GEOCRES NO:
42P - 1

SLOPE INSTABILITY OF
MOOSE RIVER BANKS
MOOSONEE, ONTARIO

Prepared for:

MINISTRY OF TREASURY, ECONOMICS
AND INTERGOVERNMENTAL AFFAIRS

WILLIAM TROW ASSOCIATES LIMITED
Toronto, Hamilton, Sudbury
London, Sarnia

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90 Milvan Drive,
Weston, Ontario.
749-1290

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TEXT

DRAWINGS

SLOPE INSTABILITY OF MOOSE RIVER BANKS MOOSONEE, ONTARIO

SUMMARY

Four exploratory boreholes were put down for the purpose of assessing the subsoil conditions at the site. The soil stratigraphy consisted generally of marine silty clay overlain by silt. Underlying the marine clay is a dense granular glacial till. Stability analyses were carried out in terms of total and effective stresses. Results showed that the critical condition existed at the "end of construction" stage. Various slopes for the banks were examined and it is suggested that the banks be sloped at 4 horizontal to 1 vertical, which will satisfy both "long term" and "end of construction" conditions, and provide a factor of safety against failure of at least 1.3,

GENERAL

During the past 5 to 10 years the instability of the west river bank of the Moose River adjacent to the town of Moosonee, Ontario, has resulted in the loss of tableland. This loss of land takes the form of a series of land slips when the river erodes the toe of the slope. This report is intended to provide factual data and engineering recommendations for the safe long term slope angle. Further reports by others will supplement this data and indicate the necessary river training and toe protection.

A preliminary report, J 6702, was prepared March 1972 to indicate the general site conditions prior to this more detailed investigation. The report prepared by Dr. E.I. Robinsky titled "Report on Earth Slide, Moosonee Agency, Imperial Oil Limited" and dated April 21st, 1972 was also used to assist in determining the recommendations to be made for this site. The recommendations in this report are intended to cover the river bank from Butler Creek to Store Creek, since the soil conditions are known to be similar over this distance.

The main purpose of this field work was to provide undisturbed samples of the marine clay for detailed laboratory analysis. The results of these laboratory tests have been used to indicate the stable slope criteria.

FIELD AND LABORATORY WORK

Four exploratory boreholes were put down at the approximate locations shown on Dwg. 1 by means of a diamond drill rig adapted for soil sampling purposes.

Samples of the overburden were obtained at required depths by: (1) a 2-inch O.D. split-spoon sampler, which was hammered into the soil in accordance with the specifications for the standard penetration test, and

(2) using a 2-inch and 3-inch I.D. Shelby tube in the cohesive portions of the overburden. These tubes were manually pushed into the soil. In-situ vane tests were carried out, wherever possible, in the cohesive portions of the overburden, to determine the insitu undrained shear strength characteristics.

All samples were subjected to careful visual examination in the field and subsequently in the laboratory. Following this examination, laboratory testing was carried out on selected samples to determine the following physical properties of the subsoil:

Natural Moisture Content
Natural Unit Weight
Atterberg Limits
Grain Size Distribution
Undrained Shear Strength
Drained Shear Strength Parameters

The results of these tests are plotted on the borelog sheets and also presented as Dwgs. 6 to 14.

SUBSOIL CONDITIONS

The subsoil at the site consists of a 3 feet to 12 feet of loose to dense silt to silty sand. Overlying this granular material at the borehole 1 location is a 17 feet deposit of fill, which is silt mixed with decayed wood and organic matter. Underlying the surficial granular stratum is the predominant stratum of marine silty clay having a thickness which ranges from 17 feet at Borehole #1 to 31 feet at Borehole #2. This compressible marine clay is followed by a glacial till, which has a sandy silt matrix. An exception to this was found in Borehole #3 where the marine clay was underlain by clayey silt to silt.

From the point of view of stability of the river banks the properties of the marine silty clay are the most important. The engineering properties, as determined by field and laboratory testing for the marine silty clay, are presented on Table 1.

TABLE 1

PROPERTIES OF MARINE CLAY

Identity Tests	Range
Natural Unit Weight (γ) (pcf)	114 - 123
Liquid Limit (W_L) (%)	26 - 38
Plastic Limit (W_P) (%)	14 - 18
Natural Moisture Content (W) (%)	22 - 38
Standard Penetration Resistance (N) (blows/foot)	1 - 5 (two tests only)
Undrained Shear Strength (C_u) (psf)	
(1) Field Vanes	350 - 900
(2) Penetrometer	400 - 800
(3) Undrained Triaxial	400 - 900
Drained Parameters	
(1) Effective Cohesion Intercept (C') (psi)	0 - 4
(2) Effective Angle of Shearing (ø') Resistance (degrees)	30.3 - 32
Sensitivity	2.0 - 8.0

GROUNDWATER CONDITIONS

The groundwater level conditions across the site during the period of investigation (September 1972) were measured using piezometers. The results of the readings are shown as footnotes on the borelog sheets.

The water level records indicate that the groundwater level varies between elevation 10 and 18. An artesian pressure was observed at Borehole #3, once the borehole penetrated below 43 feet. Once the aquifer was encountered the water rose rapidly in the casing, stabilizing itself at elevation 18, which corresponds to a level approximately 7.5 feet above the existing ground surface. The artesian water flow was sealed, at the source, following the completion of the boring operations. The other boreholes (nos. 1, 2 and 4) were terminated above the aquifer to avoid the problems associated with sealing the boreholes.

It is generally agreed that the shear strengths of the clay in terms of effective stresses are more reliable for long term stability of slopes, and the analysis called $\phi = 0$ using undrained parameters is best suited to evaluate the "end of construction" stability of the slopes.

Soil parameters were measured in terms of total and effective stresses and the analyses carried out for "long term" and "end of construction" stability are presented below.

STABILITY ANALYSIS

(1) Long Term Stability

The long term stability was analysed in terms of effective stress using the values of c' and ϕ' obtained from 16 drained tests. In the standard drained test consolidation takes place under an equal all-round pressure, and the sample is then sheared by increasing the axial load at a sufficiently slow rate to prevent any build-up of excess pore pressure. Since the pore pressure is zero, the effective stresses are equal to the applied stresses and the strength envelope in terms of effective stress is obtained directly from the stress circles at failure. The results of the 16 drained tests are presented as strength envelopes in Dwgs. 8 to 14 with respective c' and ø' values.

(2) "End of Construction" Stability

To analyse the stability,undrained shear strengths were measured in the field by vane tests and in the laboratory by conducting undrained triaxial tests. In these tests drainage is not permitted and hence no dissipation of pore pressure is allowed during the application of the all-round stress. The results of the testing are plotted on the individual borehole logs and also on Dwg. 6.

The results of the stability analyses which were obtained by using an electronic computer are presented in Table 2 as follows:

TABLE 2

SLOPE	ASSUMPTIONS									SAFETY FACTOR (S.F.)	
	ELEVATION	ø	ø'	Cu (psf)	C' (psf)	γ (pcf)	γ' (pcf)	TENSION CRACK	GROUNDWATER LEVEL		
1:1	23 to 13	30°	-	0	-	120	-	0	Elev. 13		T/S.
	13 to -9	0	-	500	-	120	58				
	-9 to -15	0	-	700	-	123	61				
	-15 to -19	0	-	900	-	123	61				
	-19 to -27	40°	-	0	-	132	70				
	-27 to →	45°	-	9000	-	160	100			1.07	
2:1	23 to 13	30°	-	0	-	120	-	10 feet	Elev. 13		T/S.
	13 to -9	0	-	500	-	120	58				
	-9 to -15	0	-	700	-	123	61				
	-15 to -19	0	-	900	-	123	61				
	-19 to -27	40°	-	0	-	132	70				
	-27 to →	45°	-	9000	-	160	100			1.25	
2:1	23 to 13	30°	-	-	-	120	-	10 feet	Elev. 13		e/S
	13 to -19	-	31.3°	-	280	120	58				
	-19 to -27	30°	-	-	0	132	70				
	-27 to →	45°	-	-	9000	160	100			1.62	
3:1	23 to 13	30°	-	0	-	120	-	10 feet	Elev. 13		T/S
	13 to -9	0	-	350	-	120	58				
	-9 to -19	0	-	600	-	123	61				
	-19 to -27	40°	-	0	-	132	70				
	-27 to →	45°	-	9000	-	160	100			1.08	
3:1	23 to 13	30°	-	0	-	120	-	8 feet	Elev. 13		T/S.
	13 to -9	0	-	500	-	120	58				
	-9 to -15	0	-	700	-	123	61				
	-15 to -19	0	-	900	-	123	61				
	-19 to -27	40°	-	0	-	132	70				
	-27 to →	45°	-	0	-	160	100			1.70	

TABLE 2

SLOPE	ASSUMPTIONS									SAFETY FACTOR (S.F.)
	ELEVATION	ø	ø'	Cu (psf)	C' (psf)	γ (pcf)	γ' (pcf)	TENSION CRACK	GROUNDWATER LEVEL	
4:1	23 to 13	30°	-	0	-	120	-	10 feet	Elev. 13	
	13 to -9	0	-	350	-	120	58			
	-9 to -19	0	-	600	-	123	61			
	-19 to -27	40°	-	0	-	132	70			
	-27 to →	45°	-	0	-	160	100			1.29
4:1	23 to 13	30°	-	0	-	120	-	8 feet	Elev. 13	
	13 to -9	0	-	500	-	120	58			
	-9 to -15	0	-	700	-	123	61			
	-15 to -19	0	-	900	-	123	61			
	-19 to -27	40°	-	0	-	132	70			
	-27 to →	45°	-	0	-	160	100			1.99
4:1	23 to 13	30°	-	-	0	120	-	0 feet	Elev. 13	
	13 to -19	-	31.3°	-	280	120	58			
	-19 to -27	40°	-	-	0	132	70			
	-27 to →	45°	-	9000	0	160	100			2.62

Note: Unreasonably large values were assigned to the underlying silt till to force the slip circles to pass through the cohesive marine clay.

