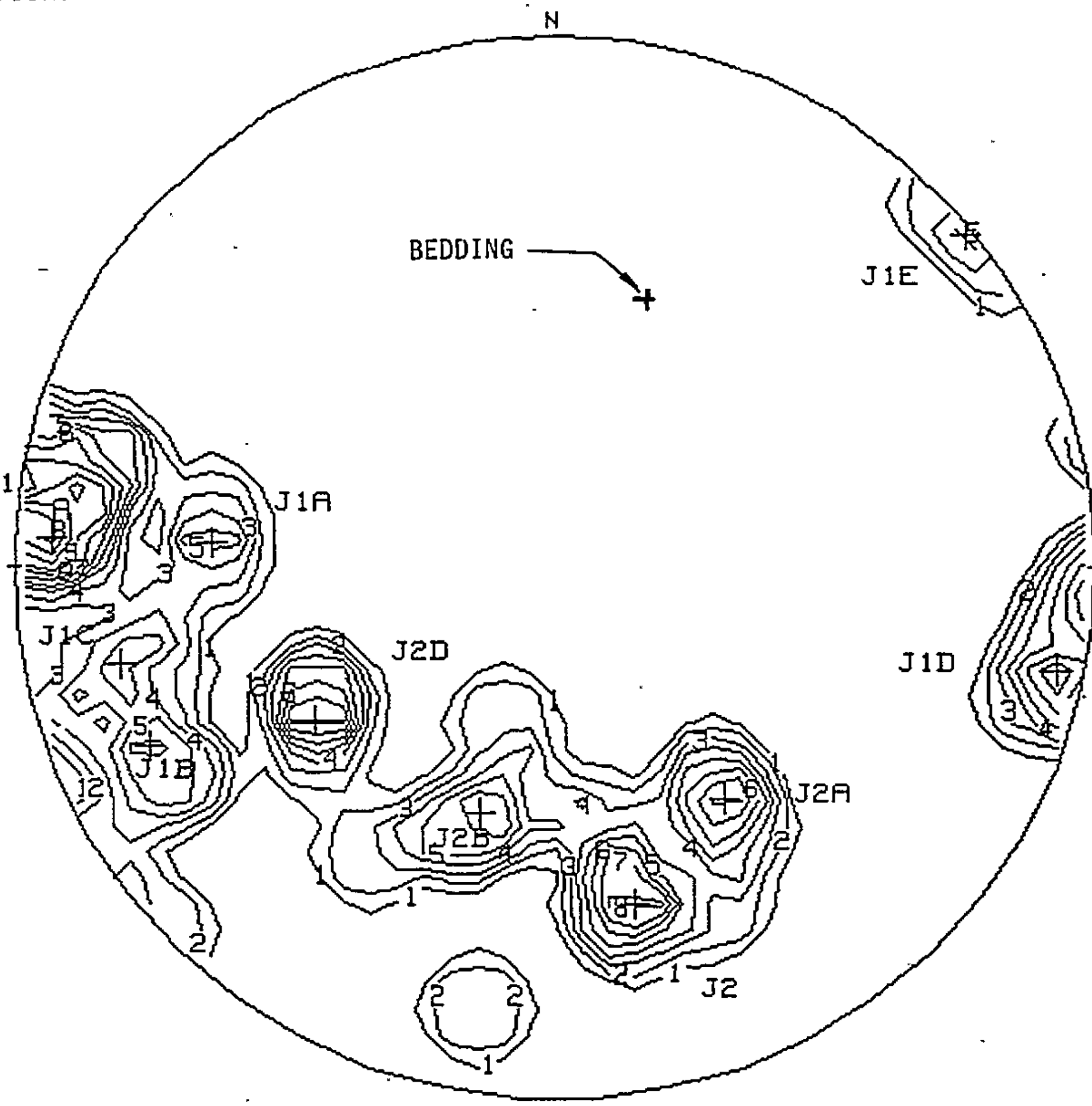
GEODAT: LOWER HEMISPHERE EQUAL AREA PROJECTION

ROTATED JOINTS IN SD 1 (BD 044/31)

By:	Date:
PMH	APR 85
Page:	Job#:
339-X4-B1	MH

OBSERVATIONS: 37
POPULATION: 37

CONTOUR PLOT



LABEL	DIP DIRECTION	DIP	CONCENTRATION (%)
J1	093	82	12
J1A	094	53	5
J1B	066	71	6
J1C	077	71	5
J1D	282	84	8
J2	347	55	8
J2A	324	45	8
J2B	017	40	7
J2D	057	44	8
J1E	231	88	5

