APPENDIX C

APPENDIX C

RADON MODEL CALCULATION, LONG-TERM MOISTURE LAB TEST RESULTS AND BULK DENSITY CALCULATIONS

Canonie Environmental

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By mmj Date 2/20/91 Subject UNC Sheet No. 1 of ____

Chkd. By SJvM Date 3-1-91 RADON BARRIER Proj. No. 96-060-24

1/4" X 1/4"

PURPOSE: TO DETERMINE THE REQ'D SOIL COVER THICKNESS TO LIMIT RADON EMISSIONS FROM THE RECLAIMED UNC TAILINGS IMPOUNDMENT TO 20 $pCi/m^2/sec$ USING NRC APPROVED METHODS AND INPUTS

METHOD: DETERMINE GEOTECHNICAL AND RADIOLOGICAL PROPERTIES OF THE TAILINGS AND SOIL COVER MATERIALS BASED ON NRC-ACCEPTABLE METHODS. USE THE EXISTING DATABASE OF VALUES INCLUDING INTERIM RECLAMATION OF THE NORTH AND CENTRAL CELLS AND OTHER PARAMETERS AS DISCUSSED AND AGREED ON WITH NRC. INPUT THESE THE PARAMETERS INTO THE RADON COMPUTER CODE.

RESULTS: FOR THE FOLLOWING INPUTS, THE REQUIRED THICKNESS IS 1.5 FEET.

LAYER	POROSITY	MASS DENSITY	RADIUM ACTIVITY	MOISTURE CONTENT	DIFF COEFF	EMAN FRACTION	THICK
FINE TAILS	0.48	1.45 g/cc	547 pCi/gm	6.0%	0.040 cm^2/sec	0.26	16.4 ft
COARSE TAILS	0.47	1.56 g/cc	154 pCi/gm	6%	0.036 cm^2/sec	0.26	7.0
COVER	0.33	1.73	0	12.9%	0.00360 cm^2/sec	NA	1.5 ft

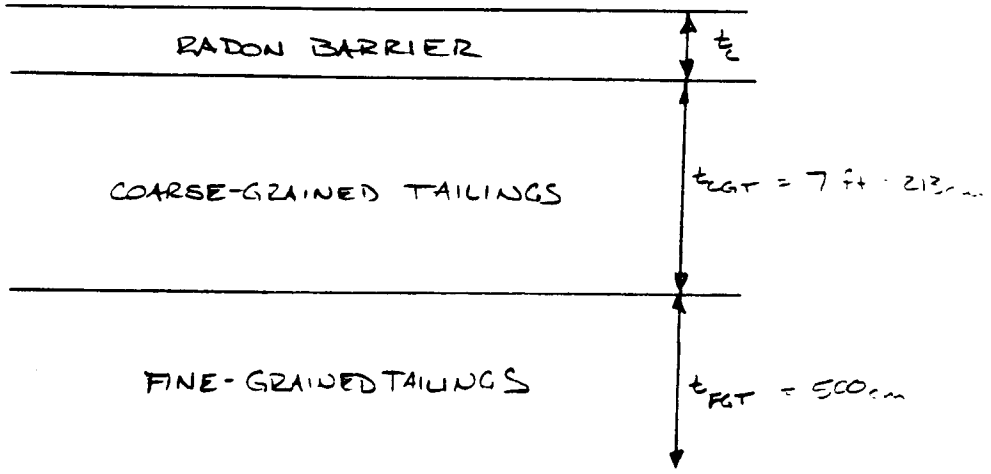
CALCULATIONS

THE RADON CODE REQUIRES INPUT OF THE FOLLOWING PARAMETERS FOR ALL TAILINGS AND SOIL COVER LAYERS:

- LAYER THICKNESS (cm);
- POROSITY;
- MASS DENSITY (g/cm^3);
- RADIUM ACTIVITY (pCi/g), SOURCE TERM ($pCi/cm^2 s$) OR ORE GRADE PERCENTAGE;
- EMANATION COEFFICIENT
- WEIGHT PERCENT MOISTURE (LONG-TERM); AND

INPUTS HAVE BEEN DEVELOPED IN ACCORDANCE WITH NRC-ACCEPTED CRITERIA AND HAVE BEEN AGREED ON WITH NRC

THE FOLLOWING SOIL PROFILE WILL BE MODELED.



LAYER THICKNESSES

(t_{FGT})

THE THICKNESS OF THE FINE-GRAINED TAILINGS WILL BE ASSUMED TO BE EFFECTIVELY AN INFINITELY THICK RADON SOURCE. IN ACCORDANCE WITH NRC CRITERIA (REG GUIDE 3.64, p 3.64-5) A VALUE OF 500 cm WILL BE USED.

$t_{FGT} = 500 cm$

A MINIMUM OF 7 FEET OF COARSE TAILINGS ARE TO BE PLACED OVER FINE-GRAINED TAILINGS DURING REGRADING OF THE TAILINGS IMPOUNDMENT. THIS OPTIMIZES THE COARSE-GRAINED TAILINGS EFFECTIVENESS IN REDUCING RADON FLUX FROM THE FINE-GRAINED TAILINGS. ACCORDINGLY THE THICKNESS OF COARSE-GRAINED TAILINGS, t_{CGT} = 7 ft or 213 cm

$t_{CGT} = 213 cm$

THE SOIL COVER THICKNESS WILL BE OPTIMIZED BY THE RADON COMPUTER CODE.

$t_c = ?$

MASS DENSITY

THE MASS DENSITY OF THE FINE-GRAINED TAILINGS IS OBTAINED BY AVERAGING IN-SITU BULK DRY DENSITIES OF SAMPLES OBTAINED FROM THE SITE AND INCREASING BY 5% TO ACCOUNT FOR CONSOLIDATION. TABLE 1, ATTACHED, PRESENTS THE IN-SITU DENSITY DATA. THE AVERAGE IN-SITU DRY DENSITY OF THE FINE GRAINED TAILINGS IS 86 pcf. INCREASE 5% FOR CONSOLIDATION EQUALS 90 pcf

$$\rho_{FGT} = 90 pcf \Big/ 62.4 \frac{pcf}{g/cm^3} = 1.45 g/cm^3$$

MASS DENSITY (CONT.)

THE MASS DENSITY OF COARSE-GRAINED TAILINGS IS OBTAINED BY AVERAGING INSITU DRY BULK DENSITIES OF SAMPLES OBTAINED DURING INVESTIGATION ACTIVITIES PRIOR TO DEVELOPMENT OF THE RECLAMATION PLAN. TABLE 2, ATTACHED, SHOWS THAT THE AVERAGE DRY BULK DENSITY FROM 11 SAMPLES IS 97.5 pcf. THIS IS CONSERVATIVE AS COARSE TAILINGS PLACED OVER FINE-GRAINED TAILINGS WILL BE COMPACTED BY EQUIPMENT TRAFFIC AND THE TOP 1 FT MUST BE COMPACTED TO 95% RELATIVE COMPACTION DENSITY. THE CONSERVATIVE VALUE OF 97.5 pcf WILL BE USED

$$\rho_{CGT} = 97.5 \text{ pcf} / 62.4 \text{ pcf/g/cm}^3 = 1.56 \text{ g/cm}^3$$

THE MASS DENSITY OF THE COMPACTED SOIL COVER IS OBTAINED BY DEVELOPING AVERAGE STD PROCTOR (MAXIMUM) DRY DENSITIES FROM INTERIM (RECLAMATION) SOIL COVER PLACEMENT TO DATE FOR ACCEPTABLE SOIL COVER MATERIALS IN 3 CLASSIFICATIONS. FIGURE 1 SHOWS THE ACCEPTABLE GRADATION RANGE FOR SOIL COVER MATERIAL. CLASSIFICATIONS FOR DENSITIES WILL BE FOR USCS CLASSIFICATIONS CL, ML, AND SM-SC. THEN, THE EXISTING DATABASE OF SOIL SAMPLE GRADATION ANALYSES WILL BE USED TO DETERMINE THE RELATIVE PROPORTION OF EACH ACCEPTABLE SOIL TYPE (CL, ML, SM-SC) IN THE BORROW AREAS ON-SITE. THE AVERAGE MAXIMUM DRY DENSITY FOR EACH SOIL TYPE WILL BE SUBJECT TO A WEIGHTED AVERAGE CALCULATION USING THE PROPORTIONS OF THOSE SOIL TYPES ON-SITE

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By [illegible] Date 2/20/91 Subject LINC Sheet No. 5 of

Chkd. By [illegible] Date 3-1-91 RADON BARRIER Proj. No. 86-060-24

1/4" X 1/4"

MAX. PROCTOR DRY DENSITIES FOR LOW PLASTICITY CLAYS (CL)

LOCATION	$\gamma_{dry_{max}}$ (PCF)
NORTH CELL	109.2
	113.2
	113.7
	110.1
	109.0
CENTRAL CELL	114.6
	113.0
	112.3
AVG =	111.9

MAX PROCTOR DRY DENSITIES FOR SILTS (ML)

LOCATION	$\gamma_{dry\ max}$ (PCF)
NORTH CELL	116.9
CENTRAL CELL	111.3
	114.1

MAX. PROCTOR DRY DENSITY FOR SILTY AND CLAYEY SANDS (SC-SM)

LOCATION	$\gamma_{dry\ max}$ (PCF)
NORTH CELL	119.1
	115.5
	121.0
	114.7
	112.2
	~~118.3~~ DOES NOT MEET GRADATION SPEC.
CENTRAL CELL	114.7
	118.0
AVG =	116.5

USE GRADATION ANALYSES FROM BORROW AREA AND INTERIM SOIL COVER SAMPLES TO DETERMINE THE PROPORTION OF EACH SOIL TYPE ON-SITE.

