Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

JAN 12 1990

FEDERAL EXPRESS ONLY

Mr. Paul H. Lohaus
Branch Chief, Operations Branch
Division of Low-Level Waste
Management & Decommissioning
Office of Nuclear Materials Safety
and Safeguards
1 White Flint North
11555 Rockville Pike
Rockville, MD 20852

Dear Mr. Lohaus:

Per your request, enclosed for your review with the Green River RAP is a set of responses to NRC comments concerning the permeability tests performed on the radon barrier of the Green River disposal cell. A copy of the permeability tests is also enclosed.

Should you have any questions, please contact Chris Watson of my staff at FTS-845-5651.

Sincerely,

Frank D. Bosiljevac
for

Mark L. Matthews
Acting Project Manager
Uranium Mill Tailings Project Office

Enclosures

cc w/enclosures:
B. Jagannath, NRC-HQ
S. Wastler, NRC-HQ
R. Peel, JEG

cc w/o enclosures:
F. Bosiljevac, UMTRA
S. Hill, JEG

1/1

UMTRA DOCUMENT REVIEW FORM

SECTION 1

Site: Green River Date: 31 October 1989

Document: Comments on RAIP

Commentor: NRC

Comment:

ADDITIONAL INFORMATION AND JUSTIFICATION NEEDED IN GREEN RIVER FINAL REMEDIAL ACTION PLAN

ISSUE: Tests to verify the placement density and moisture content of the contaminated materials placed in the disposal cell were not required at a frequency of one test per 1000 cubic yards of material placed, as recommended in NRC staff guidance and as generally performed at other UMTRA sites. Rather, a performance specification was set and less frequent "non-record" verification tests were performed.

RESOLUTION: DOE needs to provide a detailed justification that the field and laboratory testing performed, in conjunction with the performance specification, is adequate to provide reasonable assurance that the in-place contaminated materials meet the RAP design requirements for density and moisture. In formulating this justification, DOE should consider, and provide detailed information on, the following:

- The uniformity of the contaminated materials, as supported gradation tests, resulting gradation parameters, and Proctor compaction tests.
- The results and locations of all density and moisture tests that were performed, including results of the trial compaction, and an analysis of the data which provides the basis for confidence that the moisture/density requirements are met.

SECTION 1 (Continued)

Moisture content and density testing frequency requirements given in Rev. C of the Remedial Action Inspection Plan (RAIP) are considered adequate based on the characteristics of the contaminated materials and the success of the compaction procedures used. Specific characteristics of contaminated materials include both the predominantly dry moisture contents in situ and predominantly coarse-grained nature which made the material easily amenable to two consistent compaction procedures. The compaction procedures were verified both at the beginning of placement of tailings and off-pile materials and during placement. The enclosed analysis of density and moisture data provides the detailed documentation justifying the adequacy of testing.

Additional justification of adequacy of the as-placed moisture contents of contaminated materials for groundwater protection compliance has been made elsewhere by DOE and is not repeated in this response. This response only serves to document that the testing frequency for moisture content is sufficient to show that the as-placed moisture contents of all materials are known with a high level of confidence.

SECTION 2

Plans for Implementation: As above.

SECTION 3

Confirmation of Implementation:

Checked By: _____ Date: _____

Approved By: _____ Date: _____

UMTRA PROJECT - GREEN RIVER
ANALYSIS OF CONTAMINATED
MATERIAL MOISTURE CONTENT AND DENSITY IN-PLACE

Analysis and information are provided below to document that in-place density of contaminated materials meets the requirements of the Remedial Action Plan and that in-place moisture content is known with confidence.

A list of types of information requested by the Nuclear Regulatory Commission is reproduced below in boldface with accompanying information and analyses.

1. **"RAP design requirements to be complied with in terms of placement density and moisture content of contaminated materials placed in the disposal cell.**

   - **Tailings materials.**
   - **Windblown and Vicinity Property materials".**

   All tailings, windblown contamination and contaminated vicinity property material are specified to be compacted to at least 90% of maximum dry density based on ASTM D-698 (Reference 1, Section 02200, Rev. 4, Part 3.8A). Moisture content requirements proposed by DOE have been submitted to the NRC, including documentation that the as-placed moisture contents comply with groundmoisture protection requirements.

2. **"Basis and supporting justification for the proposed density and moisture requirements."**

   The contaminated materials density requirement is the UMTRA project standard. Design calculations submitted previously demonstrate that the density requirement is adequate for the Green River site.

   Moisture content requirements for the contaminated materials will limit infiltration seepage from the embankment during the 1000-year design period.

   Rationale for moisture content requirements for contaminated materials was presented by DOE previously and is currently under NRC review.

3. **"QA/QC qualified data from all field and laboratory tests performed by the DOE on these materials. The types of information to be provided are:**

- **Information on the particle size gradation of the contaminated materials. In addition to the particle size gradation curves, provide parameters that reflect the particle gradation such as - Effective Diameter (D10), Percent grain size (D30, D60, D85), Coefficient of Uniformity (Cu), percent finer than No. 200 sieve size, etc. Provide analyses of these data to evaluate the uniformity nature of these materials".**

Gradation data for tailings are presented on pages D-222 through D-224, D-249, D-254 through D-256, D-261 through D-262, D-265 and D-276 through D-279 of Reference 2 and on pages D-1 through D-3 of Reference 3. Inspection of the tailings gradation data, taken prior to construction, indicates the tailings generally consist of fine SAND with a maximum of about 20% by weight of silty and/or clayey fines.

Contaminated soils other than tailings (described herein as "offpile" contaminated soils) consisted of the following:

- Subpile soils
- Windblown-contaminated soils, both from on-site and vicinity properties adjacent to the site.
- Vicinity property soils from several locations away from the site.

Gradation data for subpile and windblown contaminated soils are presented on pages D-251 through D-253, D-257 through D-258, D-263, D-266 through D-267 and D-280 of Reference 2.

Visual descriptions of contaminated materials are also available from borings made prior to construction (RAP) and during construction (Reference 4 enclosed). These data indicate that off-pile contaminated materials predominantly consist of silty sands with some sandy SILTS and gravelly SANDS.

- **Information on Proctor compaction tests performed to establish the design placement density. The compaction curves should also include information on density at moisture contents dry of optimum and in the vicinity of the actual placement moisture contents achieved in the field.**

Data from compaction tests performed on tailings are presented on pages D-299 through D-301 of Reference 2 and on pages D-8 through D-10 of Reference 3.

Results of compaction tests, performed to control placement of "windblown" contaminated materials and tailings in the field, are presented in Reference 4 and summarized Tables 1 and 2, respectively.

- **Information on the trial compaction conducted at the beginning of contaminated material placement and the final compaction procedure that was adopted for placing the contaminated materials in the disposal cell. Information should also include density and moisture content tests performed in this phase.**

Compaction procedures were verified both at the beginning of placement of contaminated materials and continuously during subsequent placement and compaction work. Verification testing was performed at the beginning of tailings placement, resulting in two compaction procedures (Reference 1, Rev. 4, Specification Section 02200, Part 3.5.D). The predominant portion of off-pile materials were placed prior to tailings pile and subpile materials. Following initial verification testing, quality control personnel verified that the established compaction procedures were followed for all contaminated materials.

Even though compaction procedures were continuously verified, in-place density tests and determinations of relative compaction were made at a minimum frequency of one test for every 6,000 cubic yards placed. The combination of verification of compaction method at the beginning of placement and continuous confirmation that the adopted procedure was used made it unnecessary to apply a testing frequency of one in-place density test for every 1000 cubic yards placed. The greater frequency is primarily applicable to cases where specific compaction procedures are not required and may be highly variable, i.e., where the density and relative compaction results stand as the sole documentation of adequate compaction. At the Green River site, entries in the "Daily Inspection Reports"* provide documentation that established compaction procedures were followed.

The requirement for in-place density tests following verification of a suitable compaction procedure could have been considered superfluous. It was deemed prudent, however, to record in-place density in order to provide precise information on the as-built condition of the tailings embankment. The information was considered particularly important if a reanalysis of seepage through the contaminated materials was required, and in fact, such an analysis was made. Since in-place density tests were made, relative compaction was readily determined to serve as additional confirmation that unforeseen conditions did not result in inadequate compaction.

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* Available on request.

Nine in-place density tests made at the beginning of off-pile material placement (Reference 4, Test Nos. CM-S-001 through CM-S-009) resulted in a compaction procedure that required 4 passes with a static tamping-foot roller and 4 passes of a vibratory smooth-drum roller. Initial test results indicated that 4 passes of the vibratory smooth-drum roller alone would not consistently result in a minimum density of 90 percent of maximum dry density by ASTM D698 (Reference 4, Test Nos. CM-S-001 through CM-S-005). Subsequently, materials were compacted by 4 passes of each roller, and density test results confirmed that in-place densities gave relative compaction values significantly greater than 90 percent consistently (Reference 4, Test Nos. CM-S-006 through CM-S-009).

Nine in-place density tests taken at the beginning of tailings material placement confirmed that 4 passes of the specified smooth-drum vibratory roller gave densities consistently greater than 90 percent of maximum dry density by ASTM D698 (Reference 4, Test Nos. CM-S-010 through CM-S-018).

- **Information on all density and moisture content tests performed to verify the placement density and moisture contents of the contaminated materials placed in the disposal cell. The location of the tests should be shown on a plan of the cell along with the elevation of the test location. This is the areal and vertical control information for the test locations.**

- **Data on all moisture content tests performed to determine the placement moisture contents for the contaminated materials placed in the disposal cell. This will be the raw data of the as-placed moisture contents that will be used by DOE in justifying the groundmoisture protection design for this project. For all these moisture contents, the DOE may estimate the as-placed density based on actual density/moisture data collected earlier during the trial compaction at this site. However, these estimated densities should be identified as such and should not be combined with the measured densities in the statistical analyses of the data.**

- **Information on the locations (both areal and vertical) of density determinations within the disposal cell locations of actual density determination by field tests and of estimated density (based on placement moisture contents) should be identified separately.**

Dry density, percentage compaction, moisture content and moisture content relative to optimum moisture content of all density determinations performed on contaminated materials are presented in Tables 3A and 3B. Coordinates and elevations of the compaction determinations are presented in Tables 4A and 4B and plotted on Figure 1. Based on the scatter of test locations on Figure 5, it is judged the moisture content-density data are not biased to any

particular zone of the disposal cell.

Numerous additional moisture content determinations without density measurements were made on contaminated materials to comply with the specified frequency of a minimum of one moisture content test for each 2000 cubic yards placed. As reported in Reference 5, there is no significant statistical difference between the moisture content values of the moisture content-density pairs and the moisture content only data.

"Statistical analyses of the data (mean, standard deviation, coefficient of variances etc.) and a basis for the confidence in the data".

Mean values, standard deviations and coefficients of variation (i.e., standard deviation divided by mean value) of the density, moisture contact, percent compaction and moisture content relative to optimum moisture content of contaminated materials are presented in Tables 3A and 3B. Mean and standard deviation values of optimum moisture content and maximum dry density of "windblown" contaminated soils and tailings are presented in Tables 1 and 2, respectively.

The theoretical upper bound on the probability that dry density of contaminated material at any random location in the disposal cell will be less than the density corresponding to 90 percent compaction is presented in Table 5 (see Reference 6, enclosed).

The actual probability of non-compliance at any random location is expected to be much smaller than the theoretical upper bound probability. In point of fact, of the 79 measurements made on contaminated materials compacted in accordance with the procedural specification in Reference 1, only one had a density smaller than 90 percent compaction.

REFERENCES

1. "UMTRAP, Green River, Utah Subcontract Documents - Final Design for Construction", Rev. 4, September, 1988.

2. "Remedial Action Plan and Final Design For Stabilization of the Inactive Uranium Mill Tailings at Green River, Utah - Final -Volume II, Appendix D", February 1988.

3. "Remedial Action Plan and Final Design for Stabilization of the Inactive Uranium Mill Tailings at Green River, Utah - Final, Volume IIA - Appendix D: Supplement, Site Characterization", January 1989.

4. "Contaminated Material Moisture Content, Density and Compaction Data - Green River, Utah", prepared by MK-ES, (enclosed).

5. "MK-ES Calculation", UMTRA-GRN, Tailings, Off-pile, Buffer Materials In-place Parameter Characterization", 27 July 1989 (enclosed).

6. MK-ES Calculation, "UMTRA-GRN, Compaction of Contaminated Materials - Statistical Evaluation", 25 October 1989 (enclosed).

TABLE 1

"Windblown" Contaminated Soils

Test No.	Optimum Moisture Content	Maxium Dry Density (pcf)
CM-4-008	10.9	120.6
CM-4-009	10.9	124.7
CM-4-010	10.7	124.2
CM-4-011	10.2	125.2
CM-4-019	13.2	111.2
CM-4-020	11.9	116.5
CM-4-021	7.9	130.9
MEAN	10.8	121.9
STANDARD DEVIATION	1.6	6.5

TABLE 2

TAILINGS

TEST NO.	Optimum Moisture Content (%)	Maximum Dry Density (%)
CM-4-029	15.2	102.3
CM-4-033	13.5	104.4
CM-4-034	13.8	103.5
CM-4-036	13.1	107.6
CM-4-037	15.0	101.0
CM-4-038	15.0	102.3
CM-4-039	13.7	104.2
CM-4-040	14.8	103.1
CM-4-042	13.8	101.2
MEAN	14.2	103.3
STANDARD DEVIATION	0.8	2.0

TABLE 3A

OFF-PILE CONTAMINATED MATERIAL
(Sheet 1 of 2)

Sample No.*	Dry Density (pcf)	Percent Compaction	Moisture Content(%)	Percent Dryer than OMC
MKE-001	108.7	97.8	5.5	7.6
MKE-002	113.4	91.3	5.6	5.1
MKE-003	105.2	90.3	6.3	5.6
MKE-004	112.2	90.3	5.6	5.1
MKE-005	114.1	91.1	6.8	3.4
MKE-006	118.2	94.4	5.6	4.6
MKE-007	120.7	92.2	4.1	3.8
MKE-008	118.7	94.5	7.0	3.0
MKE-009	117.2	94.4	5.4	5.3
MKE-010-R1	118.1	95.1	5.1	5.6
MKE-011	117.2	96.3	7.5	3.3
MKE-012	115.0	94.5	5.7	5.1
MKE-013	116.8	96.0	6.3	4.5
MKE-014	115.3	94.7	4.4	6.4
MKE-015	119.5	96.8	6.0	4.6
MKE-016	119.0	96.4	5.0	5.6
MKE-017	115.6	93.7	6.6	4.0
MKE-018	111.2	96.9	7.0	5.3
MKE-019	117.0	94.8	6.8	3.8
MKE-020	118.1	95.7	6.0	4.7
MKE-021	111.7	90.5	6.6	4.0
MKE-022	119.3	96.1	7.6	3.1
MKE-023	114.2	91.9	5.8	4.9
MKE-024	117.8	96.8	4.8	6.0
MKE-025	121.3	99.7	6.4	4.4
MKE-026	114.5	98.3	5.8	6.1
MKE-027	114.6	98.4	5.7	6.2
MKE-028	119.7	96.2	4.8	6.0
MKE-029	113.1	91.1	5.3	5.9
MKE-030	113.0	97.0	5.3	5.6

*Note: 1 failed point not included.

TABLE 3A

OFF-PILE CONTAMINATED MATERIAL
(Sheet 2 of 2)

Sample No.*	Dry Density (pcf)	Percent Compaction	Moisture Content(%)	Percent Dryer Than OMC
MKE-031	105.2	90.3	6.3	5.6
MKE-032	114.9	98.6	4.7	7.2
MKE-033	114.0	91.6	7.0	3.8
MKE-034	115.1	92.5	7.7	3.1
MKE-035	119.4	97.1	5.7	5.2
MKE-036	119.2	96.9	4.1	6.8
MKE-037	105.5	90.9	5.4	7.1
MKE-077	108.7	96.4	4.9	7.6
MKE-078	115.1	92.7	6.1	4.6
MKE-079	120.0	96.6	5.7	5.0
MEAN	115.19	94.67	5.85	5.14
STANDARD DEVIATION	4.19	2.71	0.91	1.25
Coefficient of Variation	.0364	0.0286	0.1560	0.2435
Coefficient of Skewness	--	-0.215	--	--

*Note: 1 failed point not included.