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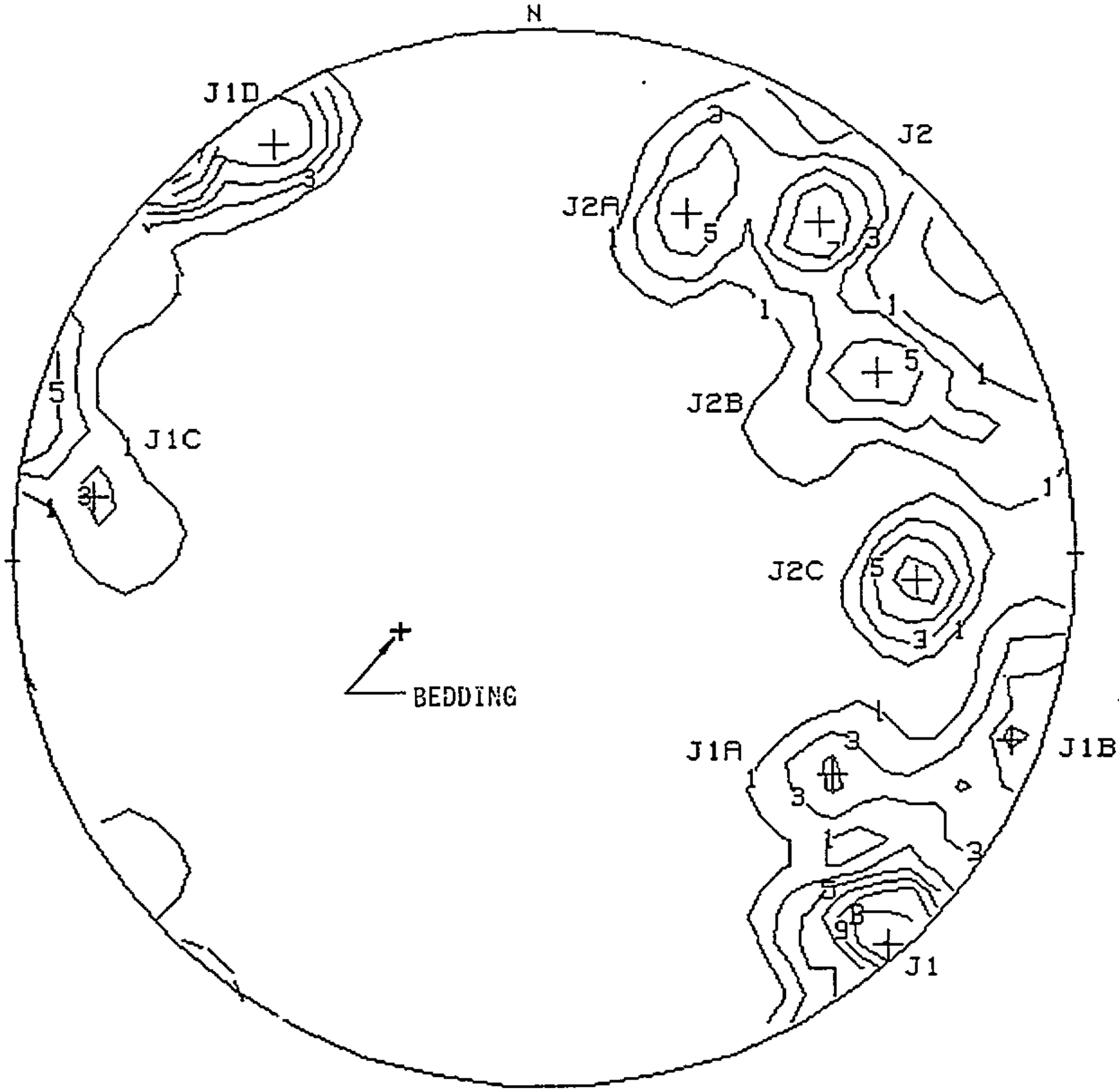
GEODAT: LOWER HEMISPHERE EQUAL AREA PROJECTION

ROTATED JOINTS IN SD 2 (BD198/46)

By:	Date:
PMH	APR 85
Page: 339-X4-B2	Job#:

OBSERVATIONS: 37
POPULATION: 37

CONTOUR PLOT



LABEL	DIP DIRECTION	DIP	CONCENTRATION (%)
J1	319	87	13
J1A	308	57	5
J1B	292	84	8
J1C	098	74	4
J2	220	71	9
J2A	203	60	7
J2B	241	61	6
J2C	274	60	8
J1D	148	82	9

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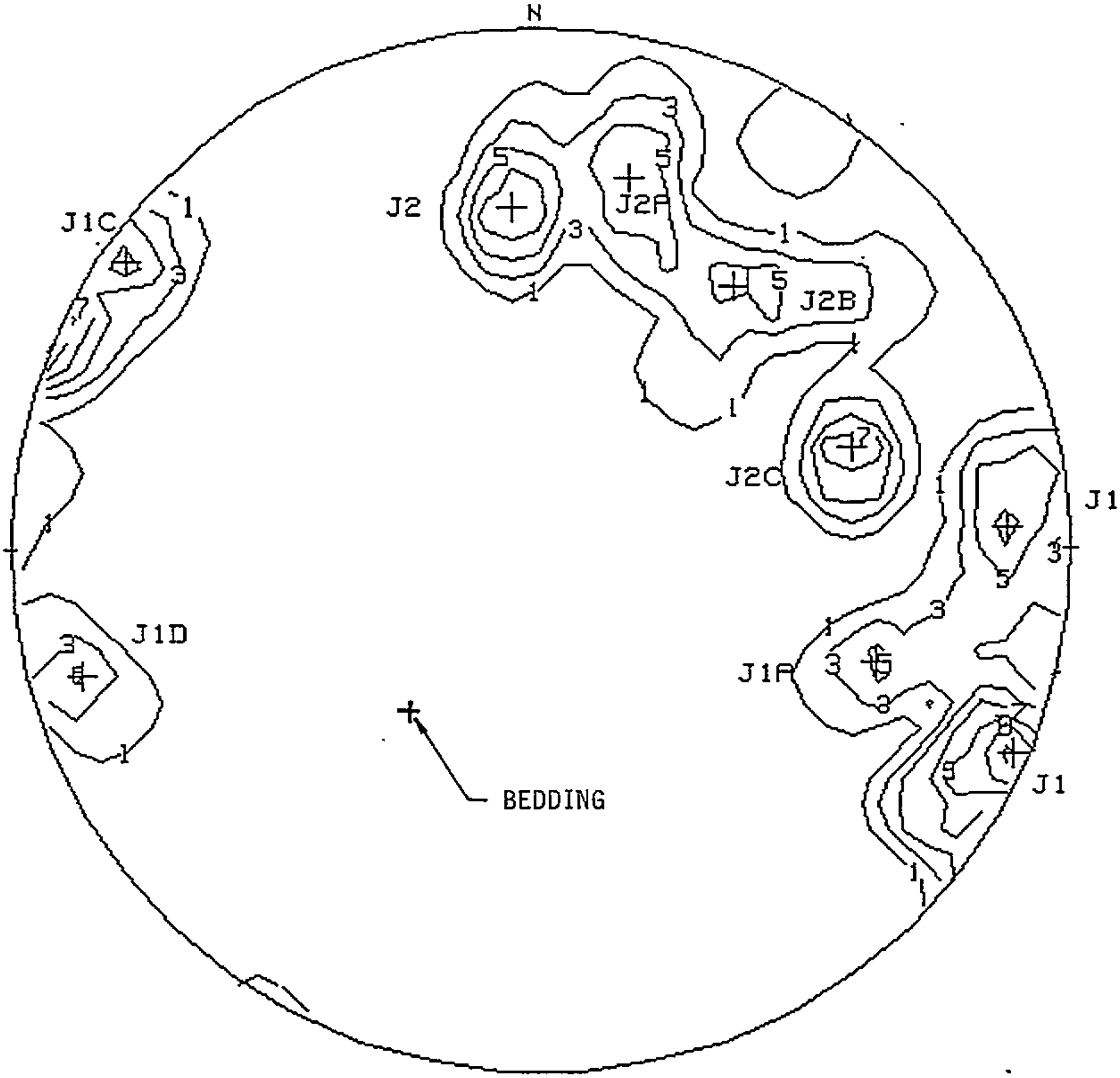
GEODAT: LOWER HEMISPHERE EQUAL AREA PROJECTION
ROTATED JOINTS IN SD 3 (BD 064/25)

