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Project 204-498

ANALYSES AND SEDIMENTATION TESTS ON MATERIALS ASSOCIATED WITH THE HAT CREEK COAL DEPOSIT

Prepared For

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1.0 SUMMARY

Results of saturated paste alkalinity analyses and particle size determinations are presented.

Sedimentation tests on selected samples indicated that chemical treatment would be required to obtain acceptable suspended solids levels in realistic settling pond residence times.

Aluminum sulphate (alum) was effective in improving supernatant clarity and settling rate for all samples tested. Tests done at conservatively high suspended solids levels indicated alum dosage requirements up to 180 mg/l. In practice, lower dosages (controlled in response to raw waste water flow rate and solids content) would be anticipated.

Data on interface free settling rates in 6 in. dia. columns are presented as a basis for planning of settling pond configurations.

2.0 INTRODUCTION

2.1 Background

Cominco Limited and Monenco Limited (Cominco-Monenco Joint Venture, CMJV), have been retained by the British Columbia Hydro and Power Authority to prepare a detailed feasibility study and plans for development of the Hat Creek, B.C. coal deposit. For this program, data are required on the reclamation (revegetation) potential of soils and overburden materials, and on the probable quality of drainage water from areas disturbed by the development.

Following conversations between Messrs. D.P. Mahony and J.P. Christensen of the CMJV and Dr. R.O. McElroy, B.C. Research was authorized to perform laboratory studies to determine relevant physical/chemical properties of selected surficial and overburden materials.

2.2 Objectives

The objectives of this study were: to determine relevant physical/chemical properties of selected materials by detailed saturated paste salinity analyses, to determine the sedimentation behaviour of selected materials, to evaluate (as required) flocculants and coagulants, and to determine the quality of supernatant (i.e. discharge) water after the indicated flocculant/coagulant treatment.

Terms of reference for the study are presented in Appendix 1. Subsequent to issuance of these initial terms of reference, B.C. Research was requested by Mr. John Christensen of the CMJV to undertake only preliminary settling tests on Sample No. 1, and to perform particle size analysis and full sedimentation tests on the "Acres Limited" waste rock samples (see also Appendix 1).

3.0 MATERIALS AND METHODS

3.1 Test Materials

Fifteen test samples were provided by the CMJV for the test program. Table 1 includes a list of these samples by identification number and a description of each material copied from the sample bag.

On receipt, samples were checked and split by riffle into portions for required tests.

3.2 Test Methods

The saturated paste alkalinity test was performed according to procedures specified in Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, C.A. Black, ed., American Society of Agronomy Inc., Madison, 1965. Subsequent analyses were done according to procedures outlined in Standard Methods for Analysis of Water and Waste Water, 14th edition, APHA-AWWA-WPCF, 1975.

Particle size analyses were performed by Golder Associates Limited.

Weighed samples were prepared for sedimentation tests by soaking overnight in distilled water, followed by agitation for 1 minute to disperse fine solids, then washed on a 2 mm screen. The -2 mm slurry was then split into portions for sedimentation and flocculant/coagulant tests. Sample preparation was done in plastic containers to avoid possible contamination from borosilicate glassware.

All sedimentation and flocculation tests were done at a solids concentration corresponding to dispersal of 50 g of original (i.e. coarse plus fine) solids per litre of distilled water.

Initial sedimentation tests were done in 2-l graduated cylinders; samples were taken by pipet from selected depths.

Flocculants and coagulant were tested by adding concentrated reagent solutions to a stirred 500 ml portion of sample. In the screening tests, reagent was added by measuring pipet until floc formation was observed. The stirring rate was then reduced and clarity of the supernatant was evaluated visually with subsequent reagent addition if necessary to produce acceptable supernatant clarity. Finally, samples of supernatant were taken after 10 minutes quiescent settling for suspended solids analysis to ensure that suspended solids levels were below 50 mg/l.

In column sedimentation tests, the slurry samples were transferred to 6 in. dia. clear polyethylene columns and agitated by aeration during addition of the predetermined quantity of coagulant. Samples of column supernatant were taken through sample ports at times and depths indicated by observation of the settling interface.

4.0 RESULTS AND DISCUSSION

4.1 Soil Analyses

4.1.1 Saturated paste alkalinity

Results of saturated paste alkalinity analyses are presented in Tables 1-A (analytical results) and 1-B (calculated alkalinity values in milliequivalents per 100 g of soil).

All samples exhibited strong moisture retention in the saturated paste, so it was difficult to obtain an adequate volume of filtrate for the complete set of analyses requested. Following discussion of this problem with Messrs. John Christensen and Eric Stathers of the CMJV, it was agreed that the alkalinity titrations which require a relatively large volume of sample would have the lowest priority for analysis. Thus for several samples - unfortunately including some with relatively high pH values - alkalinity values were not determined. Similarly, several boron values are reported as below specified detection limits because there was insufficient sample material.

4.1.2 Particle size analyses

Results of particle size analyses conducted by Golder Associates are presented in Appendix 1. These data indicate that only samples 2 (glacial till) and 3 (slide debris) contain very high (19% and 36% respectively) proportions of "fine grained" material. Nevertheless, sedimentation test data (see below) indicate that significant quantities of slow settling material are present in all samples tested.

4.2 Sedimentation Tests

4.2.1 Sedimentation of untreated solids

Results of preliminary settling tests on slurries prepared from the selected materials are presented in Table 2 and Figures 1 - 7.

These data indicate a wide range of initial suspended solids levels. After 24 h quiescent settling, surface samples (Table 2) indicate appreciable settling, but at a depth of 11 cm (in a 33 cm column) only Samples 1 and 3 (glacial fluvial sand/gravel and slide debris respectively) had suspended solids below 1000 mg/l. Thus it is apparent that water heavily contaminated with solids (as in these tests) could not be adequately clarified in a 24 h retention pond without some form of chemical treatment to improve sedimentation.

4.2.2 Evaluation of polyacrylamide flocculants and aluminum sulphate (alum)

Qualitative evaluation of commercial anionic, cationic and non-ionic polyacrylamide flocculants indicated that none of the formulations tested produced a satisfactory supernatant at dosages up to 50 mg/l. However, the anionic formulation (Alchem 8173) did produce partial flocculation at dosages in the 5 - 10 mg/l range.

Tests with aluminum sulphate addition indicated that good flocculation and satisfactory supernatant water quality could be obtained. Minimum dosages for acceptable supernatant were found to be as follows:

Sample No.	Description	mg $Al_2(SO_4)_3$ Required per Litre
1	Glacial fluvial sand/gravel	10
2	Glacial till	60
3	Slide debris	80
4	Waste rock	160
9 of 9	Low grade waste	160
-	Composite of above	100
A6	Acres Ltd. waste rock	160

These dosage levels are generally high but it should be noted that the initial suspended solids levels were very high (see Table 2 for approximate values). Such high suspended solids levels would be expected to occur only in abnormal circumstances such as flooding or erosion induced slumping of unstable material. In general, the alum dosage requirement would be roughly proportional to suspended solids content down to a threshold dosage level of about 10 mg/l below which little effect is observed.

In practice, if surface drainage is to be treated with alum, the rate of addition should be controlled in response to both flow rate and suspended solids levels.

4.2.3 Column settling tests

Results of settling tests on alum treated samples in 6 in. dia. columns are presented graphically in Figures 8 - 13.

The initial linear portions of these curves represent the following free settling rates:

Sample No.	Description	Free Interface Settling Rate (ft/hr)
2	Glacial till	8.3
3	Slide debris	4.7
4	Waste rock	0.3
9 of 9	Low grade waste	0.4
-	Composite of above (plus glacial/fluvial sand and gravel)	1
A6	Acres Ltd. waste rock	0.3

These data can be used to calculate - to a first approximation - the depth reached by the settling interface in a fixed time or the time required for settlement to a selected depth. For example, in a 24 hour residence period (assuming adequate pond depth) the settling interface of a composite waste slurry would reach a depth of (24 hr x 1 ft hr^{-1}) 24 ft.

To take a worst case analysis, slurry from the waste rock samples would settle to a depth of (24 x 0.3) 7.2 ft in 24 hr.

A settling pond is a dynamic system with some lateral flow and (potentially) some turbulence, so results of static tests must be used with caution in projecting performance. However, the high settling rates and clear settling interfaces observed in these tests indicate that alum treatment followed by (effectively) quiescent settling in ponds of adequate size should be a practical approach to clarification of drainage water containing substantial amounts of suspended solids.

The times and depths of column samples containing <50 mg/l of suspended solids are also noted on Figures 8 - 15. These times (at depth) should be regarded as the maximum time required to reach this level of clarity, since the solids interface was the primary parameter monitored. The results do indicate, however, that suspended solids levels reach values ≤ 50 mg/l only a short distance above the interface. This is an expected result since the coagulated solids form a "blanket" of loosely agglomerated material which collects further fine material as it settles.

Raw experimental data (interface depth, time, suspended solids and turbidity) from the column tests are presented in Appendix 3. The relationship of turbidity values to suspended solids levels is somewhat variable, as expected due to the (assumed) presence of different mineral species in separate samples. Turbidity values are generally quite low, but reference to the quality of receiving waters would be advisable to assess possible effects of treated water discharge.

In planning of outfall structures and pond depths, a safety margin should be allowed to minimize the effect of turbulence from the outflow on the settled solids. Despite the relatively high settling velocity of coagulated solids, they can be resuspended or even broken up by excessive turbulence.

The data presented in Figures 8-13 could be analyzed to assess hindered and compressive settling rates, but for these parameters the value of static test data is very limited. Similarly, volumes of settled solids in these tests cannot be usefully extrapolated.

With regard to volume (or density) of settled solids, the data do suggest that settled density may be relatively low. Thus it will be necessary to monitor the accumulation of solids in settling ponds at regular intervals to determine when pond cleaning will be required to maintain the required free settling depth.

4.2.4 Quality of supernatant water from column tests with coagulant

Results of analyses on supernatant water from the column settling tests are presented in Table 3.

Comparison of these data to the saturated paste analyses indicates a significant elevation in sulphate content as expected due to the high alum dosage required. (NB. The alum dosage is a function of solids content in the raw waste water. These tests were done on highly contaminated raw waste water to model a realistic worst case, so lower alum dosages and correspondingly lower sulphate levels would be expected in practice).

The pH values of supernatant from "Waste Rock" (Sample 4) and "Low Grade Waste" (Bag 9 of 9) were reduced to 4.8 and 4.9 respectively by addition of alum. Saturated paste pH values for these samples (Table 1-a) were 8.3 and 8.7 respectively, but calcium plus magnesium levels were low indicating (potentially at least) poor buffering capability. The alum dosage of 160 mg/l required for sedimentation is equivalent - in the test - to addition of 4.4×10^{-2} milliequivalents of sulphuric acid per grain of soil. For these two samples, it appears that - at high suspended solids levels - use of the required amount of alum may make the treated effluent pH marginally too low for discharge. However, it should be noted that the suspended solids levels (and corresponding alum dosage) were very high. Lower alum dosages required for less heavily contaminated water would result in higher pH values. Also, the pH of the composite sample supernatant was 7.2, indicating that other waste materials have more buffering capacity. In any event, the pH of treated effluent could - if necessary - be easily adjusted by controlled lime addition at the point of discharge.

Other water quality parameters appear to be within acceptable limits for discharge to receiving waters.

4.2.5 Staged flocculant/coagulant treatment

In view of the relatively high dosage of alum required to obtain adequate settling, a limited number of qualitative tests were done on staged addition of polyacrylamide flocculant followed by decreased alum dosage. Two procedures were identified as having potential for decreasing the alum dosage requirement:

- treatment with 5 mg/l of anionic polyacrylamide, followed by a short (∿2 minute) period of low shear mixing and alum addition at half the (optimum) dosage.

- treatment with 5 mg/l of anionic polyacrylamide, settlement, and decantation of the cloudy supernatant for treatment with half the optimum alum dosage.

Visually, both these procedures appeared to result in supernatant water of marginally acceptable quality. No analyses or followup tests were undertaken, however, as this area of work was not covered specifically in the terms of reference.

Further tests on staged reagent addition would only be justified if projected alum costs appear excessive or if there is some overriding objection to elevated sulphate levels in treated waste water.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Evaluation of the particle size- and saturated paste alkalinity data with respect to reclamation was not included in the terms of reference for the study.

With regard to sedimentation behaviour of the materials tested, it is apparent that under some conditions (i.e. high runoff periods with consequent erosion of disturbed areas) surface drainage will require treatment to obtain acceptable suspended solids levels for discharge.

Aluminum sulphate (alum) was found to be an effective coagulant for all materials tested. Laboratory results indicate that alum dosages of up to 160 mg/1 could be necessary for heavily contaminated waste water. However - in practice - dosage(s) would be controlled in response to raw waste water flow rate(s) and suspended solids content(s).

Apart from clarification, elevated sulphate content is the only apparent effect of alum treatment on supernatant water quality.