TABLE 3 PRESENTS CLASSIFICATION DATA FOR INTERIM SOIL COVER SAMPLES. TABLE 4 PRESENTS CLASSIFICATION DATA FOR POTENTIAL BORROW SOILS IN PIPELINE ARROYO. TABLE 5 PRESENTS CLASSIFICATION DATA FOR THE BORROW PIT 2 STOCKPILE.

NOTE: SOIL SAMPLES NOT MEETING THE GRADATION REQ'MTS SHOWN ON FIGURE 1 WILL NOT BE USED IN THE EVALUATION. HOWEVER, ONCE OUT OF SPEC SOILS FROM THE BORROW AREA ARE LOADED IN A SCRAPER, DUMPED, SPREAD, COMPACTED AND MIXED W/ OTHER BORROW SOILS ON THE SOIL COVER, IT WILL LIKELY MEET SPECIFICATIONS.

ASSUME THAT SAMPLES LISTED IN TABLES 3 THRU 5 ARE REPRESENTATIVE OF BORROW SOILS ON SITE. THEREFORE

20/39 SAMPLES (51%) ARE CL,
12/39 SAMPLES (31%) ARE SM-SC; and
7/39 SAMPLES (18%) ARE ML

CALCULATE A WEIGHTED AVERAGE MAX DRY DENSITY FOR THE COMPACTED SOIL COVER.

$$\gamma_{d\,max} = \frac{20\,(111.9\ pcf) + 12(116.5\ pcf) + 7(114.1)}{39}$$

$$\gamma_{d_{max}} = 113.7\ pcf$$

ALL COVER SOILS MUST BE COMPACTED TO A MINIMUM OF 95% OF MAX. STD. PROCTOR DRY DENSITY, THEREFORE

$\gamma_{min_{DRY}} = 0.95\,(113.7) = 108.0\ pcf$ [$\rho_d = 1.73$]

By mmm Date 2/20/91 Subject LINC Sheet No. 7 of

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1/4" X 1/4"

NOTE: USE OF γ_{dry} = 108.0 pcf FOR THE SOIL COVER IS CONSERVATIVE. ACTUAL IN PLACE DENSITY TESTS PERFORMED ON THE INTERIM SOIL COVE OF THE NORTH AND CENTRAL CELLS OF THE TAILINGS IMPOUNDMENT HAVE SHOWN THAT THE AVERAGE DRY DENSITY OF THE SOIL COVER IS 113.6 pcf FOR THE NORTH CELL AND 111.1 pcf FOR THE CENTRAL CELL. THESE TESTS WERE PERFORMED AS PART OF CONSTRUCTION QC DURING THE CONSTRUCTION SEASONS OF 1989 AND 1990, RESPECTIVELY.

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By [illegible] Date 2/20/91 Subject UNC Sheet No. 8 of

Chkd. By SWM Date 3-1-91 RADON BARRIER Proj. No. 86-060-24

1/4" X 1/4"

POROSITY

THE POROSITY OF THE FINE-GRAINED TAILINGS WILL BE CALCULATED USING THE CALCULATED BULK DENSITY AND THE AVERAGE SPECIFIC GRAVITY PRESENTED ON TABLE 1

$$e = G_s \, \rho_w / \rho_d - 1$$
$$= 2.78 \, (1/1.45) - 1 = 0.92$$
$$\eta = e/1+e = .92/1.92$$

$$\eta = 0.48$$

IN-SITU POROSITIES OF SAMPLES OF COARSE-GRAINED TAILINGS IS PRESENTED IN TABLE 2. USE THE OUTER-BOUND 95% CONFIDENCE UNIT VALUE OF 0.47

THE SOIL COVER POROSITY IS CALCULATED FROM BULK DENSITY AND SPECIFIC GRAVITY

$$e = 2.6 \, (1/1.73) - 1$$
$$= 0.50$$

$$\eta = 0.50/1.50 = 0.33$$

$$\eta_c = 0.33$$

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By mjj Date 2/20/91 Subject UNC Sheet No. 9 of

Chkd. By [illegible] Date 3-[illegible] RADON BARRIER Proj. No. 86-06[illegible]-24

1/4" X 1/4"

RADIUM ACTIVITY, SOURCE TERM, OR ORE GRADE %

RADIUM ACTIVITY WILL BE INPUT FOR TAILINGS

THE RADIUM ACTIVITY INPUT FOR THE FINE-GRAINED TAILINGS WILL BE TAKEN FROM MEASURED VALUES WHICH ARE PRESENTED IN TABLE 1. THE AVERAGE VALUE WILL BE CHOSEN. THIS VALUE IS 547 pCi/gm

$$R_{FGT} = 547 \text{ pCi/gm}$$

THE RADIUM ACTIVITY INPUT VALUE FOR THE COARSE-GRAINED TAILINGS WILL BE TAKEN FROM MEASURED VALUES WHICH ARE PRESENTED IN TABLE 2. THE AVERAGE VALUE WILL BE CHOSEN. THIS VALUE IS 154 pCi/gm

$$R_{CGT} = 154 \text{ pCi/gm}$$

THE RADIUM ACTIVITY OF THE COVER MATERIALS ARE ASSUMED TO BE Ø pCi/g PER NRC GUIDANCE (REF: PAGE 10, REG. GUIDE 3.64) SINCE SOIL COVER MAT'LS ARE NOT ASSOCIATED WITH THE ORE BODY OR RADIUM-ENRICHED SOILS. SINCE R = 0, → SOURCE TERM = 0 INPUT SOURCE TERM CONC = 0 FOR COVER IN RADON

EMANATION COEFFICIENT

EMANATION COEFFICIENT INPUT FOR THE FINE-GRAINED TAILINGS WILL BE DETERMINED FROM MEASURED VALUES WHICH ARE PRESENTED IN TABLE 1. THE AVERAGE VALUE WILL BE CHOSEN. THIS VALUE IS 0.26

$E_{FAT} = 0.26$

THE EMANATION COEFFICIENT INPUT FOR COARSE-GRAINED TAILINGS WILL BE DETERMINED FROM MEASURED VALUES WHICH ARE PRESENTED IN TABLE 2. THE AVERAGE VALUE WILL BE CHOSEN. THIS VALUE IS 0.26

$E_{CAT} = 0.26$

AN EMANATION COEFFICIENT FOR THE SOIL COVER IS NOT REQUIRED FOR INPUT INTO RADON.

NOTE: USE OF NRC'S DEFAULT VALUE OF E=0.35 FOR TAILINGS IS NOT CONSIDERED APPROPRIATE SINCE LABORATORY ANALYSES OF EMANATION COEFFICIENTS ARE AVAILABLE

LONG-TERM MOISTURE CONTENT

NRC CONSIDERS SEVERAL METHODS OF DETERMINING LONG-TERM MOISTURE CONTENTS TO BE ACCEPTABLE (REF: SECTION 1.1.3, REG GUIDE 3.64) THESE ACCEPTABLE METHODS INCLUDE:

- IN-SITU MEASUREMENTS;
- UNSATURATED FLOW COMPUTER MODELS;
- LAB TESTING FOR WILTING POINT MOISTURE; AND
- THE RAWLS/BRAKENSKI EMPIRICAL EQUATION FOR WILTING POINT MOISTURE.

SEVERAL METHODS FOR EACH SOIL TYPE WILL BE USED TO DETERMINE LONG-TERM MOISTURE FOR THAT SOIL.

FINE-GRAINED TAILINGS

TABLE 1 PRESENTS IN-SITU MOISTURE CONTENTS FOR FINE-GRAINED TAILINGS. THE AVERAGE IN-SITU MOISTURE CONTENT WAS DETERMINED TO BE 38.7% WITH A 95% CONFIDENCE INTERVAL OF 29.7% TO 47.7%. THE WORST-CASE (CONSERVATIVE) 95% CONFIDENCE INTERVAL VALUE OF 29.7% WILL BE USED FOR COMPARISON.