By:	Date:
PMH	APR 85
Page: 339-X4-B3	Job#:

OBSERVATIONS: 37
POPULATION: 37

CONTOUR PLOT



LABEL	DIP DIRECTION	DIP	CONCENTRATION (%)
J1	294	87	14
J1A	289	56	5
J1B	267	77	8
J1C	125	85	8
J1D	074	79	5
J2	176	55	8
J2A	194	62	7
J2B	216	52	5
J2C	252	52	8

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GEODAT: LOWER HEMISPHERE EQUAL AREA PROJECTION

ROTATED JOINTS IN SD 4 (BD 040/34)

By: PMH
Date: APR 85
Page: 339-X4-B4
Job#: AA

APPENDIX C

TEST PIT LOGS AND RESULTS OF GRADATION TESTS

EXPLANATION OF TERMS USED IN THE SOIL CLASSIFICATION

1. Coarse Material

- SAND	(#200 sieve to #4 sieve)
- GRAVEL	(#4 sieve to 76 mm)
- COBBLES	(76 mm to 200 mm)
- BOULDERS	(rock greater than 200 mm)

2. Percentage of Minor Components

- and	(35 to 50%)
- some	(20 to 35%)
- little	(10 to 20%)
- trace	(1 to 10%)

3. Plasticity

- High	(Liquid limit above 50)
- Medium	(Liquid limit between 30 and 50)
- Low	(Liquid limit below 30)
- Slight	(Plasticity Index between 4 and 7)

4. Structure and Sensitivity

- Stratified	(Alternating layers of varying type)
- Laminated	(Alternating layers less than 1/4", 6 mm)
- Varved	(Where the laminations consist of very fine material)
- Fissured	(Material breaks along plane of fracture)
- Slickensided	(If fracture plane appeared glossy)
- Blocky	(If material can be broken in small and hard angular lumps)
- Nuggetted	(If soil breaks into small nuggets or cubes)
- Homoegenous	(Consistent material mixture such as nonstratified clay, till)
- Lensed	(Small pockets of different texture)

Sensitivity

- High	(8 - 16)
- Medium	(4 - 8)
- Low	(2 - 4)

5. Consistency and Density (As determined by pocket penetrometer readings and SPT tests)

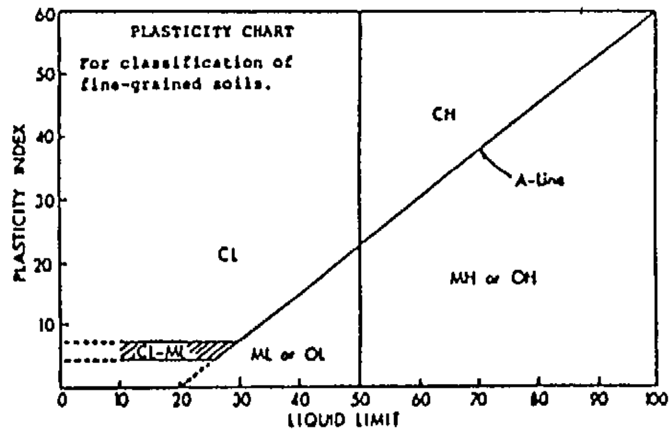
- Very soft	Less than 12 kPa (Undrained shear strength)
- Soft	12 to 24 kPa
- Firm	24 to 48 kPa
- Stiff	48 to 95 kPa
- Very stiff	95 to 190 kPa
- Hard	Greater than 190 kPa
- Very loose	0 - 4 blows/0.3 m
- Loose	4 - 10 blows/0.3 m
- Medium dense	10 - 30 blows/0.3 m (compact)
- Dense	30 - 50 blows/0.3 m
- Very dense	over 50 blows/0.3 m

6. Group Symbols (refer to following page)

GW, GP, GM, GC, SW, SP, SM, SC, ML, CL, OL, MH, CH, OH, PT

7. Laboratory Tests

MS	Mechanical Sieve
H	Hydrometer Analysis
SPD	Proctor Test
CBR	California Bearing Ratio Test
SG	Specific Gravity

MAJOR DIVISIONS			GROUP SYMBOLS	GRAPHIC SYMBOL	TYPICAL NAMES	CLASSIFICATION CRITERIA		
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve *	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW		Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines Less than 5% Pass No.200 sieve: GW, GP, SW, SP More than 12% Pass No.200 sieve: GM, GC, SM, SC 5% to 12% Pass No.200 sieve: Borderline Classification requiring use of dual symbols	$C_u = D_{60}/D_{10}$ Greater than 4 $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP		Poorly graded gravels and gravel-sand mixtures, little or no fines		Not meeting both criteria for GW	
		GRAVELS WITH FINES	GM		Silty gravels, gravel-sand-silt mixtures		Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			GC		Clayey gravels, gravel-sand-clay mixtures		Atterberg limits plot above "A" line and plasticity index greater than 7	
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW		Well-graded sands and gravelly sands, little or no fines		$C_u = D_{60}/D_{10}$ Greater than 6 $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP		Poorly graded sands and gravelly sands, little or no fines		Not meeting both criteria for SW	
		SANDS WITH FINES	SM		Silty sands, sand-silt mixtures		Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			SC		Clayey sands, sand-clay mixtures		Atterberg limits plot above "A" line and plasticity index greater than 7	
FINE-GRAINED SOILS 50% or more passes No. 200 sieve *	SILTS AND CLAYS Liquid limit 50% or less		ML		Inorganic silts, very fine sands, rock flour, silty or clayey fine sands			
			CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL		Organic silts and organic silty clays of low plasticity			
	SILTS AND CLAYS Liquid limit greater than 50%		MH		Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts			
			CH		Inorganic clays of high plasticity, fat clays			
			OH		Organic clays of medium to high plasticity			
Highly Organic Soils			PT		Peat, muck and other highly organic soils	Visual-Manual Identification, See ASTM Designation D 2488		