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TABLES

TABLE 1-a

RESULTS OF SATURATED PASTE ALKALINITY ANALYSES

Sample Number	Description	Test Sample Weight (g)	Distilled H_2O Added to Saturate (ml)	Filtrate Water Quality											
				pH	Specific Conductance (µmho/cm)	Alkalinity (mg $CaCO_3$/l)		Chemical Species (mg/l)							
						HCO_3^-	$CO_3^=$	Ca	Mg	Na	K	B	SO_4	Cl
1	Glacial-fluvial sand and gravel	634	130	7.5	480	45	ND	58.1	16.9	11.9	4.3	0.024	180	11.5
2	Glacial till	281	85	8.1	379	ND	ND	26.3	12.5	23.8	2.5	0.024	<20	9.8
3	Slide debris	266	139	7.5	4150	58	ND	271	184	615	16.5	<0.050	2060	75.5
4	Waste rock	157	98	8.3	715	ND	ND	11.2	1.3	159	5.3	<0.020	90	42.5
Bag 9 of 9	Low grade waste	750	335	8.7	2220	ND	ND	25.0	12.5	495	18.5	<0.050	620	38.0
-	Composite	125	61	8.5	2250	ND	ND	43.8	13.8	480	16.0	<0.050	580	61
1561/40	Alluvial gravel	502	107	8.1	412	ND	ND	56.2	12.5	16.2	4.1	0.124	20	8.8
1563/42	Glacial till (Medicine Creek)	709	215	7.9	605	152	ND	77.5	23.8	28.8	6.0	0.046	85	11.8
1565/44	Gritstone	155	80	8.1	2810	ND	ND	184	86.3	400	44.5	<0.050	1460	9.0
1567/23	Glacial gravels	661	180	7.7	952	ND	ND	124	47.5	39.4	5.0	0.020	466	12.0
1566/25	Coaly waste	750	307	7.3	4210	19	ND	512	350	122	58.0	1.70	3100	28.5
1568/22	Baked clay	750	237	7.7	3420	35	ND	506	178	225	22.2	<0.050	1920	128
1569/21	Bentonite	750	1033	7.9	2790	ND	ND	116	47.5	495	31.5	1.75	1600	48.8
1571/12	Colluvium (till)	750	145	7.8	9200	104	ND	43.1	1150	688	19.0	<0.050	9000	48.5
1570/20	Carbonaceous shale	750	295	5.0	3120	6	ND	606	195	51.9	7.5	0.810	1800	11.5
1 of 16	Acres Ltd. waste rock	750	371	8.7	1940	ND	ND	17.5	3.5	435	11.5	0.050	587	25.5

TABLE 1-b

RESULTS OF SATURATED PASTE ALKALINITY ANALYSES

Sample Number	Description	Salinity (milliequivalents/100 g soil)								
		Alkalinity		Ca	Mg	Na	K	B	SO_4	Cl
		HCO_3^-	$CO_3^=$							
1	Glacial-fluvial sand and gravel	184×10^{-4}	ND	0.059	0.028	0.011	0.002	15×10^{-5}	0.1	0.007
2	Glacial till	ND	ND	0.040	0.031	0.031	0.002	21×10^{-5}	0.013	0.08
3	Slide debris	440×10^{-4}	ND	0.5	0.6	1.0	0.016	$<5.4 \times 10^{-5}$	1.6	0.084
4	Waste rock	ND	ND	0.035	0.006	0.40	0.008	36×10^{-5}	0.1	0.075
Bag 9 of 9	Low grade waste	ND	ND	0.056	0.046	1.0	0.021	60×10^{-5}	0.6	0.048
-	Composite	ND	ND	0.10	0.055	1.0	0.020	$<49 \times 10^{-5}$	0.6	0.084
1561/40	Alluvial gravel	ND	ND	0.10	0.022	0.015	0.002	72×10^{-5}	0.009	0.005
1563/42	Glacial till (Medicine Creek)	921×10^{-4}	ND	0.10	0.1	0.038	0.005	39×10^{-5}	0.1	0.01
1565/44	Gritstone	ND	ND	0.50	0.40	0.90	0.059	$<72 \times 10^{-5}$	1.6	0.013
1567/23	Glacial gravels	ND	ND	0.20	0.10	0.047	0.003	15×10^{-5}	0.3	0.009
1566/25	Coaly waste	155×10^{-4}	ND	1.0	1.2	0.20	0.061	192×10^{-4}	2.6	0.033
1568/22	Baked clay	221×10^{-4}	ND	0.80	0.50	0.30	0.018	45×10^{-5}	1.3	0.01
1569/21	Bentonite	ND	ND	0.80	0.50	3.0	0.1	66.9×10^{-3}	4.6	0.2
1571/12	Colluvium (till)	402×10^{-4}	ND	0.40	1.80	0.60	0.009	$<27 \times 10^{-5}$	3.6	0.026
1570/20	Carbonaceous shale	47×10^{-4}	ND	1.2	0.6	0.10	0.008	9×10^{-3}	1.5	0.013
1 of 16	Acres Ltd. waste rock	ND	ND	0.043	0.014	0.9	0.015	72×10^{-4}	0.6	0.036

TABLE 2

SETTLING TEST IN 2-l GRADUATED CYLINDERS

Sample Number	pH	Time	S.S. (mg/l) at Indicated Depths		
			S-1 (surface)	S-2 (11 cm)	S-3 (28.5 cm)
1	7.4	15 min.	188	404	428
		4.5 hr	120	132	132
		24 hr	76	56	60
2	8.1	15 min.	2,600	5,643	5,893
		4.5 hr	510	1,980	2,670
		24 hr	45	1,040	1,360
3	8.2	15 min.	5,798	10,049	11,218
		4.5 hr	560	2,760	4,130
		24 hr	60	65	70
4	8.5	15 min.	10,000	15,000	16,640
		4.5 hr	840	9,480	10,160
		24 hr	133	5,800	7,020
9 of 9	6.9	15 min.	13,280	17,080	19,060
		4.5 hr	1,680	9,860	11,780
		24 hr	90	6,040	8,100
Composite	8.1	15 min.	7,700	10,820	12,260
		4.5 hr	2,060	5,980	7,040
		24 hr	53	3,200	4,340
Hat Creek A6	8.3	15 min.	12,500	17,080	19,160
		4.5 hr	2,410	9,400	10,920
		24 hr	120	5,400	6,920

TABLE 3

ANALYSES OF SUPERNATANT FROM COLUMN SETTLING TESTS WITH ALUMINUM SULPHATE

Sample Number	Description	Test Sample Weight (g)	Distilled H_2O Added to Saturate (ml)	Filtrate Water Quality											
				pH	Specific Conductance (μmho/cm)	Alkalinity (mg $CaCO_3$/l)		Chemical Species (mg/l)							
						HCO_3^-	$CO_3^=$	Ca	Mg	Na	K	B	SO_4	Cl
2	Glacial till	50	1000	7.3	255	55.0	-	43.5	7.0	1.3	0.5	<0.025	74.0	0.340
3	Slide debris	50	1000	7.3	435	77.0	-	42.0	14.3	34.6	2.5	<0.025	138.0	2.160
4	Waste rock	50	1000	4.8	370	1.0	-	9.0	2.0	57.0	4.7	<0.025	152.0	2.64
Bag 9 of 9	Low grade waste	50	1000	4.9	385	2.5	-	16.0	6.7	44.0	5.1	<0.025	171.0	1.08
A6	Acres Ltd. waste rock	50	1000	6.2	430	26.0	-	20.5	3.0	59.0	4.7	<0.025	178.0	0.868
-	Composite	50	1000	7.2	345	65.0	-	31.0	6.1	30.4	3.0	<0.025	106.0	0.708

TABLE 3 (continued)

ANALYSES OF SUPERNATANT FROM COLUMN SETTLING TESTS WITH ALUMINUM SULPHATE

Sample Number	Description	Salinity (milliequivalents/100 g soil)								
		Alkalinity		Ca	Mg	Na	K	B	SO_4	Cl
		HCO_3^-	$CO_3^=$							
2	Glacial till	2.198	-	4.341	1.151	0.110	0.025	<0.015	3.08	0.019
3	Slide debris	3.077	-	4.192	2.352	3.010	0.128	<0.015	5.746	0.122
4	Waste rock	0.040	-	0.898	0.329	4.958	0.240	<0.015	6.329	0.149
Bag 9 of 9	*Low grade waste*	0.100	-	1.597	1.102	3.828	0.261	<0.015	7.120	0.061
A6	Acres Ltd. waste rock	1.039	-	2.046	0.493	5.132	0.240	<0.015	7.412	0.049
-	Composite	2.598	-	3.094	1.003	2.645	0.153	<0.015	4.414	0.040

FIGURES

FIGURE 1

PRELIMINARY SEDIMENTATION TEST ON SAMPLE 1
(GLACIAL FLUVIAL SAND AND GRAVEL)

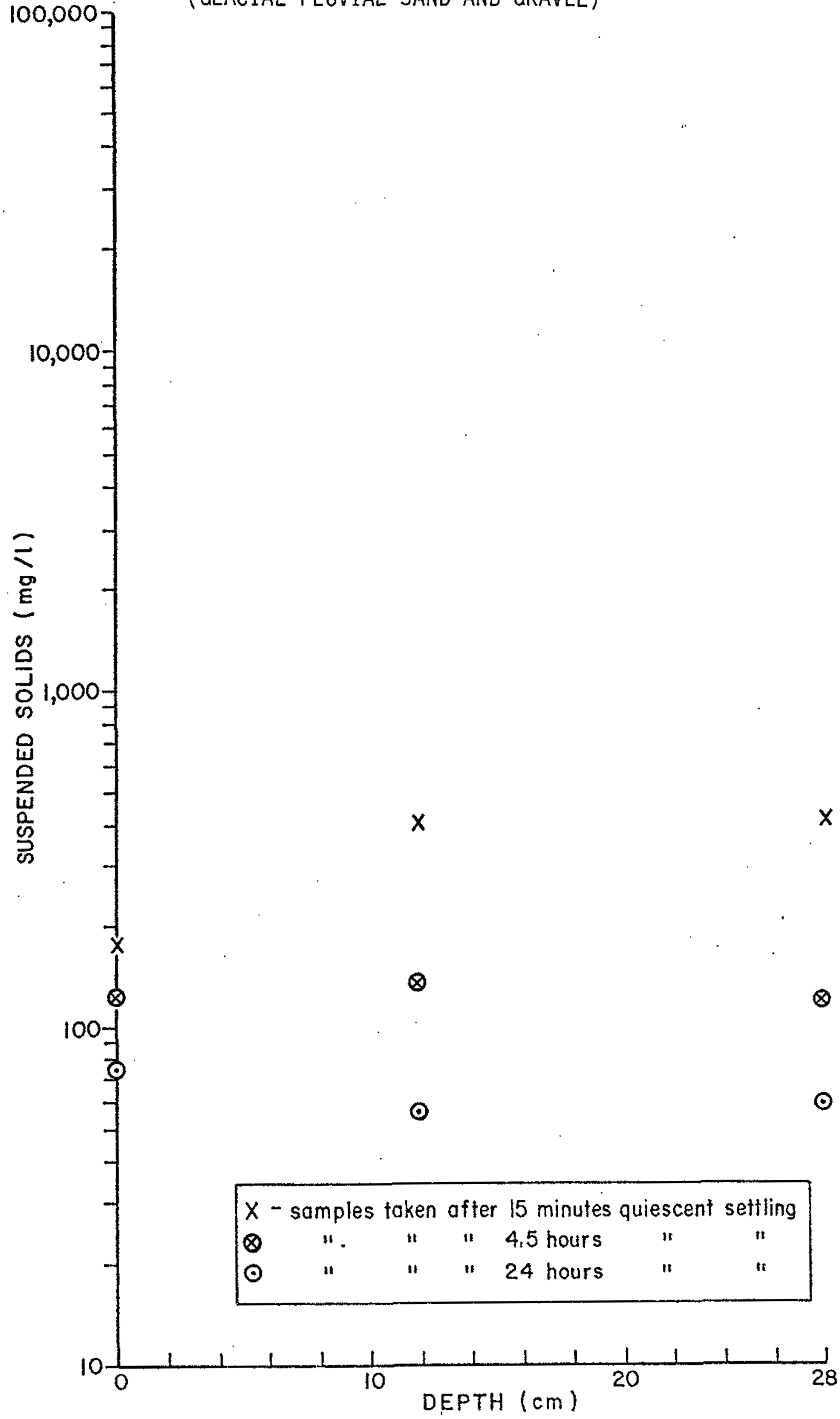


FIGURE 2

PRELIMINARY SETTLING TEST ON SAMPLE 2
(GLACIAL TILL)