TABLE 3B

TAILINGS
(Sheet 1 of 2)

Sample No.	Dry Density (pcf)	Percent Compaction	Moisture Content(%)	Percent Dryer Than OMC
MKE-038	104.2	93.7	5.9	7.4
MKE-039	104.9	94.3	3.3	9.9
MKE-040	106.9	90.0	5.5	7.7
MKE-041	102.3	98.0	2.9	10.6
MKE-042	99.4	95.2	4.4	9.1
MKE-043	100.0	95.8	4.7	8.8
MKE-044	97.1	95.2	3.7	10.8
MKE-045	96.2	95.2	3.9	11.1
MKE-046	97.8	96.8	2.8	12.2
MKE-047	98.8	96.6	3.3	11.7
MKE-048	102.0	99.7	3.0	12.2
MKE-049	99.6	97.4	5.3	9.9
MKE-050	101.2	97.1	3.9	10.4
MKE-051	97.6	93.5	4.1	9.4
MKE-052	98.8	94.6	3.4	10.1
MKE-053	95.7	91.7	5.1	8.3
MKE-054	96.3	93.0	6.3	7.5
MKE-055	99.2	95.8	3.3	10.5
MKE-056	99.1	95.7	3.3	10.5
MKE-057	97.9	96.9	6.1	8.9
MKE-058	97.0	96.0	3.2	11.8
MKE-059	96.8	95.8	4.0	11.0
MKE-060	98.1	95.2	3.7	11.1
MKE-061	101.9	98.8	5.8	8.9
MKE-062	103.1	100.0	5.4	9.4
MKE-063	98.7	97.7	1.9	13.1
MKE-064	98.1	97.1	6.7	8.9
MKE-065	97.5	96.5	5.3	9.7
MKE-066	98.4	91.4	4.1	9.0
MKE-067	101.0	93.9	5.3	7.8

TABLE 3B

TAILINGS
(Sheet 2 of 2)

Sample No.	Dry Density (pcf)	Percent Compaction	Moisture Content(%)	Percent Dryer Than OMC
MKE-068	104.4	95.0	6.7	6.6
MKE-069	102.9	99.4	4.8	9.0
MKE-070	99.5	96.1	3.9	10.2
MKE-071	96.8	93.5	5.0	8.8
MKE-072	109.9	95.1	3.9	8.8
MKE-073	97.9	96.9	3.9	11.1
MKE-074	95.2	94.3	4.2	10.8
MKE-075	98.7	95.7	5.9	8.9
MKE-076	98.7	95.7	5.2	9.6
MEAN	99.73	95.65	4.44	9.78
STANDARD DEVIATION	3.21	2.16	1.18	1.46
COEFFICIENT OF VARIATION	0.0321	0.0226	0.2654	0.1494
Coefficient of Skewness	--	-0.265	--	--

TABLE 4A

OFF-PILE CONTAMINATED MATERIALS
(Sheet 1 of 2)

Sample #	Northing (ft)	Easting (ft)	Elevation (ft)
MKE-001	59,470	58,890	4108
MKE-002	59,345	58,972	4109
MKE-003	59,528	59,230	4108
MKE-004	59,520	58,962	4109
MKE-005	59,582	59,165	4109
MKE-006	59,535	59,047	4109
MKE-007	59,535	59,848	4110
MKE-008	59,450	59,172	4111
MKE-009	59,432	59,453	4113
MKE-010-R1	59,292	59,068	4112
MKE-011	59,665	59,080	4113
MKE-012	59,452	59,047	4115
MKE-013	59,470	59,239	4115
MKE-014	59,735	59,015	4116
MKE-015	59,452	58,806	4117
MKE-016	59,398	59,172	4117
MKE-017	59,489	59,101	4119
MKE-018	59,598	58,962	4120
MKE-019	59,388	58,416	4120
MKE-020	59,610	59,108	4119
MKE-021	59,322	59,103	4121
MKE-022	59,536	59,110	4122
MKE-023	59,475	58,967	4123
MKE-024	59,616	59,030	4124
MKE-025	59,510	59,172	4125
MKE-026	59,352	59,130	4126
MKE-027	59,555	58,961	4127
MKE-028	59,413	58,870	4128
MKE-029	59,588	59,092	4128
MKE-030	59,438	59,128	4129

TABLE 4A

OFF-PILE CONTAMINATED MATERIALS
(Sheet 2 of 2)

Sample #	Northing (ft)	Easting (ft)	Elevation (ft)
MKE-031	59,308	58,994	4129
MKE-032	59,400	59,077	4130
MKE-033	59,393	58,460	4131
MKE-034	59,562	58,922	4129
MKE-035	59,487	59,200	4131
MKE-036	59,566	59,040	4129
MKE-037	59,522	58,907	4131
MKE-077	59,478	59,047	4174
MKE-078	59,442	59,082	4174
MKE-079	59,380	59,128	4165

TABLE 4B

OFF-PILE CONTAMINATED MATERIALS
(Sheet 1 of 2)

Sample #	Northing (ft)	Easting (ft)	Elevation (ft)
MKE-038	59,338	59,055	4133
MKE-039	59,603	58,995	4132
MKE-040	59,495	59,009	4134
MKE-041	59,547	59,187	4135
MKE-042	59,674	59,040	4135
MKE-043	59,484	59,137	4136
MKE-044	59,422	59,004	4137
MKE-045	59,468	58,843	4137
MKE-046	59,508	59,078	4138
MKE-047	59,581	59,028	4138
MKE-048	59,437	59,061	4139
MKE-049	59,496	58,928	4139
MKE-050	59,411	59,228	4140
MKE-051	59,302	59,122	4141
MKE-052	59,529	59,006	4141
MKE-053	59,562	59,131	4141
MKE-054	59,443	58,918	4141
MKE-055	59,353	59,230	4142
MKE-056	59,407	59,030	4142
MKE-057	59,453	58,992	4143
MKE-058	59,277	59,151	4143
MKE-059	59,600	59,061	4143
MKE-060	59,512	58,377	4144
MKE-061	59,394	59,300	4144
MKE-062	59,468	59,059	4145
MKE-063	58,920	58,900	4145
MKE-064	59,217	59,150	4146
MKE-065	59,504	58,982	4147
MKE-066	59,436	59,198	4148
MKE-067	59,368	59,089	4149

TABLE 4B

OFF-PILE CONTAMINATED MATERIALS
(Sheet 2 of 2)

Sample #	Northing (ft)	Easting (ft)	Elevation (ft)
MKE-068	59,458	58,442	4150
MKE-069	59,384	59,149	4152
MKE-070	59,494	59,041	4154
MKE-071	59,444	59,097	4157
MKE-072	59,348	59,172	4160
MKE-073	59,504	59,112	4162
MKE-074	59,425	59,094	4164
MKE-075	59,450	59,067	4168
MKE-076	59,413	59,114	4174

TABLE 5

Material	Theoretical Upper Bound on Probability of Non-Compliance with Density Specifications (%)
Off-Pile ("windblown")	7.5
Tailings	3.3

Calculation Cover Sheet

Contract No. 5057-05 Discipline UMTRA/ESLI Calc. No. C-736-10-0
No. of Sheets 11

Project
UMTRA-GRN

Feature Completion of Contaminated Materials

Item Statistical Evaluation of degree of compaction

~~Sources of Data~~

Sources of Formulae & References

1. "Mechanics of Particulate Media", Milton E. Harr, published by McGraw-Hill, 1977.
2. "Contaminated Material Moisture Content, Density, and Compaction Data - Riverton, Utah"; prepared by MK-FE (in progress).

Preliminary Calc. ☐ Final Calc. ☒ Supersedes Calc. No. ____

-	-	[illegible]	25 Oct 89	Rick Stamber	10-30-89	D. [illegible]	[illegible]

Rev No	Revision	Calculation By	Date	Checked By	Date	Approved By	Date

Form 42-110

PURPOSE

Using construction data, evaluate the likelihood that contaminated materials were compacted to less than 90% compaction.

APPROACH

In-place compacted density (and percentage compaction) are random variables. An upper bound to the probability that these random variables will be outside a specified range can be estimated using the Chebyshev Inequality which states:

$$P\left(|x - \bar{x}| > n\sigma_x\right) \leq 1/n^2 \qquad (\text{for } n > 1,\ P \geq 0)$$

where

x = a random variable

$\bar{x}$ = mean value of random variable

σ_x = standard deviation of the random variable

n = the number of σ bounds of the random variable beyond the mean of the random variable

P = probability

$$0 \leq P \leq 1$$

The Chebyshev Inequality applies regardless of the probability density function of the random variable, however, if the probability density function is approximately symmetric and has a finite upper bound*, the probability that the value of a random variable being more than n-standard deviations beyond its mean reduces to:

$$P\left(|x-\bar{x}| > n\sigma_x\right) \leq \frac{\Delta}{9n^2} \qquad \text{(ref 2, pg. 123)}$$

For symmetrical distributions, the probability that the value of a random variable will exceed n-standard deviations beyond its mean value (on one side of the mean) can be taken to be one-half the probability the value of the random variable will be more than n-standard deviations beyond its mean on both sides, i.e.,

$$P\left[(x-\bar{x}) > n\sigma_x\right] \leq \frac{2}{9n^2} \qquad \text{for} \quad x \geq \bar{x}$$

$$P\left[(\bar{x}-x) > n\sigma_{\bar{x}}\right] \leq \frac{2}{9n^2} \qquad \text{for} \quad x \leq \bar{x}$$

* To guarantee Computation's answer has a finite upper bound determined from the zero-voids condition.

The symmetry assumption may be checked by calculating the skewness of the random variable data set. The coefficient of skewness is calculated as follows:

$$\beta_1 = \frac{(1/n)\sum_{1}^{n}(x_i - \bar{x})^3}{\sigma_1^3}$$

where
- β_1 = coefficient of skewness
- n = number of random variable data points
- x_i = i^{th} random variable observation
- $\bar{x}$ = mean value of random variable
- σ_1 = standard deviation of random variable

Generally, a probability density function with $-0.5 < \beta_1 < 0.5$ may be considered to be symmetrical, although if the distribution is skewed towards the [illegible] [illegible] [illegible] [illegible] evaluation, the resulting estimate of exceedance probability may be somewhat unconservative.

For the case of the % compaction values in the [illegible] disposal cell, the random variable is the % compaction at a random location measured at regular volume intervals. Therefore, the Chebyshev Inequality may be used to estimate the upper bound on the probability that the % compaction at any random location will be less than 90% compaction.

Since probability can not be less than zero, the actual probability that compaction at any random location will be less than 90% may be estimated as one-half the upper bound probability. This value is more reasonable for design purposes because the joint probability that many of the lifts will have densities less than 90% is considerably smaller than the probability that just one lift will have a density smaller than 90% compaction.

CALCULATIONS

- Tailings % Compaction

a) Demonstration of symmetry

calculate coefficient of skew $\beta_1 = \dfrac{(1/n)\sum_{i=1}^{n}(x_i - \bar{x})^3}{\sigma^3}$

$\beta_1 = -0.265^{*} > -0.5$ * (see appended data)

∴ distribution function of percent compaction is approximately symmetric.

b) Determination of n-σ bounds

for percent compaction:

mean = 95.65 %

σ = 2.16 % (see appended data)

Let x = design compaction percentage, i.e., 90 %

$n = (\bar{x} - x)/\sigma$ for $x < \bar{x}$

$= (95.65 - 90)/2.16$

$= 2.62$

c) Calculation of Tchebycheff's bound of non-compliance

$P(x < 90\%) \leq \dfrac{2}{n^2} = \dfrac{2}{(2.62)^2} = \underline{0.292}$

i.e., the theoretical upper bound probability of non-compliance is at least than 29% if the minimum acceptable compaction is 90%

- offpile Contaminated Materials % Compaction

a) demonstration of symmetry

$\tilde{p}_1 = -0.215^{*} > -0.5$ * see appended data

∴ distribution function of percentage compaction ~ symmetric.

b) n-σ bounds

for percent compaction's

mean = 94.67 % ; see appended data

σ = 2.71 %

$n = (\bar{x} - x)/\sigma$ for $x = \bar{x}$

$= (94.67 - 90)/2.71$

$= 2$

c) Calculation of Probability of Noncompliance

$P(x < 90\%) \leq \frac{2}{n^2} = \frac{2}{4(2^2)} = \underline{0.075}$

i.e., the theoretical upper bound probability that a compaction is less than 90% at any random location is about 7.5%.

CONCLUSIONS

The theoretical upper bound probabilities of noncompliance for percent completion of tailings and off-pile contaminated materials at any random location in the disposal cell are 3.3% and 7.5%, respectively.

The "actual" probabilities of noncompliance for percent completion at a random location, which are estimated to be approximately one-half of the theoretical upper bound values, agree well with the 5.0% noncompliance rate achieved using the Method Specification in the Subcontract Documents.

Martin J Goodman
UNTRA-GRN
5957-05
31 Oct 89

A1/4

Checked 10/31/89

~~TABLE 3A~~

OFF-PILE CONTAMINATED MATERIAL ++
(Sheet 1 of 2)

Sample No.*	Dry Density (pcf)	Percent Compaction	Moisture Content (%)	Percent Dryer than OMC
MKE-001	108.7	97.8	5.5	7.6
MKE-002	113.4	91.3	5.6	5.1
MKE-003	105.2	90.3	6.3	5.6
MKE-004	112.2	90.3	5.6	5.1
MKE-005	114.1	91.1	6.8	3.4
MKE-006	118.2	94.4	5.6	4.6
MKE-007	120.7	92.2	4.1	3.8
MKE-008	118.7	94.5	7.0	3.0
MKE-009	117.2	94.4	5.4	5.3
MKE-010-R1	118.1	95.1	5.1	5.6
MKE-011	117.2	96.3	7.5	3.3
MKE-012	115.0	94.5	5.7	5.1
MKE-013	116.8	96.0	6.3	4.5
MKE-014	115.3	94.7	4.4	6.4
MKE-015	119.5	96.8	6.0	4.6
MKE-016	119.0	96.4	5.0	5.6
MKE-017	115.6	90.7	6.6	4.0
MKE-018	111.2	96.9	7.0	5.3
MKE-019	117.0	94.8	6.8	3.8
MKE-020	118.1	95.7	6.0	4.7
MKE-021	111.7	90.5	6.6	4.0
MKE-022	119.3	96.1	7.6	3.1
MKE-023	114.2	91.9	5.8	4.9
MKE-024	117.8	96.8	4.8	6.0
MKE-025	121.3	99.7	6.4	4.4
MKE-026	114.5	98.3	5.8	6.1
MKE-027	114.6	98.4	5.7	6.2
MKE-028	119.7	96.2	4.8	6.0
MKE-029	113.1	91.1	5.3	5.9
MKE-030	113.0	97.0	5.3	6.6

*Note: 1 failed point not included.

++ Data are extracted from ref 2.