* Based on the material passing the 3-in. (75-mm) sieve

UNIFIED SOIL CLASSIFICATION SYSTEM

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS

OFFICE REPORT ON SITE INVESTIGATION

Sheet 1 of 1

Contract No. SHIKANO SOUTH DUMP
Boring No. A
Northing
Compiled By HAWLEY/CLARIDGE
Location SHIKANO SOUTH DUMP
Easting
Boring Date April 4, 1985
Contractor
Elevation

SAMPLE TYPES
GS Grab sample
WS Wash sample
RC Rock core
CR CRREL barrel
SS Split spoon
TO Thin wall open
TP Thin wall piston
TYPE OF RIG
SAMPLE HAMMER: wt. drop
STICK UP (m.)

SAMPLE CONDITION
Disturbed
Fair
Good
Lost

TEST INFORMATION
● PENETROMETER kN/m²
□ UNCONFINED COMP STR kN/m²
△ DYNAMIC CONE BLOWS/0.3m
WATER CONTENT % ⊙
PLASTIC LIM — LIQUID LIM
10 30 50 70 90

Depth m	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS
0–2.1			FINE SAND - trace of silt, trace of organics, medium brown, homogeneous				A-1 (at ~1.1 m)		
2.1–4.1		2.1	SAND, GRAVEL AND COBBLES - trace of silt, cobbles to 20 cm, well-graded				A-2 (at ~3.1 m)		
4.1		4.1							

NOTES:
1. WATER NOT ENCOUNTERED IN TEST PIT.

JOB NO. .... BORING NO. ....

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS

OFFICE REPORT ON SITE INVESTIGATION

Contract No. SHIKANO SOUTH DUMP
Compiled By. HAWLEY/CLARIDGE
Boring Date. April 4, 1985
Boring No. B
Location. SHIKANO SOUTH DUMP
Contractor
Northing
Easting
Elevation

SAMPLE TYPES
GS Grab sample
WS Wash sample
RC Rock core
CR CRREL barrel
SS Split spoon
TO Thin wall open
TP Thin wall piston
TYPE OF RIG
SAMPLE HAMMER: wt. drop
STICK UP (m.)

SAMPLE CONDITION
Disturbed
Fair
Good
Lost

TEST INFORMATION
● PENETROMETER kN/m²
□ UNCONFINED COMP STR kN/m²
△ DYNAMIC CONE BLOWS/0.3m
WATER CONTENT %
PLASTIC LIM. ⊙ LIQUID LIM.
10 30 50 70 90

Depth m	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	Samples: Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS	Water content
0–0.6			FINE SAND - organic, yellow-brown							
0.6–2.3			FINE SAND - trace of silt, dense, stratified, organics, yellow - brown to 0.5 m., grey - brown below 0.5 m.				B-1			⊙

NOTES:
1. WATER NOT ENCOUNTERED IN TEST PIT.

JOB NO. ..... BORING NO.. .....

PITEAU & ASSOCIATES
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OFFICE REPORT ON SITE INVESTIGATION

Sheet 1 of 1

Contract No.. SHIKANO SOUTH DUMP..
Boring No. ....C............
Northing ....

Compiled By HAWLEY/CLARIDGE...
Location SHIKANO SOUTH DUMP... 15 m N of QSRB5020
Easting ....

Boring Date April 5, 1985 ....
Contractor ....
Elevation ....

SAMPLE TYPES

- GS Grab sample
- WS Wash sample
- RC Rock core
- CR CRREL barrel
- SS Split spoon
- TO Thin wall open
- TP Thin wall piston

TYPE OF RIG ....
SAMPLE HAMMER: wt. .... drop ....
STICK UP (m.) ....

SAMPLE CONDITION

- Disturbed
- Fair
- Good
- Lost

TEST INFORMATION

- ● PENETROMETER KN/m² (x100)
- □ UNCONFINED COMP STR KN/m²

1 2 3 4

△ DYNAMIC CONE BLOWS/0.3m

PLASTIC LIM — WATER CONTENT % ⊙ — LIQUID LIM

10 30 50 70 90

Depth m.	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	SAMPLES Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS	TEST INFORMATION
		0.15	ORGANIC SILT (PEAT)							
1			SILT - trace organics, trace of clay, medium brown to grey, stratified, very stiff, fissured				C-1			
2		2.4								
3			SILT - sandy, stiff, trace of organics				C-2			(TORVANE) (PEN) (PEN)
4		4.6								
5			SILT (ML-CL) - clayey, lightly stratified, very stiff				C-3			
6		5.9								
7										
8										

NOTES: 1. SEEPAGE ENCOUNTERED AT DEPTH OF 3.0 m.

JOB NO. .... BORING NO. ......

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GEOTECHNICAL CONSULTANTS

OFFICE REPORT ON SITE INVESTIGATION

Contract No. SHIKANO SOUTH DUMP
Boring No. D
Northing
Compiled By. HAWLEY/CLARIDGE
Location. SHIKANO SOUTH DUMP
Easting
Boring Date April 5, 1985
Contractor
Elevation

SAMPLE TYPES
GS Grab sample
WS Wash sample
RC Rock core
CR CRREL barrel
SS Split spoon
TO Thin wall open
TP Thin wall piston
TYPE OF RIG
SAMPLE HAMMER: wt. drop
STICK UP (m.)