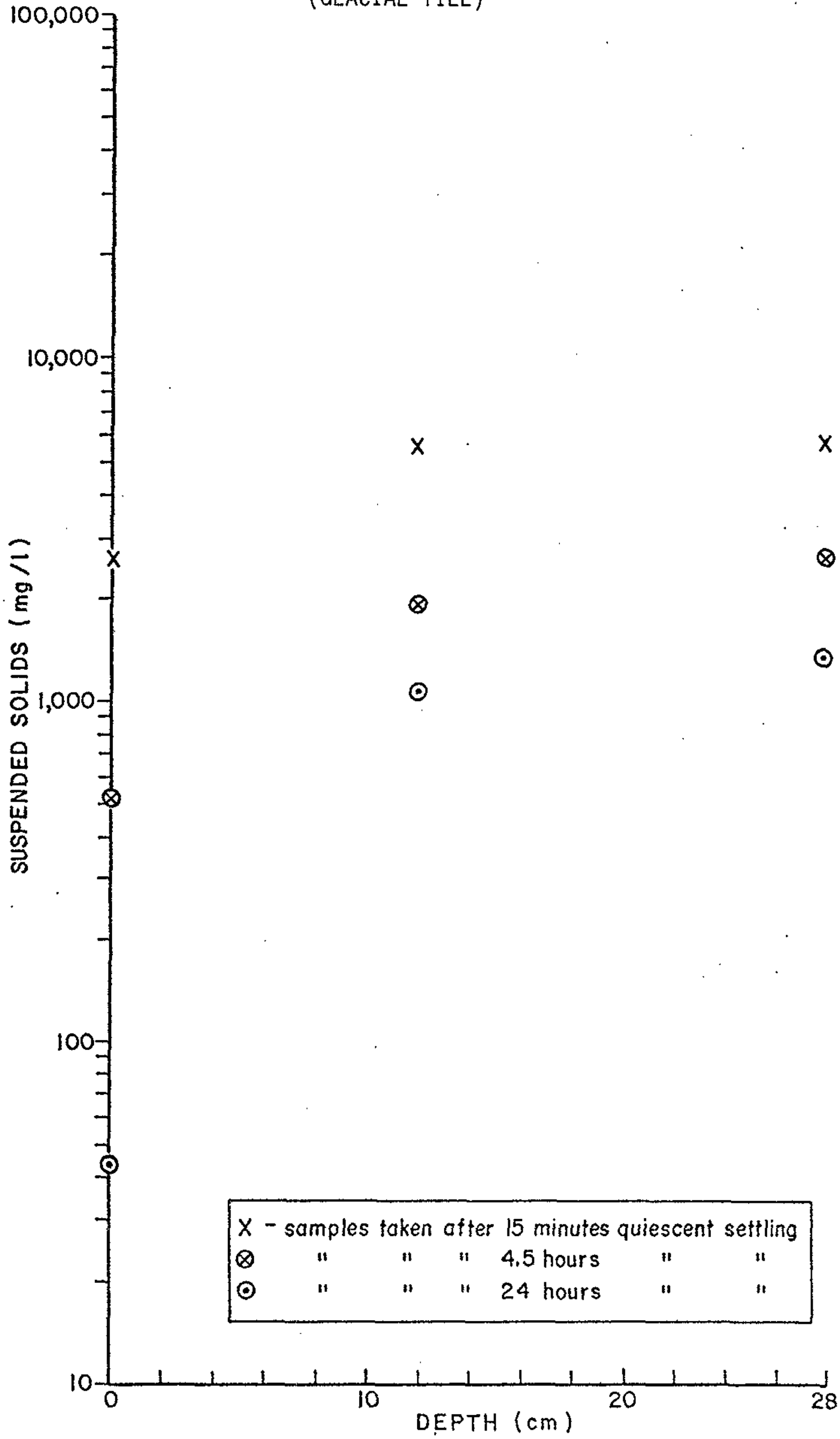


FIGURE 3

PRELIMINARY SETTLING TEST ON SAMPLE 3
(SLIDE DEBRIS)

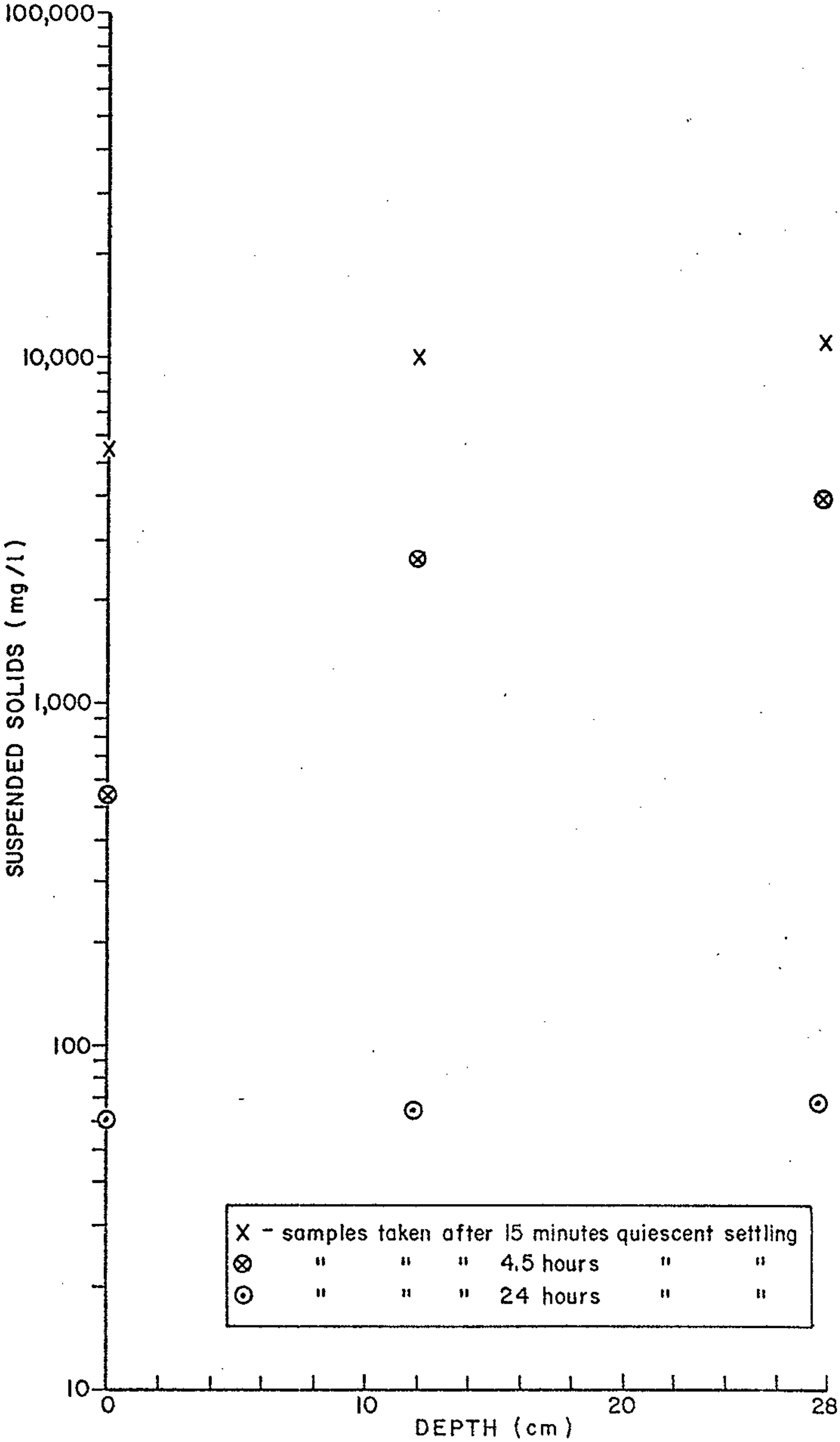


FIGURE 4

PRELIMINARY SETTLING TEST ON SAMPLE 4

(WASTE ROCK)

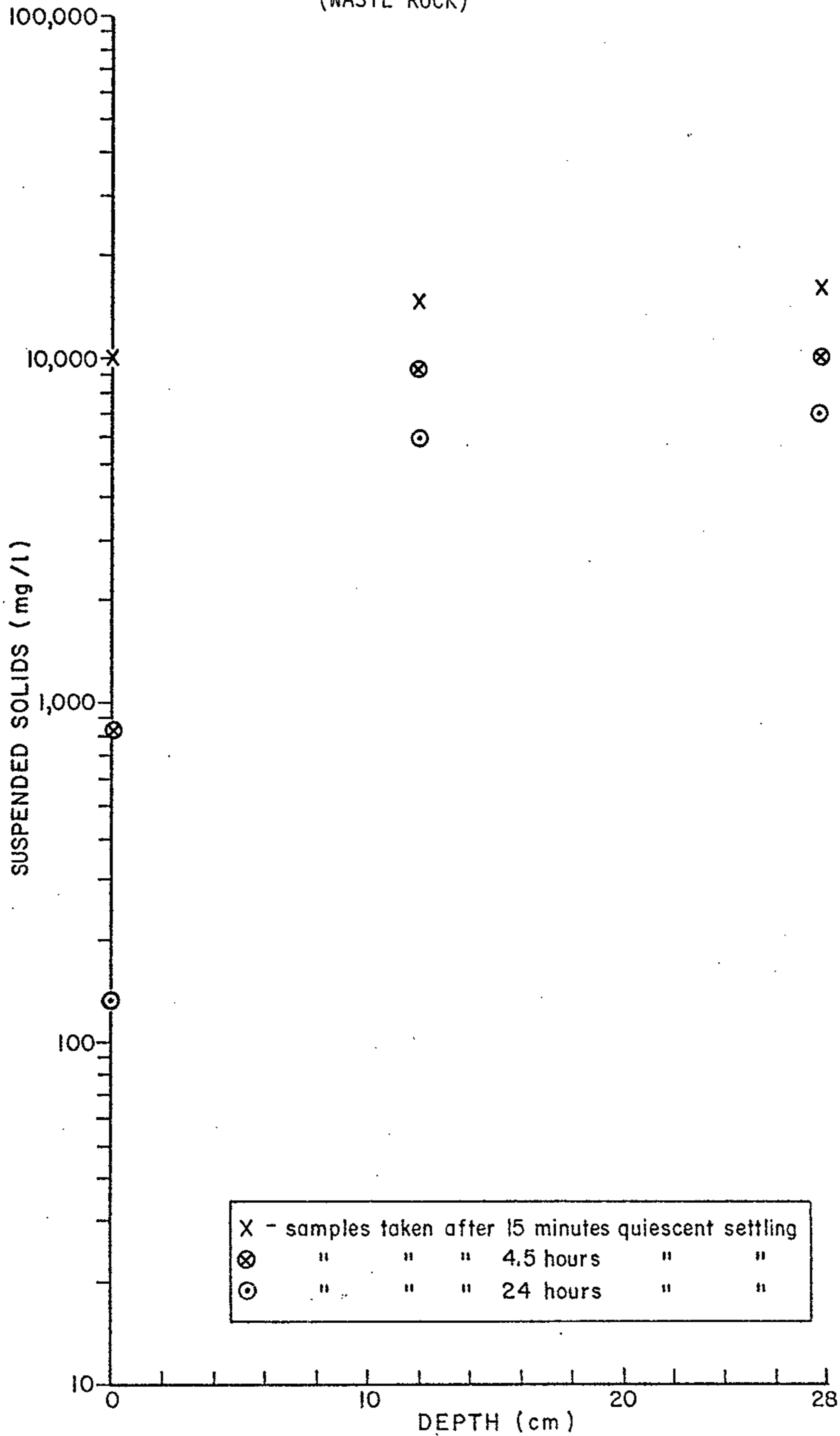


FIGURE 5

PRELIMINARY SETTLING TEST ON "BAG 9 OF 9"
(LOW GRADE WASTE)