Martin J Goodman A2/4
UMTRA-GRN
5057-05
21 Oct 89

Checked 10/31/89

~~TABLE 2A~~

OFF-PILE CONTAMINATED MATERIAL **
(Sheet 2 of 2)

Sample No.*	Dry Density (pcf)	Percent Compaction	Moisture Content(%)	Percent Dryer Than OMC
MKE-031	105.2.	90.3.	6.3.	5.6.
MKE-032	114.9.	98.6.	4.7.	7.2.
MKE-033	114.0.	91.6.	7.0.	3.8.
MKE-034	115.1.	92.5.	7.7.	3.1.
MKE-035	119.4.	97.1.	5.7.	5.2.
MKE-036	119.2.	96.9.	4.1.	6.8.
MKE-037	105.5.	90.9.	5.4.	7.1.
MKE-077	108.7.	96.4.	4.9.	7.6.
MKE-078	115.1.	92.7.	6.1.	4.6.
MKE-079	120.0.	96.6.	5.7.	3.0.
MEAN	115.19 ✓	94.67 ✓	5.85 ✓	5.14 ✓
STANDARD DEVIATION	4.19 ✓	2.71 ✓	0.91 ✓	1.25 ✓
Coefficient of Variation	.0364 ✓	0.0286 ✓	0.1560 ✓	0.2435 ✓
Coefficient of Skewness	--	-0.215 ✓	--	--

*Note: 1 failed point not included.

** Data are extracted from reference 2.

Martin J. Goodman A3/4
UMTRA-GRN
5057-05 checked 10/31/89
31 Oct 89

~~TABLE 2B~~

TAILINGS *
(Sheet 1 of 2)

Sample No.	Dry Density (pcf)	Percent Compaction	Moisture Content (%)	Percent Dryer Than OMC
MKE-038	104.2	93.7	5.9	7.4
MKE-039	104.9	94.3	3.2	9.9
MKE-040	106.9	90.0	5.5	7.7
MKE-041	102.3	98.0	2.9	10.6
MKE-042	99.4	95.2	4.4	9.1
MKE-043	100.0	95.8	4.7	8.8
MKE-044	97.1	95.2	3.7	10.8
MKE-045	96.2	95.2	3.9	11.1
MKE-046	97.8	96.8	2.8	12.2
MKE-047	98.8	96.6	3.3	11.7
MKE-048	102.0	99.7	3.0	12.2
MKE-049	99.6	97.4	5.3	9.9
MKE-050	101.2	97.1	3.9	10.4
MKE-051	97.6	93.5	4.1	9.4
MKE-052	98.8	94.6	3.4	10.1
MKE-053	95.7	91.7	5.1	8.3
MKE-054	96.3	93.0	6.3	7.5
MKE-055	99.2	95.8	3.3	10.5
MKE-056	99.1	95.7	3.3	10.5
MKE-057	97.9	96.9	6.1	8.9
MKE-058	97.0	96.0	3.2	11.8
MKE-059	96.8	95.8	4.0	11.0
MKE-060	98.1	95.2	3.7	11.1
MKE-061	101.9	98.8	5.8	8.9
MKE-062	103.1	100.0	5.4	9.4
MKE-063	98.7	97.7	1.9	13.1
MKE-064	98.1	97.1	6.7	8.9
MKE-065	97.5	96.5	5.3	9.7
MKE-066	98.4	91.4	4.1	9.0
MKE-067	101.0	93.9	5.3	7.8

* Data are extracted from reference 2.

Martin J. Goodman A4/4
UMTRA-GRN
5057-05 Checked 10/30/95
31 Oct 95

~~TABLE 3D~~ 2

TAILINGS *
(Sheet 2 of 2)

Sample No.	Dry Density (pcf)	Percent Compaction	Moisture Content (%)	Percent Dryer Than OMC
MKE-068	104.4	95.0	6.7	6.6
MKE-069	102.9	99.4	4.8	9.0
MKE-070	99.5	96.1	3.9	10.2
MKE-071	96.8	93.5	5.0	8.8
MKE-072	109.9	95.1	3.9	8.8
MKE-073	97.9	96.9	3.9	11.1
MKE-074	95.2	94.2	4.2	10.8
MKE-075	98.7	95.7	5.9	8.9
MKE-076	98.7	95.7	5.2	9.6
MEAN	99.73 ✓	95.65 ✓	4.44 ✓	9.78 ✓
STANDARD DEVIATION	3.21 ✓	2.16 ✓	1.18 ✓	1.46 ✓
COEFFICIENT OF VARIATION	0.0321 ✓	0.0226 ✓	0.2654 ✓	0.1494 ✓
Coefficient of Skewness	--	-0.265 ✓	--	--

* Data are extracted from reference 2

Mke Doc. 5057-Grn-C-01-01652-00

Calculation Cover Sheet

Contract No. 5057-05 Discipline ESCI Calc. No. 10-591-11-00 No. of Sheets 3

Project UMTRA-GRN

Feature [illegible]; 300-pig Buffer Interval

Item In-plane Parameter Characterization

Sources of Data

1. WKE document = 5057-GRN-R-02-01507-00, Coordinated Materials and Type "A" Fill Test Results; Supplied by MK-F.

~~Sources of Formulae & References~~

Preliminary Calc. ☐ Final Calc. ☐ Supersedes Calc. No. ———

Rev No	Revision	Calculation By	Date	Checked By	Date	Approved By	Date
0	———	[illegible]	[illegible]	NO Checking	[illegible]	[illegible]	[illegible]

Form 42-110

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA - GRN	Contract No. 5057-05	Sheet A-0	File No.
Feature Tailings, Offpile Buffer Materials	Designed MJF	Date 27 [illegible]	
Item Inplace Parameter Characterization	Checked WOC	Date 7-27-85	

SUMMARY

Based on available construction data, in-place buffer and contaminated material mean water content and density values are as follows (see Table 4):

MAT'L TYPE	W (%)	γ_d (pcf)	[illegible] (%)
Tailings	[illegible]	99.0	7.0
Offpile	5.5	115.2	10.6
Buffer	8.3	119.2	15.5

[illegible] values of optimum water content and maximum dry density of D-698 compaction tests and [illegible] percent of [illegible], windblown and buffer materials are presented in Table 10, sheet A-29.

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project	UMTRA-GRN	Contract No.	5057-05	Sheet	A-1
Feature	Tailings, Offpile, Buffer Mat'l:	Designed	MJL	File No.	
Item	Inplace Parameter Characterization	Checked	WOC	Date	30 June 80
				Date	7/28/80

PURPOSE

Estimate inplace (non-compacted) mean values of the following parameters for the tailings, offpile contaminated material (windblown and vicinity property) and buffer materials:

- gravimetric water content (w)
- dry density (γ_d)
- volumetric water content (θ).

PROCEDURE

1. W and γ_d test data for tailings, offpile and buffer materials [illegible] in ref. 1, are reproduced in Tables 1-3, respectively.
2. [illegible] from tests designated as "failed" or from tests [illegible] on tailings/[illegible] are excluded from the data base.
3. Mean and standard deviation values of water content and dry density tests in the data base are [illegible] for the tailings, offpile and buffer materials. [illegible] assumed that [illegible] test values are approximately equivalent to [illegible] inplace values because tests were performed at [illegible] approximate [illegible] dictated by [illegible] the [illegible] [illegible] [illegible] [illegible] [illegible] water content θ].

<PROCEDURE CONTINUED ON p. A20>

MJG
7/26/89
UNTER-GRD
5057-05
CKD WOC 7/27/89

TAILINGS*

* All data compacted in-place.

SAMPLE #	w(%)/θ(%)	γd (pcf)	
MIKE - 038	~~5.9~~	~~104.2~~	tailings mixture
- 039	~~5.3~~	~~104.9~~	" "
- 040	~~5.5~~	~~106.9~~	" "
- 041	2.9 / (4.8)	102.3	
- 042	4.4 / 7.0	99.4	
- 043	4.7 / 7.5	100.0	
- 044	3.7 / 5.8	97.1	
- 045	3.9 / 6.0	96.2	
- 046	2.6 / 4.4	97.8	
- 047	3.3 / 5.2	98.8	
- 048	3.0 / 4.9	102.0	
- 049	5.3 / 8.5	99.6	
- 050	3.9 / 6.3	101.2	
- 051	4.1 / 6.2	97.6	
- 052	3.4 / 5.1	95.8	
- 053	5.1 / 7.8	95.7	
- 054	6.3 / 9.7	96.3	
- 055	3.3 / 5.2	99.2	
- 056	3.3 / 5.2	99.1	
- 057	6.1 / 9.6	97.9	
- 058	3.2 / 5.0	97.0	
- 059	4.0 / 6.2	96.6	
- 060	3.7 / 5.8	98.1	
- 061	5.3 / 8.2	101.9	
- 062	5.4 / 8.3	103.1	
- 063	4.9 / 7.5	98.7	
- 064	6.7 / 10.2	98.1	
- 065	5.3 / 8.1	97.3	
- 066	4.1 / 6.5	98.4	
- 067	5.3 / 8.2	101.0	
- 068	6.7 / 10.3	102.7	
- 069	4.5 / 7.3	102.9	
- 070	3.9 / 6.2	99.5	
- 071	5.0 / 7.8	96.3	

TABLE 1
(standard Proctor)

MJG
26 July 89
UMTRA-GRN
5057-05 Cnd. WOC. 7/28/89

TAILINGS

Sample #	In Place		
	$w\%$ / $\theta\%$	γ_d (pcf)	
MK-E-072	~~3.9~~	~~98.9~~	mixture
-073	3.9 / 6.1	97.9	
-074	4.2 / 6.4	95.2	
-075	5.9 / 9.3	98.7	
-076	5.2 / 8.2	98.7	
CM-M-142	4.6	—	
-143	3.1	—	
-144	3.4	—	
-145	5.7		
-146	3.3		
-147	6.7		
-148	5.0		
-149	3.8		
-150	6.9		
-151	4.8		
-152	2.5		
-153	2.0		
-154	3.5		
-155	3.7		
-156	3.6		
-157	3.2		
-158	3.8		
-159	2.3		
-160	4.0		
-161	4.0		
-162	4.3		
-163	3.9		
-164	4.2		
-165	4.3		
-166	2.7		
-167	5.2		
-168	5.1		
-169	6.3		
-170	5.0		
-171	4.5		

TABLE 1 (cont)
(adapted from ref 1)

TAILINGS

MJG
26 July 89
UNITED GRN
5057-05
ckd: WOC 7/28/89

Sample #	w(%)
CM-M-172	3.1
-173	2.5
-174	4.0
-175	4.8
-176	4.6
-177	3.3
-178	7.4
-179	5.4
-180	4.1
-181	5.2
-182	3.4
-183	4.7
-184	4.1
-185	3.0
-186	2.6
-187	2.2
-188	2.6
-189	3.0
-190	2.4
-191	2.5
-192	2.5
-193	3.9
-194	4.0
-195	3.8
-196	4
-197	5.7
-198	6.6
-199	4.3
-200	3.2
-201	1.1
-202	3.9
-203	3.4
-204	3.0
-205	5.3
-206	3.2

Sample #	w(%)
CM-M-207	3.1
-208	3.3
-209	4.5
-210	4.9
-211	5.7
-212	5.1
-213	5.0
-214	6.9
-215	4.8
-216	3.5
-217	5.1
-218	5.6
-219	4.0
-220	3.9
-221	5.1
-222	4.2
-223	6.7
-224	4.4
-225	5.2
-226	5.5
-227	6.0
-228	5.3
-229	5.6
-230	5.0
-231	5.2
-232	4.4
-233	5.9
-234	6.9
-235	5.0
-236	5.5
-237	5.5
-238	4.1
-239	5.4
-240	5.6
-241	7.0

Sample #	w(%)	
CM-M-242	5.0	
-243	6.1	
-244	6.0	
-245	~~7.8~~	F
-245-R1	~~5.7~~	"
-246	~~6.0~~	"
-247	~~6.6~~	"

$\bar{x}_j$ (1-minus)
$n = 35$
$\bar{x} = 7.0$
$\bar{s}_x = 1.91$
$\frac{\bar{s}_x}{\bar{x}} = 0.27$

TABLE 1 (out)
(oil pad Pond ref 1)

11 July 89
MJC
5057-05
ULTRA-SRN

OFFPILE

MJC
7/27/89
ULTRA-CORE
5057-05
Corr work 7/28/89

Sample #	In-place W(%)/θ(%)	In-place γd (pcf)	
MLE -001	5.5 / 9.2	118.7	
-002	5.6 / 10.2	113.4	
-003	6.3 / 12.6	115.2	
-004	5.6 / 10.1	112.2	
-005	4.8 / 12.4	114.1	
-006	5.6 / 10.6	116.2	
-007	4.1 / 7.9	120.7	
-008	7.0 / 13.3	113.7	
-009	5.4 / 10.1	117.2	
-010	4.7	120.6	Failed
-010 R1	5.1 / 9.7	118.1	
-011	7.5 / 14.2	117.2	
-012	5.7 / 10.5	115.0	
-013	6.3 / 11.8	116.8	
-014	4.4 / 8.3	117.3	
-015	6.0 / 11.5	118.9	
-016	5.0 / 9.5	119.0	
-017	6.6 / 12.2	116	
-018	7.0 / 13.2	112	
-019	6.5 / 12.3	117.0	
-020	6.0 / 11.4	118.1	
-021	6.6 / 12.3	117	
-022	7.6 / 14.2	119.3	
-023	5.8 / 11.0	114.2	
-024	/	/	
-025	6.4 / 12.1	121.3	
-026	5.8 / 11.0	114.5	
-027	5.7 / 10.8	114.6	
-028	4.8 / 9.1	119.7	
-029	5.3 / 10.1	113.1	
-030	5.3 / 10.0	113.0	
-031	/	/	
-032	4.7 / 8.7	114.9	
-033	7.0 / 13.3	114.0	
-034	7.7 / 14.6	115.1	

TABLE 2
(adapted from ref [1])

NJG
7/27/89
JMTRA-GRN
5057-05
WDR 7/28/89

Offpile

Sample #	In-Place $w\%_o$ / $\theta\%$	γ_d (pcf)	
MK-E-035	5.7 / 10.9	119.4	
-036	4.1 / 7.8	119.2	
-037	5.4 / 9.1	105.5	
-077	4.9 / 5.5	108.7	
-078	6.1 / 11.3	115.1	
-079	5.7 / 11.0	120.0	
CM-M-001	7.4		
-002	7.2		
-003	~~7.0~~		FAIL
-004	5.2		
-005	~~7.4~~		FAIL
-006	6.3		
-007	~~8.2~~		FAIL
-008	7.7		
-005-R1	4.0		
-003-R1	6.7		
-009	~~8.0~~		FAIL
-009-R1	5.7		
-010	5.5		
-011	5.6		
-012	5.7		
-007-R1	6.2		
-013	5.5		
-014	7.3		
-015	7.0		
-016	7.7		
-017	5.9		
-018	5.4		
-019	5.6		
-020	6.5		
-021	6.2		
-022	5.2		
-023	5.8		
-024	5.1		
-025	5.3		

TABLE 2 (cont'd)
(Embankment Phase, Cell 1)

OFFPILE

NJG
7/27/89
CENTRAL-CORN
5057-05
CKD. WOC 7/28/89

Sample #	Inplace w (%)	
CM-M-026	6.3	
-027	5.6	
-028	4.9	
-029	4.8	
-030	5.6	
-031	4.6	
-032	3.7	
-033	5.0	
-034	5.9	
-035	6.8	
-036	4.6	
-037	5.6	
-038	4.1	
-039	4.2	
-040	~~5.9~~	F1
-041	3.9	
-042	~~5.5~~	F2
-043	5.7	
-040-R1	4.2	
-042-R1	4.3	
-044	5.5	
-045	5.0	
-046	5.4	
-047	4.0	
-048	4.2	
-049	5.4	
-050	4.4	
-051	4.0	
-052	5.4	
-053	4.6	
-054	5.2	
-055	4.9	
-056	6.8	
-057	5.7	
-058	6.5	