THE RAWLS EMPIRICAL EQUATION IS:

$\theta = 0.026 + 0.005Z + 0.0158Y$ WHERE

θ = VOLUMETRIC LONG-TERM MOISTURE CONTENT

Y = ORGANIC MATTER CONTENT (%) OF THE SOIL

Z = CLAY FRACTION OF THE SOIL (%)

(REF: PG 9, REG. GUIDE 3.64)

ASSUME Y = 0 AND FROM TEST RESULTS IN ATTACHMENT 1:

$Z = 13 + 6/2 = 9.5\%$

$\theta = 0.026 + 0.005(9.5) + 0.0158(0)$

$\theta = 0.0735 = 7.35\%$

CONVERT TO WT. PERCENT MOISTURE

$$mc_w = \frac{mc_v \rho_w}{\epsilon_{FLT}} = \frac{7.4(1)}{1.45} = 5\%$$

THIS IS LOWER THAN NRC'S DEFAULT VALUE THEREFORE, USE THE DEFAULT VALUE OF 6%.

$$mc_{FLT} = 6\%$$

COARSE-GRAINED TAILINGS

TABLE 2 PRESENTS IN-SITU MOISTURE CONTENTS FOR COARSE-GRAINED TAILINGS. THE AVERAGE IN-SITU MOISTURE CONTENT WAS DETERMINED TO BE 21.5% WITH A RANGE OF 6.1% TO 34.1%. THE AVERAGE MOISTURE CONTENT IS NOT CONSIDERED REPRESENTATIVE OF LONG-TERM CONDITIONS

THE LONG-TERM MOISTURE (OF COARSE-GRAINED TAILINGS) IS EXPECTED TO APPROACH THAT OF NATURAL SOILS HAVING A SIMILAR PARTICLE SIZE GRADATION. A REVIEW OF PREVIOUS GEOTECHNICAL REPORTS (SHB, 1978) IDENTIFIED THE MOISTURE CONTENTS OF SIMILAR NON-TAILINGS SANDS FOUND ON-SITE. 19 SAMPLES WERE SELECTED BASED ON A GRADATION SIMILAR TO THAT OF THE COARSE TAILINGS. MOISTURE CONTENTS FOR THESE SAMPLES WERE ANALYZED TO ESTIMATE THE LONG-TERM MOISTURE OF COARSE-TAILINGS. THE AVERAGE MC WAS 10.1%

THE RAWLS/BRAKENSKI EMPIRICAL EQUATION CAN ALSO BE USED. IT IS ANTICIPATED THAT THE FINES CONTENT OF THE COARSE-GRAINED TAILINGS IS APPROXIMATELY 15% TO 25%. ASSUME A 10% FRACTION OF MATERIAL

$$\theta = 0.026 + 0.005(10) + 0.0158\,Y$$
$$\theta = 7.6\%$$

CONVERT TO WT PERCENT MOISTURE

$$wc_w = \frac{7.6\,(1)}{1.56} = 5\%$$

THIS IS BELOW THE DEFAULT VALUE. THEREFORE USE NRC'S DEFAULT VALUE FOR TAILINGS LONG-TERM MOISTURE IS 6%

THEREFORE, CHOOSE THE COARSE TAILINGS LONG-TERM MOISTURE CONTENT TO BE 6% FOR CONSERVATISM.

$$MC_{LT_{CGT}} = 6\%$$

SOIL COVER

THE LONG-TERM MOISTURE CONTENT OF THE SOIL COVER MATERIAL WILL BE CALCULATED 3 WAYS. A LITERATURE-BASED VALUE IS ALSO AVAILABLE FOR COMPARISON

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By [illegible] Date 2/20/91 Subject [illegible] Sheet No. 14 of

Chkd. By [illegible] Date [illegible] RADON BARRIER Proj. No. 86-060-2-4

1/4" X 1/4"

A COVER SOIL SAMPLE WAS LABORATORY TESTED FOR DETERMINATION OF LONG-TERM MOISTURE. THE SAMPLE WAS SUBJECT TO A TENSION OF 15 ATMOSPHERES WHICH IS THE NRC-ACCEPTED CRITERIA FOR THE PERMANENT WILTING POINT OR LONG-TERM MOISTURE. TEST METHOD ASTM-D-3152 WAS PERFORMED ON THE SAMPLE WHICH HAD A -200 FRACTION OF 65%. THAT IS 8% MORE FINES THAN THE AVERAGE SOIL SHOWN ON FIG 1. THE LONG-TERM MOISTURE WAS DETERMINED TO BE 13.6%.

THE RAWLS EQUATION CAN BE CALCULATED TO DETERMINE THE LONG-TERM MOISTURE CONTENT. THE CLAY FRACTION CAN BE TAKEN FROM FIGURE 1, THE ALLOWABLE SOIL COVER GRADATION.

THE AVG CLAY FRACTION (0.002 mm) IS 18%

$$\theta = 0.026 + 0.005(18) = 11.6\%$$

$$mc_w = 11.6\left(1/1.73\right) = 7\%.$$ THIS IS CONSIDERED TOO CONSERVATIVE.

LINSLEY AND FRANZINI REPORT THAT THE LONG-TERM (WILTING POINT) MOISTURE OF A SILTY LOAM SOIL IS APPROXIMATELY 13%. THE AVG SOIL FROM FIGURE 1 IS GENERALLY A CL OR AT WORST AN ML. THEREFORE THIS VALUE IS APPROPRIATE AND CONSERVATIVE.

IN-SITU MOISTURE CONTENTS FOR SAMPLES MEETING THE GRADATION REQUIREMENT OF FIGURE 1. IN THE 120 cm TO SURFACE DEPTH CRITERIA OF REG GUIDE 3.64 WERE ANALYZED. THIS DATA IS DIRECTLY CORRELATED TO VOLUMETRIC MOISTURE CONTENT.

47 SAMPLES MEETING THE CRITERIA AND LOCATED IN POTENTIAL BORROW SOURCE AREA WERE IDENTIFIED. THE AVG. MOISTURE CONTENT WAS 12.9 %. THIS CALC IS PRESENTED IN ATTACH. CALC BRIEF.

THE VALUE OF 12.9 % WILL BE USED AS INPUT TO THE EATON MODEL

DIFFUSION COEFFICIENTS

DIFFUSION COEFFICIENTS WILL BE DETERMINED BY THE COMPUTER MODEL.

---------- RADON ----------

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U.S. Nuclear Regulatory Commission Office of Research

RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS
ARE CALCULATED FOR MULTIPLE LAYERS

UNC RADON BARRIER 1/91

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
SPECIFIC GRAVITY OF COVER & TAILINGS	2.65	

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	3	
DESIRED RADON FLUX LIMIT	20	pCi m^-2 s^-1
NO. OF THE LAYER TO BE OPTIMIZED	3	
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
SURFACE FLUX PRECISION	.001	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 FINE-GRAINED TAILINGS

THICKNESS	500	cm
POROSITY	.48	
MEASURED MASS DENSITY	1.45	g cm^-3
MEASURED RADIUM ACTIVITY	547	pCi/g^-1
MEASURED EMANATION COEFFICIENT	.26	
CALCULATED SOURCE TERM CONCENTRATION	9.022D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.181	
CALCULATED DIFFUSION COEFFICIENT	4.003D-02	cm^2 s^-1

LAYER 2 COARSE-GRAINED TAILINGS

THICKNESS	213	cm
POROSITY	.47	
MEASURED MASS DENSITY	1.56	g cm^-3
MEASURED RADIUM ACTIVITY	154	pCi/g^-1
MEASURED EMANATION COEFFICIENT	.26	
CALCULATED SOURCE TERM CONCENTRATION	2.791D-04	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.199	
CALCULATED DIFFUSION COEFFICIENT	3.759D-02	cm^2 s^-1

LAYER 3 SOIL COVER

THICKNESS	50	cm
POROSITY	.33	
MEASURED MASS DENSITY	1.73	g cm^-3
MEASURED SOURCE TERM CONCENTRATION	0	pCi cm^-3 s^-1
WEIGHT % MOISTURE	12.9	%
MOISTURE SATURATION FRACTION	.676	
CALCULATED DIFFUSION COEFFICIENT	3.569D-03	cm^2 s^-1

BARE SOURCE FLUX FROM LAYER 1: 5.815D+02 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	5.0000+02	1.895D+02	2.821D+05
2	2.1300+02	3.418D+01	1.657D+05
3	4.562D+01	1.998D+01	0.0000+00

18 in = 1.5 ft

TABLES

TABLE 1

Fine-Grained Tailings Laboratory Test Data

General Description	Boring Number	Depth	Specific Gravity	Dry Bulk Density (pcf)	Porosity	Moisture Content (%)	Radium Content (pCi/g)	Diffusion Coefficient (cm^2/sec)	Emanation Coefficient
Fine-Grained Tailings Slimes	659	37.5'	2.72	78	.54	29.6	602	0.0056	0.16
	660	8.0'	2.81	74	.58	44.27	341	0.0000011	0.37
	660	15.0'	2.84	94	.47	60.0	1099	0.0000016	0.31
	660	27.5'	2.75	89	.48	32.2	285	0.0000016	0.26
	660	37.5'	2.84	79	.56	41.4	526	0.0000027	0.28
	662	40.0'	2.72	84	.51	36.4	574	0.0000062	0.21
	662	42.5'		89	.55	43.8			
	658	10.0'	2.81	88	.50	17.4	402	0.0067	0.22
	658	32.5'		97	.55	43.6			
Averages			2.78	86	.53	38.7	547	1.76×10^{-3}	.26
95 Percent Confidence Interval			2.73 to 2.83	N.A.	0.50 to 0.56	29.7 to 47.7	296 to 798	0.00022 to 0.0053	0.20 to 0.32