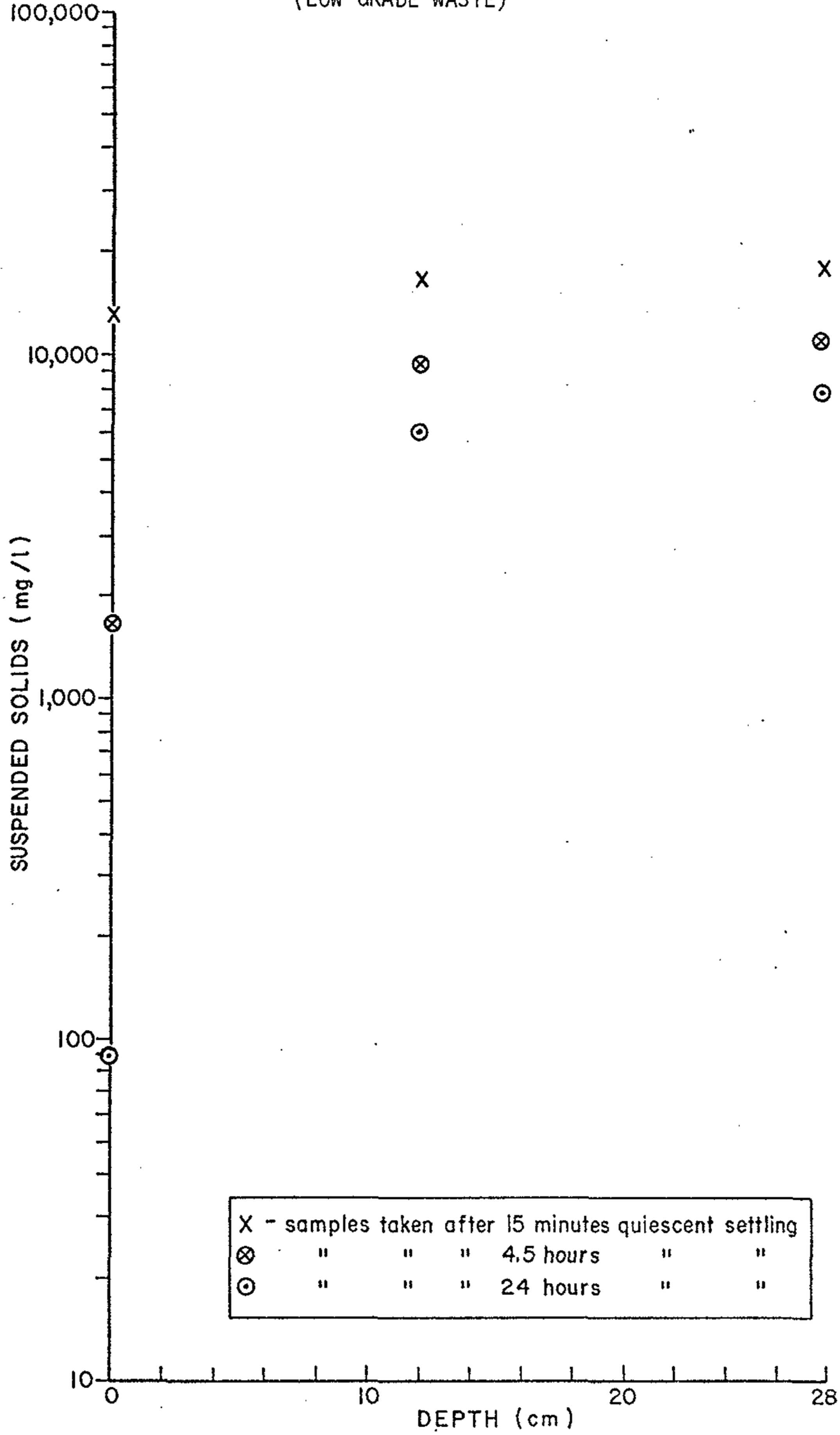


FIGURE 6

PRELIMINARY SETTLING TEST ON LAB COMPOSITE SAMPLE

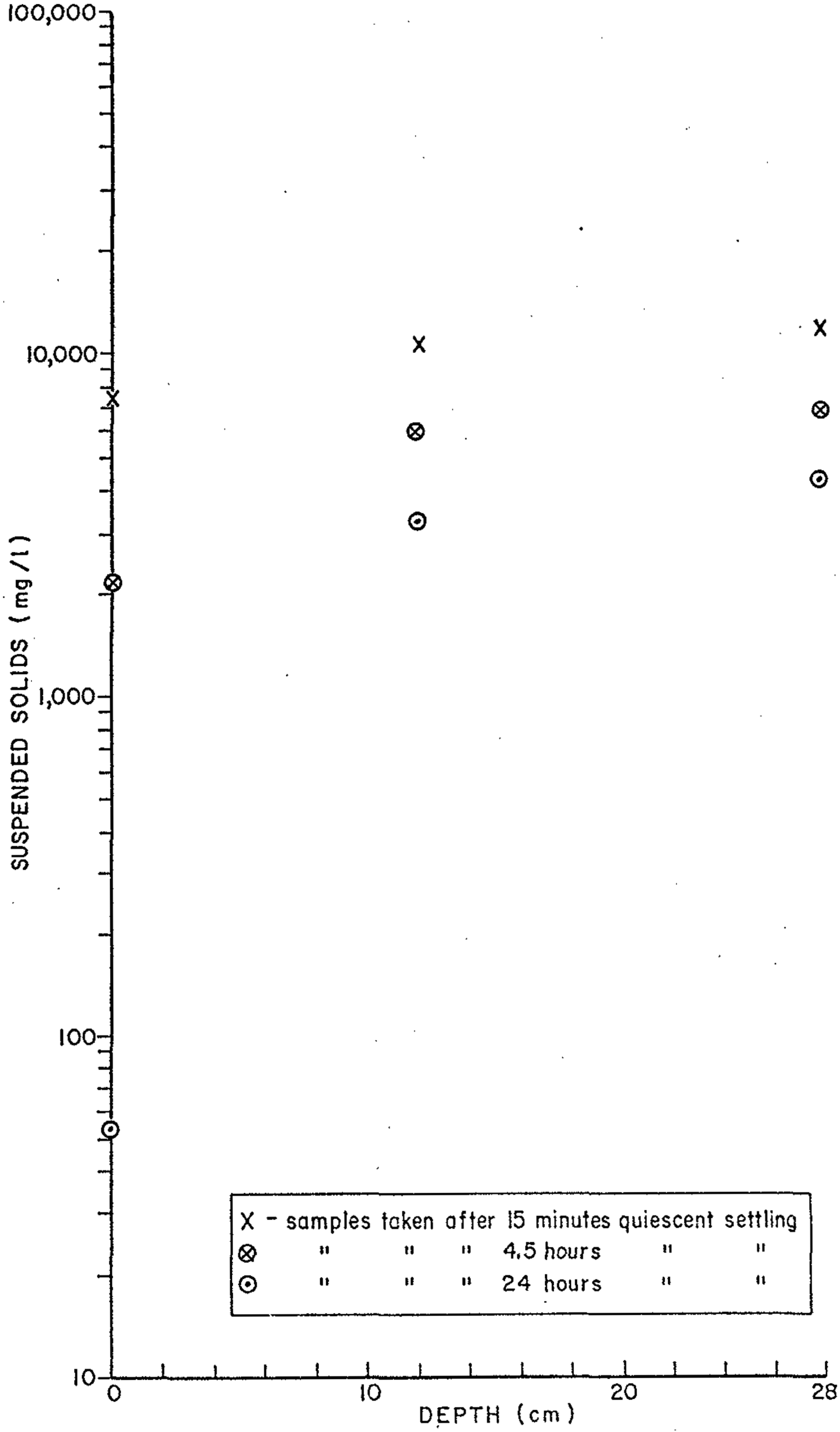


FIGURE 7

PRELIMINARY SETTLING TEST ON SAMPLE A-6

(ACRES LTD. WASTE ROCK)

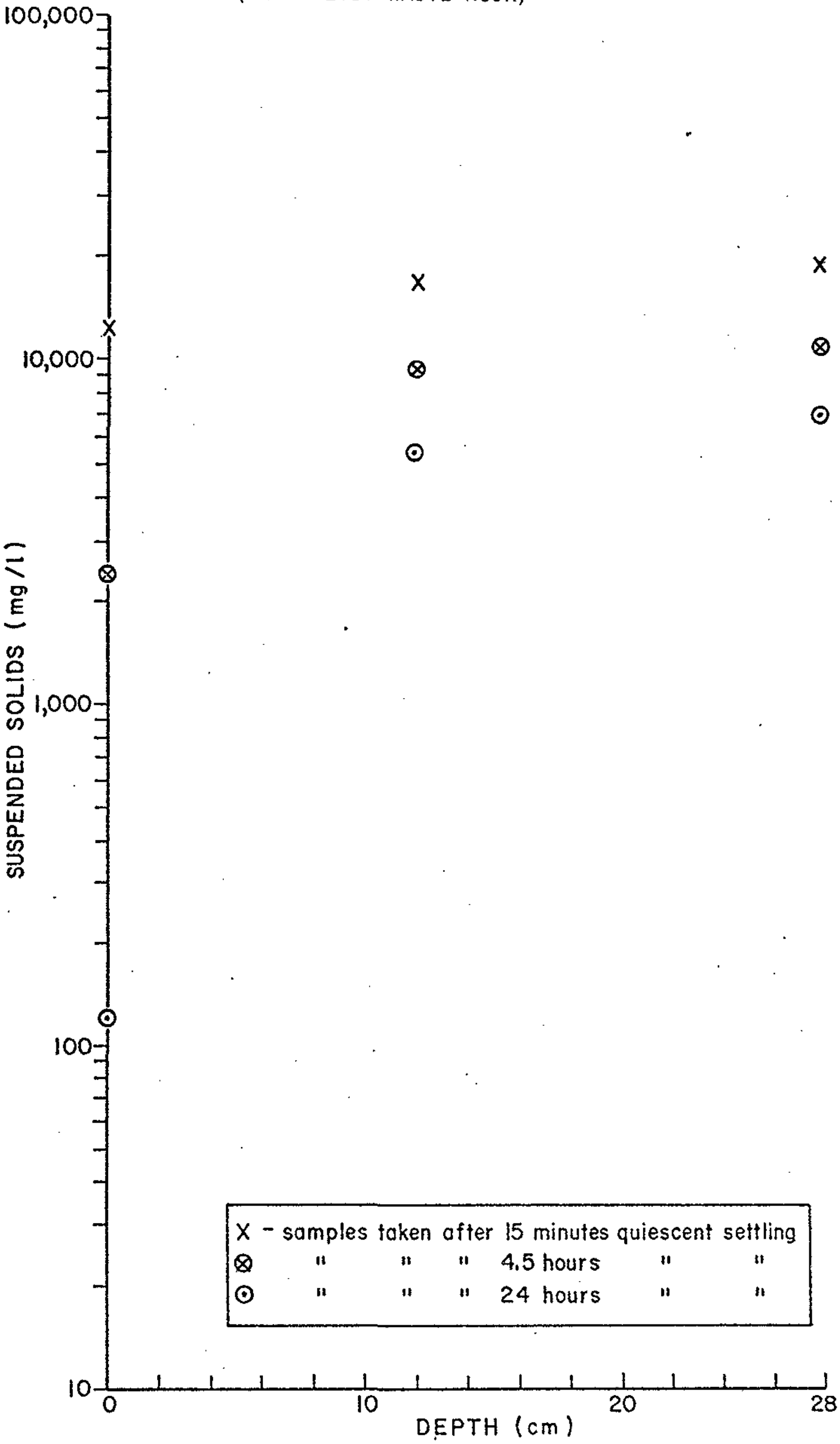


FIGURE 8

COLUMN SEDIMENTATION TEST ON SAMPLE 2 (GLACIAL TILL)

Alum dosage: 100 mg $Al_2(SO_4)_3$/l

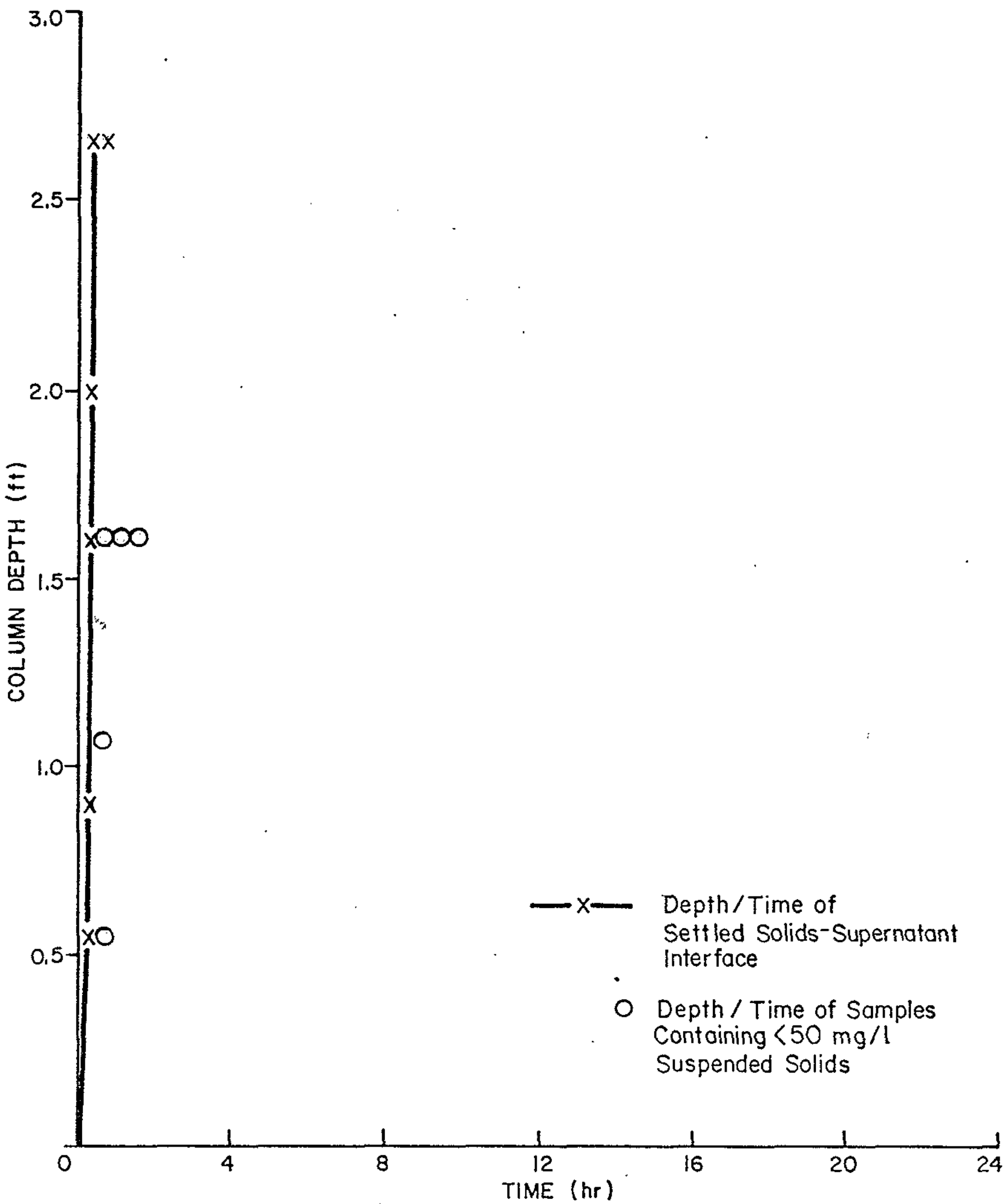


FIGURE 9

COLUMN SEDIMENTATION TEST ON SAMPLE 3 (SLIDE DEBRIS)