Sample #	Inplace w (%)
CM-M-059	6.7
-060	6.7
-061	5.9
-062	6.1
-063	5.5
-064	6.3
-065	5.5
-066	4.8
-067	4.0
-068	5.2
-069	6.0
-070	7.6
-071	6.0
-072	4.8
-073	4.3
-074	7.0
-075	5.8
-076	5.9
-077	4.6
-078	5.8
-079	6.0
-080	7.1
-081	6.5
-082	5.7
-083	6.7
-084	4.7
-085	6.5
-086	6.0
-087	6.7
-088	6.3
-089	6.4
-090	5.1
-091	5.7
-092	5.9
-093	5.2

(Duplicate from p. 4)

OFFPILE

MJG
7/27/89
ULTRA-GRN
5:57-05
cag WOC 7/28/89

+-2

SAMPLE #	Inplace W(%)	
CM-M-094	7.0	
-095	4.9	
-096	6.9	
-097	4.9	
-098	4.9	
-099	6.0	
-100	5.4	
-101	5.9	
-102	5.4	
-103	5.2	
-104	7.2	
-105	7.3	
-106	6.1	
-107	5.5	
-108	5.8	
-109	4.7	
-110	5.5	
-111	5.1	
-112	4.7	
	5.7	
	5.4	
	~~5.5~~	F
	0.2	F
-152	5.5	
-2	5.8	
	1.5	
	5.4	
	4.1	
-120	4.3	
-121	4.8	
-122	5.6	
	4.1	
-124	6.0	
-125	5.6	
-126	5.9	

Sample #	Inplace W%
CM-M-127	6.6
-128	6.5
-129	5.4
-130	4.2
-131	1.9
-132	3.6
-133	2.8
-134	2.8
-135	3.3
-136	4.4
-137	3.9
-139	3.5
-139	2.0
-140	5.1
-141	3.6
-248	5.3
-249	3.6
-250	7.8
-251	6.3
-252	4.1
-253	1.9
-254	3.6

TABLE 2 (cont)
(Inplace Densities)

D (Summary)

$\bar{x}$ = -0

s_x = 0.8

$s_{\bar{x}}$ = -0

D = $t_{.05} s_{\bar{x}}$ = 0.16

Buffer Mat'l
(i.e., Type A Special Fill)

MJG
7/27/89
UMTRA-GJPO
5037-05
CKJ WOL 7/27/89

Test #	γ_d (pcf) (data)	w (%)	ϕ (°) (calculated)	
SFA-S-004	118.9	5.1	9.72	
-005	120.0	6.7	12.88	
-006	122.2	4.7	9.20	
-007	123.0	4.6	9.07	
SFA-N-008 ↓ 011	see attached sheets			
SFA-S-062	~~116.4~~	~~6.0~~		Fail
-062-R1	117.5	6.0	11.30	
-062-R2	118.3	9.2	17.44	
-063	~~114.2~~	~~5.5~~		Fail
-063-R1	119.0	6.6	12.54	
-064	119.0	6.3	12.01	
-065	123.6	6.6	13.05	
-066	125.3	5.5	12.06	
-067	116.0	7.7	14.56	
-068	121.1	7.3	14.17	
-069	119.9	10.1	19.39	
-070	124.9	5.1	10.2	
-071	122.6	8.4	15.49	
-072	~~116.4~~	5.0		Fail
-072-R1	120.2	9.3	17.81	
-073	120.1	7.8	15.01	
-074	122.6	8.0	15.55	
-075	125.0	7.0	14.02	
-076	119.1	10.0	19.09	
-077	123.4	9.3	18.74	
-078	121.0	8.9	17.26	
-079	123.3	7.6	15.02	

TABLE 3
(continued from ref 1)

MK-FERGUSON COMPANY

JOB: 2050 ... Bulk

DATE: 3/27/89

ORIGINAL

CONTRACT # 3050

GREEN RIVER, UTAH

DEN REQUIREMENTS BY: SUM 3/30/89

QA ENTRY NO. 617

TEST SPECIFICATIONS: 02200 REV 2 - 95% of D 698
02200 REV 2 OPT. MOISTURE TO -4% of OPT. MOISTURE

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE	% OF MAX. DRY DENSITY	PASS/ FAIL
SFA-d-008	N59,450 E58,850 ELEV 4099 1ST 12" LEFT	SFA-4-004	Silty Sand	124.9	8.7	130.2	121.3	7.3	SD 3/89 97.1 2	PASS
SFA-d-009	N59,330 E58,978 ELEV 4099 1ST 12" LEFT	SFA-4-004	Silty Sand	124.9	8.7	124.7	119.1	4.8	95.4	PASS
** SFA-d-010	N59,390 E59,032 ELEV 4099 1ST 12" LEFT	SFA-4-004	Silty Sand	(one-point) 127.8	10.1 ~~8.7~~	130.2	122.1	6.7	95.5	PASS
SFA-d-011	N59,482 E58,955 ELEV 4099 1ST 12" LEFT	SFA-4-004	Silty Sand	127.8	10.1	129.7	122.3	6.1	95.7	PASS
SFA-d-012	N59,528 E58,891 ELEV 4100 2ND 12" LEFT	SFA-4-004	Silty Sand	127.8	10.1	~~128.3~~	~~119.1~~	~~7.7~~	~~93.2~~	(FAIL)
(RETEST) SFA-d-012-R1	N59,528 E58,891 ELEV 4100 2ND 12" LEFT	SFA-4-004	Silty Sand	127.8	10.1	132.7	121.7	9.0	SD 3/89 95.1 2	PASS
** SFA-d-013	N59,408 E58,810 ELEV 4100 2ND 12" LEFT	SFA-4-005	Clayey Silt	(four point) 125.4	10.8	127.7	119.5	6.9	SD 3/89 95.1 3	PASS
SFA-d-014	N59,414 E59,038 ELEV 4100 2ND 12" LEFT	SFA-4-005	Clayey Silt	125.4	10.8	130.3	119.3	9.2	95.1 ~~97.0~~ SUM 3/89	PASS
SFA-d-015	N59,302 E59,002 ELEV 4100 2ND 12" LEFT	SFA-4-005	Clayey Silt	125.4	10.8	131.2	122.2	7.4	97.4	PASS

(TROXLER 3440 CS 50 5337 AM 1711137)

TABLE I (cont) Evaluated (Comment 1)

MJG 7/27/89
[illegible]
S 8 57-05
CKD. WOC 7/28/89

OPERATOR: [illegible]

REVIEWED BY: Steve Dike

A-10

ORIGINAL
CONTRACT # 3050
GREEN RIVER, UTAH

JOB: 3050 - Green River DATE: ~~3-30-89~~

QA [illegible] REQUIREMENTS
BY SDM 3/31/89
QA ENTRY NO. 634

TEST SPECIFICATIONS: 02700 Rev 2 - 95% of A D698
02200 Rev 2. Opt. Moisture ±3% - 4% of Opt. Moisture

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE		% OF MAX. DRY DENSITY	PASS/FAIL
SFA-11-016	N59635 E58964 Elev. 4099	SFA-4-005	Clayey Silt	125.4	10.8	132.5	122.2	8.4	[illegible]	97.4	PASS
SFA-11-017	N59633 E59097 Elev. 4099	SFA-4-005	Clayey Silt	(	(	130.3	119.9	8.7	16.28	95.6	PASS
* ** SFA-11-018	N59500 E59111 Elev. 4099	SFA-4-005	|	(	(	131.9	121.5	8.6	16.25	96.9	PASS
SFA-11-019	N59475 E59212 Elev. 4099	SFA-4-005	|	(	(	131.7	120.5	9.3	17.26	96.1	PASS
SFA-11-020	N59585 E59135 Elev. 4099	SFA-4-005	Clayey Silt	125.4	10.8	131.1	119.4	9.8	16.25	95.2	PASS
SFA-11-021	N59355 E59050 Elev. 4101	SFA-4-005	Clayey Silt	125.4	10.8	131.2	120.7	8.7	16.83	96.3	PASS
SFA-11-022	N59360 E59125 Elev. 4101	SFA-4-005	Clayey Silt	125.4	10.8	130.5	119.7	9.0	17.26	95.5	PASS
** SFA-11-023	N59380 E58975 Elev. 4101	SFA-4-003	Silty Sand	123.9	10.0	132.3	120.8	9.5	16.39	97.5	PASS
SFA-11-024	N59450 E58960 Elev. 4101	SFA-4-003	Silty Sand	(	(	132.9	120.9	9.9	17.19	97.6	PASS
* ~~SFA-11-025~~	N59410 E58810 ~~Elev. 4101~~	SFA ~~4-003~~	Silty ~~Sand~~	~~123.9~~	~~10.0~~	~~134.4~~	~~121.4~~	(10.7)	20.52	98.0	FAIL
Gtroxler 3440		CS-50 50		5337	AM-47	11737				UMTRCA-QIP / CSD. Acc. 7/28/89	MJG 7/27/89

TABLE 3 (cont) {adapted from r.f. 1}

OPERATOR: Steve Dike

REVIEWED BY: [illegible signature]

4

ORIGINAL
CONTRACT # 3050
GREEN RIVER, UTAH

JOB: ~~3050~~ Green River   DATE: ~~3-31-89~~

REQUIREMENTS: Sam 4/3/89
QA ENTRY NO. 613

TEST SPECIFICATIONS: 02200 Bal 2 - 95% of A 698
[illegible]

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE	% OF MAX. DRY DENSITY	PASS/FAIL
STA N 125 KI	N59490 E58810 Elev. 4101	STA-4-003	Silty Sand	123.9	10.0	133.4	122.0	9.1	98.5	PASS
STA N 026	N59637 E58963 Elev 4100	STA-4-003	Silty Sand	123.9	10.0	125.0	117.9	6.1	95.2	PASS
STA N 027	N59568 E59062 Elev. 4100	STA-4-003	Silty Sand	123.9	10.0	133.4	122.6	8.8	99.0	PASS
STA N 028	N59460 E59160 Elev. 4100	STA-4-003	Silty Sand	123.9	10.0	131.6	122.1	7.7	98.5	PASS
STA N 029	N59470 E59258 Elev. 4100	STA-4-003	Silty Sand	123.9	10.0	131.2	120.3	9.0	97.1	PASS

(Troxler 3440 CS-50 5337 Am-241 737)

TABLE 3 (cont)

(adapted from ref 1)

MJG 7/27/89
UMTRA-GRN
5057-05
CKD. WOC 7/28/89

OPERATOR: Steve Dile   REVIEWED BY: Steven Mott

ORIGINAL
CONTRACT # 3050
GREEN RIVER, UTAH

JOB: ~~3050~~ Green River

DATE: ~~3/31/87~~

TEST SPECIFICATIONS: 02200 Sec 2 – 95% of A 2628 OPTIMUM MOISTURE 10 – 12% of OPT. MOISTURE

QUALITY REQUIREMENTS BY [illegible] QA ENTRY NO. 6-1-1

NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE	% OF MAX. DRY DENSITY	PASS/FAIL
SFA-N-030	N 57,560 E 59,180 Elev 4100	SFA-4 -001	Silty Sand	123.9	10.0	129.7	119.5	8.5	96.4	PASS
SFA-N-031	N 59,696 E 59,065 Elev 4100	SFA-4 -003	Silty Sand	123.9	10.0	128.1	118.2	8.4	95.4	PASS
SFA-N-032	N 59,444 E 58,830 Elev 4102	SFA-4 -003	Silty Sand	123.9	10.0	132.4	121.7	8.8	98.2	PASS
SFA-N-033	N 59,365 E 58,918 Elev 4102	SFA-4 -003	Silty Sand	123.9	10.0	130.8	120.7	8.4	97.4	PASS
SFA-N-034	N 59,270 E 59,020 Elev 4102	SFA-4 -005	Clayey Silt	125.4	10.8	129.4	120.4	7.5	96.0	PASS
SFA-N-035	N 57,505 E 58,922 Elev 4102	SFA-4 -005	Clayey Silt	125.4	10.8	132.1	122.3	8.0	97.5	PASS
SFA-N-036	N 59,394 E 59,038 Elev 4102	SFA-4 -005	Clayey Silt	125.4	10.8	133.2	122.3	8.9	97.5	PASS

(TROXLER 3440 CS-50 5337 AM 4711737)

TABLE 3 (cont)

(Completed Sheet 1 of 1)

M.G.
7/27/87
UMTRA-GRN
5057-05

CKD. WOC 7/28/87

OPERATOR: [illegible]

REVIEWED BY: [illegible]

4.

ORIGINAL

CONTRACT # 3050

GREEN RIVER, UTAH

Q VIEWED FOR QUALITY REQUIREMENTS BY SJM 4/4/89

QA ENTRY NO 662

CLIENT / COMPANY

JOB: 3050 - GREEN RIVER

DATE: 4/3/89

TEST SPECIFICATION: 95% of A. ASTM D2216 R.D.Z. — Optimum moisture to +2% of optimum moisture

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE	% OF MAX. DRY DENSITY	PASS/FAIL
SFA-N-037	N59605 E58440 Elev. 4101	SFA-4-006	Silty Sand	** 118.2	12.3	116.0	109.5	5.4	92.6	FAIL
SFA-N-038	N59640 E59100 Elev. 4101			~~118.2~~	~~12.3~~	~~115.1~~	~~109.6~~	~~5.0~~	~~92.7~~	~~FAIL~~
* SFA-N-039	N59515 E59100 Elev. 4104			118.2	12.3	132.2	118.0	12.0	99.8	PASS
SFA-N-037R1	N59635 E58990 Elev. 4101			~~118.2~~	~~12.3~~	~~122.9~~	109.4 ~~113.2~~	~~8.6~~	92.6 ~~95.8~~	FAIL ~~PASS~~
SFA-N-038R1	N59640 E59100 Elev. 4101			~~118.2~~	~~12.3~~	~~126.7~~	112.2 ~~116.1~~	~~9.1~~	94.9 ~~98.2~~	FAIL ~~PASS~~
SFA-N-040	N59545 E59215 Elev. 4104			~~118.2~~	~~12.3~~	~~122.8~~	109.2 ~~113.0~~	~~8.7~~	92.4 ~~95.6~~	FAIL ~~PASS~~
SFA-N-041	N59255 E59050 Elev. 4103	SFA-4-006	Silty Sand	~~118.2~~	12.3	124.5	110.2 ~~114.0~~	9.2	93.2 ~~96.4~~	FAIL ~~PASS~~
* SFA-N-042	N59320 E58965 Elev. 4103	SFA-4-007	Silty Sand	** ~~117.2~~	~~11.7~~	~~126.7~~	110.1 ~~113.9~~	~~11.2~~	93.9 ~~97.2~~	FAIL ~~PASS~~

→ See sand cone correlation SFA-C-009. Test numbers SFA-N-037-R1, SFA-N-038-R1, SFA-N-040, SFA-N-041 and SFA-N-042 were retested on 4/4/89. See density evaluation for sand cone correlation SFA-C-009. (See SFA-DE-009)

TABLE 3 (cont) { adapted from ref 1 }

5057-005 Encl. Nov 7 1989

UMTRA-DOE

OPERATOR: [signature]

REVIEWED BY: [signature]

MK FERGUSON COMPANY

ORIGINAL
CONTRACT # 3050
GREEN RIVER, UTAH

QA [illegible] FOR
QUA[illegible] REQUIREMENTS
BY SDM 4/4/89
QA ENTRY NO 663

JOB: [illegible] GREEN RIVER

DATE: 4/[illegible]

TEST SPECIFICATIONS: [illegible] REV 2 - 95% of [illegible] D698
[illegible] OPT. MOISTURE TO -4% of OPT. MOISTURE