TABLE 2

Coarse Tailings Laboratory Test Data

General Description	Boring Number	Depth	Specific Gravity	Dry Bulk Density (pcf)	Porosity	Moisture Content (%)	Radium Content (pCi/g)	Diffusion Coefficient (cm^2/sec)	Emanation Coefficient
Tailings	658	15'		105	.40				
Sands	658	20'	2.83	104	.41	23.5	160	0.0000053	0.32
	658	30'	2.81	98	.44	23.4	141	0.000019	0.27
	658	40'	2.89	92	.49	31.2	212	0.000002	0.25
	659	10'	2.84	95	.46	6.1	125	0.037 *	0.18
	659	20'	2.83	94	.47	10.5	227	0.023 *	0.21
	659	30'	2.74	97	.43	13.1	132	0.016 *	0.20
	659	32.5'		106	.47	8.1	115	0.042 *	0.27
	662	20'		97	.49	34.1			
	662	25'	2.78	96	.36	25.1	108	0.0000025	0.33
	662	30'	2.79	94	.46	29.6	177	0.0000013	0.28
Supplemental							143.1		
Averages			2.81	97.5	0.45	21.5	154	0.029	0.26
95 percent Confidence Interval			2.77 to 2.84	N.A.	0.43 to 0.47	N.A.	125.0 to 183.0	0.018 to 0.041	0.25 to 0.27

TABLE 5

SUMMARY OF GEOTECHNICAL PROPERTIES
NORTH AND CENTRAL CELL INTERIM COVER SOILS

Estimated Borrow Volume: 45,000 cubic yards

Sample Identification	Depth of Sample	Liquid Limit	Plasticity Index	Unified Soil Classification	(U.S. Standard Sieve Size Numbers) Percent Passing 200	100	40	10	4	3/8	3/4
North Cell:											
89 NC-1	0-5	26	10	CL	61	80	94	96	96		100
89 NC-2	0-5	--	NP	SM	47	70	92	98	99	100	
89 NC-3	0-5	27	10	CL	61	84	95	98	100		
89 NC-4	0-4	33	16	CL	70	89	97	99	100		
89 NC-5	0-1	--	NP	SM	45	69	99	100			
89 NC-6	0-1	25	8	CL	56	76	87	92	97	100	
~~89 NC-7~~	~~0-2~~	~~27~~	~~8~~	~~SC - SM~~	~~48~~	~~63~~	~~70~~	~~74~~	~~79~~	~~86~~	~~91~~
89 NC-8	0-1	31	13	CL	63	80	96	97	98	99	100
89 NC 9	0-1	34	17	CL	60	85	98	99	100		
~~89 NC-10~~	~~0-1~~	~~--~~	~~NP~~	~~SM~~	~~20~~	~~25~~	~~43~~	~~48~~	~~56~~	~~65~~	~~73~~
89 NC-11	0-1	22	7	SC - SM	43	63	90	98	99	99	100
89 NC-12	0-1	43	21	CL	63	82	100				
Central Cell:											
90 CC-1	SURFACE	27	9	CL	60	83	94	96	97	99	100
90 CC-2	SURFACE	32	16	CL	61	84	96	99	100		
90 CC-3	SURFACE	35	15	CL	65	86	96	98	99	100	
90 CC-4	SURFACE	30	15	CL	68	86	96	98	99	100	
90 CC-5	SURFACE	31	11	CL	66	87	96	98	99	100	
90 CC-6	SURFACE	26	12	SC	48	56	90	93	94	96	98
90 CC-7	SURFACE	26	8	CL	59	85	95	97	98	99	100
~~Average:~~					~~56.0~~	~~75.4~~	~~90.7~~	~~93.8~~	~~95.3~~	~~96.9~~	~~98.1~~
~~Standard Deviation:~~					~~11.9~~	~~15.5~~	~~13.3~~	~~12.4~~	~~10.6~~	~~8.82~~	~~6.10~~
95 Percent Confidence Level (+/-):					5.33	6.96	5.97	5.59	4.78	3.97	2.03

Notes:

1. NP = Non plastic.
2. All results listed above are laboratory test results obtained from the "North Cell Interim Stabilization As-Built Report" dated January 1990 and preliminary field data from the Central Cell Interim Stabilization.

TABLE 4

SUMMARY OF GEOTECHNICAL PROPERTIES
PIPELINE ARROYO BORROW MATERIAL

Estimated Borrow Volume: 300,000 cubic yards

Sample Identification	Depth of Sample	Liquid Limit	Plasticity Index	Unified Soil Classification	Grain Size Analysis (U.S. Standard Sieve Size Numbers) Percent Passing 200	100	40	10	4	3/8	3/4
74 SMB-2	10	38	20	CL	93	98	99	99	100		
78 SMB-7	2.5-4.5	26	5	ML CL	57	84	99				
	6.0-7.5	--	NP	SM	31	62	99				
78 SMB-8	9.5-10.5	31	14	CL	63	84	96	98	100		
78 SMB-13	0-1.5	22	1	SM	49	81	99				
78 SMB-14	0-1.5	28	12	CL	57	80	91	94	95	99	100
78 SMB-30	9.5-11	--	NP	SM	23	74	100				
78 SMB-31	4.5-6	29	14	CL	55	79	90	95	98	100	
78 SMB-42	4.5 6	28	14	CL	65	74	82	87	92	96	100
86-RP-P2	10.5-11	NI	NI	CL	100						
86 RP P3	10.5-11	NI	NI	SM	66	96	100				
86-RP-P4	5.5-6	NI	NI	SM ML	32	56	84	97	98	100	
86 RP P5	0 3	NI	NI	ML	65	86	98	99	100		
86 RP P5	3 6	NI	NI	ML	68	87	98	99	99	100	
86 RP P5	6-6.5	NI	NI	SM	48	83	95	97	98	100	
86 RP P6	0 3	NI	NI	CL	70	89	98	99	100		
86 RP P6	3 6	NI	NI	SM	51	80	97	98	99	99	100
86-RP-P8	11-11.5	NI	NI	ML	93	99	100				
86-RP-TP1	5-6	NI	NI	SM	18	32	87	97	99	100	
86 RP TP2	6 7	NI	NI	SM ML	40	67	95	97	98	100	
86 RP TP3	0-10	NI	NI	CL ML	85	97	99	100			
				Average:	58.5	80 6	95 5	97.9	98.8	99.7	100 0
				Standard Deviation:	22.5	16.0	5.48	3.05	2.02	0.90	0 0
				95 Percent Confidence Level (+/-):	9.01	6.84	2 34	1.30	0.86	0 39	0 0

Notes:

1. NI - Not tested.
2. NP - Non plastic.
3. Data also include the South Diversion Ditch and the Runoff Control Ditch material

TABLE 5

SUMMARY OF GEOTECHNICAL PROPERTIES
EXISTING SOIL STOCKPILE

Estimated Borrow Volume: 100,000 cubic yards

Boring Identification	Depth of Sample	Liquid Limit	Plasticity Index	Unified Soil Classification	Grain Size Analysis (U.S. Standard Sieve Size Numbers) Percent Passing 200	100	40	10	4	3/8	3/4
78 SMB-18	4.5	26	11	CL	52	79	90	95	99		100
	~~14.5~~	~~32~~	~~11~~	~~CL~~	~~92)~~	~~98~~	~~99~~	~~100~~			
78 SMB-19	4.5	22	NP	SM	41	64	82	88	94	98	100
78 SMB-31	9.5	26	11	CL	52	83	98	99	100		
78 SMB-33	4.5	27	9	CL	51	77	98	100			
	14.5	21	NP	SM	47	86	99	100			
~~78 SMB-32~~	~~4.5~~	~~--~~	~~NP~~	~~SM~~	~~29)~~	~~78~~	~~96~~	~~100~~			
89 SS-1	SURFACE	--	NP	ML	55	80	97	99	100		
90 SS-1	SURFACE	23	3	SC-SM	50	79	92	94	96	98	100
90 SS-2	10.5 12.5	26	7	ML-CL	54	84	94	97	98	100	
				Average:	52.3	80.0	94.5	97.2	98.7	99.6	100.0
				Standard Deviation:	16.0	9.1	5.34	3.91	2.11	0.84	0.0
				~~95 Percent Confidence Level (+/-):~~	~~9.92~~	~~5.64~~	~~3.31~~	~~2.42~~	~~1.31~~	~~0.52~~	~~0.0~~

Note: NP - Non plastic.