Alum dosage: 120 mg $Al_2(SO_4)_3/l$

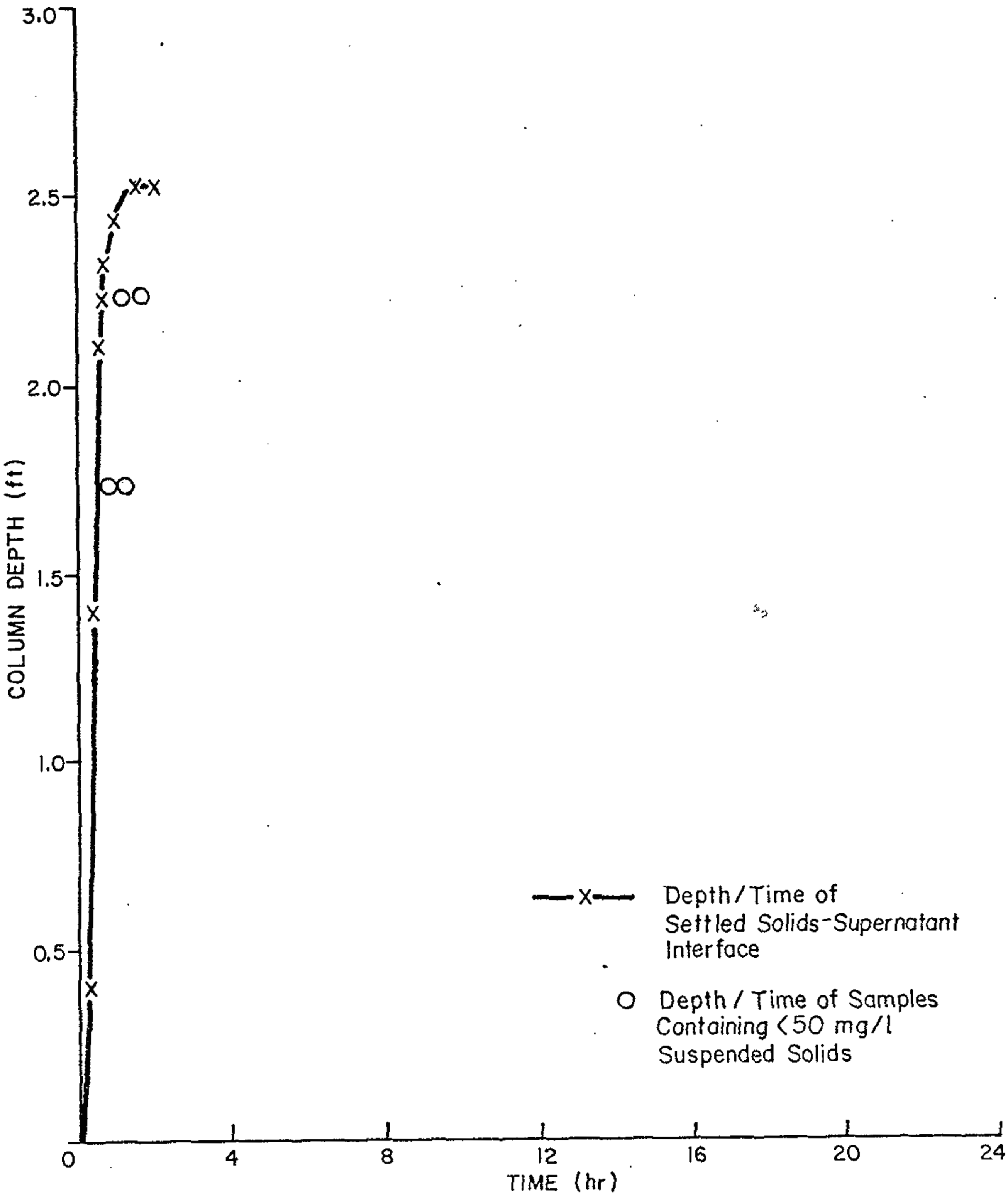


FIGURE 10

COLUMN SETTLING TEST ON SAMPLE 4 (WASTE ROCK)

Alum dosage: 206 mg $Al_2(SO_4)_3$/l

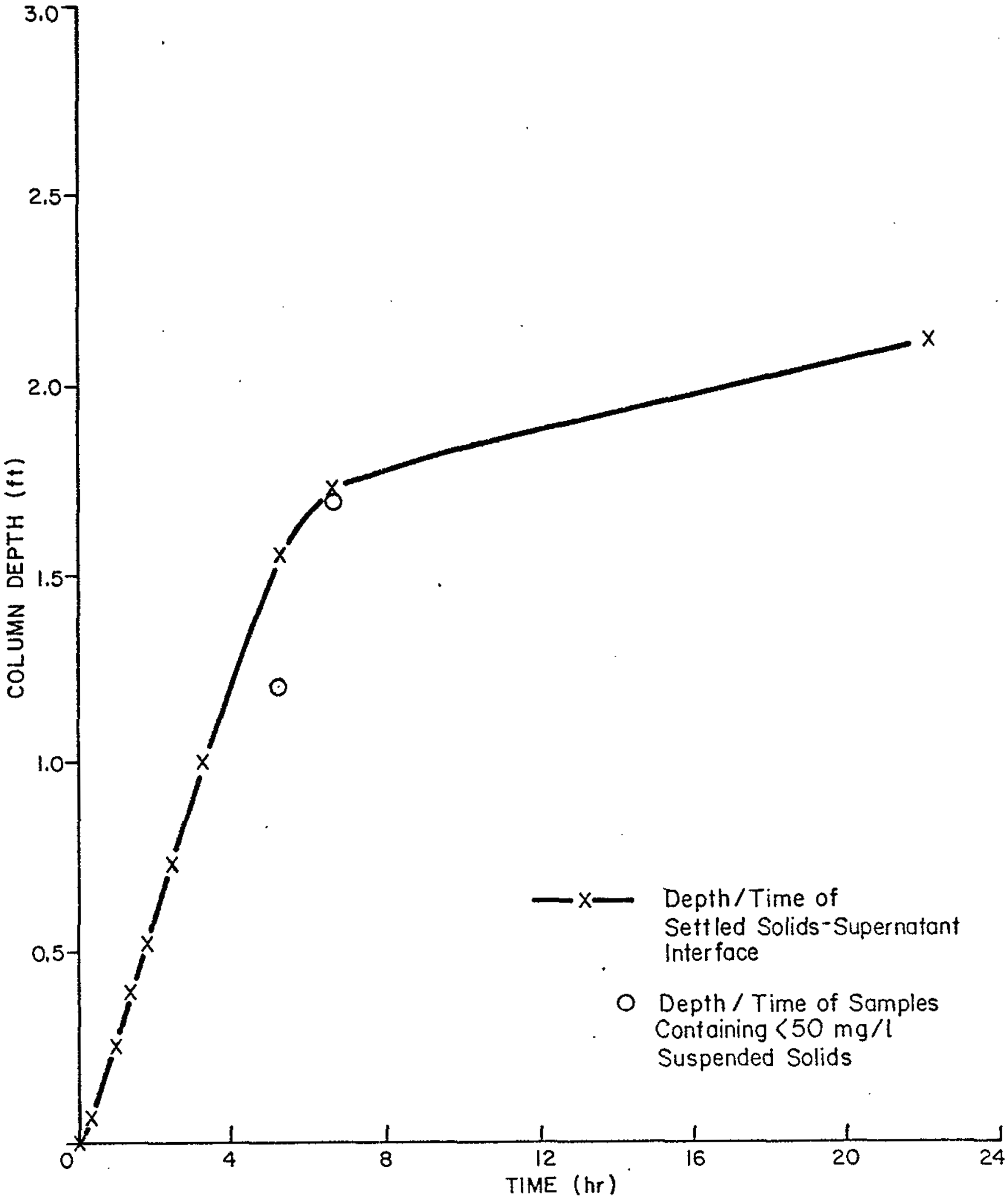


FIGURE 11

COLUMN SETTLING TEST ON "BAG 9 OF 9" (LOW GRADE WASTE)