SAMPLE CONDITION
Disturbed
Fair
Good
Lost

TEST INFORMATION
● PENETROMETER kN/m² (x 100)
□ UNCONFINED COMP STR kN/m²
1 2 3 4
△ DYNAMIC CONE BLOWS/0.3m
WATER CONTENT %
PLASTIC LIM ⊙ LIQUID LIM
10 30 50 70 90

Depth m	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS	Test information
0–2.2			PEAT - dark brown, amorphous to fibrous				D-1			476.2
2.2			SILT - clayey, trace of sand and gravel, grey, stratified, soft, wet							
2.8			CLAY, SILT, SAND, GRAVEL AND COBBLES (TILL) - occasional boulders (to 30 cm), medium to very stiff consistency, lenses of very stiff clayey silt				D-2	Gradation test		
							D-3			
4.9										

NOTES:
1. Pit located near swamp.
2. Seepage encountered at depth of 1.0 m.

JOB NO. .... BORING NO. .....

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OFFICE REPORT ON SITE INVESTIGATION

Sheet 1 of 1

Contract No. SHIKANO SOUTH DUMP
Boring No. E
Northing

Compiled By HAWLEY/CLARIDGE
Location SHIKANO SOUTH DUMP
Easting

Boring Date April 5, 1985
Contractor
Elevation

SAMPLE TYPES
GS Grab sample
WS Wash sample
RC Rock core
CR CRREL barrel
SS Split spoon
TO Thin wall open
TP Thin wall piston

TYPE OF RIG
SAMPLE HAMMER: wt. ... drop ...
STICK UP (m.)

SAMPLE CONDITION
Disturbed
Fair
Good
Lost

TEST INFORMATION
● PENETROMETER kN/m^2 (x100)
□ UNCONFINED COMP STR kN/m^2
1 2 3 4
△ DYNAMIC CONE BLOWS/0.3m
WATER CONTENT %
PLASTIC LIM ⊙ LIQUID LIM
10 30 50 70 90

Depth m	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS	TEST INFORMATION
0 – 3.1			CLAY - some sand, some silt, mottled brown, trace of organics, very stiff, stratified, fissured				E-1	Gradation test		
3.1 – 5.0		3.1	SILT AND CLAY - trace of fine sand, brown to grey, stiff, stratified, fissured, trace of organics				E-2			(TORVANE) (PEN)
5.0		5.0								

NOTES: 1. Seepage encountered at depth of 3.0 m.

JOB NO. .... BORING NO. ......

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS

OFFICE REPORT ON SITE INVESTIGATION

Contract No. SHIKANO SOUTH DUMP
Compiled By HAWLEY/CLARIDGE
Boring Date April 5, 1985
Boring No. F
Location SHIKANO SOUTH DUMP
Contractor
Northing
Easting
Elevation

SAMPLE TYPES

GS Grab sample
WS Wash sample
RC Rock core
CR CRREL barrel
SS Split spoon
TO Thin wall open
TP Thin wall piston

TYPE OF RIG
SAMPLE HAMMER: wt. drop
STICK UP (m.)

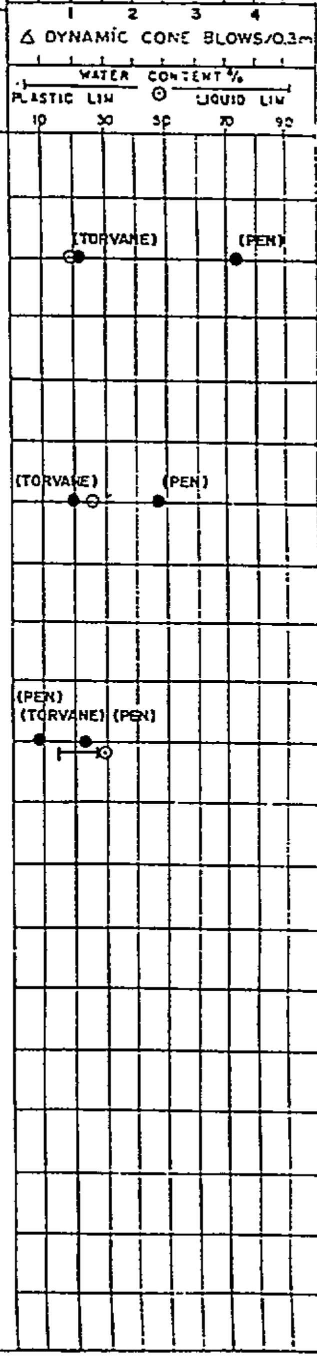
SAMPLE CONDITION

Disturbed
Fair
Good
Lost

TEST INFORMATION

● PENETROMETER kN/m² (x100)
□ UNCONFINED COMP STR kN/m²
△ DYNAMIC CONE BLOWS/0.3m
WATER CONTENT %
PLASTIC LIM ⊙ LIQUID LIM

Depth m.	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	Samples: Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS
0–0.25			ORGANIC SILT (TOPSOIL)						
0.25–1.7			SILT AND FINE SAND - very stiff, stratified, mottled yellow-brown, trace of organics				F-1		
1.7–4.2			SILT - sandy, trace of clay, very stiff, stratified, trace of organics, grey				F-2		
4.2–5.9			SILT - clayey, trace of fine sand, trace of fine gravel, medium consistency, grey				F-3		



NOTES: 1. Water not encountered in test pit.

JOB NO. .... BORING NO. ......

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS

OFFICE REPORT ON SITE INVESTIGATION

Sheet 1 of 1

Contract No. SHIKANO SOUTH DUMP
Boring No. G
Northing
Compiled By. HAWLEY/CLARIDGE
Location SHIKANO SOUTH DUMP
Easting
Boring Date April 6, 1985
Contractor
Elevation

SAMPLE TYPES
- GS Grab sample
- WS Wash sample
- RC Rock core
- CR CRREL barrel
- SS Split spoon
- TO Thin wall open
- TP Thin wall piston

TYPE OF RIG
SAMPLE HAMMER: wt. drop
STICK UP (m.)