Legend:
- ø is the apparent angle of shearing resistance or friction in terms of total stress.
- ø' is the effective angle of shearing resistance or friction in terms of effective stress.
- Cu is the apparent cohesion in terms of total stress.
- c' is the effective cohesion intercept in terms of effective stress.
- γ is the unit weight of the soil (bulk density)
- γ' is the unit weight of submerged soil.

ENGINEERING CONSIDERATIONS

The results of the stability analyses showed that in all cases the safety factors were higher when total stress parameters were used. This indicates that the critical condition exists at the "end of construction" stage, or after the Spring break-up when the toe of the slope has been scoured and steepened.

It is suggested that the Moose River banks be sloped at 4 horizontal to 1 vertical.

The slope of 4 horizontal to 1 vertical provides a safety factor of 1.3 when the shear strength of the clay is assumed to be 350 psi. Laboratory and field measurements have shown the low range of measurements to approach this value (i.e. 400 psi) and it is not considered prudent to increase the shear strength in the theoretical calculation above the value of 350 psi. The recommended slope of 4:1 provides for some latitude in the heights of the slopes and also considers the site conditions where stable slopes greater than 4:1 do not appear to be present. This recommendation also follows closely the values recommended at Butler Creek, J 5462. The recommended slope of 4:1 assumes that this slope angle will continue below river level.

A brief review of the surface drainage conditions in this area shows that if the embankments are trimmed to the recommended slopes the adjacent drainage should also be improved. No water must be allowed to flow down the slope except in paved channels or pipes. Along Revillion Road the ditches must be improved so that water cannot pond anywhere near the crest of the slope and the water collected in these ditches must be removed via paved ditches down the slope or culverts. The small local creeks tending to drain into the river should be channelized and preferably lead to a central drainage culvert.

The final slope must be protected by deep rooted grass such as crown vetch.

The slope improvement must only be considered in conjunction with the river training and toe protection to be provided by others.

WILLIAM TROW ASSOCIATES LIMITED

Shaheen A. Ahmad, P.Eng.

K.R. Peaker, P.Eng.

SAA:SC
Enc.
Dist: Ministry of Treasury, Economics
and Intergovernmental Affairs, (8)
801 Bay Street,
8th Floor,
Toronto, Ontario.
Attention: Mr. J.F. Brown, Supervisor
Urban Renewal Section,
Municipal Services Division

BOREHOLE LOG

JOB No. J 7019 BOREHOLE No. 1 DRAWING No. 2

PROJECT River Bank Instability,
LOCATION Moosonee, Ontario.

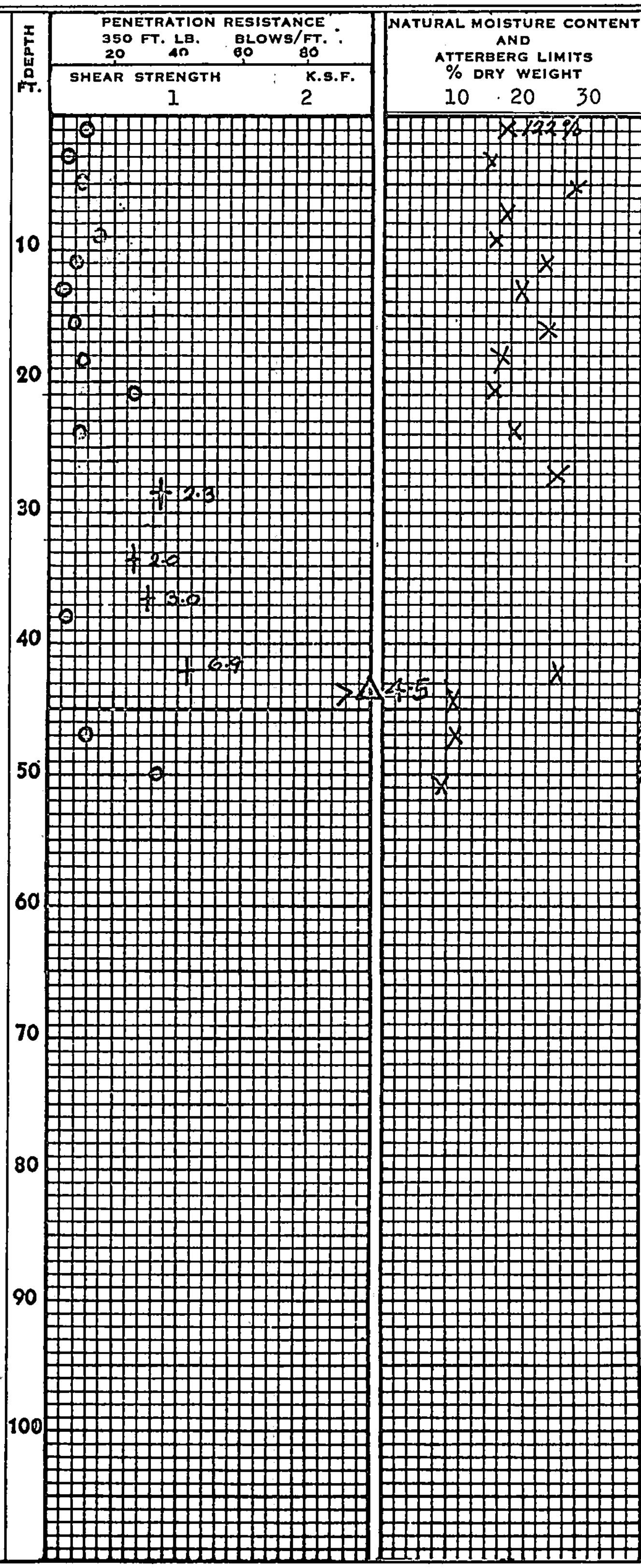
HOLE LOCATION AND DATUM SEE DRAWING No. 1

2" O.D. SPLIT TUBE
2" I.D. SHELBY TUBE
2" DIA. CONE
PUSHED P
VANE TEST AND SENSITIVITY (S) +S

NATURAL MOISTURE ×
PLASTIC AND LIQUID LIMIT
UNDRAINED TRIAXIAL AT OVERBURDEN PRESSURE
% STRAIN AT FAILURE

SOIL DESCRIPTION	ELEV. FEET 23.4
FILL-silt, brown, trace of organic material at surface. Loose to compact, brown.	13.8 / 9.4
SILT-pieces of decayed wood, trace of organics. Loose to compact, brown.	- 2.1
SILTY CLAY-occasional seams of sand. Firm to stiff, grey.	-19.1
SANDY SILT-with trace of gravel. (glacial till). Compact to dense.	-27.1
END OF BOREHOLE	

NATURAL UNIT WEIGHT P.C.F.: 138.5



NOTES:

1) Samples taken off a diamond drill, hole cased to full depth.

2) Piezometer readings:

DATE	WATER LEVEL
Sept. 22/72.	9.6 feet

3) Chemical Test Results:
PH value 7.8 sulphate content traces.

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BOREHOLE LOG

JOB No. J 7019 — BOREHOLE No. 2 — DRAWING No. 3

PROJECT River Bank Instability.

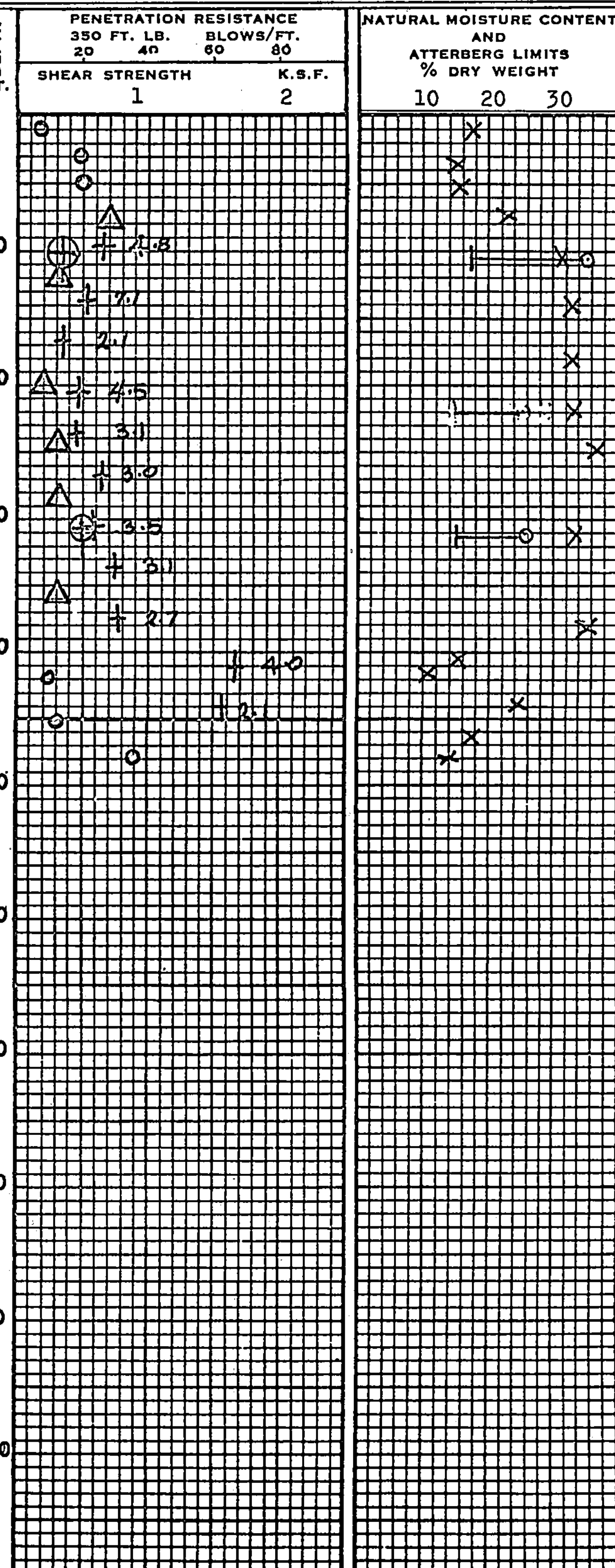
LOCATION Moosonee,
Ontario.