Alum dosage: 125 mg $Al_2(SO_4)_3/l$

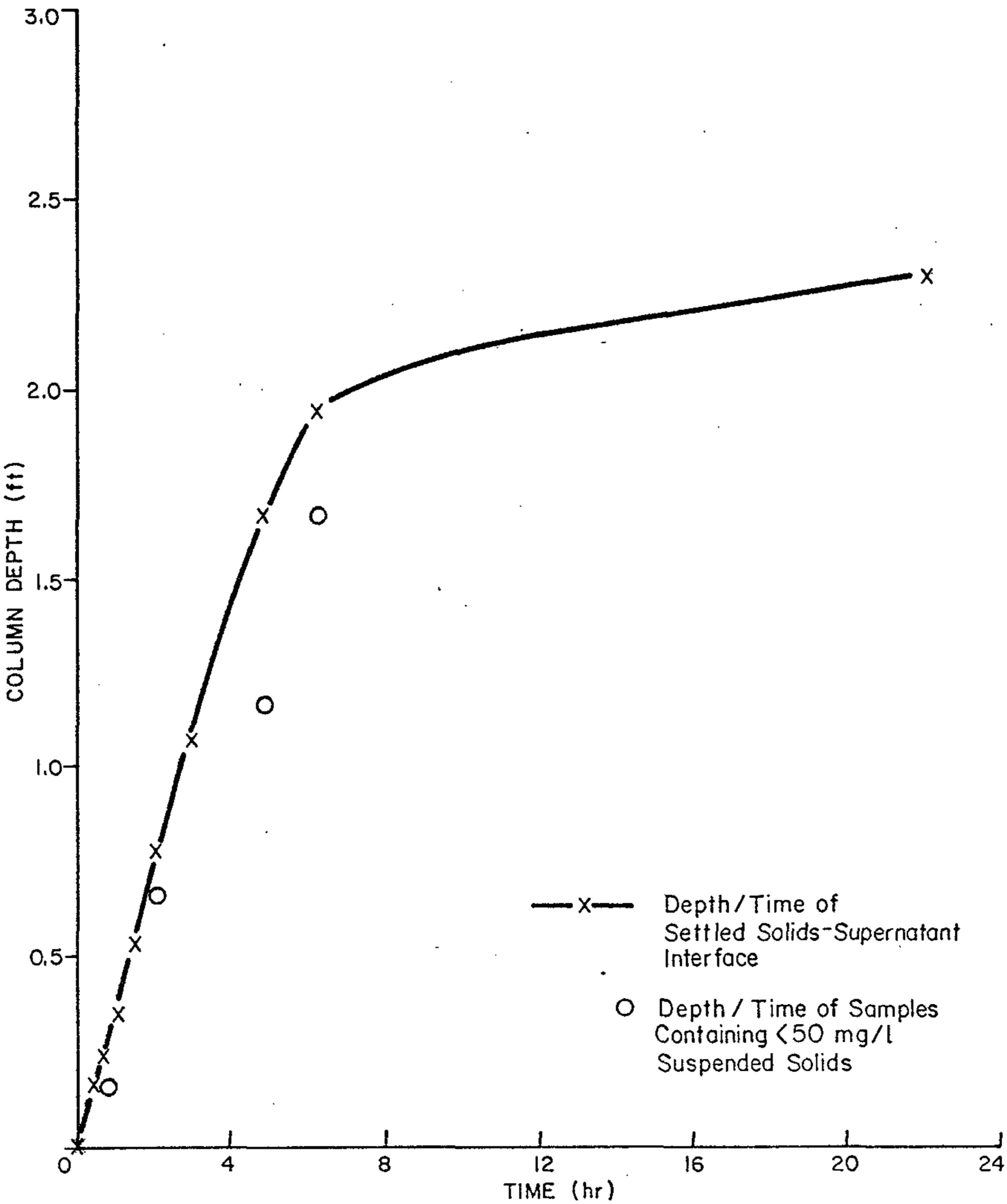


FIGURE 12

COLUMN SEDIMENTATION TEST ON LAB COMPOSITE SAMPLE

Alum dosage: 206 mg $Al_2(SO_4)_3/l$

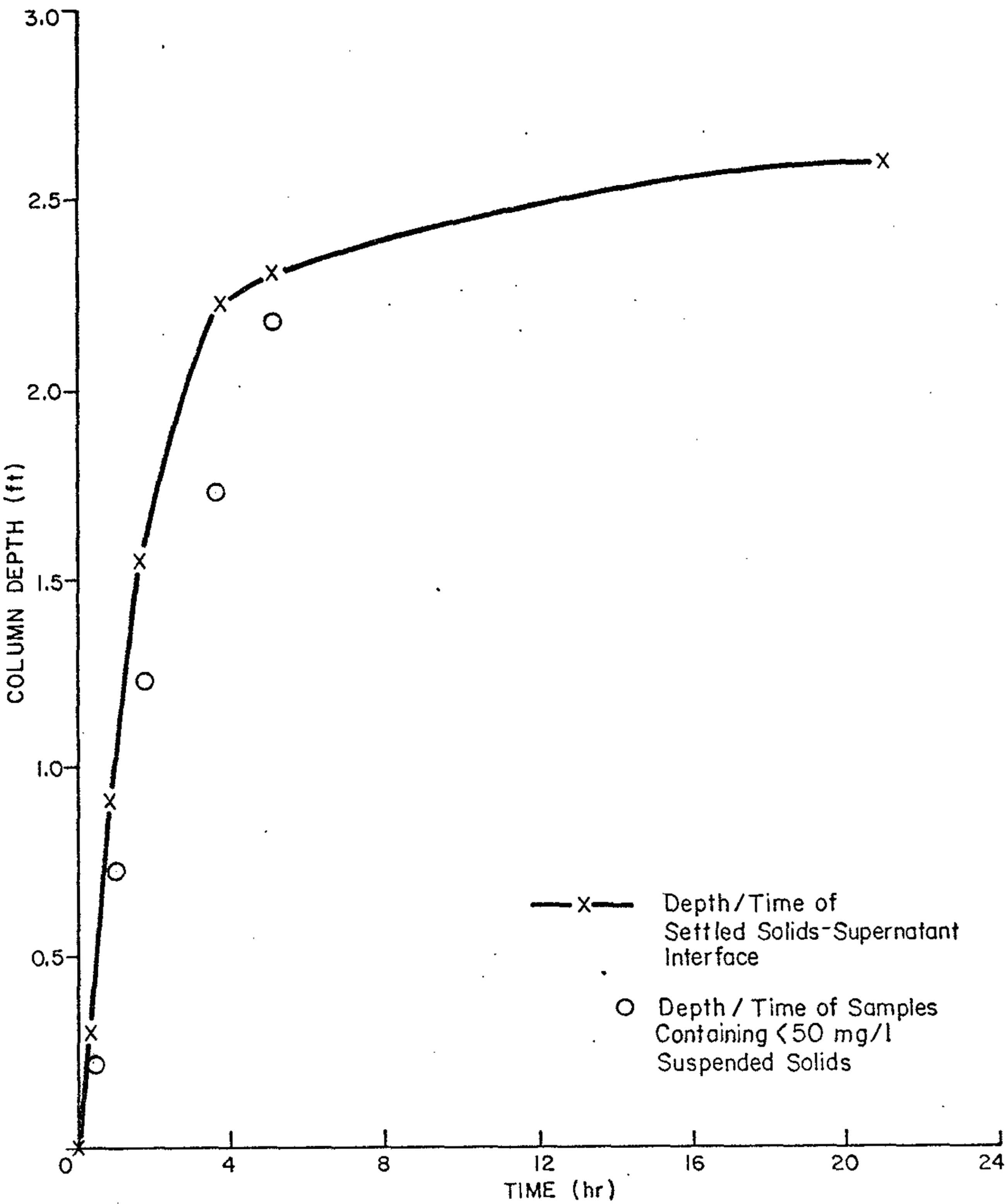
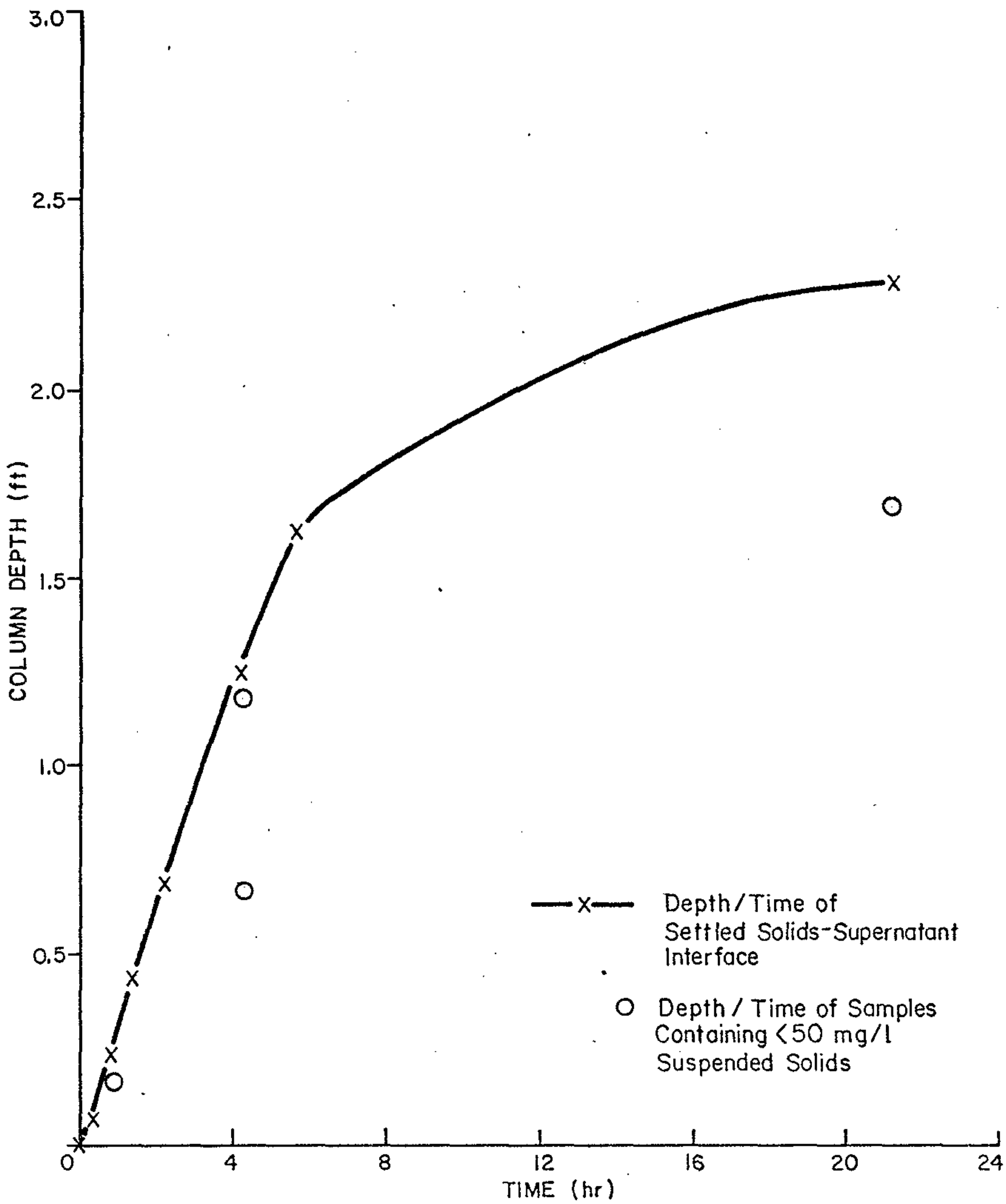


FIGURE 13

COLUMN SEDIMENTATION TEST ON SAMPLE A-6 (ACRES LTD. WASTE ROCK)

Alum dosage: 206 mg $Al_2(SO_4)_3/l$



APPENDICES

APPENDIX 1

TERMS OF REFERENCE

2-04-498

cominco-monenco joint venture

monenco

April 12, 1978

File 800/600

B.C. Research Limited
3650 Westbrook Mall
Vancouver, B.C.
V6S 2L2

Attention: Mr. R. MacElroy

Dear Rod,

This letter will confirm authorization to proceed with laboratory analysis as per previous discussions and as detailed below. It is our understanding that all sample materials have now been delivered to your offices.

A. Preliminary bench scale tests on five samples (nos 1,2,3,4 and Bag 9 of 9 - Low Grade Waste) including suspended solids, turbidity and specific conductance at selected intervals over 24 hours.

B. Bench scale tests to determine suitable coagulant(s) and dosage(s) for each of the samples in "A" plus one composite sample.

C. Column sedimentation tests on six samples as per "B" using identified coagulant(s). Monitoring to include suspended solids and turbidity profiles at selected times over 24 hours as well as recording settling interface level vs. time if possible. After 24 hour settlement, supernatant water samples will be taken for salinity analysis (Ca, Mg, K, Na, HCO_3^-, $CO_3^=$, $SO_4^=$, Cl^-, specific conductance, pH boron, and dissolved solids).

D. Detailed salinity analysis using saturated paste for:

. . . 2

1199 West Pender Street Vancouver, British Columbia V6E 2R5 Telephone: (604) 684-7411 Telex: 04-50047

Order for table - vole change

No	Sample		Test
1	Glacio Fluvial Sand & Gravel	)	
2	Glacial Till	)	Ca, Mg, K, Na
3	Slide Debris	)	HCO_3^-, $CO_3^=$, $SO_4^=$, Cl^-
4	Waste Rock	)	pH
Bag 9 of 9	Low Grade Waste	)	Electrical Conductivity
-	Composite	)	B
1561/40	Alluvial Gravel	)	
1563/42	Glacial Till (Medicine Creek)	)	
1565/44	Gritstone	)	
1567/23	Glacial Gravels	)	
1568/22	Baked Clay	)	
1569/21	Bentonite	)	
1571/12	Colluvium (Till	)	
1566/25	Coaly Waste	)	
1570/20	Carbonaceous Shale	)	

E. Grain size distribution analysis for sample numbers 1, 2, 3, and 4.

Estimated cost of the program - reference your letter to CMJV 3/4/78 and subsequent telephone discussions - totals approximately $3000.00. Any costs in excess of this estimate must have prior written approval from CMJV. Standard test methods to be applied on all analysis. It is our understanding that the program results will be in our hands no later than 28/4/78.

Yours truly,

O.I. Johnson
Project Manager

D Paul Mahony
per
D.P. Mahony
Senior Resource Planner

DPM/cw

cc: OIJ
FJV
JJF
FGH
JC
JES
WDA

File 600/800

April 17, 1978

B.C. Research Limited
3650 Westbrook Mall
Vancouver, B.C.
V6S 2L2

Attention: Mr. R. MacElroy

Dear Rod:

Re: Hat Creek Project

This is to confirm our telephone discussion today.

In order to give better coverage of the waste rock material the "Acres" waste rock sample will be added to the program for Tests A, B, C, D, and E (ref. letter 12/4/78).

The glacio fluvial sand and gravel sample will be tested as for A, D, and E but removed from programs B and C.

Yours truly,

O.I. Johnson, P. Eng.
Project Manager

per
J.P. Christensen, P.Eng.