SAMPLE CONDITION
- ☒ Disturbed
- ▥ Fair
- ▨ Good
- ■ Lost

TEST INFORMATION
- ● PENETROMETER KN/m² (x100)
- ☐ UNCONFINED COMP STR KN/m²
- 1 2 3 4
- △ DYNAMIC CONE BLOWS/0.3m
- WATER CONTENT %: PLASTIC LIM ⊙ LIQUID LIM
- 10 30 50 70 90

Depth m	METHOD	SOIL/ROCK DESCRIPTION	ICE	Sample Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS
0 – 0.3	0.3	PEAT - fibrous, dark brown						
0.3 – 2.3	2.3	SAND (TILL) - silty, trace of clay, trace of gravel, stiff to very stiff, trace of organics, medium brown				G-1		
2.3 – 5.0	5.0	CLAY, SILT, SAND, GRAVEL AND COBBLES (TILL) - hard, cobbles to 20 cm, dark grey				G-2		

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8

NOTES: 1. Water not encountered in test pit.

JOB NO. .... BORING NO. ......

PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS	OFFICE REPORT ON SITE INVESTIGATION	Sheet 1 of 1

Contract No.. SHIKANO SOUTH DUMP.. Compiled By. HAWLEY/CLARIDGE... Boring Date. April 6, 1985 ...
Boring No........ H............ Location . SHIKANO NORTH DUMP.... Contractor ....
Northing .... Easting .... Elevation ....

SAMPLE TYPES

GS	Grab sample	TO	Thin wall open
WS	Wash sample	TP	Thin wall piston
RC	Rock core		
CR	CRREL barrel		
SS	Split spoon		

TYPE OF RIG...
SAMPLE HAMMER: wt. .... drop.......................
STICK UP (m.) ....

SAMPLE CONDITION

☒ Disturbed
▥ Fair
▨ Good
■ Lost

TEST INFORMATION

● PENETROMETER kN/m²
□ UNCONFINED COMP STR kN/m²
△ DYNAMIC CONE BLOWS/0.3m
WATER CONTENT % ⊙ PLASTIC LIM. LIQUID LIM.
10 30 50 70 90

Depth m.	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	SAMPLES Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS
0			PEAT - fibrous, dark brown						
1									
2		2.0	CLAY, SILT, SAND, GRAVEL AND COBBLES (TILL) - occasional boulders, medium consistency, dark grey				H-1	Gradation test	
3		3.0	BEDROCK - sedimentary rock						
4			NOTE:						
			1. Terrain poorly drained.						
5			2. Water table at ground surface.						
6									
7									
8									

NOTES:

JOB NO. ..... BORING NO ......

PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS	OFFICE REPORT ON SITE INVESTIGATION	Sheet 1 of 1

Contract No... SHIKANO SOUTH DUMP. Compiled By. HAWLEY/CLARIDGE... Boring Date. April 6, 1985 ....
Boring No.......... 1.......... Location. SHIKANO NORTH DUMP.... Contractor ....
Northing.................... Easting.................. Elevation...................

SAMPLE TYPES
GS Grab sample TO Thin wall open
WS Wash sample TP Thin wall piston
RC Rock core TYPE OF RIG..........................
CR CRREL barrel SAMPLE HAMMER: wt.......... drop..................
SS Split spoon STICK UP (m.).. ....

SAMPLE CONDITION
Disturbed
Fair
Good
Lost

TEST INFORMATION
● PENETROMETER kN/m² (x 100)
□ UNCONFINED COMP STR kN/m²
1 2 3 4
△ DYNAMIC CONE BLOWS/0.3m
WATER CONTENT %
PLASTIC LIM ⊙ LIQUID LIM
10 30 50 70 90

Depth m	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	Samples: Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS
			PEAT - fibrous, dark brown						
		0.45	FINE SAND - silty, stiff, mottled brown						
1							I-1		
		1.3	CLAY, SILT, SAND AND GRAVEL (TILL) - occasional cobbles and boulders, stiff						
2							I-2		
3									
		3.3	BEDROCK - siltstone · hard (R2 - R3)						
4									
5			NOTE: 1. Water table at ground surface						
6									
7									
8									

NOTES:

JOB NO. ...... BORING NO.. ....

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS

OFFICE REPORT ON SITE INVESTIGATION

Sheet 1 of 1

Contract No. SHIKANO SOUTH DUMP
Boring No. J
Northing
Compiled By. HAWLEY/CLARIDGE
Location. SHIKANO NORTH DUMP
Easting
Boring Date. April 6, 1985
Contractor
Elevation

SAMPLE TYPES
GS Grab sample
WS Wash sample
RC Rock core
CR CRREL barrel
SS Split spoon
TO Thin wall open
TP Thin wall piston
TYPE OF RIG
SAMPLE HAMMER: wt. drop
STICK UP (m.)

SAMPLE CONDITION
Disturbed
Fair
Good
Lost

TEST INFORMATION
● PENETROMETER KN/m² (x100)
□ UNCONFINED COMP STR KN/m²
△ DYNAMIC CONE BLOWS/0.3m
WATER CONTENT % ⊙ PLASTIC LIM — LIQUID LIM

Depth m.	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	Samples: Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS
0			PEAT - amorphous, dark brown						
0.4			SAND - fine to medium, trace of organics, loose to moderately dense, grey				J-1		
1.3			CLAY, SILT, SAND, GRAVEL AND COBBLES (TILL) - very stiff, grey to mottled brown, wet				J-2		
5.0									

NOTES: 1. Seepage encountered at depth of 1.2 m.

JOB NO. .... BORING NO. ......

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS

OFFICE REPORT ON SITE INVESTIGATION

Sheet 1 of 1

Contract No. SHIKANO SOUTH DUMP
Boring No. K
Northing
Compiled By. HAWLEY/CLARIDGE
Location. SHIKANO NORTH DUMP
Easting
Boring Date. April 6, 1985
Contractor
Elevation

SAMPLE TYPES
GS Grab sample
WS Wash sample
RC Rock core
CR CRREL barrel
SS Split spoon
TO Thin wall open
TP Thin wall piston
TYPE OF RIG
SAMPLE HAMMER: wt. drop
STICK UP (m.)