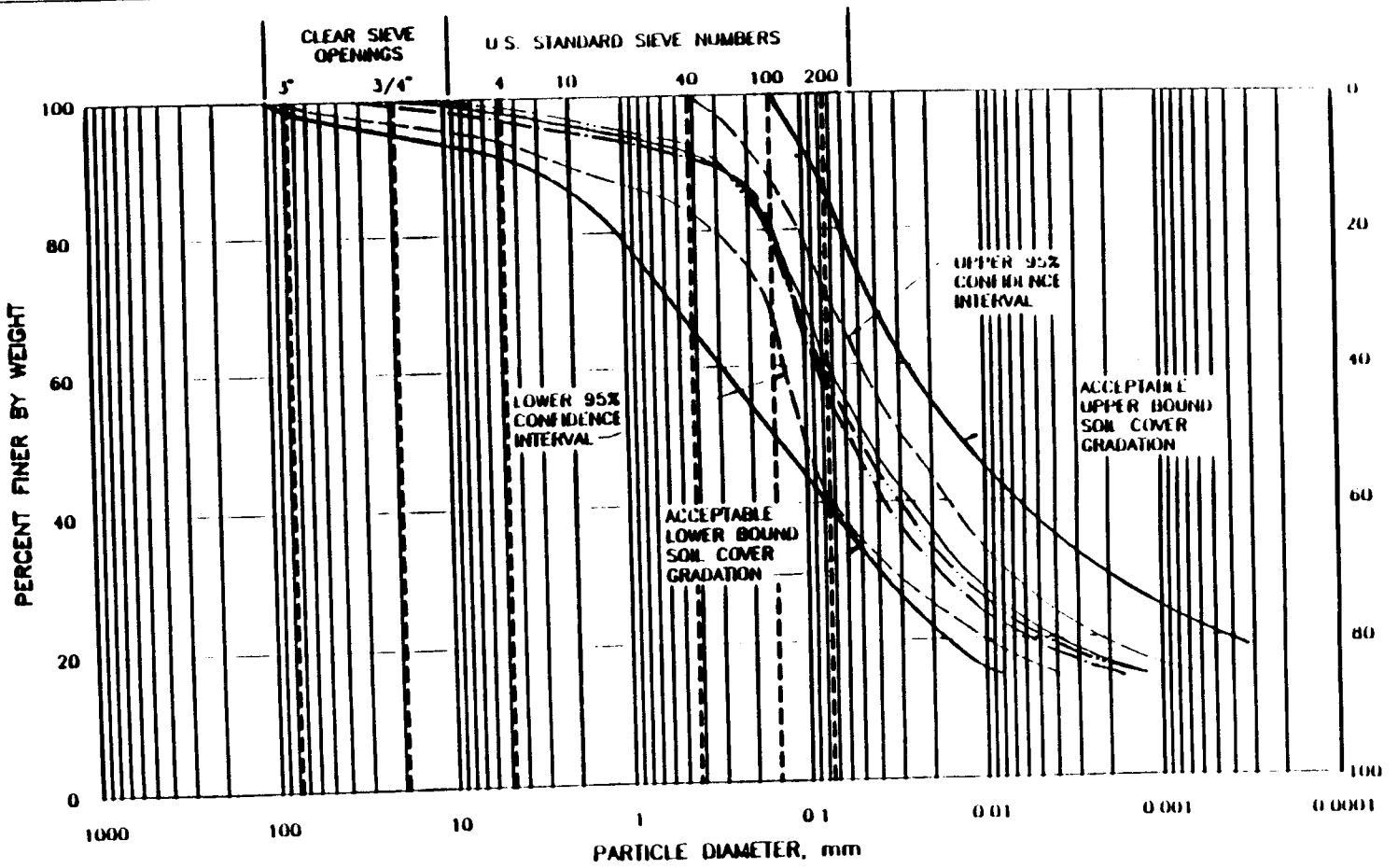
Canonie Environmental

By _____ Date _____ Subject _____ Sheet No. _____ of _____

Chkd. By _____ Date _____ _____ Proj. No _____

1/4 X 1 4

FIGURES



NOTE:

1. AVERAGES DERIVED FROM AVAILABLE FIELD AND LABORATORY TEST DATA TO DATE IN DESIGNATED BORROW AREAS

LEGEND:

- AVERAGE PIPELINE ARROYO BORROW SOILS
- AVERAGE NORTH AND CENTRAL CELLS INTERIM COVER SOILS
- AVERAGE EXISTING SOIL STOCKPILE SOILS

ACCEPTABLE SOIL COVER GRAIN SIZE ENVELOPE

UNC MINING AND MILLING
GALLUP, NEW MEXICO

Canonie

C-25

ATTACHMENTS

CHEN & Associates
and engineers and scientists

Denver
Fort Collins
Denwood Springs
Rock Springs
Salt Lake City
San Antonio

August 31, 1988

Subject: Laboratory Testing, Canonie Project
No. 86-060-04

Job No. 1 719 88

Mr. Matthew J. Yovich
Canonie Environmental Services Corporation
94 Inverness Terrace East, Suite 100
Englewood, Colorado 80112

Dear Mr. Yovich:

As requested, we have performed gradation analyses on four soil samples received July 27, 1988, at our Denver laboratory. These results are presented on Figs. 1 and 2. In addition, we have performed a Harvard miniature compaction test (Fig. 3) and a capillary-moisture relationship test (Table 1 and Fig. 4) on Sample No. 88-RP-P-5 at 0 to 3 feet. All testing assigned to date has been completed.

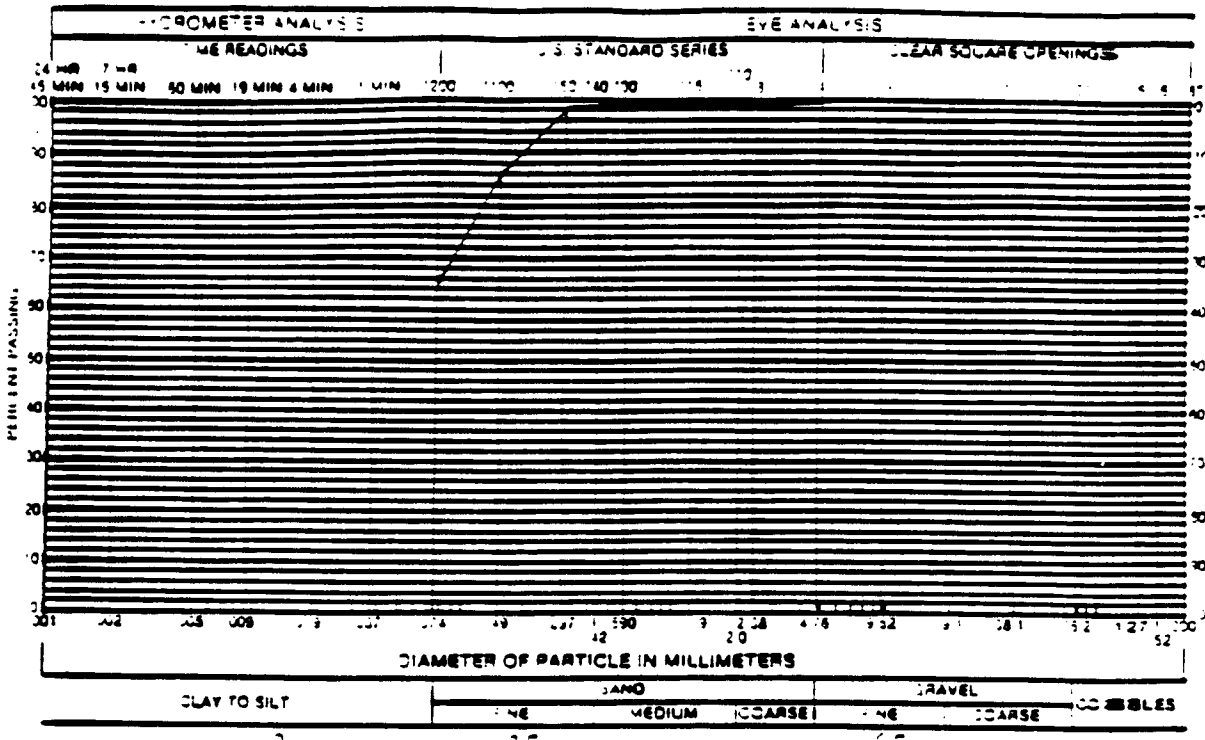
If you have any questions or need further assistance, please feel free to call.

Sincerely,

CHEN & ASSOCIATES, INC.