HOLE LOCATION AND DATUM SEE DRAWING No. 1

Legend	Symbol
2" O.D. SPLIT TUBE	—o—o—o—o—
2" I.D. SHELBY TUBE	—x—x—x—x—
2" DIA. CONE	———
PUSHED	P
VANE TEST AND SENSITIVITY (S)	+S
NATURAL MOISTURE	×
PLASTIC AND LIQUID LIMIT	⊢—o
UNDRAINED TRIAXIAL AT OVERBURDEN PRESSURE, % STRAIN AT FAILURE	⊕ (15, 5, 10)
Pocket Penetrometer	△

GWL	SYMBOL	SOIL DESCRIPTION	ELEV. FEET
			22.3
		SILT-sandy, loose to compact, brown, grey.	
▽			15.3
		SILTY CLAY-with trace of sand. Soft to firm, grey.	
			-15.2
		SANDY SILT-with some gravel, trace of clay (glacial till). Compact to dense, brown.	
		END OF BOREHOLE	-27.7

Chart columns: PENETRATION RESISTANCE 350 FT. LB. BLOWS/FT. (20, 40, 60, 80); SHEAR STRENGTH K.S.F. (1, 2); DEPTH FT. (10–100); NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS % DRY WEIGHT (10, 20, 30); NATURAL UNIT WEIGHT P.C.F.



NATURAL UNIT WEIGHT P.C.F.: 123.0, 118.0, 119.0, 118.5, 117.0, 115.0, 123

NOTES:

1) Samples taken off a diamond drill rig, hole cased to full depth.

2) Piezometer readings:

DATE	WATER LEVEL
Sept. 20/72.	5.6 feet
Sept. 22/72.	6.1 feet

William Trow Associates Ltd.

BOREHOLE LOG

JOB No. J 7019 BOREHOLE No. 3 DRAWING No. 4

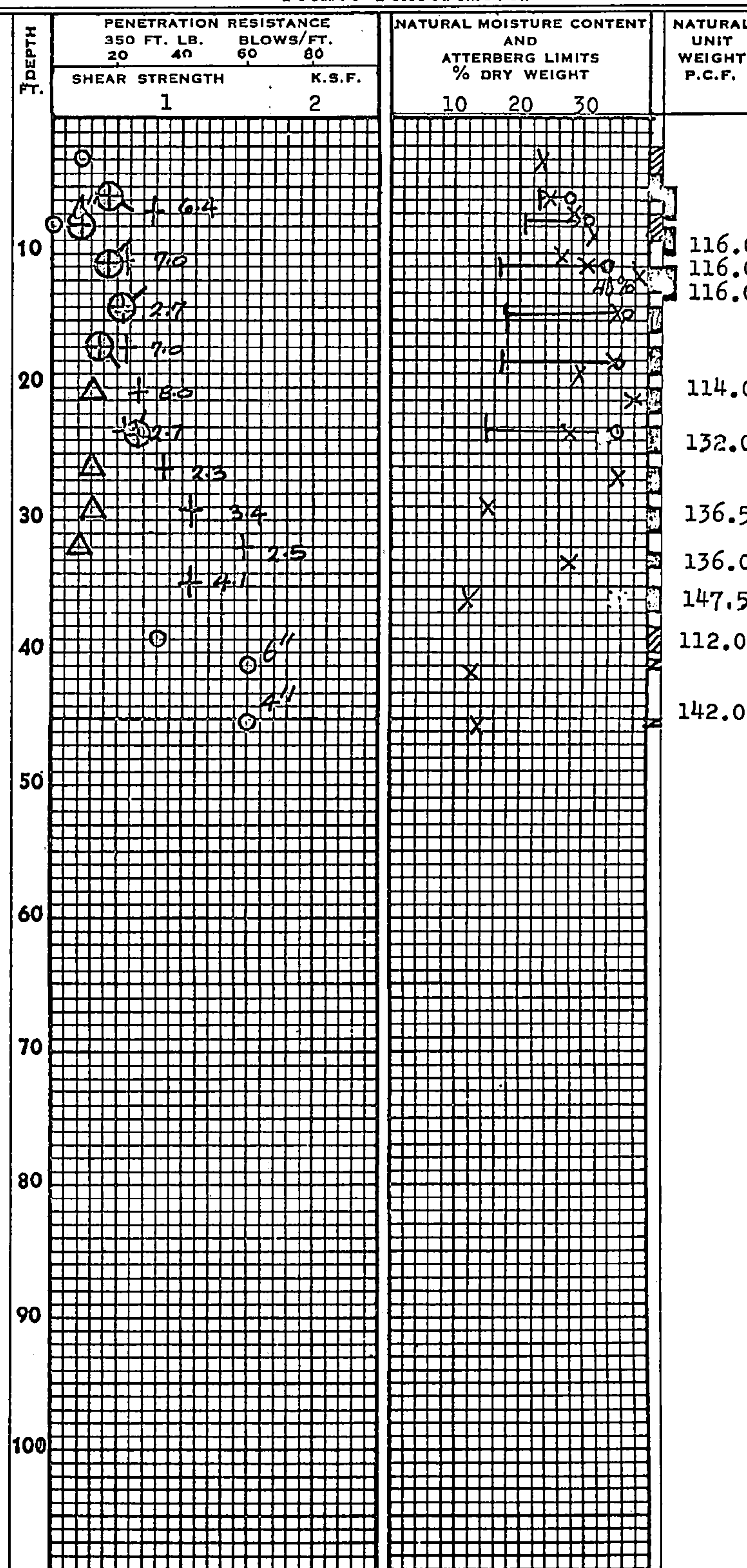
PROJECT River Bank Instability,
LOCATION Moosonee,
Ontario.

HOLE LOCATION AND DATUM SEE DRAWING No. 1

2" O.D. SPLIT TUBE
2" I.D. SHELBY TUBE
2" DIA. CONE
PUSHED P
VANE TEST AND SENSITIVITY (S)

NATURAL MOISTURE X
PLASTIC AND LIQUID LIMIT
UNDRAINED TRIAXIAL AT OVERBURDEN PRESSURE
% STRAIN AT FAILURE
Pocket Penetrometer △

SOIL DESCRIPTION	ELEV. FEET
	18.2
	10.7
SAND-fine, silty, loose.	9.7
SILTY CLAY-with trace of sand. Firm to stiff.	7.7
CLAYEY SILT TO SILT-with trace of sand, fragments of rock.	-13.3
END OF BOREHOLE	-35.6



NOTES:

1) Samples obtained off a diamond drill, holes cased to full depth.

2) Piezometer readings:
A) Lower Piezometer;

DATE	WATER LEVEL
Sept. 19/72.	5.7feet above ground
Sept. 20/72.	5.7feet above ground
Sept. 22/72.	7.5feet above ground

B) Upper Piezometer;

DATE	WATER LEVEL
Sept. 19/72.	0.5feet below ground
Sept. 20/72.	0.7feet below ground
Sept. 22/72.	1.0feet below ground

William Trow Associates Ltd.