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE		% OF MAX. DRY DENSITY	PASS/ FAIL
STA II-043	N59460 E59040 Elev. 4103	STA-4 -007	Silty Sand	117.2	11.7	122.3	112.4	8.8	15.8	95.9	PASS
STA II-044	N59,615 E58,830 @ ELEV 4103	STA-4 -007	Silty Sand	117.2	11.7	124.0	114.1	8.7	15.9	97.4	PASS
STA II-045	N59,430 E58,930 @ ELEV 4103	STA-4 -007	Silty Sand	117.2	11.7	123.5	112.8	9.5	17.17	96.2	PASS
STA II-046	N59,620 E58,965 @ ELEV 4102	STA-4 -007	Silty Sand	117.2	11.7	125.1	115.0 SD 4/89	8.7	16.0	98.1 2 SD 4/89	PASS
* STA II-047	N59,440 E59,195 @ ELEV 4102	STA-4 -007	Silty Sand	117.2	11.7	126.1	113.47 SD 4/89	10.9	13.66	97.0 SD 4/89 96.9	PASS

*Test [illegible] 3440 AM 4711737 [illegible] - 50 5337

TABLE 3 (cont)

(adapted from ref 1)

MJT 12/4 (-[illegible]) E057-05
GEO. NOC 1/28/89

MJC 7/27/89

OPERATOR: [illegible]

REVIEWED BY: [illegible]

ORIGINAL

~~CONTRACT # 3050~~

GREEN RIVER, UTAH

JOB: ~~[illegible]~~ Green River

DATE: ~~4-4-89~~

QU[illegible] REQUIREMENTS BY Sam 4/5/89

QA ENTRY NO. 624

TEST SPECIFICATIONS: 02200 [illegible] 2 – 95% of A D698 – [illegible] – [illegible] moisture [illegible] of opt. moisture

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE		% OF MAX. DRY DENSITY	PASS/FAIL
SFA II [illegible] R2	N59635 E58990 Elev. 4101	SFA-4.006	Silty Sand	118.2	12.3	128.9	118.1	9.2	[illegible]	99.9	PASS
SFA II 039 R2	N59640 E59100 Elev. 4101	)	)	)	)	124.8	113.0	10.4	[illegible]	95.6	PASS
SFA II 040 R1	N59545 E59215 Elev. 4101	)	)	)	)	128.9	116.9	10.3	[illegible]	98.9	PASS
SFA II 041 R1	N59255 E59050 Elev. 4103	)	)	)	)	123.9	113.6	9.1	[illegible]	96.1	PASS
* SFA II 042 R1	N59320 E58965 Elev. 4103	SFA-4.006	Silty Sand	~~118.2~~ 117.2	~~12.3~~ 11.7	125.9	114.~~4~~	10.1	[illegible]	~~96.6~~ 97.6	PASS
SFA II 048	N59505 E59255 Elev. 4102	SFA-4.007	Silty Sand	117.2	11.7	124.9	115.2	8.4	[illegible]	98.3	PASS
SFA II 049	N59565 E59000 Elev. 4102	)	)	)	)	126.8	116.3	9.0	[illegible]	99.2	PASS
SFA II 050	N59590 E58950 Elev. 4103	)	)	)	)	127.8	116.9	9.3	[illegible]	99.7	PASS
SFA II 051	N59430 E58860 Elev. 4104	SFA-4.007	Silty Sand	117.2	11.7	126.7	116.2	9.0	[illegible]	99.1	PASS
* SFA II 052	N59535 E58930 Elev. 4104	SFA-4.007	Silty Sand	** 119.2	10.8	130.1	119.9	8.5	[illegible]	100.6	PASS

** [illegible] same [illegible] for all [illegible]

TABLE 3 (cont)

UMTRA-GJ [illegible]

MJC 7/27/89

OPERATOR: [illegible]

REVIEWED BY: [illegible]

ORIGINAL
CONTRACT # 3050
GREEN RIVER, UTAH

RECEIVED COMPANY

JOB: ~~3050~~ Green River

DATE: ~~4-4-89~~

REVIEWED FOR QUALITY REQUIREMENTS
BY: SDM 4/5/89
QA ENTRY NO. 625

TEST SPECIFICATIONS: [illegible]

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE	% OF MAX. DRY DENSITY	PASS/FAIL
STA II 053	NS9675 ES9080 Elev. 4103	STA-4-002	Silty Sand	119.2	10.8	122.8	114.2	7.5	95.8	PASS
STA II 054	NS9380 ES9020 Elev. 4104	)	)	)	)	126.6	115.4	9.7	96.8	PASS
STA II 055	NS9350 ES9140 Elev. 4104	)	)	)	)	126.8	115.9	9.4	97.2	PASS
STA II 056	NS9490 ES9155 Elev. 4103	STA-4-002	Silty Sand	119.2	10.8	127.2	117.5	8.3	98.6	PASS

(Troxler 3440 CS-50 5337 MA-471173?)

TABLE 3 (cont)
(adapted from [illegible])

CCS. MOC 7/18/89

Slope Dike

REVIEWED BY: [signature]

ORIGINAL

CONTRACT # 3050 GREEN RIVER, UTAH

REVIEWED FOR QUALITY REQUIREMENTS BY [illegible] PA ENTRY NO. 692

REPORT [illegible] COMPANY

JOB: 3050 Green River

DATE: 4-5-89

TEST SPECIFICATIONS: [illegible] 95% of [illegible]

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE		% OF MAX. DRY DENSITY	PASS/FAIL
SIA II 057	N59570 E59175 Elev. 4103	SIA-4-002	Silty Sand	119.2	10.8	127.9	117.1	9.2	12.26	98.3	PASS
SIA II 058	N59500 E59260 Elev. 4104					124.5	116.4	7.0	13.06	97.7	PASS
SIA II 059	N59460 E59115 Elev. 4104					126.0	115.9	8.7	16.16	97.2	PASS
SIA II 060	N59610 E59115 Elev. 4104					123.5	114.5	7.9	14.[illegible]	96.0	PASS
SIA II 061	N59680 E58980 Elev. 4104	SIA-4-002	Silty Sand	119.2	10.8	122.5	114.4	7.1	13.02	96.0	PASS

(TROXLER 3440 CS-50 5337 [illegible])

TABLE 3 (cont)

([illegible] of 1)

JMT/2A-G-[illegible] 5057-05 [illegible] 7/[illegible]/89

MJG 7/7/89

Steve Dike

REVIEWED BY: Steve Mock

INPLACE BUFFER (summary)

77 data pts (see incl: A-1 through A-18)

	γ_d (pcf)	W (%)	$\frac{1}{2}$ (decimal)
$\bar{X}$	112.2	9.3	15.9
σ	3.18	1.43	2.64
$J = \sigma/\bar{x}$	0.027	0.173	0.167

TABLE 2 (cont)

Procedure (cont)

4. Calculate θ for each (w, γ_d) data pair for each material type using the following formula:

$$\theta = w \frac{\gamma_d}{\gamma_w}$$

where $\gamma_w = 62.4$ pcf.

5. The mean value (and the standard deviation) of θ for each of the materials is calculated from the individual θ's in the data base (see step 4, above).

Results

Mean values of w, γ_d and θ for the three types of materials are presented in Table 4.

Standard deviation, σ, and coefficient of variation, $V = \sigma/\text{mean}$ of θ for the three materials are presented in Table 5.

Mean values and standard deviations of the other material properties for the materials γ_d and θ are presented in Table 6.

MAT'L TYPE	$\bar{w}$ (%)	$\bar{\gamma}_d$ (pcf)	$\bar{\Delta}$ (%) Method 1 ①	$\bar{\Delta}$ (%) Method 2 ②
Tailings	4.56	98.90	7.0	7.2
Offpile	5.52	115.19	10.8	10.2
Borrow	8.30	119.2	15.8	15.9

NOTES

① $\bar{\Delta}$ estimated as mean value of n individual Δ values; i.e.,

$$\bar{\Delta} = \frac{1}{n\gamma_0} \sum_{i=1}^{n} w_i \gamma_{di}$$

where (w_i, γ_{di}) are (water content, dry density) measurements on the triplicate specimens

n = number of (w_i, γ_{di}) pairs

② $\bar{\Delta}$ estimated from mean w and γ_d values; i.e.,

$$\bar{\Delta} = \frac{1}{\gamma_0} (\bar{w})(\bar{\gamma}_d)$$

where $\bar{w}$ and $\bar{\gamma}_d$ are the mean values of w and γ_d on the specimens for which both w and γ_d data are available

PAGE 4

MATL TYPE	$\bar{C}$ (1)		
	Mean	σ	v (2)
Tailings	7.0	1.91	0.27
Office	10.8	1.70	016
Buffer	15.8	2.64	0.17

NOTES

(1) See data summaries, Tables 1-3.

(2) $v = \sigma / \text{mean}$

TABLE 5

COMPLETE DATA SET

MAT'L	# Data Points	Grav. Water Content	
		Mean	σ
Tailings	135	4.56	1.43
Offpile	193	5.52	1.13

TABLE 6a

SUBSET USED TO ESTIMATE $\hat{\sigma}$

MAT'L	# Data Points	Grav. Water Content	
		Mean	σ
Tailings	35	4.41	1.19
Offpile	40	5.85	0.91

TABLE 6b

DISCUSSION

1. The mean values of ~~D~~ estimated herein are not significantly different than would be estimated using mean values of W and γ_d (see Table 4).

2. Fewer γ_d tests were performed than W tests, based on a comparison of the mean value and standard deviation of all water contents measured and of the mean and standard deviation of water contents for which γ_s data are also available. It can be seen that computed water content (and presumably γ_d) of the data set used to compute ~~D~~ is not significantly different than compacted water content (and γ_d) of the complete data set.

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA-GRN	Contract No. 5057-05	Sheet A-25	File No.
Feature Tailings, Offpile, Buffer Materials	Designed MJC	Date 27 July
Item Input Parameter Characterization	Checked WDC	Date 7/28/88

SUPPLEMENT

Purpose

Determine the mean values of optimum water content (OMC) and maximum dry density ($\gamma_{d\,max}$) based on ASTM D-698 of compaction tests used to control compaction of tailings, offpile and buffer materials.

Procedure

1. OMC and $\gamma_{d\,max}$ test data from ref. 1 are reproduced in Tables 7-9.
2. Mean values of OMC and $\gamma_{d\,max}$ are calculated using conventional formulae. Results are presented in Table 10.

Results

1. Mean OMC and $\gamma_{d\,max}$ values of offpile materials are similar to those of the buffer materials. This corroborates that the buffer material is composed of the same materials as the offpile materials.

MJG
5057-05
12 July 89
UMTRA-GJRN
CKD. HDC 7/18/89

TAILINGS

CONTROL CURVE	D-698 * OMC (%)	D-698 * $\gamma_{d\,max}$ (pcf)	
CM-4-001	18.2	97.6	
I.D. number	14.9	103.6	
CM-4-002	16.5	99.5	
CM-4-024	14.8	103.0	
CM-4-025	14.1	105.1	
CM-4-026	14.0	104.8	
CM-4-027	13.9	103.5	
CM-4-028	15.8	99.6	
CM-4-029	15.2	102.3	
CM-4-032	~~13.5~~	~~107.3~~	~ 95% tailings (not included in avg
CM-4-033	13.5	104.4	
CM-4-034	13.5	103.5	
CM-4-035	14.5	102.0	
CM-4-036	13.1	107.6	
CM-4-037	15.0	101.0	
CM-4-038	15.0	102.3	
CM-4-039	13.7	104.2	
CM-4-040	14.8	103.1	
CM-4-041	13.9	101.2	
CM-4-042	~~12.3~~	110.	~ minimum amount of native soil in mix, not included in avg
CM-4-043	~~12.7~~	~~112.6~~	
CM-4-044	~~9.1~~	~~123.0~~	
$\bar{x}$ =	18	18	
$\bar{x}$ =	14.70	102.7	does not include tailings mixed w/ other matl.
σ_x =	1.22	2.32	
$\sigma - \bar{x}$ =	0.083	0.122	

+ 4-pt compaction tests

TABLE 7
(adapted from ref 1)

ENGINEERS
AND
CONSTRUCTORS

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

HEADQUARTERS OFFICE
ONE ERIEVIEW PLAZA
CLEVELAND OHIO U.S.A. 44114
PHONE (216) 523-5600/TELEX 985542

REPLY TO MK-FERGUSON COMPANY
REMEDIAL ACTIONS
CONTRACTOR-UMTRA PROJECT
P.O. BOX 9136
ALBUQUERQUE NEW MEXICO U.S.A. 87119

October 12, 1989

89-3050-773

Mr. Mark L. Matthews
Acting Project Manager
U.S. Department of Energy
Uranium Mill Tailings Remedial Action Project Office
First National Bank Building
5301 Central Avenue N.E.
Suite 1700
Albuquerque, New Mexico 87108

SUBJECT: Green River - Permeability Tests

REFERENCE: Contract No. DE-AC04-83AL18796

Dear Mr. Matthews:

Enclosed for your records are two letters from Fox Consultants to John Singleton, dated August 31, 1989 and September 27, 1989.

These letters provide a complete set of permeability tests performed on radon barrier placed on the Green River cell.

If you have any questions, please contact Rob Cooney.

Sincerely,

MK-Ferguson Company

for J. R. Oldham
Project Director

JGO/JRB/kja

Enclosures

cc: C. Watson, DOE/UMTRA (w/enc.)
F. Bosiljevac, DOE/UMTRA (w/o enc.)

3562K

FOX CONSULTANTS
OF COLORADO, INC.
GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS
DENVER ALBUQUERQUE

DIST.	ACT	INFO
J. SINGLETON	✓	
L. BIGLEY		
D. LEWIS		
D. THOMPSON		
G. STOWE		
IND. HYGIENE		
S. MARTZ	✓	
FILE: 7.1		✓

August 31, 1989

M-K Ferguson Company
PO Box 361
Green River, Utah 84525

Attention: Mr. John Singleton

Job No. 1-4250-7993-10

Dates of Testing: August 11 through August 29, 1989

Subject: Field Sampling and Laboratory Testing, Radon Barrier, Green River, Utah

Dear Mr. Singleton:

At your request, an engineering technician was provided to obtain samples for laboratory testing at the subject project. The technician obtained permeability block samples PB-1 through 4 and bulk samples GRN-3 through 6 on August 11, 1989. Permeability block samples PB-5 through 8 and bulk samples GRN-7 through 10 were obtained on August 24, 1989. The permeability block samples were obtained in accordance with the Bureau of Reclamation Earth Manual, Des. E-2, Part A. Sample locations are shown on Figure 1. All samples were returned to our laboratory for testing.

The results of moisture-density relations testing performed on bulk samples GRN-3 through 10 are presented on Figures 2 through 9. The results of permeability testing performed on permeability block samples PB-1 through 3 are presented on Figures 10 through 12. The results of sieve analysis and plasticity index testing performed on permeability block samples PB-1 through PB-3 are presented on Figures 13 through 15. Test results have been summarized on Table 1 for your convenience.

M-K Ferguson Company
Attention: Mr. John Singleton
Job No. 1-4250-7993-10
August 31, 1989
Page 2

Further laboratory testing is in progress and results will be transmitted to you as they become available. If we may be of further assistance in evaluating these data, please contact us at your convenience.

Respectfully submitted,

FOX CONSULTANTS OF COLORADO, INC.

Mary H. Broncucia

Mary H. Broncucia, C.E.T.

Reviewed by:

Donald R. Clark, P.E.
Principal Engineer

MHB/nh

Copies: 3

Attached: Location Map, Figure 1
Moisture-Density Curves, Figures 2-9
Permeability Results, Figures 10-12
Sieve Analysis/Plasticity Index, Figures 13-15
Summary, Table 1

REGISTERED PROFESSIONAL ENGINEER
DONALD R. CLARK
5280
STATE OF UTAH

DAILY DIARY

PROJECT: GREEN RIVER RADON BARRIER

LOCATION: GREEN RIVER, UTAH

SOURCE:

PROJECT NO: 1-4250-7993-10 **REPORT NO:** N/A **DATE:** 8/11/89

PROCTOR NO: N/A **TIME:** N/A

SAMPLE NO: N/A **ENGINEERING TECHNICIAN:** BASHAM

WORK PERFORMED:

The contractor, MK Ferguson Company, had prepared the north face of the radon barrier cell prior to my arrival on-site. I obtained four permeability block samples, 1-4, and four bulk soil samples, 5-8, from the given locations and elevations. The samples were returned to our laboratory for Proctor testing, classification, moisture content, and permeability determinations.