JPC/cw

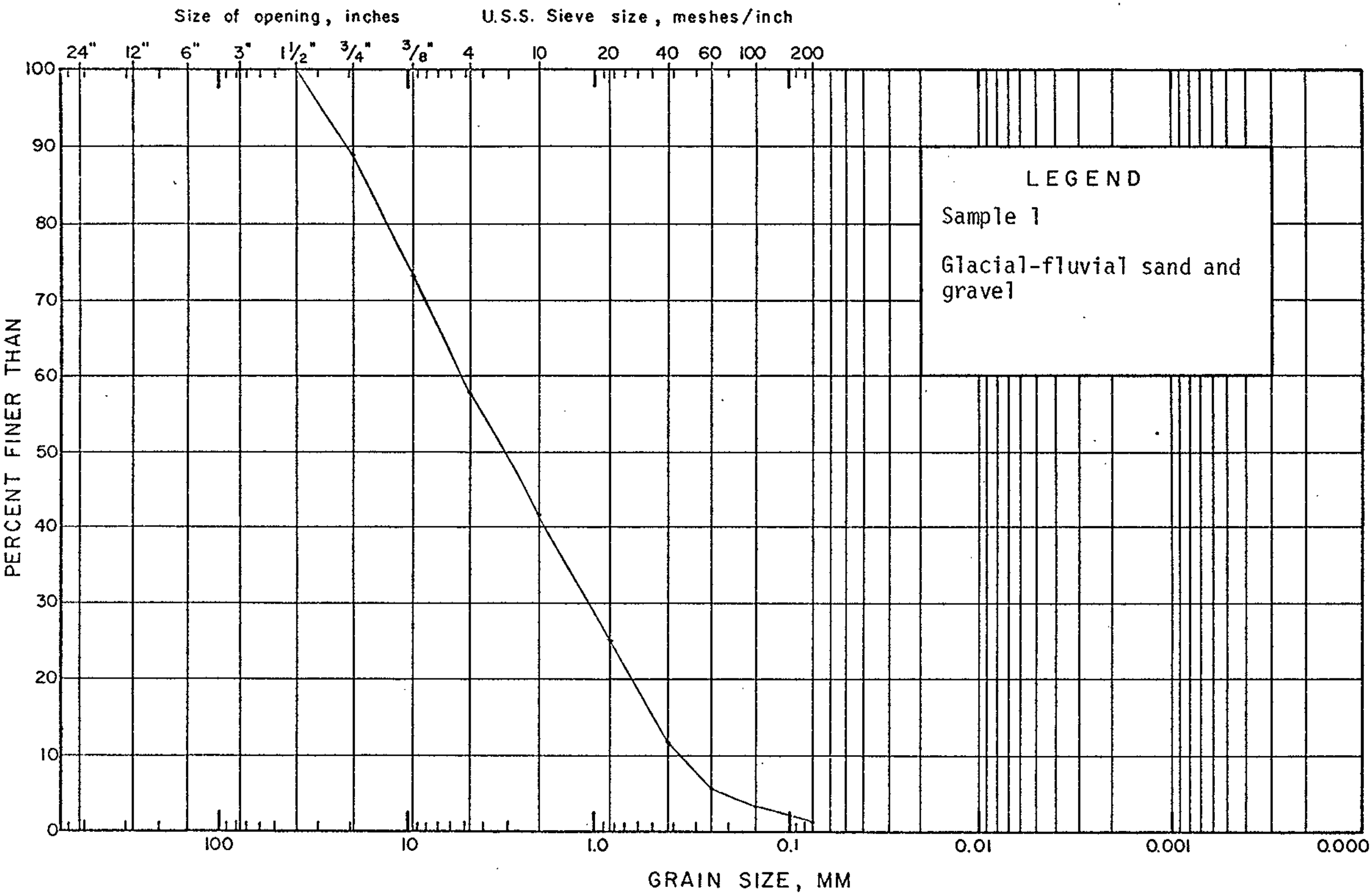
cc: JJF
FGH
FJV
OIJ
DPM
JES
WDA

APPENDIX 2

PARTICLE SIZE DISTRIBUTION OF SELECTED MATERIALS

Project No. V78067 Drawn D.K. Reviewed ______ Date ______

M.I.T. GRAIN SIZE SCALE

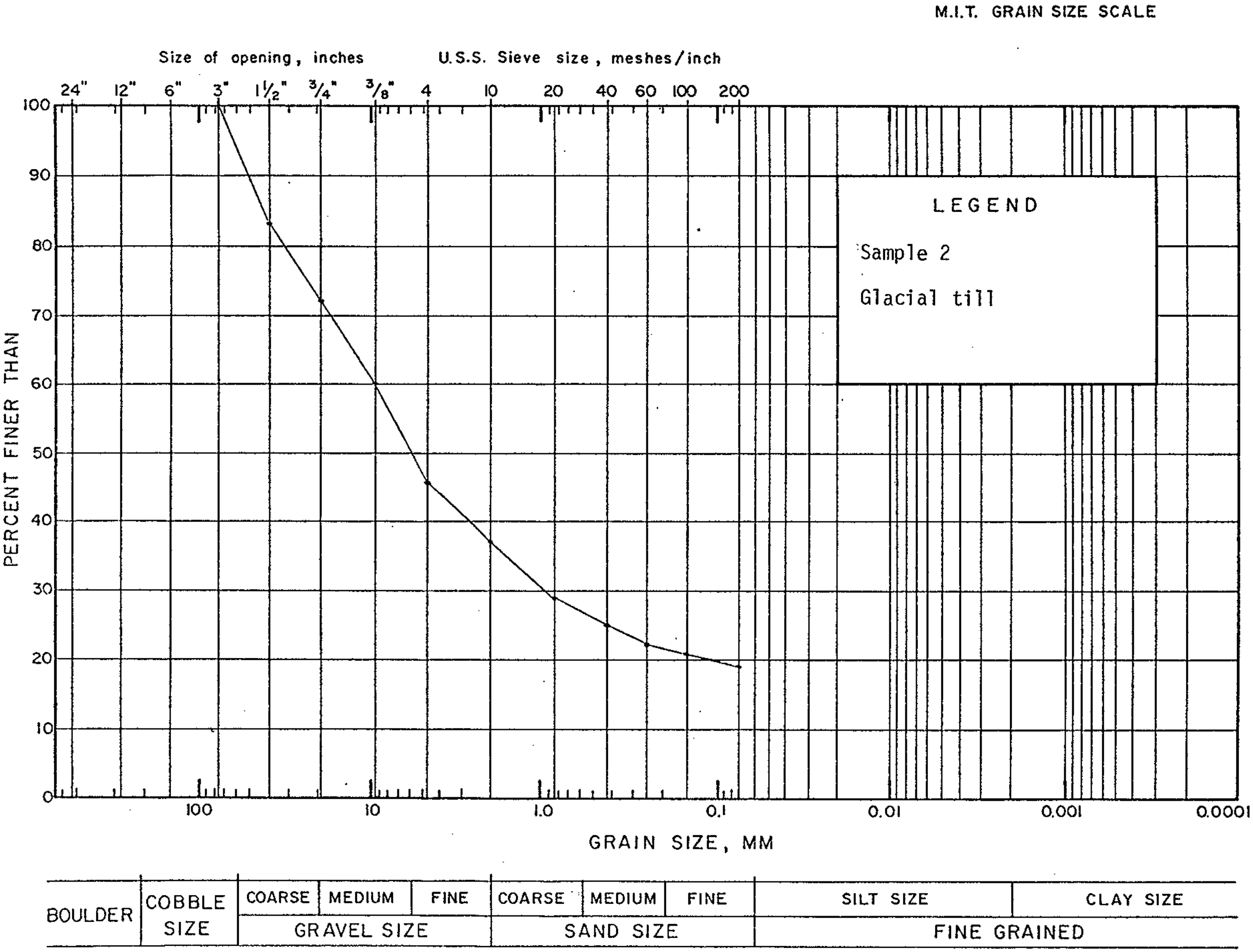


BOULDER	COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE
		GRAVEL SIZE			SAND SIZE			FINE GRAINED	

Golder Associates

Figure

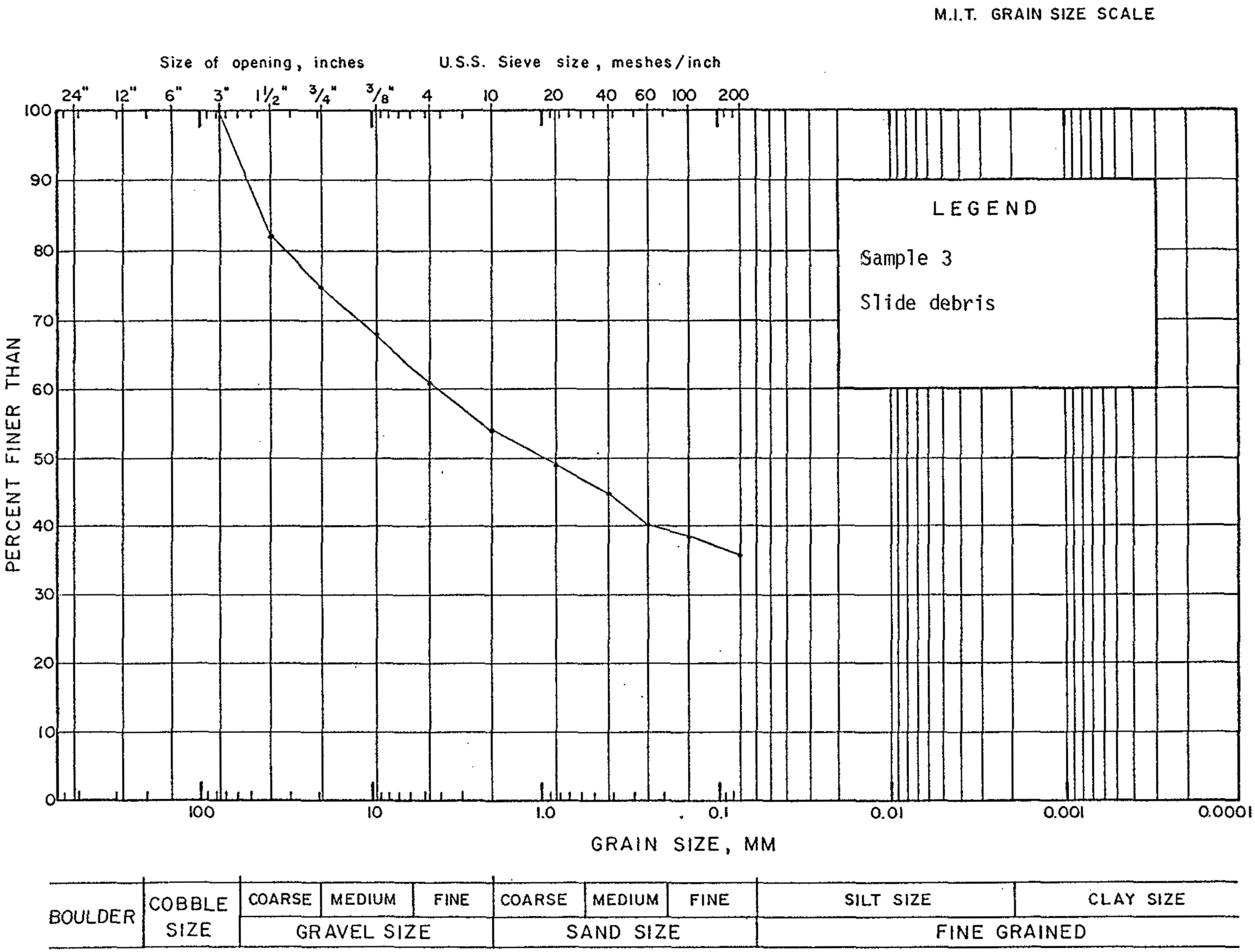
Project No. V78067 Drawn D.K. Reviewed ______ Date ____________



Golder Associates

Figure

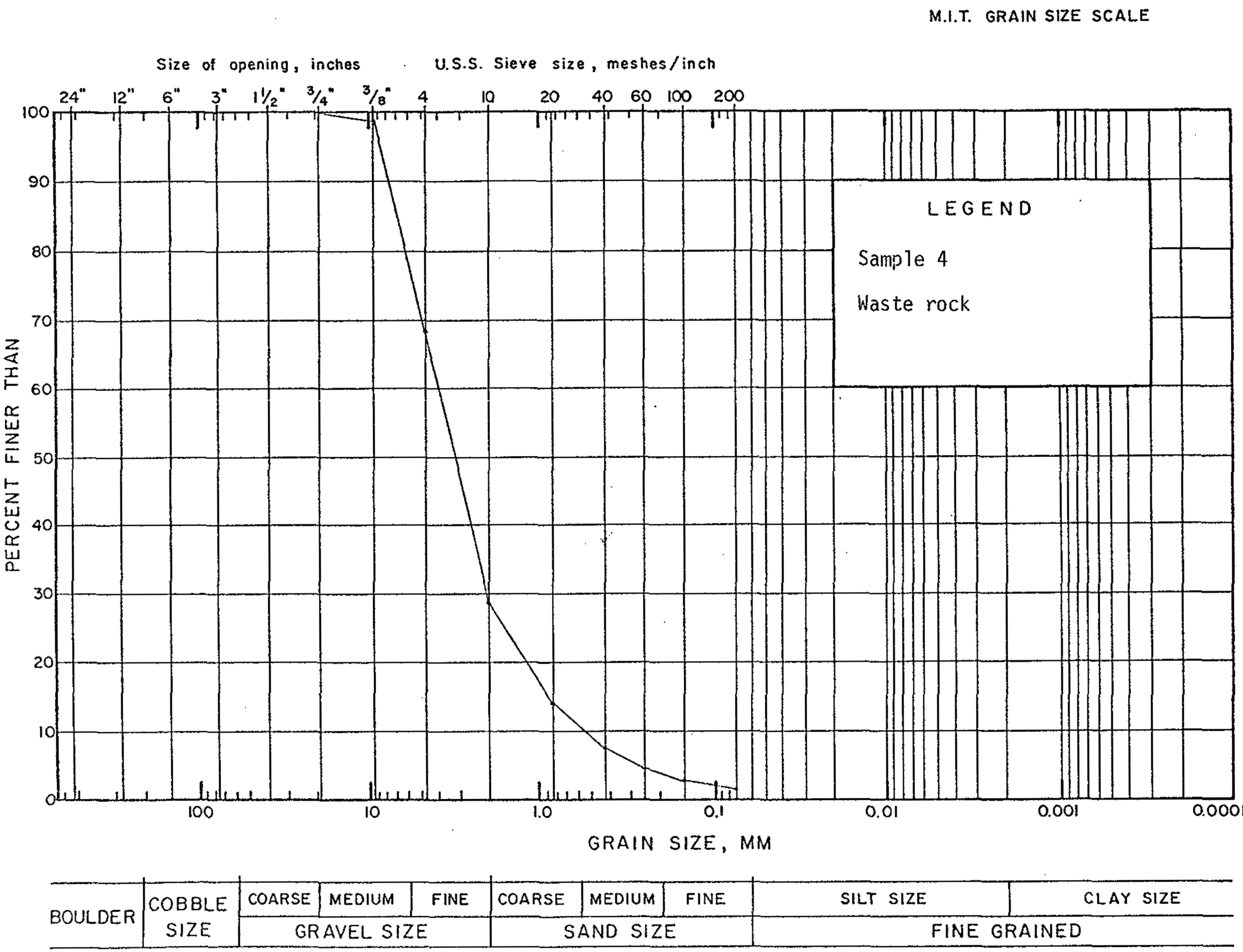
Project No. V78267 Drawn D.K. Reviewed ______ Date ______