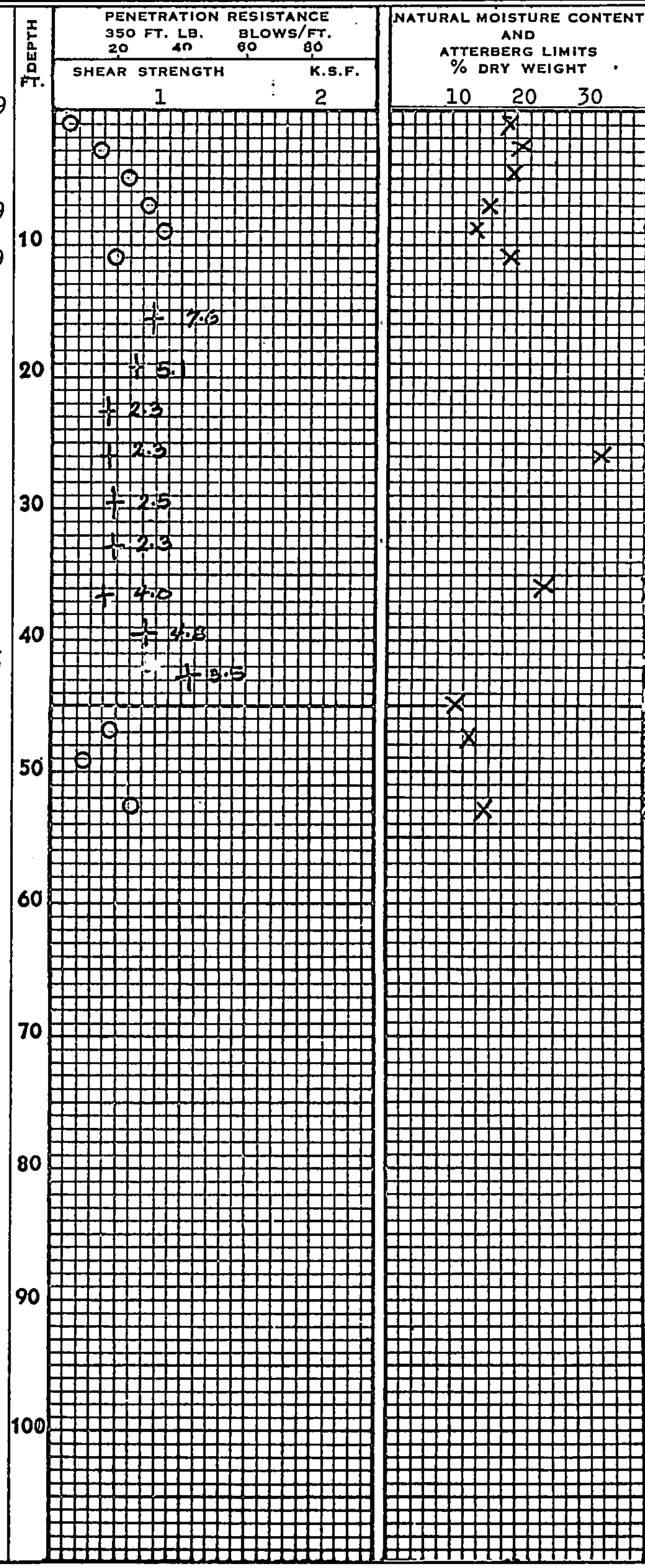
BOREHOLE LOG

JOB No. J 7019 | BOREHOLE No. 4 | DRAWING No. 5

PROJECT River Bank Instability.
LOCATION Moosonee, Ontario.
HOLE LOCATION AND DATUM SEE DRAWING No. 1

Symbol	Meaning
2" O.D. SPLIT TUBE	—o—o—o—o—
2" I.D. SHELBY TUBE	—x—x—x—x—
2" DIA. CONE	———
PUSHED	P
VANE TEST AND SENSITIVITY (S)	+S
NATURAL MOISTURE	X
PLASTIC AND LIQUID LIMIT	⊢—o
UNDRAINED TRIAXIAL AT OVERBURDEN PRESSURE / % STRAIN AT FAILURE	0, 5, 10, 15

SOIL DESCRIPTION	ELEV. FEET	NATURAL UNIT WEIGHT P.C.F.
	24.9	
8 inches TOPSOIL over SILT-loose to dense, random layers of sand up to 1 inch in size, occasional clayey silt pockets.	17.9	138.5
	12.9	
SILTY CLAY-trace of sand. Soft to stiff, grey.	-17.6	
SANDY SILT-with trace of gravel, (glacial till). Compact, brown.		137.0
END OF BOREHOLE	-28.6	



NOTES:

1) Samples taken off diamond drill, hole cased to full depth.

2) Piezometer readings:

DATE	WATER LEVEL
Sept. 22/72.	7.0 feet

3) Chemical Test Results: PH value 7.6 Sulphate Content Traces.

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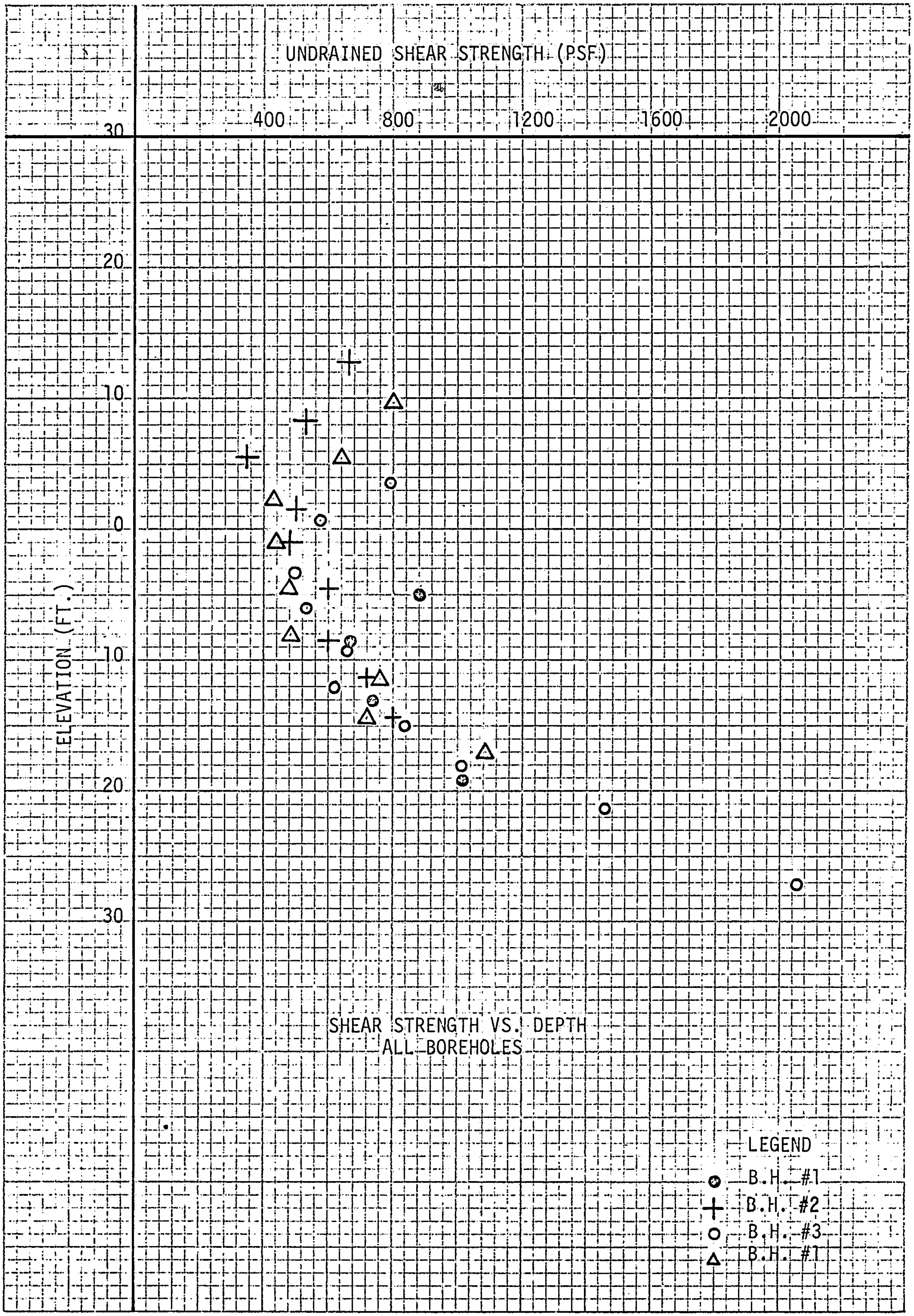
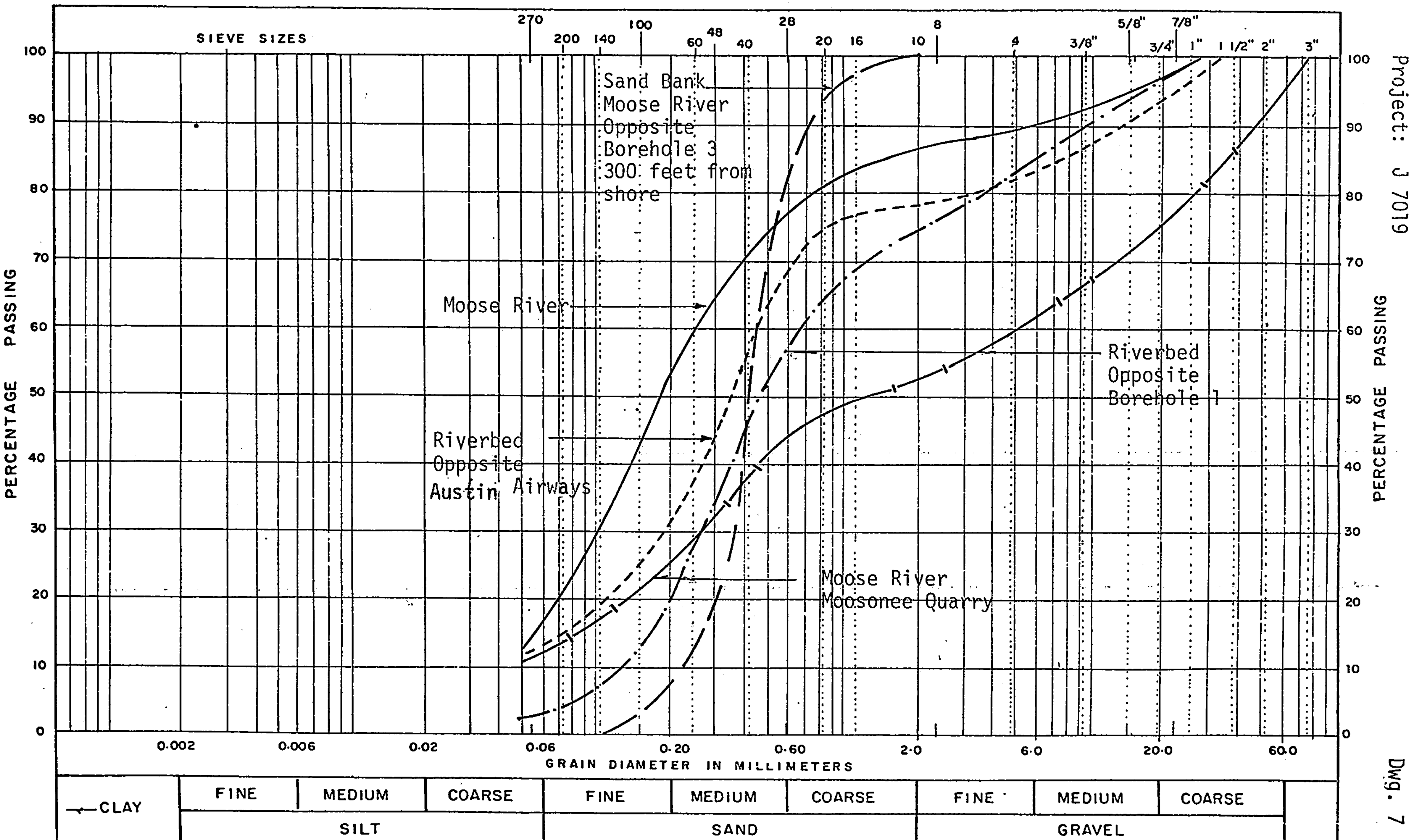