By Sally K. Miller
Sally K. Miller, A.E.T.
Soils Laboratory Supervisor

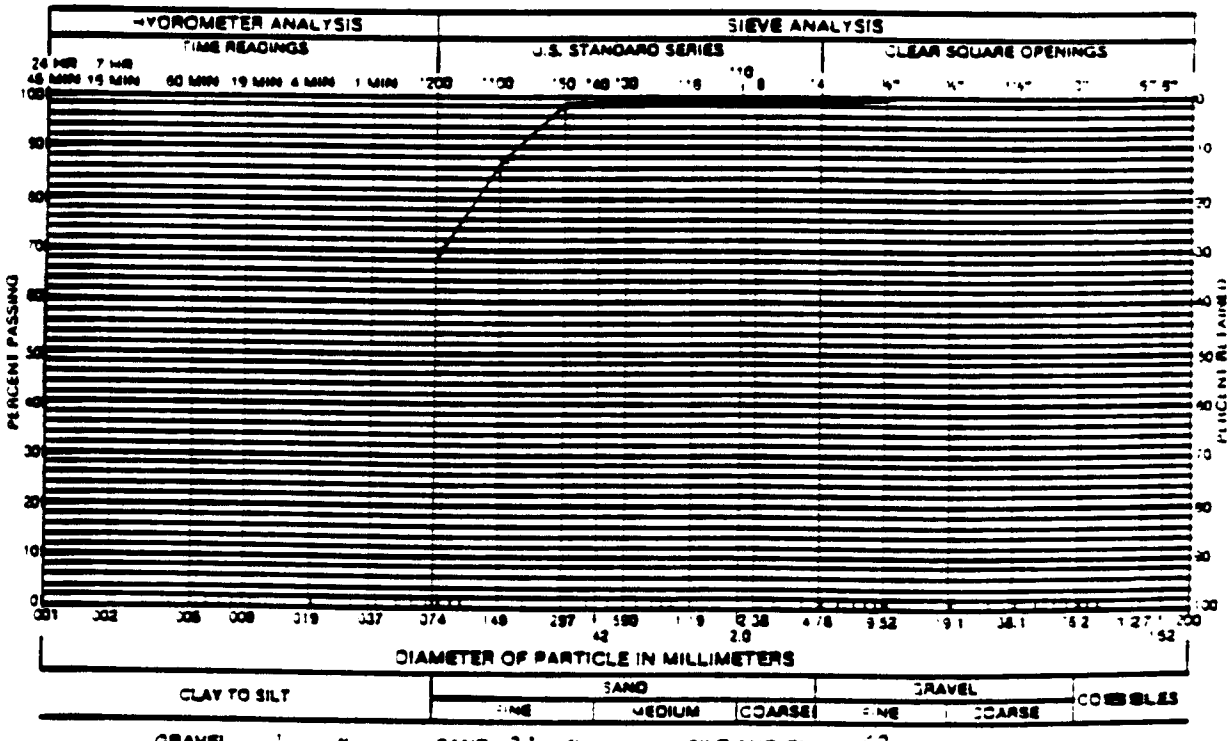
SKM/djb
Rev. By: KRC



GRAVEL 0 % SAND 35 % SILT AND CLAY 65 %

LIQUID LIMIT % PLASTICITY INDEX %

SAMPLE OF FROM Hole 88-RP-9-5 at depth 0' to 3'



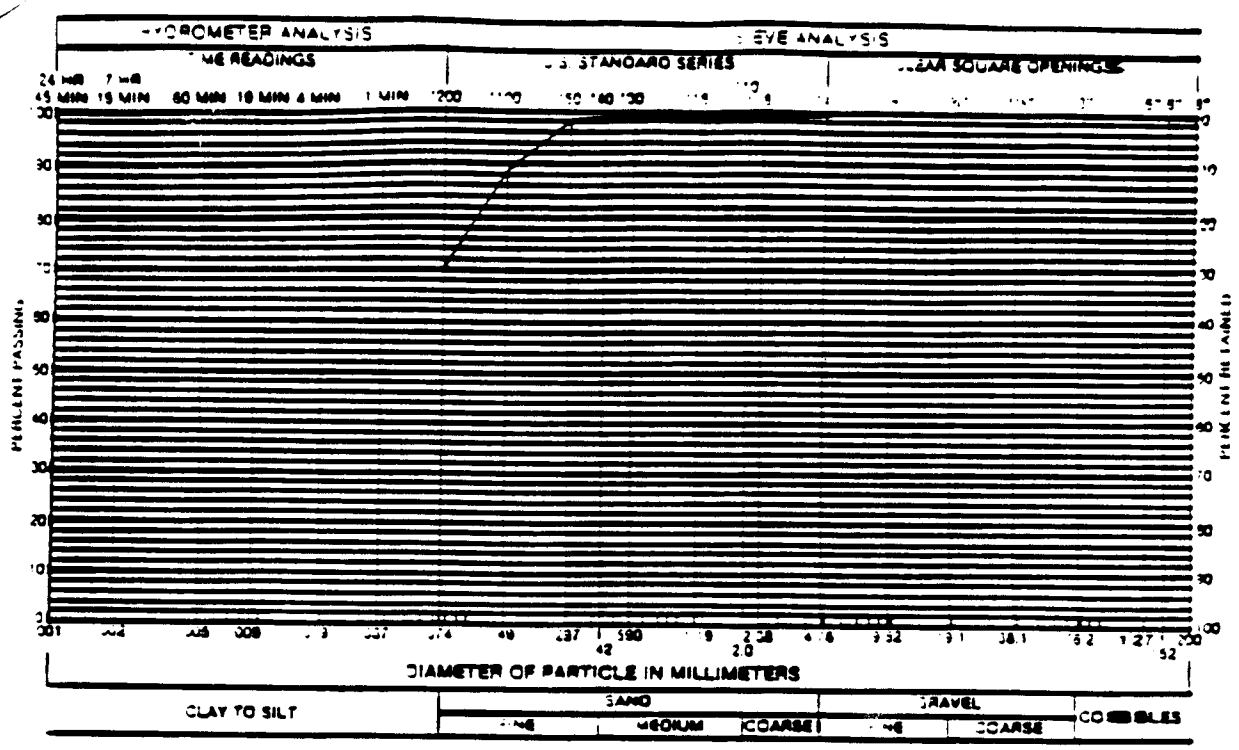
GRAVEL 1 % SAND 31 % SILT AND CLAY 68 %

LIQUID LIMIT % PLASTICITY INDEX %

SAMPLE OF FROM Hole 88-RP-9-5 at depth 3' to 6'

1 719 88

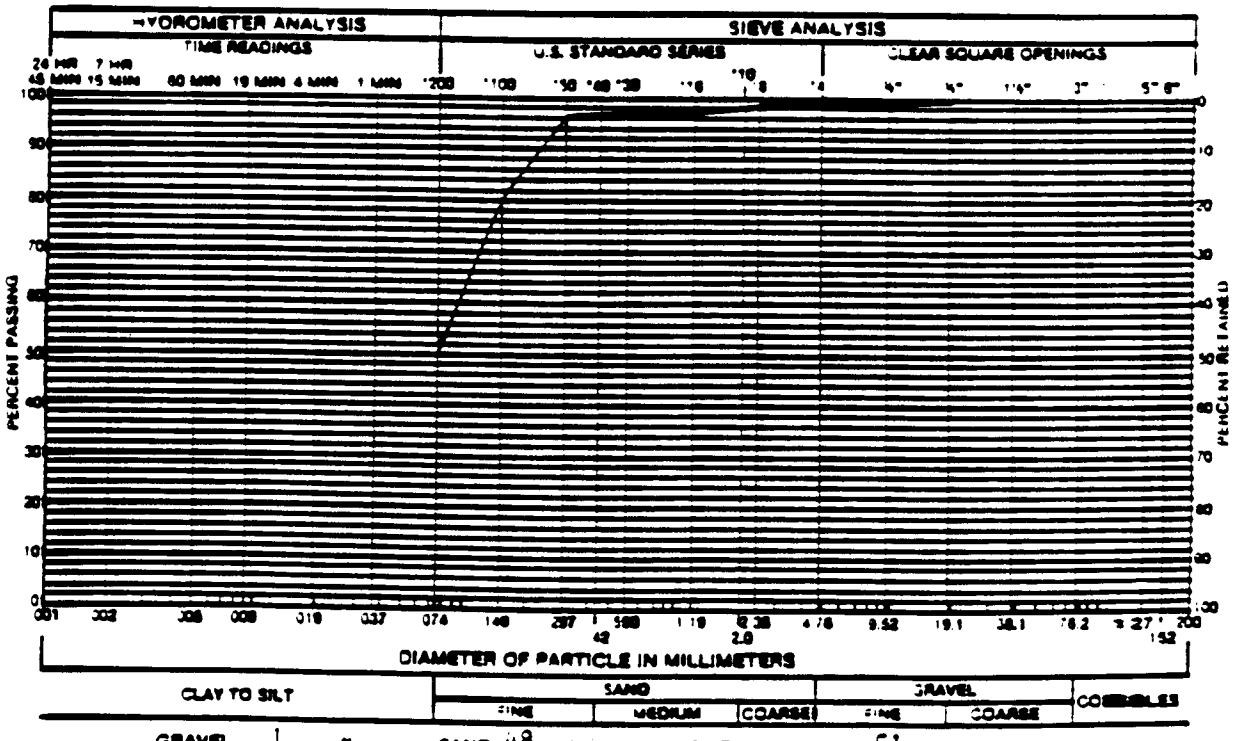
GRADATION TEST RESULTS Fig.