The sample labeled as PB-1 has a diagonal fracture line running through it. Further investigation at the site determined that this fracture line was caused by a thin line of undercompacted soil that ran horizontally along the embankment for more than six feet, the width of the test hole. I reported this to Steve Martz before leaving the site.

@ 2:1 slope

DAILY DIARY

PROJECT: GREEN RIVER RADON BARRIER

LOCATION: GREEN RIVER, UTAH

SOURCE: RADON BARRIER

PROJECT NO: 1-4250-7993-10 **REPORT NO:** N/A **DATE:** 8/24/89

PROCTOR NO: N/A **TIME:** N/A

SAMPLE NO: N/A **ENGINEERING TECHNICIAN:** BASHAM

WORK PERFORMED:

Permeability block samples 5-8 were obtained along with bulk soil samples 7-10. These samples and permeability blocks were transported to our laboratory for Proctor value determination, permeability tests, classification, and moisture content tests. The locations and elevations for the samples are on the attached locations map.

REMARKS:

Steve Martz made some elevation corrections on the permeability block samples obtained on the first trip, August 11, 1989.

Only four samples were obtained because of delays in the progress to the north slope (5:1) of the cell. Steve Martz stated that high winds had dried the soil out and the contractor was reworking that area.

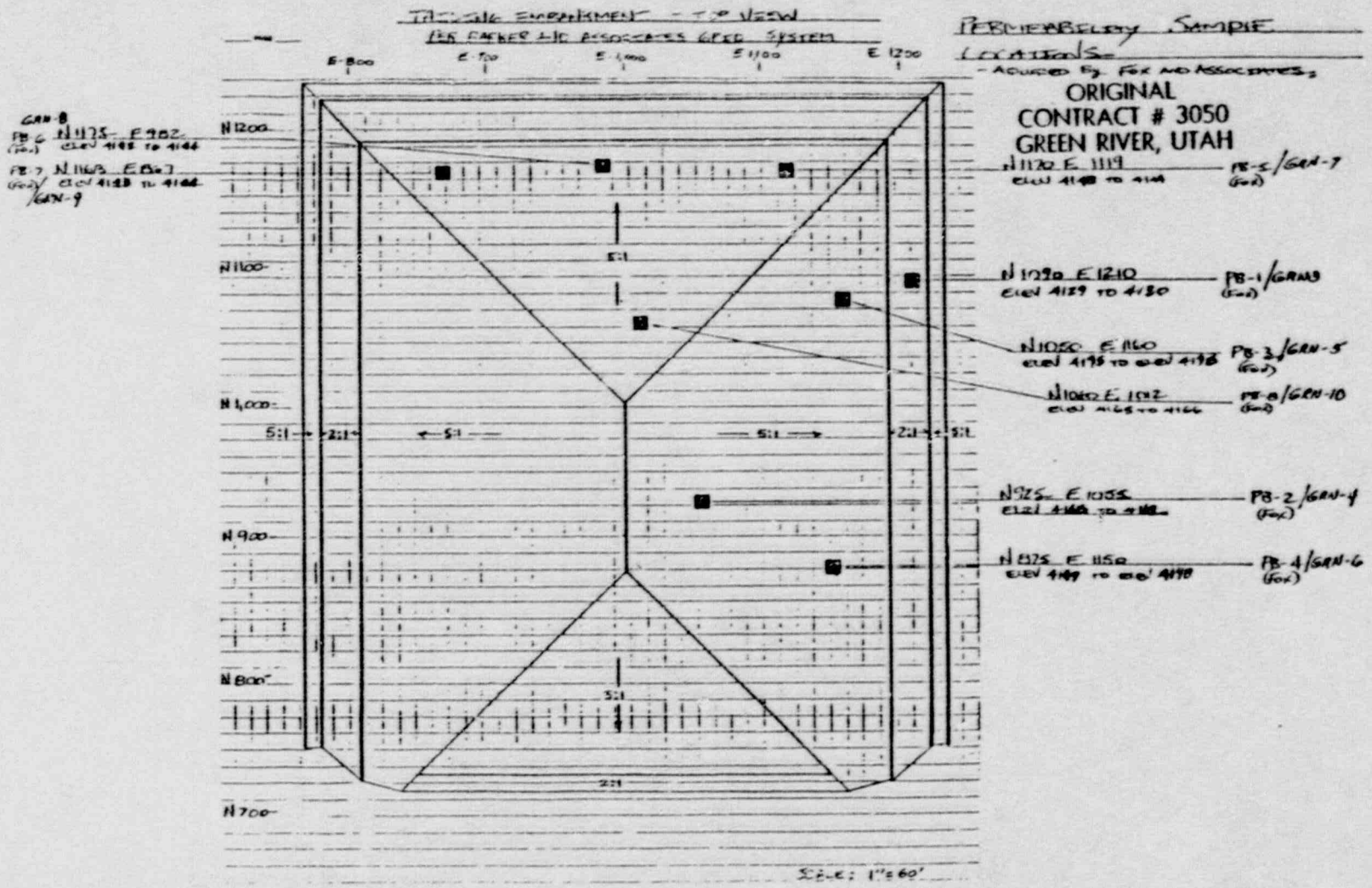
Fox Consultants of Colorado, Inc.

Green River Radon Barrier
Job No. 1-4250-799C-10
August 28, 1989

Laboratory Testing Summary

SAMPLE I.D.	MAX.DRY PCF	OPTIMUM M.C.%
GRN-3	119.0	12.5
GRN-4	116.0	12.0
GRN-5	115.0	12.0
GRN-6	112.0	15.0
GRN-7	116.0	11.5
GRN-8	112.5	13.5
GRN-9	117.0	12.0
GRN-10	115.0	14.0

SAMPLE I.D.	CLASSIFICATION	PERM. CM/SEC.	NATURAL DRY PCF	NATURAL M.C.%	SPECIFIC GRAVITY
PB-1	CL A-6(9)	5.8X10E-9	119.3	13.6	2.71
PB-2	CL A-6(3)	6.2X10E-9	117.1	17.0	2.69
PB-3	CH A-7-6(24)	9.0X10E-9	115.2	15.7	2.71



TYPICAL EMBANKMENT - TOP VIEW

FOR PARKER HE ASSOCIATES GREEN SYSTEM

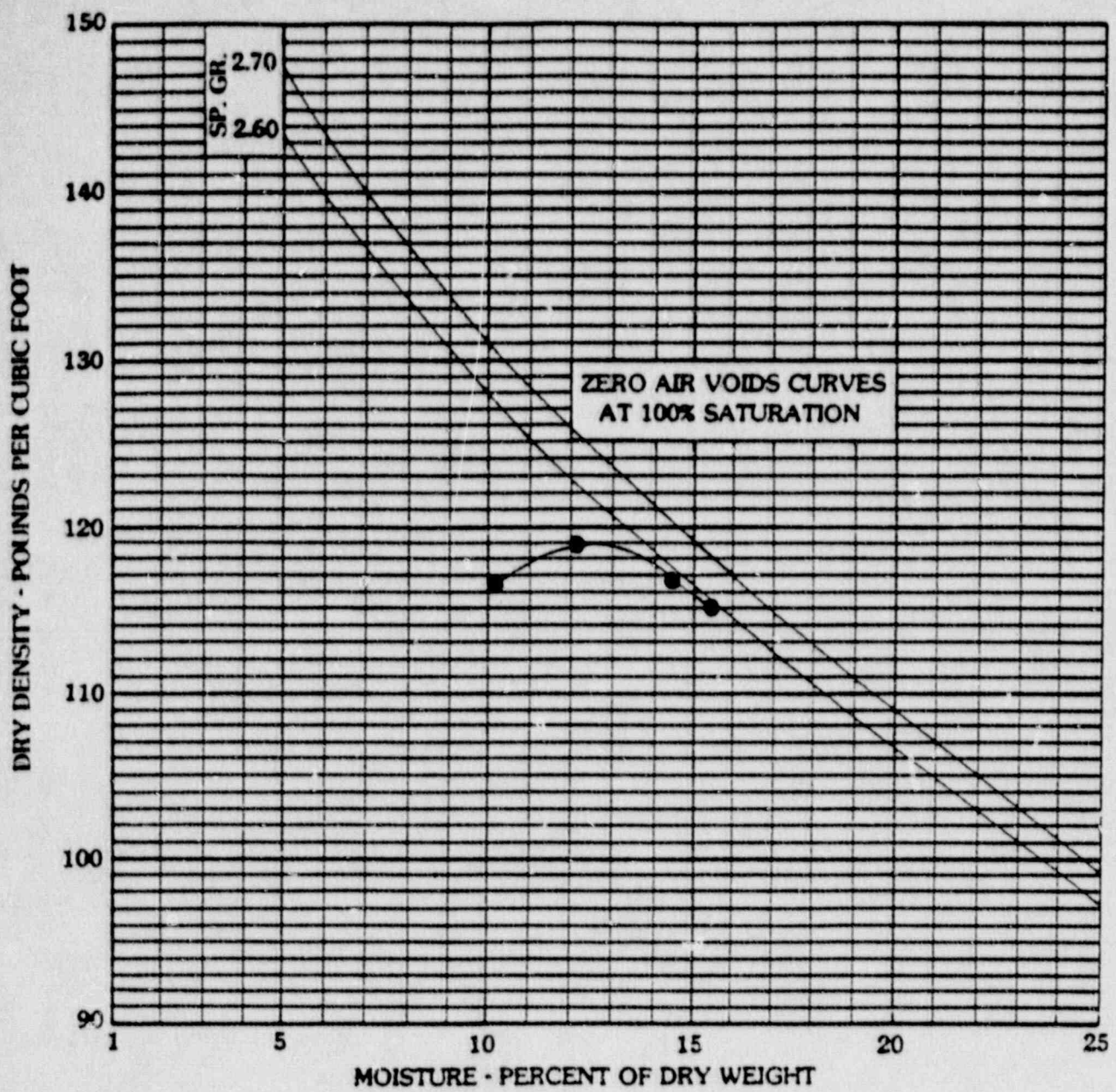
PERMEABILITY SAMPLE LOCATIONS

- ACQUIRED BY FOX AND ASSOCIATES

ORIGINAL
CONTRACT # 3050
GREEN RIVER, UTAH

SCALE: 1" = 60'

LABORATORY MOISTURE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 119.0 pcf **OPTIMUM MOISTURE CONTENT :** 12.5%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-3, PB-1

AMT. OF MATL. FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PL : PI :

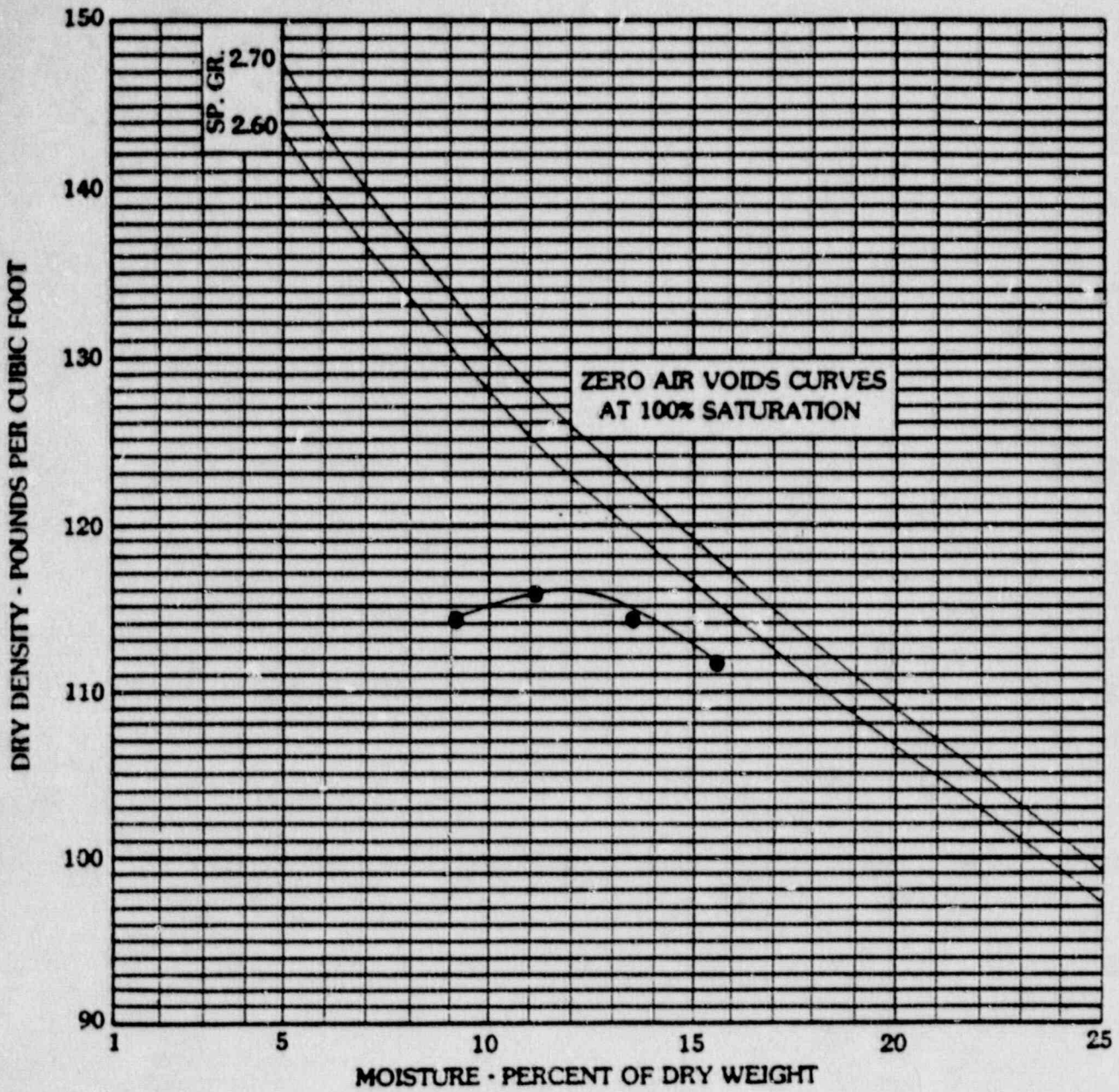
SWELL/CONSOLIDATION RESULTS :

UNCONFINED COMPRESSIVE STRENGTH :

CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOX GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 2

LABORATORY MOISTURE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 116.0 pcf **OPTIMUM MOISTURE CONTENT :** 12.0%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-4, PB-2

AMT. OF MAT'L. FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PL : PI :