UNDRAINED SHEAR STRENGTH (PSF)
400
800
1200
1600
2000
30
20
10
0
10
20
30
ELEVATION (FT.)
SHEAR STRENGTH VS. DEPTH
ALL BOREHOLES
LEGEND
B.H. #1
B.H. #2
B.H. #3
B.H. #1

MECHANICAL ANALYSIS



Project: J 7019

MODIFIED M.I.T. CLASSIFICATION

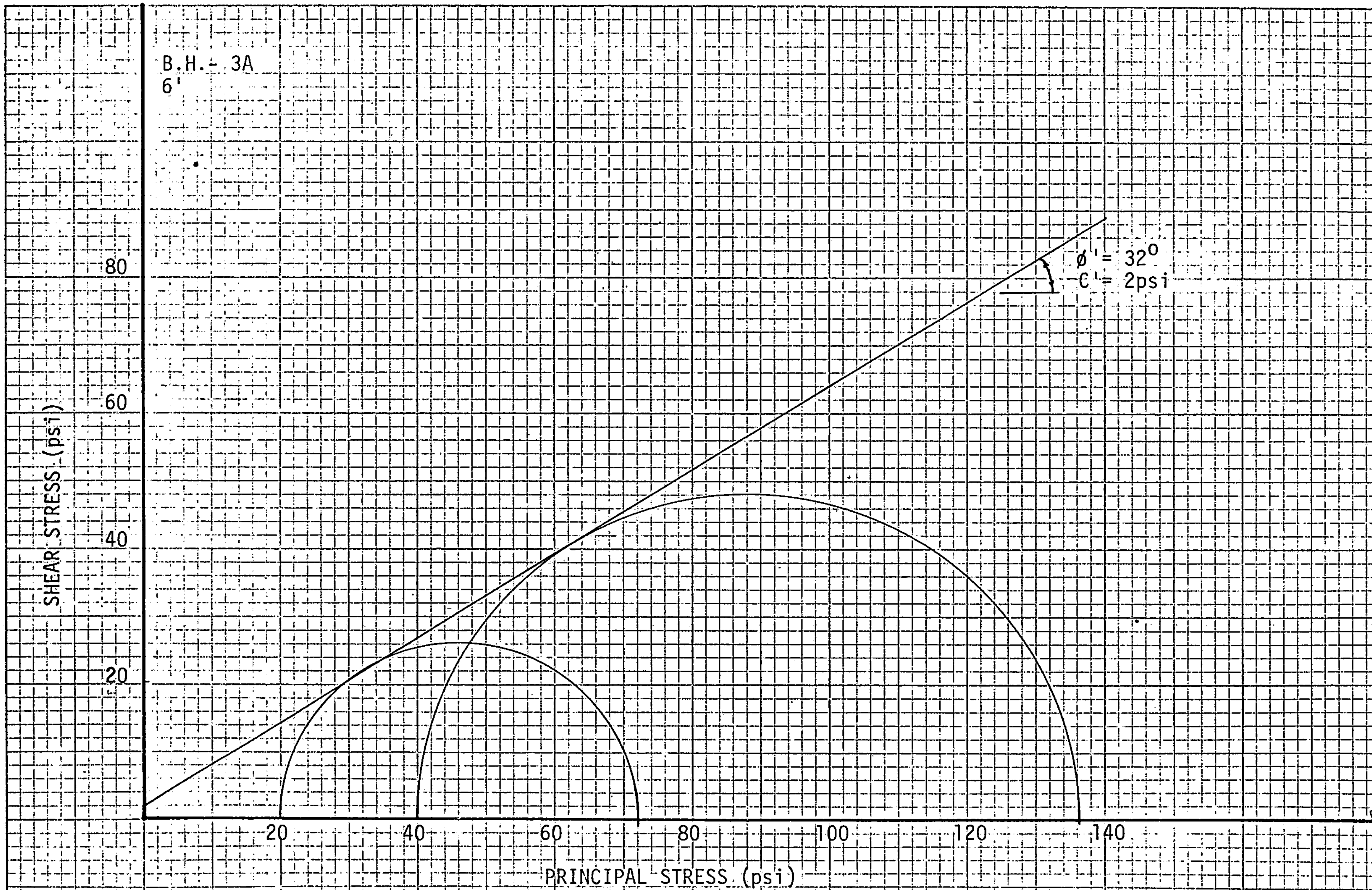
Various types of soils in the Moosonee River Area

Moosonee, Ontario.

WILLIAM TROW ASSOCIATES LTD.