SAMPLE CONDITION
Disturbed
Fair
Good
Lost

TEST INFORMATION
● PENETROMETER kN/m² (x 100)
□ UNCONFINED COMP STR kN/m²
1 2 3 4
△ DYNAMIC CONE BLOWS/0.3 m
WATER CONTENT %
PLASTIC LIM ⊙ LIQUID LIM
10 30 50 70 90

Depth m	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	SAMPLES Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS
0–4.0			CLAY, SILT, SAND, GRAVEL AND COBBLES (TILL) - (clay, moisture content increases with depth) occasional boulders to 40 cm, very stiff, brown, becoming grey with depth				K-1		
4.0		4.0	BEDROCK-						

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8

NOTES: 1. Seepage encountered at depth of 2.0 m.

JOB NO. BORING NO

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS

OFFICE REPORT ON SITE INVESTIGATION

Contract No. SHIKANO SOUTH DUMP
Boring No. 1
Northing
Compiled By HAWLEY/CLARIDGE
Location SHIKANO NORTH DUMP
Easting
Boring Date April 6, 1985
Contractor
Elevation

SAMPLE TYPES
GS Grab sample
WS Wash sample
RC Rock core
CR CRREL barrel
SS Split spoon
TO Thin wall open
TP Thin wall piston
TYPE OF RIG
SAMPLE HAMMER: wt. drop
STICK UP (m.)

SAMPLE CONDITION
Disturbed
Fair
Good
Lost

TEST INFORMATION
● PENETROMETER kN/m²
□ UNCONFINED COMP STR kN/m²
△ DYNAMIC CONE BLOWS/0.3m
WATER CONTENT % ⊙ PLASTIC LIM LIQUID LIM
10 30 50 70 90

Depth m	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	Samples Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS
			FILL - silt, sand and gravel (with logs) (adjacent to road).						
0.9			FINE SAND - trace of organics, loose, grey-brown				L-1		
1.5			BEDROCK - Friable carbonaceous shale (R1/R2)						

NOTES: 1. Water not encountered in test pit.

JOB NO. BORING NO

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS

OFFICE REPORT ON SITE INVESTIGATION

Sheet 1 of 1

Contract No. SHIKANO SOUTH DUMP
Boring No. H
Northing

Compiled By. HAWLEY/CLARIDGE
Location. SHIKANO PLANTSITE DUMP
Easting

Boring Date. April 6, 1985
Contractor
Elevation

SAMPLE TYPES
GS Grab sample
WS Wash sample
RC Rock core
CR CRREL barrel
SS Split spoon
TO Thin wall open
TP Thin wall piston
TYPE OF RIG
SAMPLE HAMMER: wt. drop
STICK UP (m.)

SAMPLE CONDITION
Disturbed
Fair
Good
Lost

TEST INFORMATION
● PENETROMETER kN/m²
□ UNCONFINED COMP STR kN/m²
△ DYNAMIC CONE BLOWS/0.3m
WATER CONTENT %
PLASTIC LIM ⊙ LIQUID LIM
10 30 50 70 90

Depth m	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS	Water content (%)
0–2.0			SAND - fine to medium, moderately dense, brown-grey				H-1			⊙ ~30
2.0–5.0		2.0	SAND AND GRAVEL - occasional cobbles to 20 cm, loose to moderately dense, sand is coarse				H-2			⊙ ~15
5.0		5.0								

NOTES: 1. Water not encountered in test pit.

JOB NO. BORING NO

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS

OFFICE REPORT ON SITE INVESTIGATION

Contract No. SHIKANO SOUTH DUMP	Compiled By. HAWLEY/CLARIDGE	Boring Date. April 6, 1985
Boring No. N	Location. SHIKANO PLANTSITE DUMP	Contractor
Northing	Easting	Elevation

SAMPLE TYPES

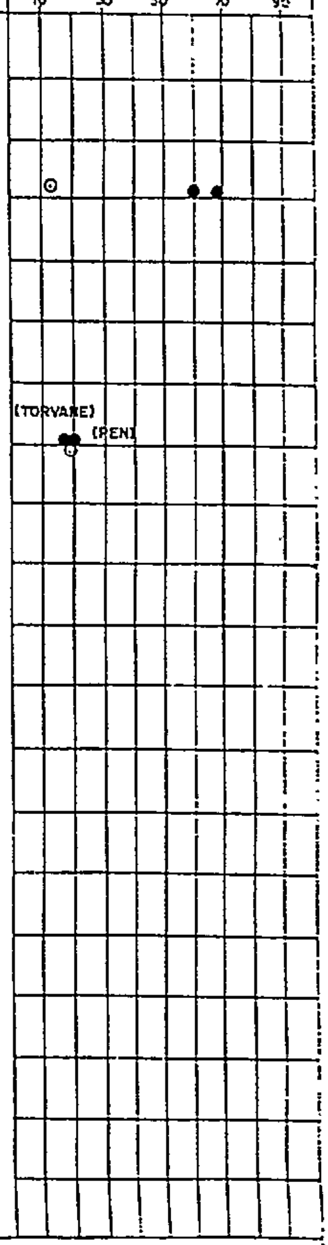
GS	Grab sample	TO	Thin wall open	
WS	Wash sample	TP	Thin wall piston	
RC	Rock core	TYPE OF RIG		
CR	CRREL barrel	SAMPLE HAMMER: wt.	drop	
SS	Split spoon	STICK UP (m.)		

SAMPLE CONDITION: Disturbed, Fair, Good, Lost

TEST INFORMATION

● PENETROMETER kN/m² (x100)
□ UNCONFINED COMP STR kN/m²
1 2 3 4
△ DYNAMIC CONE BLOWS/0.3m
WATER CONTENT % ⊙ PLASTIC LIM. LIQUID LIM.
10 30 50 70 90

Depth m	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS
0–0.65			PEAT - amorphous, dark brown, layer of silty fine sand from 0.35 m to 0.55 m						
0.65–2.4			SILT, SAND AND GRAVEL (TILL) - trace of clay, medium consistency, grey				N-2		
2.4–5.7			SILT - some sand, trace of clay, trace of organics, very stiff, dark grey				N-1		



NOTES: 1. Seepage encountered at depth of 0.3 m.