GRAVEL 0 % SAND 30 % SILT AND CLAY 70 %

LIQUID LIMIT % PLASTICITY INDEX %

SAMPLE OF FROM Hole 88-RP-P-6 at depth 0' to 3'



GRAVEL 1 % SAND 48 % SILT AND CLAY 51 %

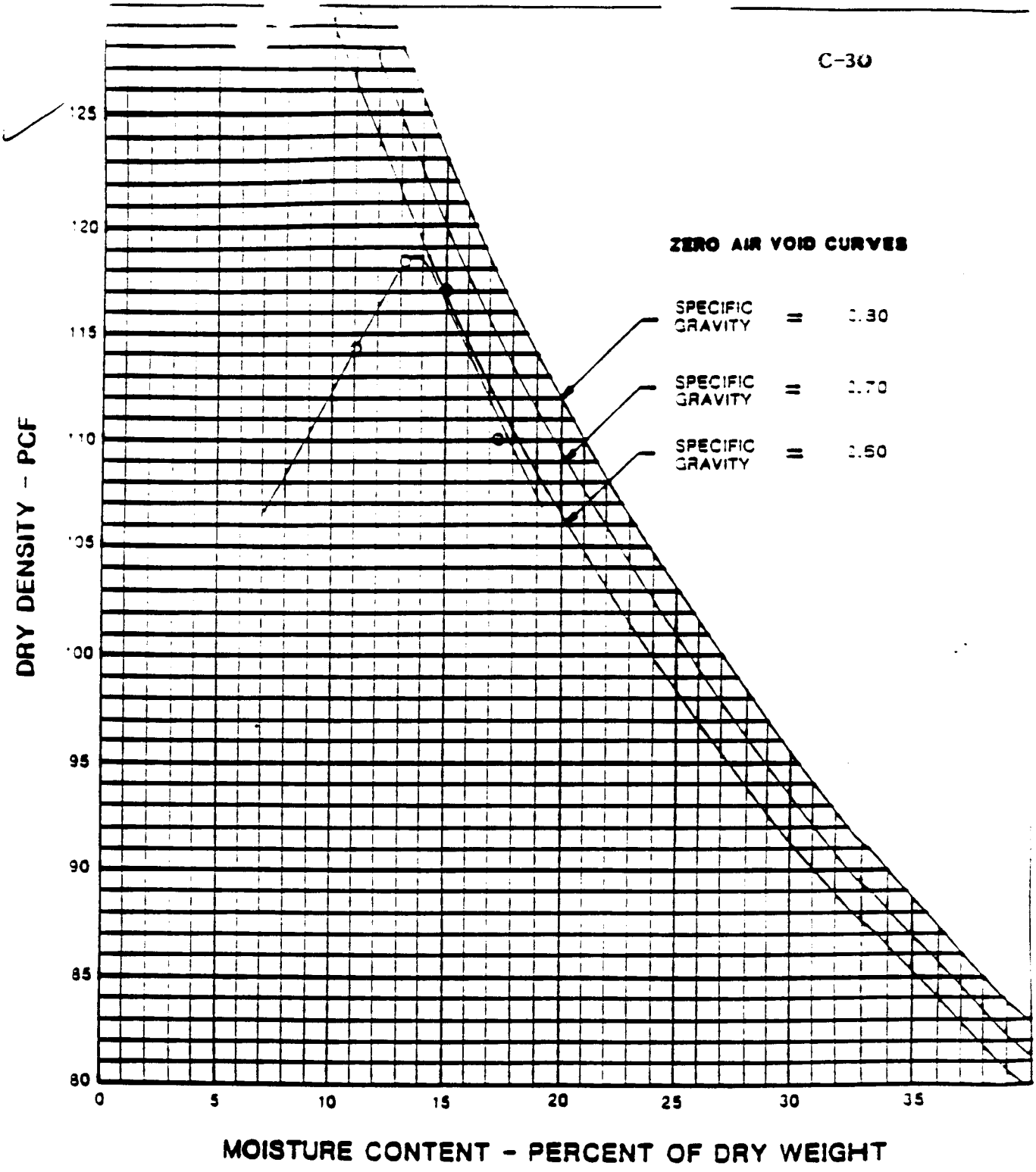
LIQUID LIMIT % PLASTICITY INDEX %

SAMPLE OF FROM Hole 88-RP-P-6 at depth 3' to 6'

1 719 88

GRADATION TEST RESULTS

Fig. 2



LOCATION :	MOISTURE-DENSITY RELATIONSHIPS
HOLE NO. : 88-RP-9-5 DEPTH : 0'-3' SAMPLE NO. :	
SOIL DESCRIPTION :	Chen & Associates
MAX. DRY DENSITY : 118.5 PCF OPT. MOIST. CONTENT : 13.6 %	PROCEDURE : HARVARD MINIATURE
LIQUID LIMIT : PLASTICITY INDEX :	JOB NO. : 1 719 88 / FIG. NO.
GRAVEL : 0 % SAND : 35 % SILT AND CLAY (-200) : 65 %	DATE : August 3, 1988 / 3

August 2', 1988
#86-060-04
Job No. 1 719 88

CHEN AND ASSOCIATES, INC.

TABLE I

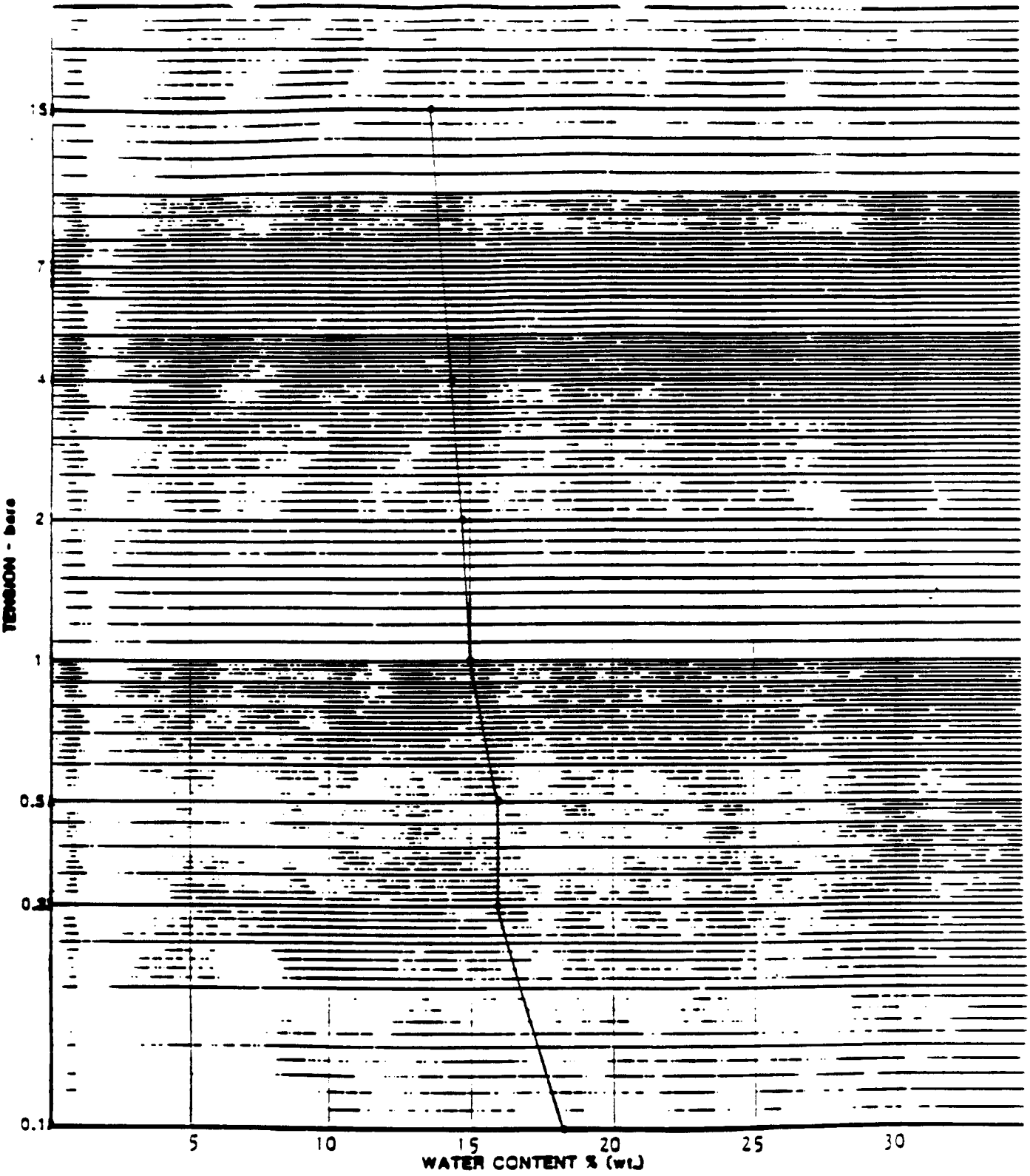
Summary of Capillary-Moisture Relationship Test Results

Sample No. 88-RP-P-5 @ 0-3'

Average Initial Moisture Content, % = 14.6

Average Initial Dry Density, pcf = 112.6

Tension, bars	Moisture Content, %
0.1	18.29
0.3	15.89
0.5	16.00
1.0	14.96
2.0	14.88
4.0	14.43
15.0	13.63



LOCATION: _____

HOLE: B-5 DEPTH: 0-3' SAMPLE NO: _____

DESCRIPTION: Sandy Clay Average DRY DENSITY pcf: 112.6 Average WATER CONTENT %: 14.6

LIQUID LIMIT: - PLASTIC LIMIT: - PLASTIC INDEX: - -200: 55

1 719 88	**Chen & Associates**	CAPILLARY-MOISTURE RELATIONSHIPS Fig. -

Chen-Northern, Inc.