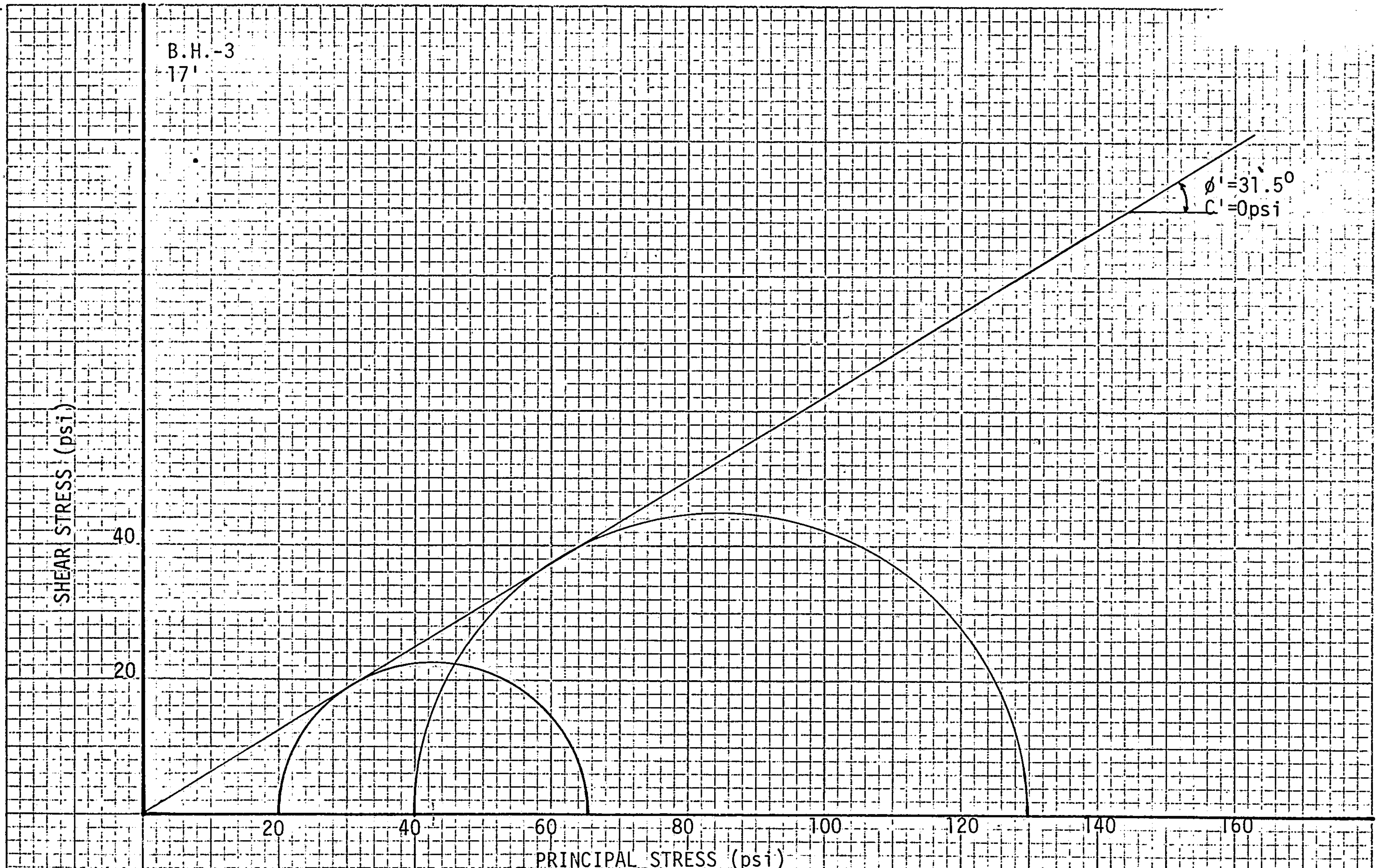
Dwg. 7

Project: 7019



DETERMINATION OF DRAINED STRENGTH PARAMETERS

Dwg. 8

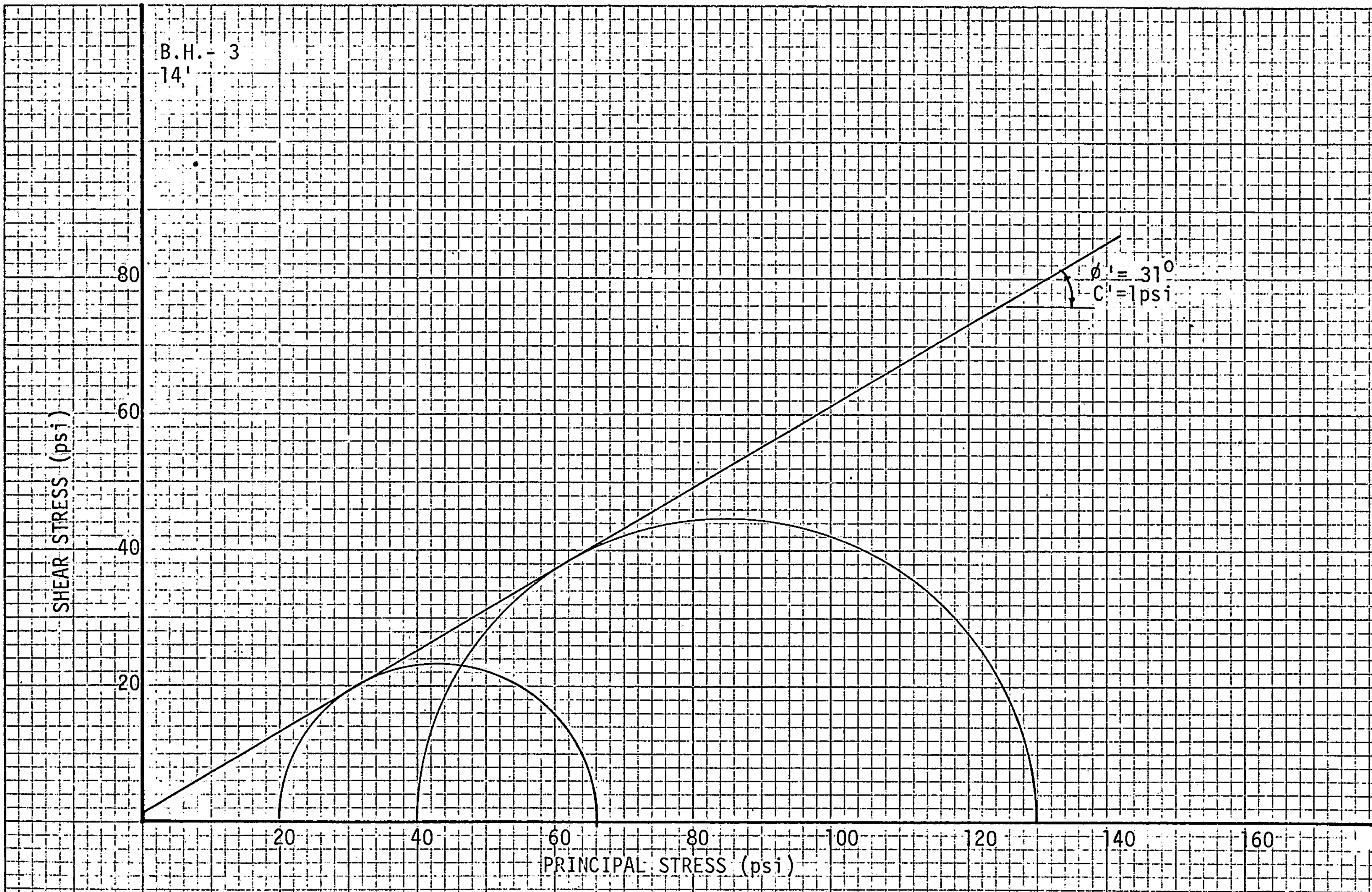


DETERMINATION OF DRAINED STRENGTH PARAMETERS

Project: 7019

Dwg. 9

KE 10 X 10 TO THE INCH 46 0782
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