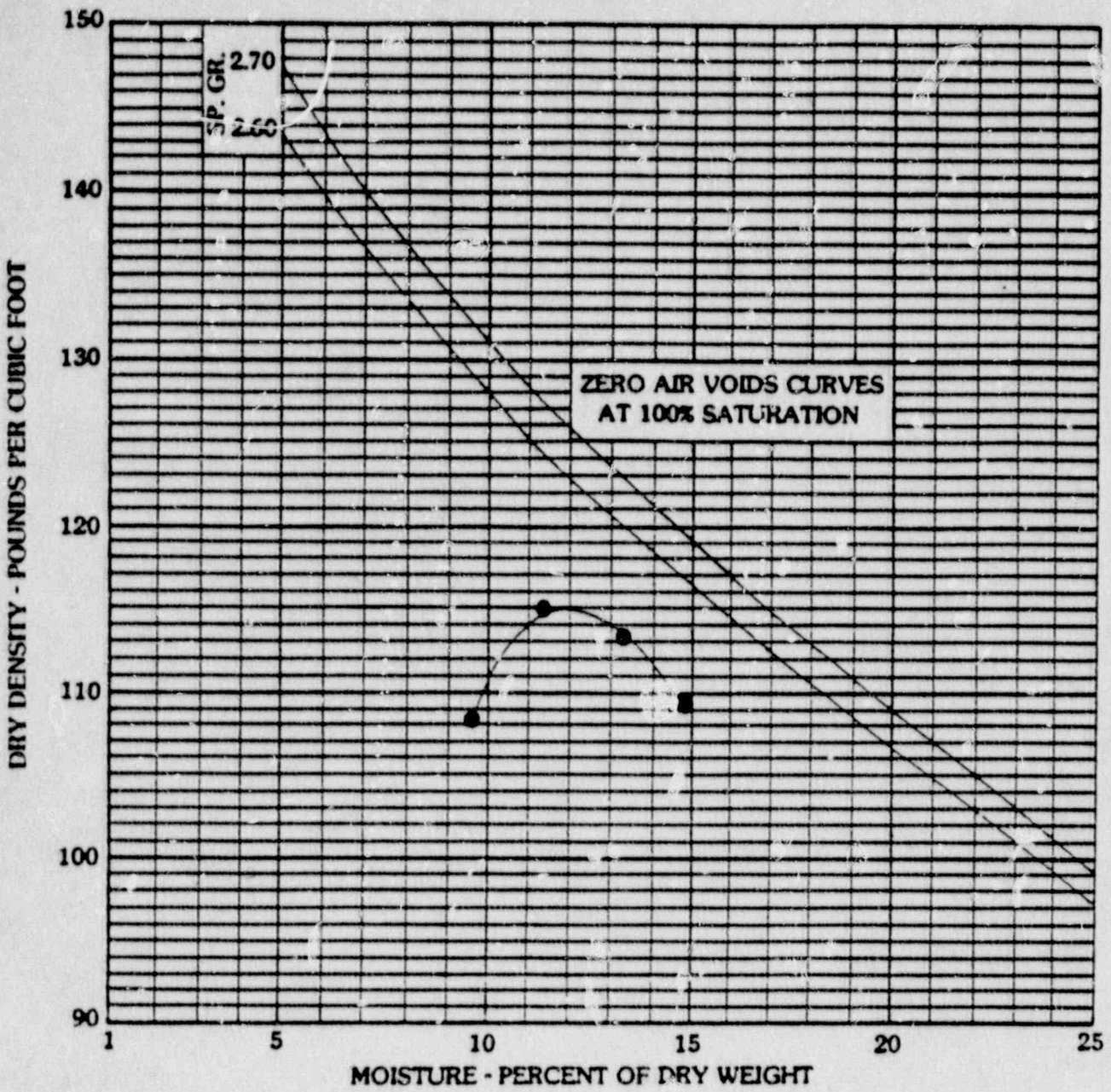
SWELL/CONSOLIDATION RESULTS :

UNCONFINED COMPRESSIVE STRENGTH :

CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOX GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 3

LABORATORY MOISTURE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 115.0 pcf OPTIMUM MOISTURE CONTENT : 12.0%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-5 PB-3

AMT. OF MAT'L. FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PL : PI :

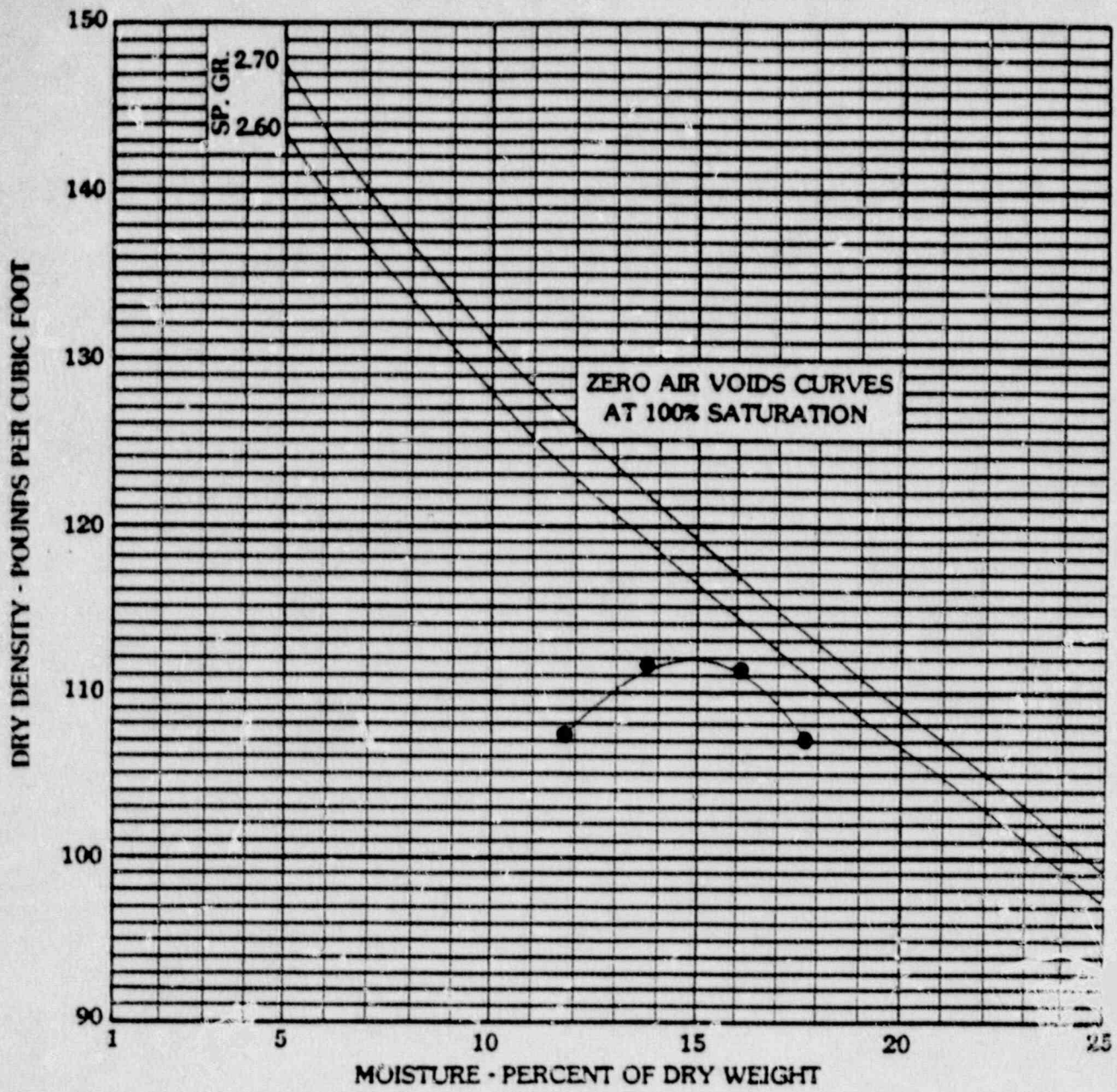
SWELL/CONSOLIDATION RESULTS :

UNCONFINED COMPRESSIVE STRENGTH :

CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOX GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 4

LABORATORY MOISTURE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 112.0 pcf OPTIMUM MOISTURE CONTENT : 15.0%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-6, PB-4

AMT. OF MAT'L. FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PL : PI :

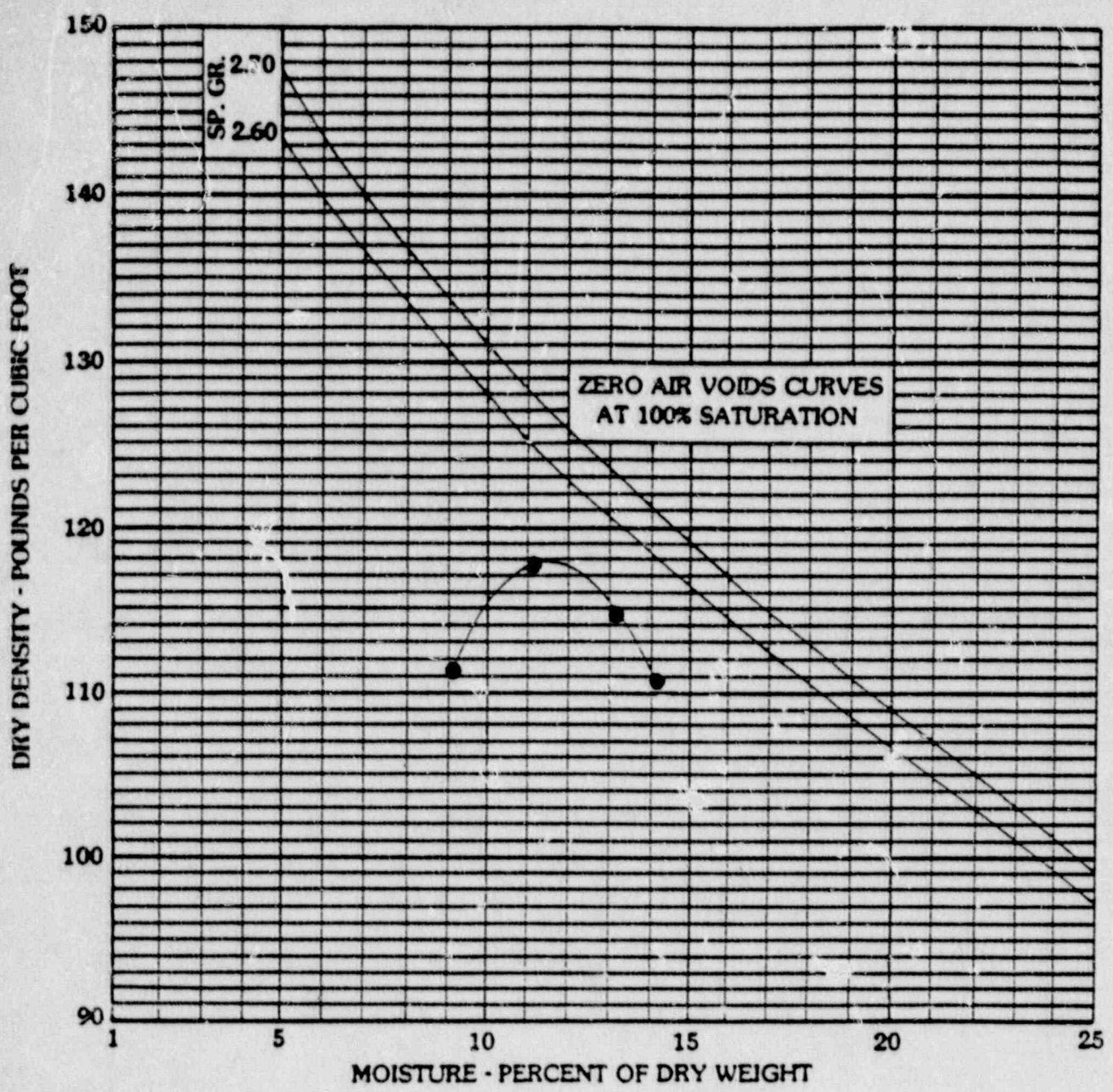
SWELL/CONSOLIDATION RESULTS :

UNCONFINED COMPRESSIVE STRENGTH :

CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOX GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 5

LABORATORY MOISTURE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 118.0 pcf **OPTIMUM MOISTURE CONTENT :** 11.5%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-7, PB-5

AMT. OF MAT'L. FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PL : PI :

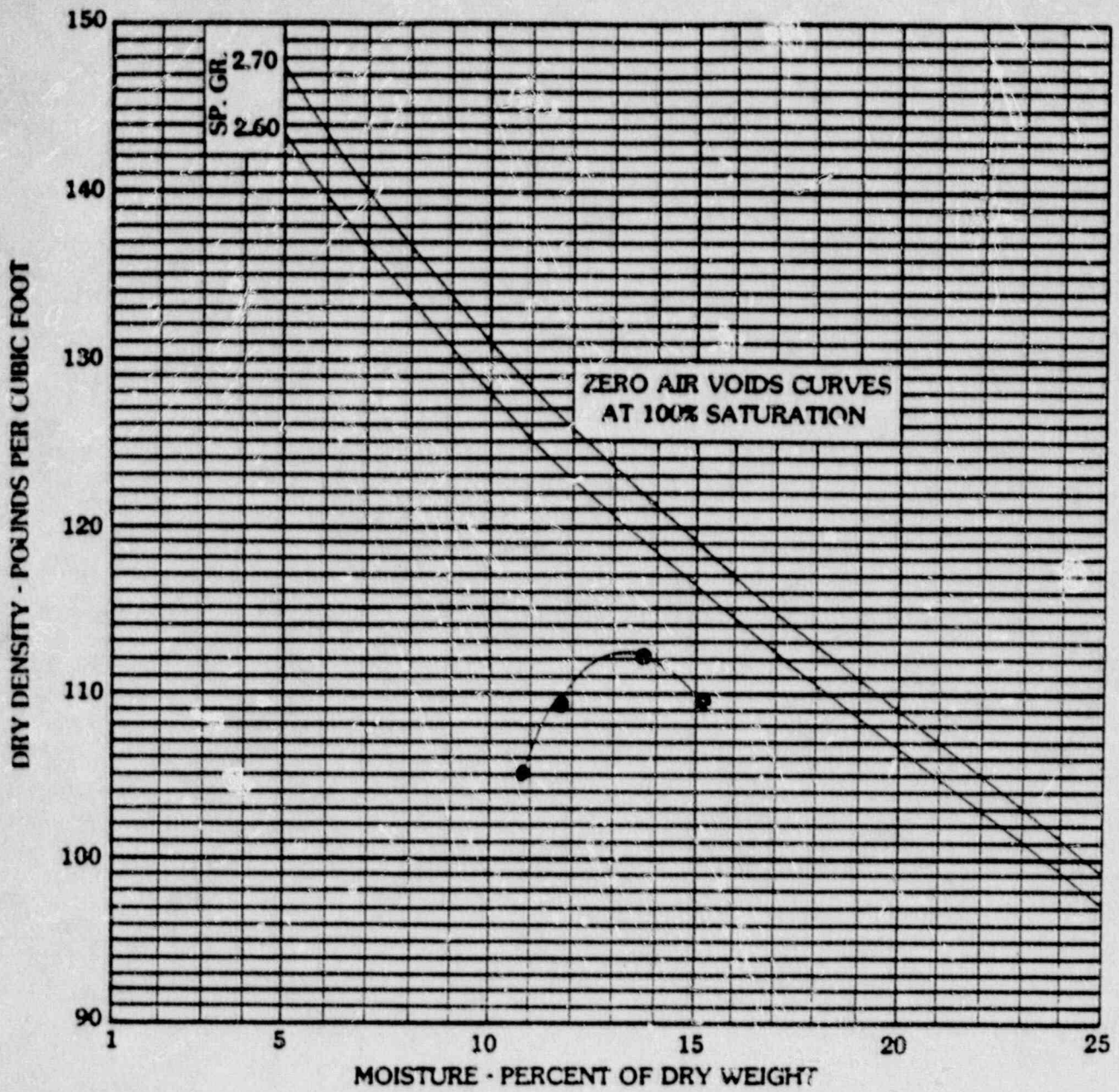
SWELL/CONSOLIDATION RESULTS :

UNCONFINED COMPRESSIVE STRENGTH :

CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOY GEOTECHNICAL MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 6

LABORATORY MOISTURE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 112.5 pcf **OPTIMUM MOISTURE CONTENT :** 13.5%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-8, PB-6

AMT. OF MAT'L. FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PL : PI :