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS

OFFICE REPORT ON SITE INVESTIGATION   Sheet 1 of 1

Contract No. SHIKANO SOUTH DUMP   Compiled By HAWLEY/CLARIDGE   Boring Date April 6, 1985
Boring No. D   Location SHIKANO PLANTSITE DUMP   Contractor
Northing   Easting   Elevation

SAMPLE TYPES
- GS Grab sample
- WS Wash sample
- RC Rock core
- CR CRREL barrel
- SS Split spoon
- TO Thin wall open
- TP Thin wall piston

TYPE OF RIG
SAMPLE HAMMER: wt. drop
STICK UP (m.)

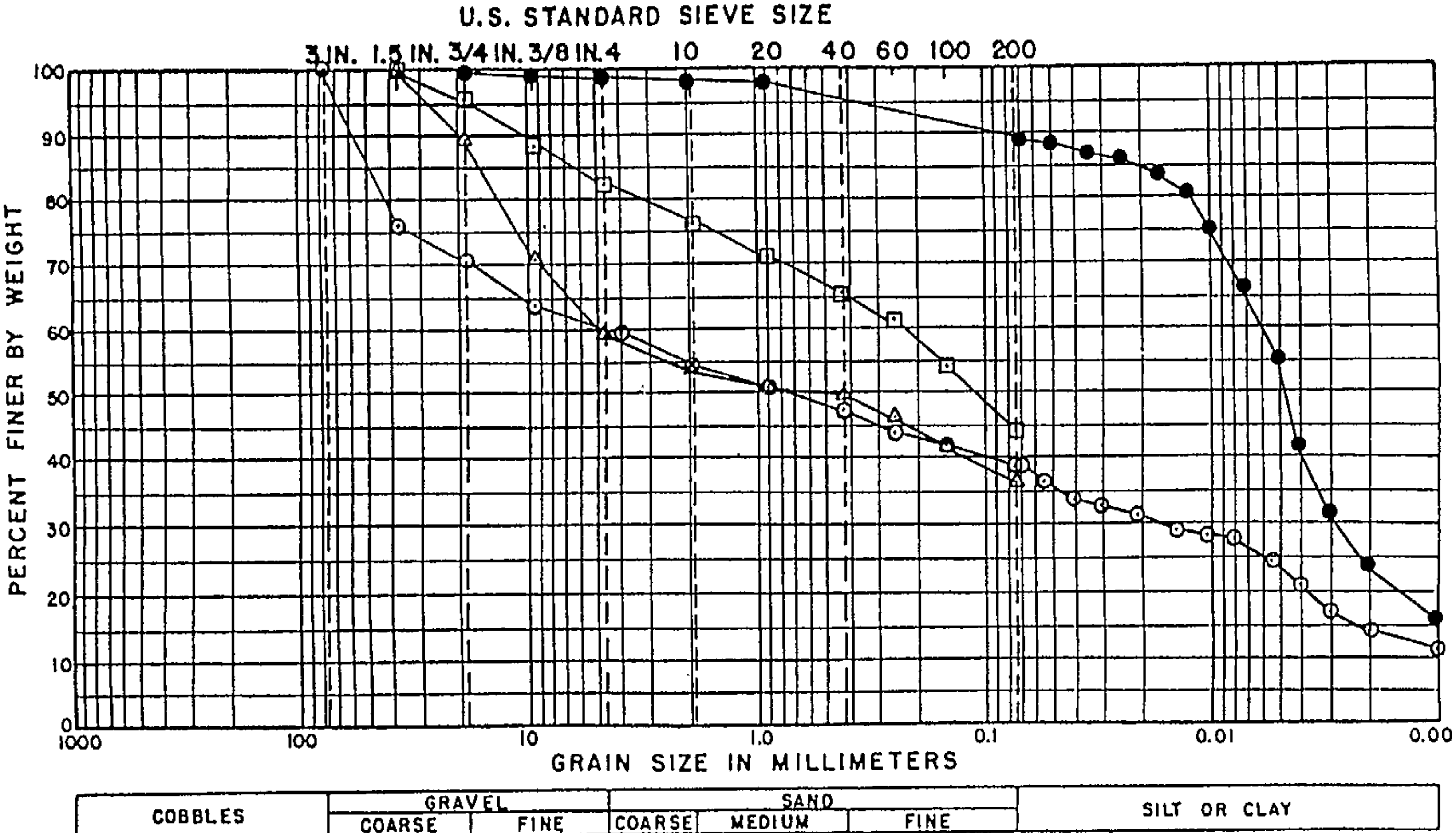
SAMPLE CONDITION
- Disturbed
- Fair
- Good
- Lost

TEST INFORMATION
- ● PENETROMETER kN/m²
- □ UNCONFINED COMP STR kN/m²
- △ DYNAMIC CONE BLOWS/0.3m
- WATER CONTENT % — PLASTIC LIM ⊙ LIQUID LIM (10, 30, 50, 70, 90)

Depth m	Symbol	METHOD	SOIL/ROCK DESCRIPTION	ICE	Type	Condition	Number	SPT N-value (Blows/0.3m)	PIEZOMETER DETAILS	Water content %
0–0.4			PEAT - amorphous to fibrous, brown							
0.4–5.9			SAND AND GRAVEL - trace of silt, loose, sand is fine to coarse							
2							D-1			⊙ ~28
5.9			NOTE: 1. Water table at ground surface							

NOTES:

JOB NO.   BORING NO.



	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	

LEGEND

- ○ - D - 2
- ● - E - 1
- □ - H - 1
- △ - I - 2

QUINTETTE COAL LIMITED
DENISON MINES LIMITED
SHIKANO DEVELOPMENT

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

GRAIN SIZE ANALYSES

BY:	DATE:
FBC	APR 85
APPROVED: MA	DWG: 339-X4-D1