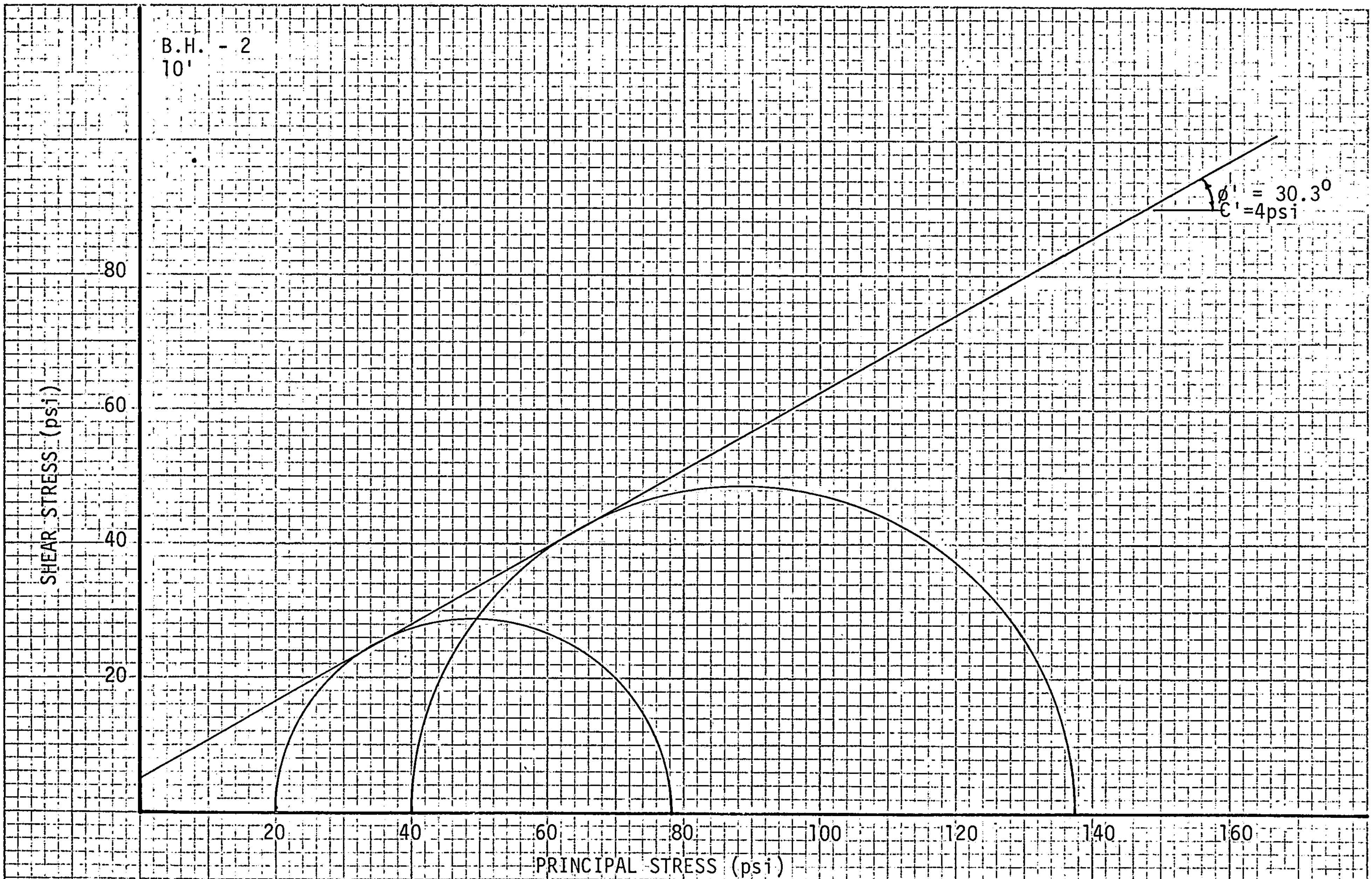


DETERMINATION OF DRAINED STRENGTH PARAMETERS

Project: 7019

Dwg. 10

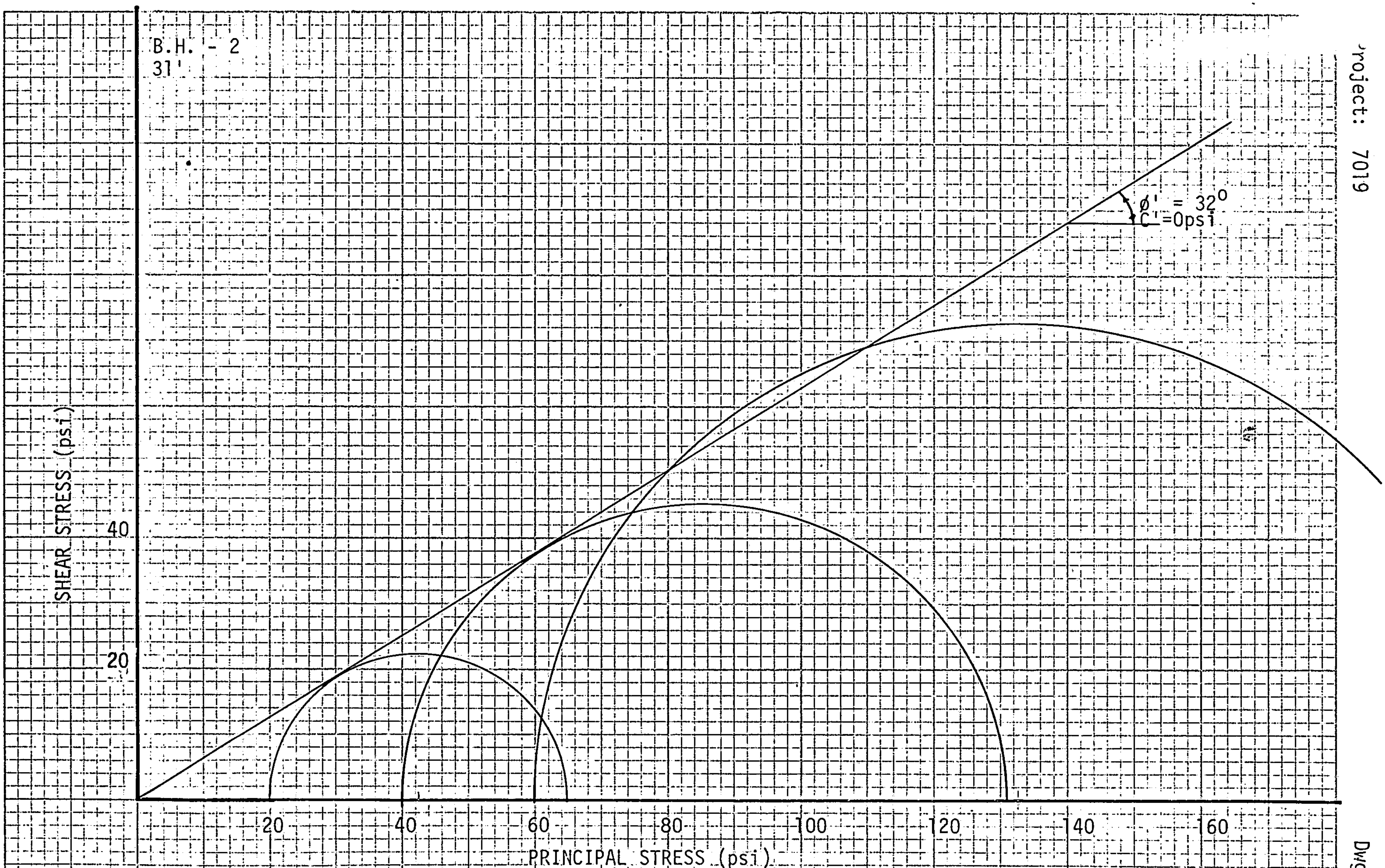
Project: 7019



DETERMINATION OF DRAINED STRENGTH PARAMETERS

Dwg. 11

Project: 7019

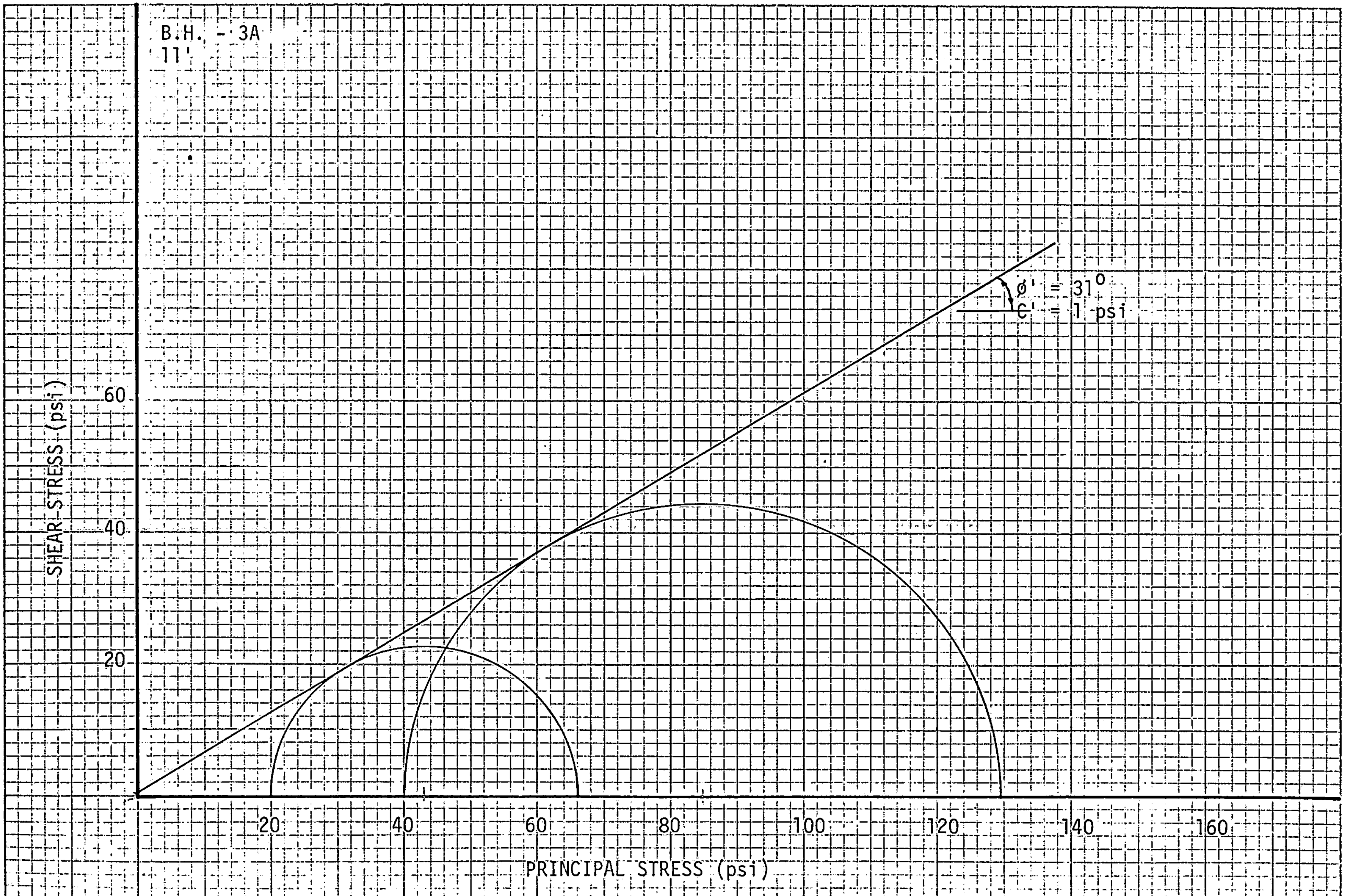


DETERMINATION OF DRAINED STRENGTH PARAMETERS

Dwg. 12

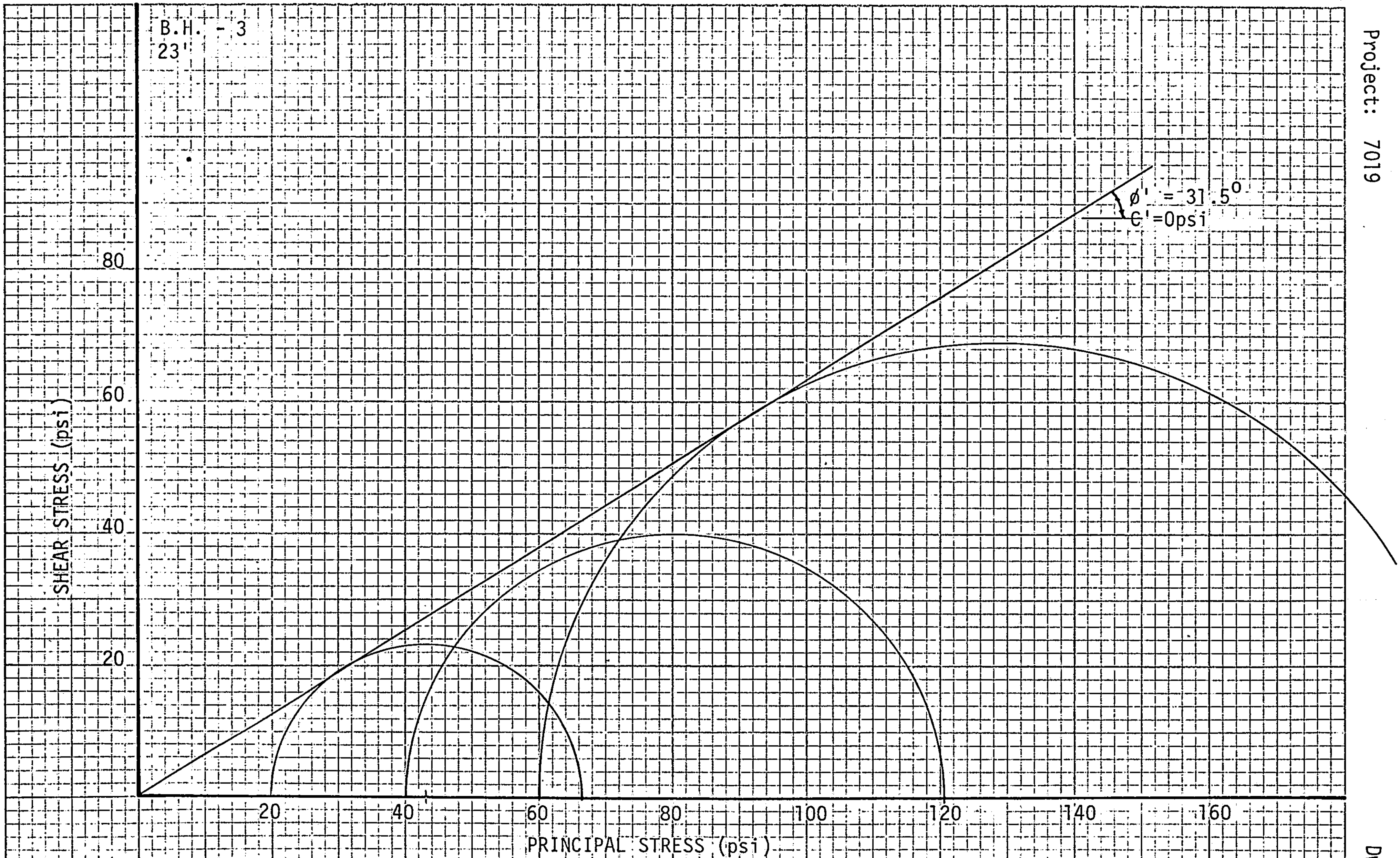
10 X 10 TO THE INCH 46 0782
7 X 10 INCHES
KEUFFEL & ESSER CO.