Golder Associates

Figure

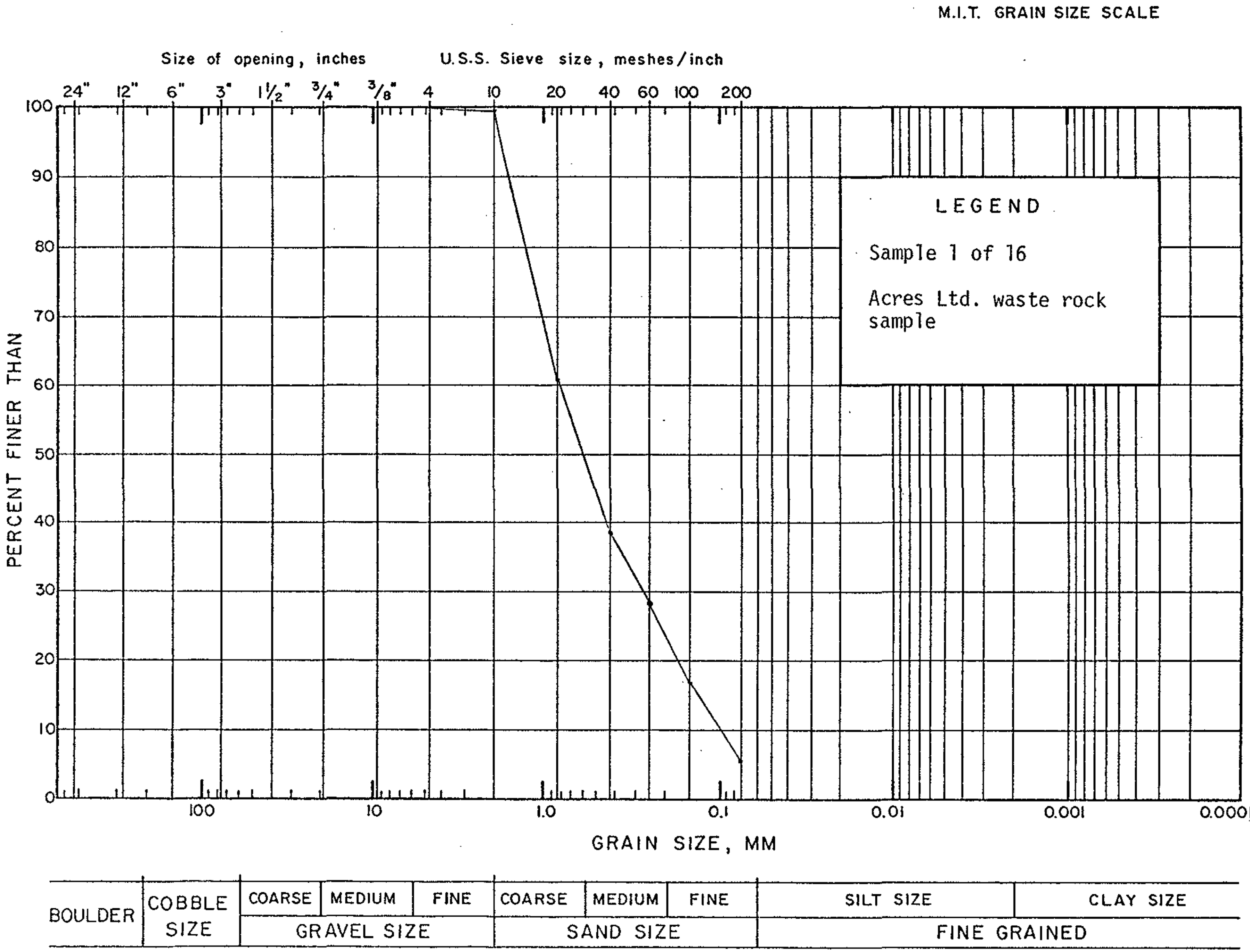
Project No. V78267 Drawn D.K. Reviewed ______ Date ______



Golder Associates

Figure

Project No. V7806/1 Drawn D.K. Reviewed .... Date ....



Golder Associates

Figure

APPENDIX 3

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS FOR COLUMN SEDIMENTATION TESTS

COLUMN SETTLING TESTS

Sample Number	Time	Interface Depth (ft)	Depth of Sample (ft)	Suspended Solids (mg/1)	Turbidity (NTU)
2					
-	0 min.	0	0	-	-
2-1	4	0.54	0.08	97	46
2-2	7	0.88	0.54	111	46
2-3	12	1.58	1.08	73	31
2-4	17	2.00	0.54	35	18
2-5	17	2.00	1.08	40	18
2-6	17	2.00	1.58	44	21
2-7	22	2.67	1.58	24	13
2-8	37	2.67	1.58	19	7.5
3					
-	0 min.	0	0	-	-
3- 1	6	0.41	0.17	234	98
3- 2	21	1.42	0.66	114	48
3- 3	21	-	1.17	131	46
3- 4	25	1.83	1.17	91	36
3- 5	25	-	1.67	128	44
-	31	2.08	-	-	-
3- 6	39	2.21	1.17	68	29
3- 7	39	-	1.67	71	29
3- 8	49	2.33	1.67	48	22
3- 9	49	-	2.12	96	36
3-10	55	2.42	1.67	45	20
3-11	55	-	2.12	62	26
3-12	77	2.54	2.12	45	22
3-13	94	2.56	2.12	42	21
4					
-	0 hr	0	0	-	-
-	0.30	0.06	-	-	-
4-1	0.93	0.25	0.19	105	32
-	1.40	0.38	-	-	-
-	1.90	0.52	-	-	-
4-2	2.5	0.73	0.67	66	23
-	3.37	1.00	-	-	-
4-3	5.32	1.56	1.21	5	3.2
4-4	6.73	1.75	1.71	4	2.2
-	22.56	2.10	-	-	-

FGH

cc

Cominco

monenco

Memorandum

For Use Within The Company Only

To	Mr. J.J. Fitzpatrick Attn: F.G. Hathorn (Use Title if Possible)	Date	May 15, 1978
From	O.I. Johnson/per D.P. Mahony (Use Title if Possible)	File No.	CMV 6125-9/800
Subject	LAB ANALYSIS PROGRAMS	Reference	

Attached please find one copy of the report prepared for CMJV by B.C. Research Ltd. regarding salinity and sedimentation tests.

We have reviewed the document and find the work completed satisfactorily. Payment has therefore been authorized.

As per the telecon between Messrs. Hathorn and Mahony, a xerox of the report will be forwarded to Acres Ltd. and ESCLEC Ltd. for their use.

DPM/cw

Att.

D. Patrick Mahony

cc: OIJ
JJF
DPM
FJV
KFR
JC
JES
RTG
NED

Signed

FILE 6044-1301.4-2

THERMAL DIV.

MAY 19 1978

ROUTE		INIT
	DIV. MGR.	
	PROJ. CONTROL	
	POWER PLANT	
2	MINING	
	CONSTRUCTION	
1	Project Engineer	PM
	Sen. Staff Eng'r.	
	TEAM	

ACTION FGH - W/Rec

COPIES

CH.J 6175 7 / [illegible]

B.C. RESEARCH

3650 Wesbrook Mall, Vancouver, Canada V6S 2L2

Phone (604) 224-4331 • Cable 'RESEARCHBC' • Telex 04-507748

May 12, 1978

Our File: 204-498

Mr. D.P. Mahony
Cominco Monenco Joint Venture
1199 West Pender Street
Vancouver, B.C.
V6E 2R5

Dear Pat:

Please find enclosed six copies - five bound and one unbound - of our final report "Analyses and Sedimentation Tests on Materials Associated with the Hat Creek Coal Deposit".

The only significant changes from the draft version are Appendix 3, which includes results of turbidity determinations on column test supernatant, and a discussion of the low pH values caused by alum treatment of samples "4" and "9 of 9".

As indicated in the final report, the low pH values are due to production of acid by hydrolysis of alum and to the apparent low buffering capacity of the materials. Considering that the composite sample pH was 7.2 and that large alum dosages were required to deal with the high solids concentration used for testing, I would not expect low treated effluent pH to be a problem in practice. In the unlikely event that the problem did occur, it could be easily corrected by controlled lime addition at the appropriate pond inflow or outfall.

I have also enclosed our invoice for this test program. The amount in excess of the authorized expenditure of $3,000 is due to addition of particle size and salinity analyses on the Acres Ltd. waste rock sample as requested.

In accordance with our telephone conversation, the remaining solid samples will be stored at B.C. Research for up to one year pending instructions regarding disposal. There will be no storage charge, but any cost associated with subsequent handling or shipping will be invoiced.

I trust that the final report is satisfactory. If you have any questions or comments please contact me.

Yours very truly,

B.C. RESEARCH

R.O. McElroy
Extractive Metallurgist
Division of Applied Chemistry

ROM:jf

Enclosures

B.C. RESEARCH

INVOICE NUMBER 26294

3650 Wesbrook Mall, Vancouver, Canada V6S 2L2

Phone (604) 224-4331 • Cable 'RESEARCHBC' • Telex 04-507748

Technical Operation of the BRITISH COLUMBIA RESEARCH COUNCIL, a Non-profit Industrial Research Society

DATE May 11, 1978.

Cominco/Monenco Joint Venture
300 - 1199 West Pender Street
Vancouver, B.C.

2COM/MON
CUSTOMER CODE

2-04-498
ACCOUNT NUMBER

PARTICULARS			AMOUNT
Analyses and Sedimentation Tests on Materials associated with the Hat Creek Coal Deposit.			
Initially authorized cost		$ 3,000.00	
Extra costs due to processing of one extra sample (Acres Ltd. Waste Rock, Hat Creek A-G)			
	Particle Size	55.00	
	Full Salinity	45.00	
	TOTAL	$ 3,100.00	$ 3,100.00

CMU 6125-9 / 800 - Environment (EH) / 600 - Support Facil (IWB)

12/5/78
OK

FINAL INVOICE.

TERMS: NET 30 DAYS. OVERDUE INVOICES ARE SUBJECT TO 1½% PER MONTH (18% PER ANNUM) INTEREST CHARGES FROM DATE OF INVOICE. PLEASE RETURN ONE COPY OF THIS INVOICE WITH YOUR PAYMENT OR REFER TO IT BY INVOICE NUMBER.

ORIGINAL INVOICE

COLUMN SETTLING TESTS (continued)

Sample Number	Time	Interface Depth (ft)	Depth of Sample (ft)	Suspended Solids (mg/l)	Turbidity (NTU)
<u>9 of 9</u>					
-	0 hr	0	0	-	-
-	0.37	0.17	-	-	-
9-1	0.57	0.25	0.17	11	7.2
-	0.85	0.35	-	-	-
-	1.33	0.54	-	-	-
9-2	1.93	0.79	0.67	21	8.8
-	2.80	1.08	-	-	-
9-3	4.75	1.67	1.17	8	5.2
9-4	6.16	1.94	1.67	2	2.4
-	22.0	2.29	-	-	-
<u>Composite</u>					
-	0 hr	0	0	-	-
C-1	0.32	0.31	0.23	20	16
C-2	0.90	0.92	0.73	9	6.5
C-3	1.77	1.54	1.23	7	4.5
C-4	3.72	2.21	1.73	3	4.2
C-5	5.13	2.29	2.17	5	2.8
-	21.0	2.58	-	-	-
<u>Hat Creek A-6</u>					
-	0 hr	0	0	-	-
-	0.31	0.08	-	-	-
A6-1	0.71	0.23	0.17	28	11
-	1.27	0.44	-	-	-
-	2.16	0.69	-	-	-
A6-2	4.11	1.25	0.67	2	2.5
A6-3	4.19	1.25	1.19	21	7.5
-	5.53	1.62	-	-	-
A6-4	21.36	2.27	1.69	25	8.2