C-33

[illegible]
Denver, Colorado [illegible]

303 744 [illegible]
303 744 [illegible] Facsimile

February 25, 1991

Mr. Matthew Yovich
Canonie Environmental Services Corporation
94 Inverness Terrace East
Englewood, Colorado 80112

Subject: Laboratory Testing

Job No. 1 305 91, Part 3

Dear Mr. Yovich:

As requested, we have performed a grain-size analysis including hydrometer analysis on each of two tailings samples which we received at our Denver laboratory on February 15, 1991. Testing was performed in accordance with ASTM D422-63. The results of the tests are presented on Figure 1, attached.

If you have any questions or if we can be of further assistance, please call.

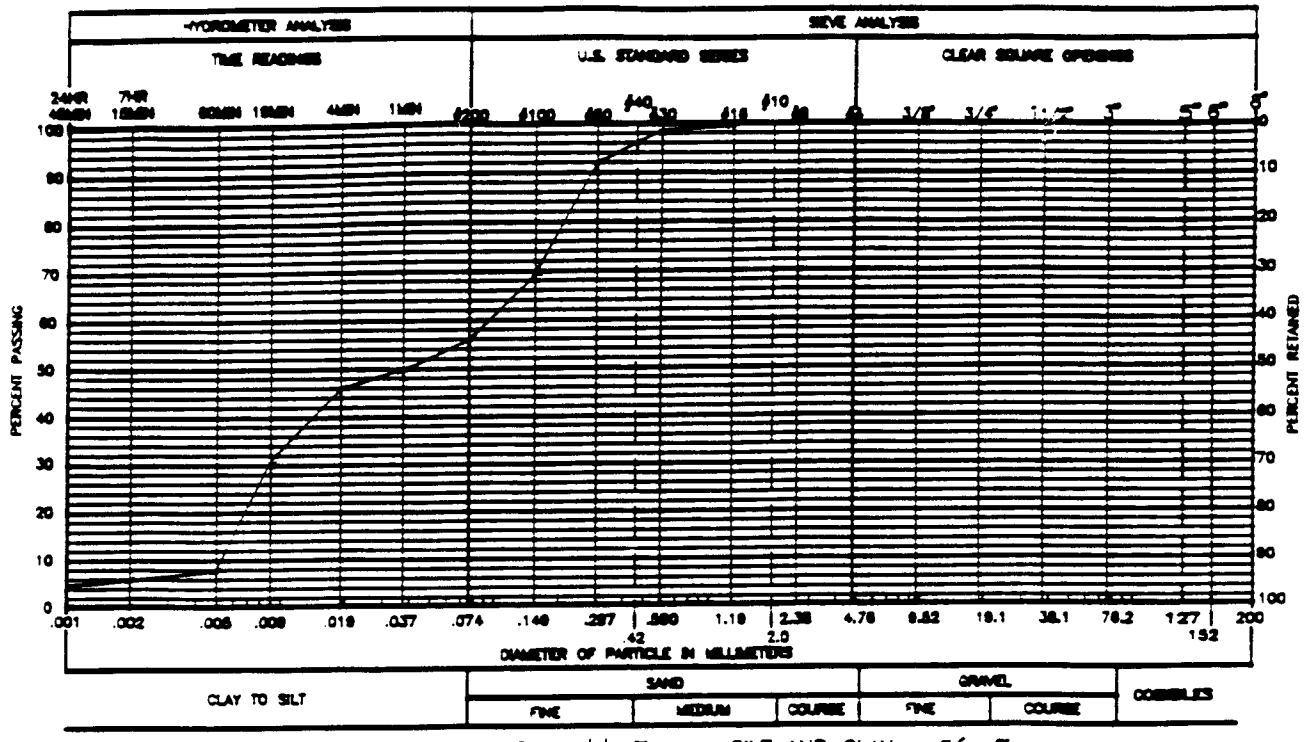
Sincerely,

Chen-Northern, Inc.

Sally K. Miller

Sally K. Miller, A.E.T.
Laboratory Supervisor

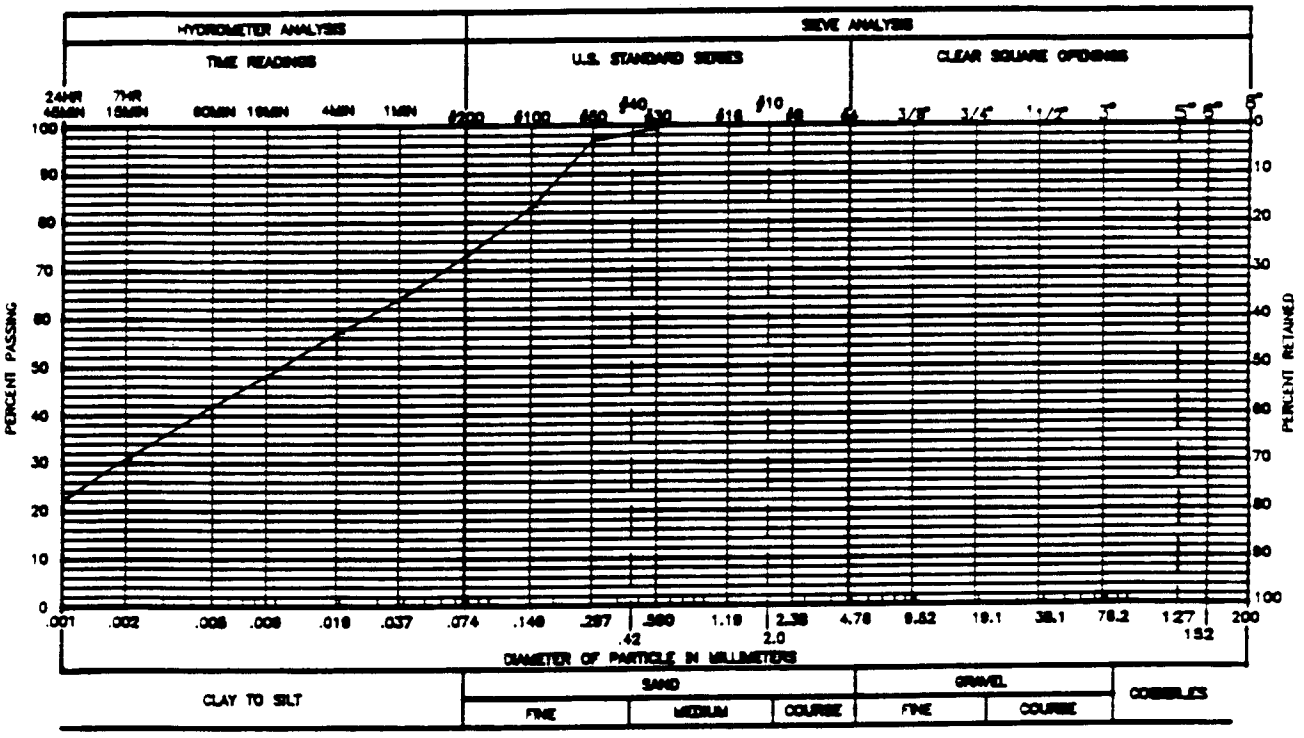
Rev. by: NFL
SKM/kd
Enclosure



GRAVEL 0 % SAND 44 % SILT AND CLAY 56 %

LIQUID LIMIT % PLASTICITY INDEX %

SAMPLE OF Tailings FROM "East"



GRAVEL 0 % SAND 27 % SILT AND CLAY 73 %

LIQUID LIMIT % PLASTICITY INDEX %

SAMPLE OF Tailings FROM "West"

1 305 91	Chen Northern, Inc.	GRADATION TEST RESULTS	Fig. 1

APPENDIX D