Project: 7019



DETERMINATION OF DRAINED STRENGTH PARAMETERS

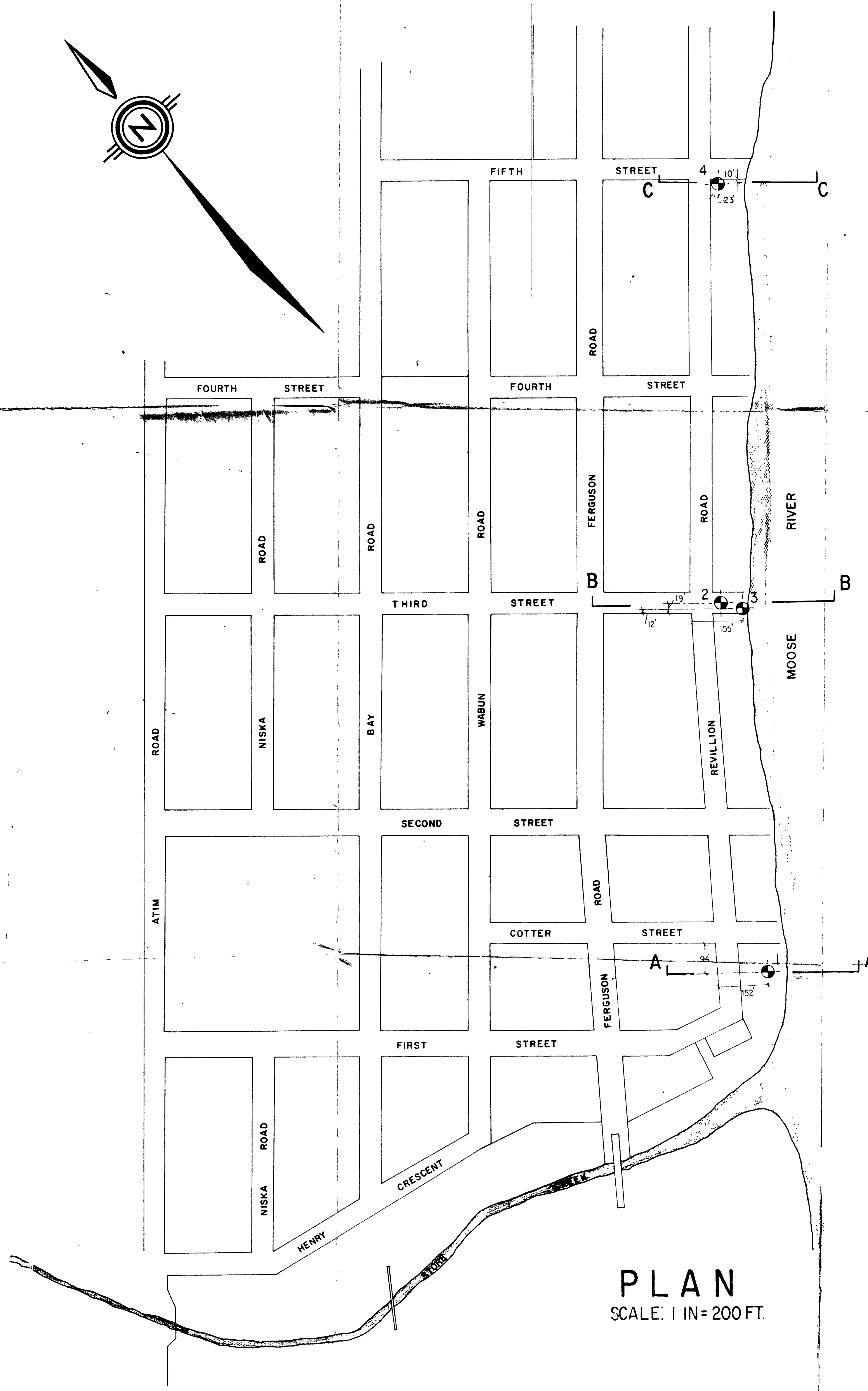
Dwg. 13



DETERMINATION OF DRAINED STRENGTH PARAMETERS

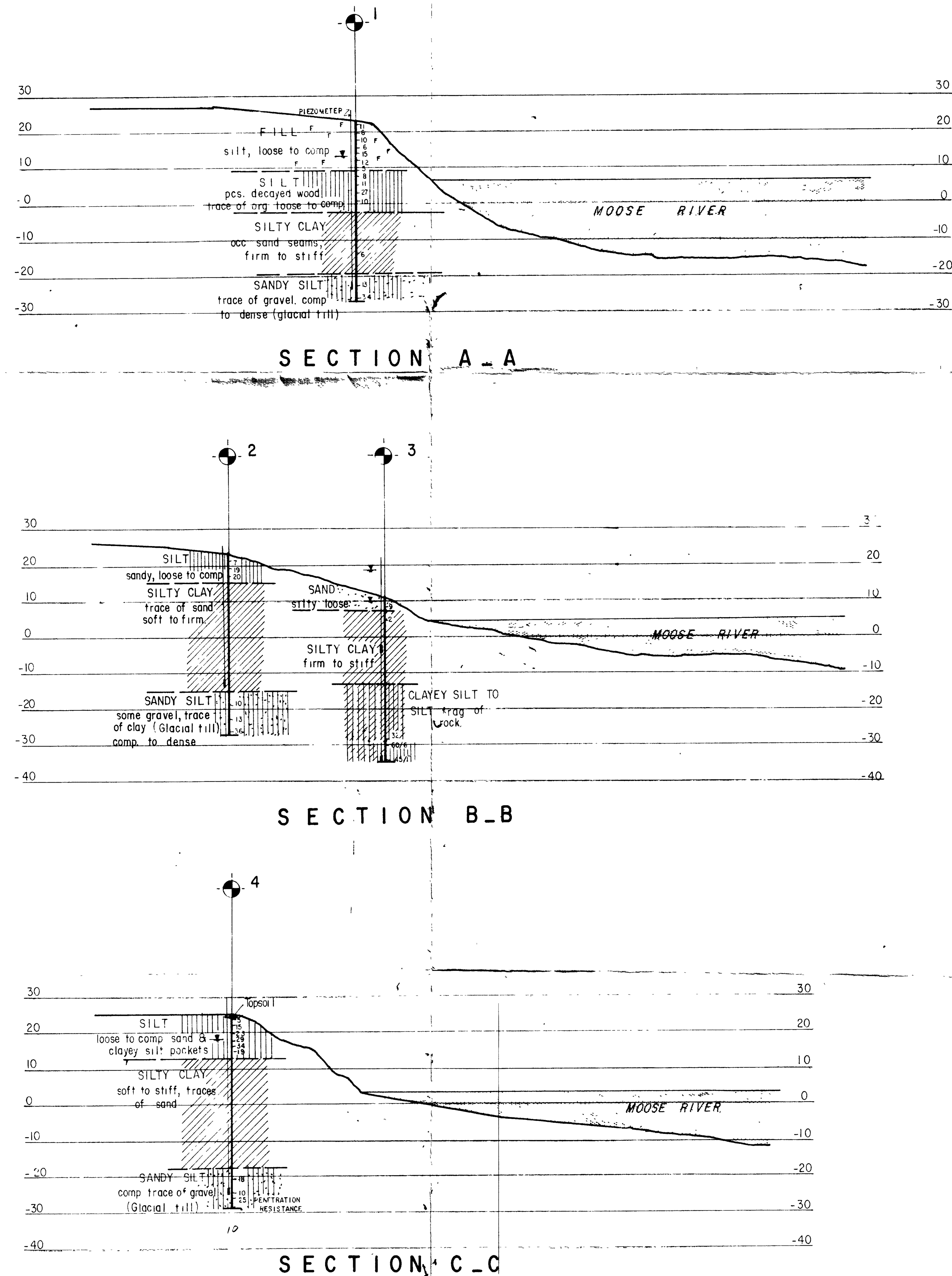
Project: 7019

Dwg. 14



PLAN

SCALE: 1 IN = 200 FT.



INTERPRETED SUBSOIL STRATIGRAPHY

SCALE: HOR. 1 IN = 30 FT. VERT. 1 IN = 20 FT.

— NOTE —

1) The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence and may be subject to considerable error.
2) Soil samples will be retained in storage for 3 months and then destroyed unless client advises that an extended time period is required.
3) Topsoil quantities should not be established from the information provided at the borehole locations.

William Trow Associates Ltd.

FOUNDATION INVESTIGATION

RIVER BANK INSTABILITY

MOOSONEE ONTARIO

PROJ. 7019	DATE OCT. 1972	DWG. № 1