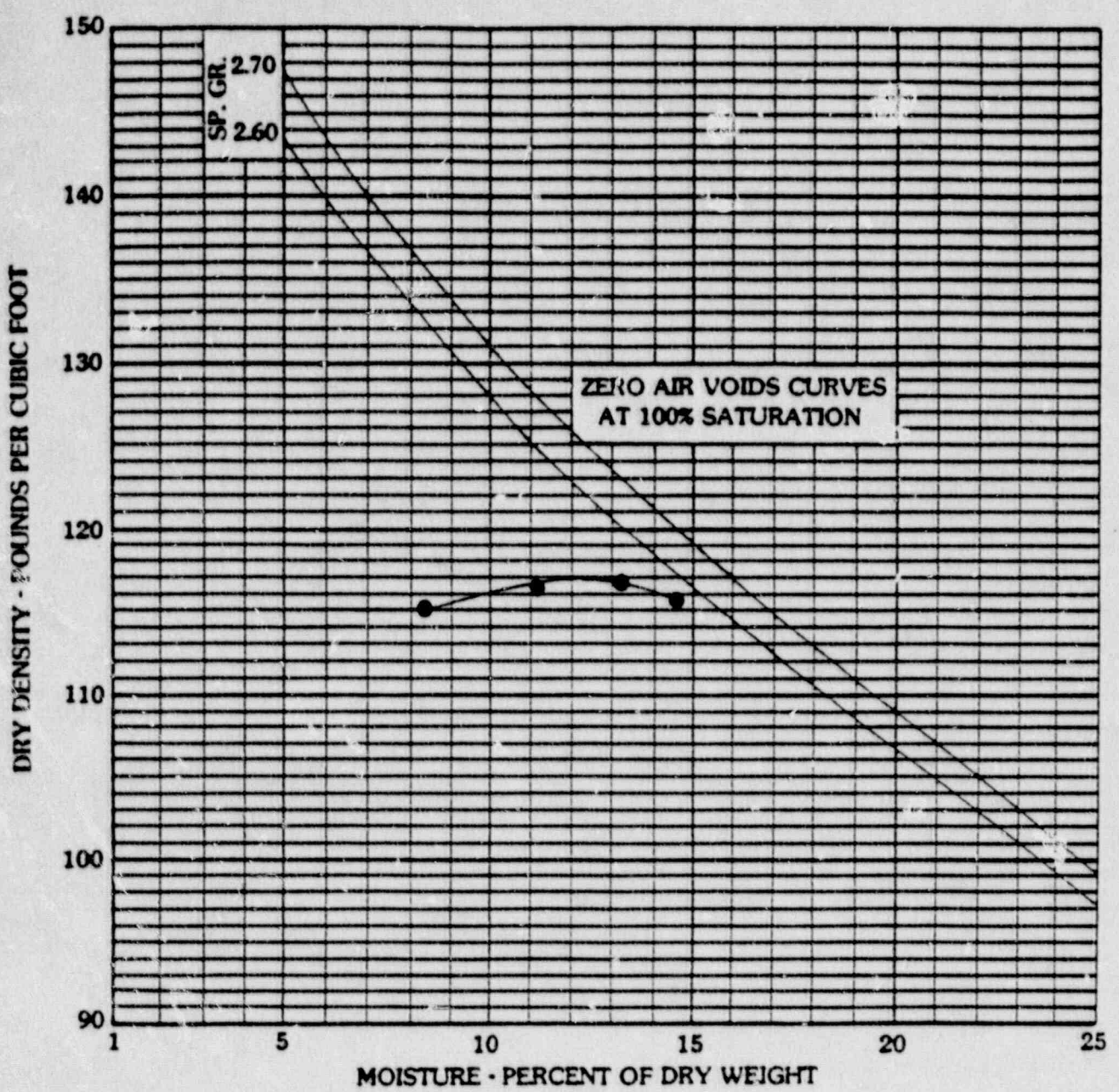
SWELL/CONSOLIDATION RESULTS :

UNCONFINED COMPRESSIVE STRENGTH :

CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOX GEOTECHNICAL MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 7

LABORATORY MOISTURE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 117.0 pcf OPTIMUM MOISTURE CONTENT : 12.0%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-9, PB-10

AMT. OF MAT'L. FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PL : PI :

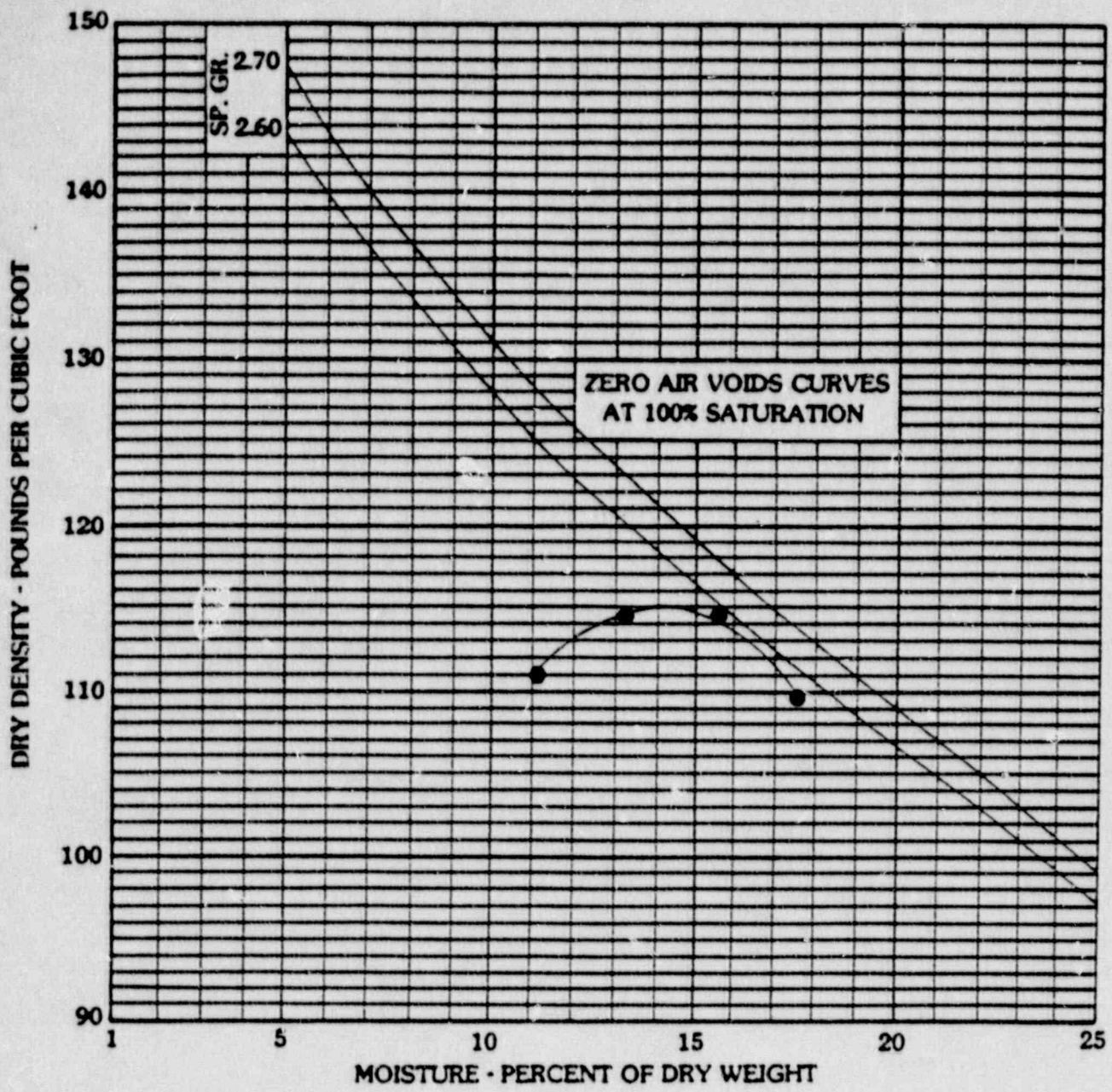
SWELL/CONSOLIDATION RESULTS :

UNCONFINED COMPRESSIVE STRENGTH :

CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOX GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 8

LABORATORY MOISTUKE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 115.0 pcf **OPTIMUM MOISTURE CONTENT :** 14.0%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-10, PB-8

AMT. OF MAT'L. FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PL : PI :

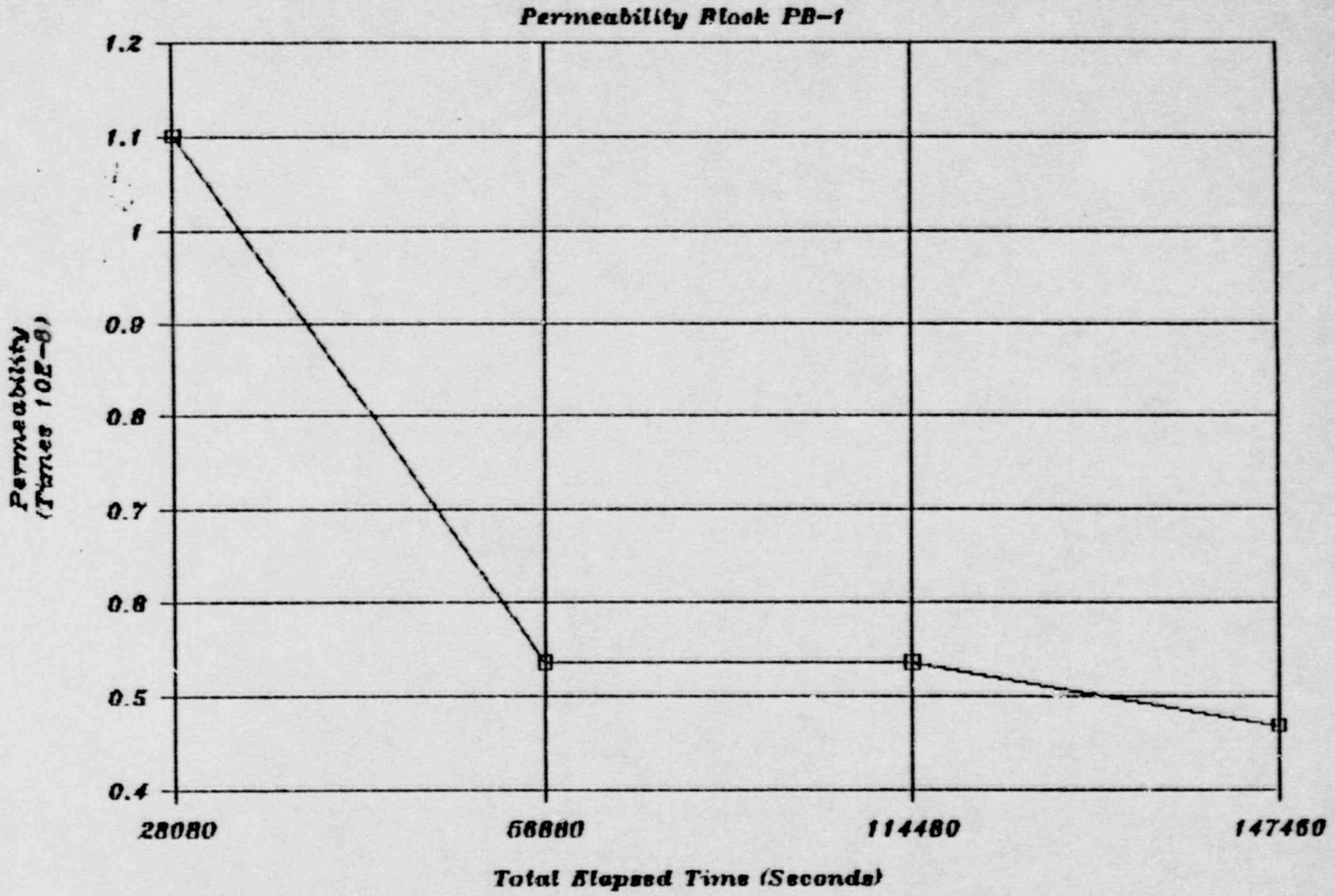
SWELL/CONSOLIDATION RESULTS :

UNCONFINED COMPRESSIVE STRENGTH :

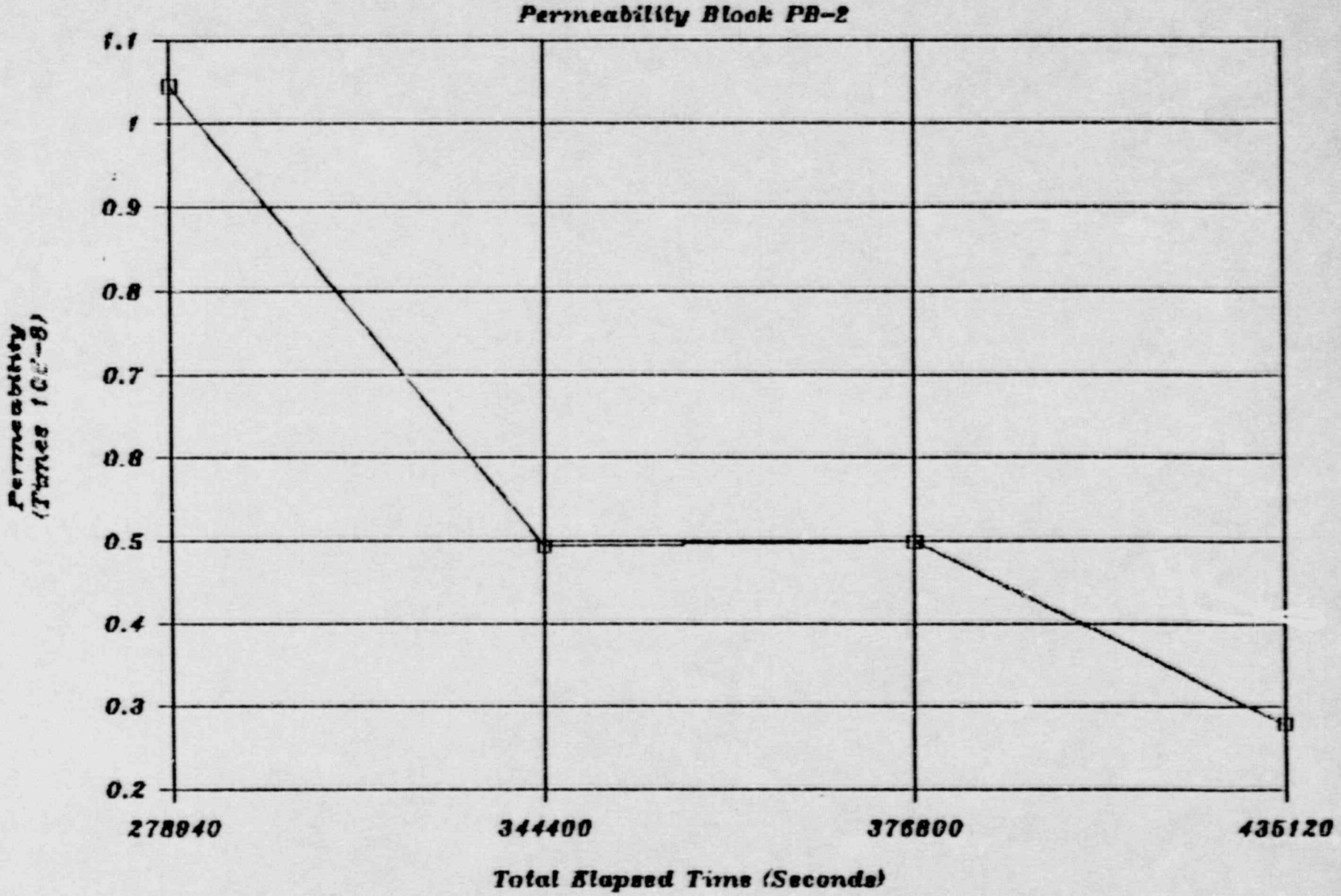
CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOX GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 9

Green River Radon Barrier



Green River Radon Barrier



Green River Radon Barrier

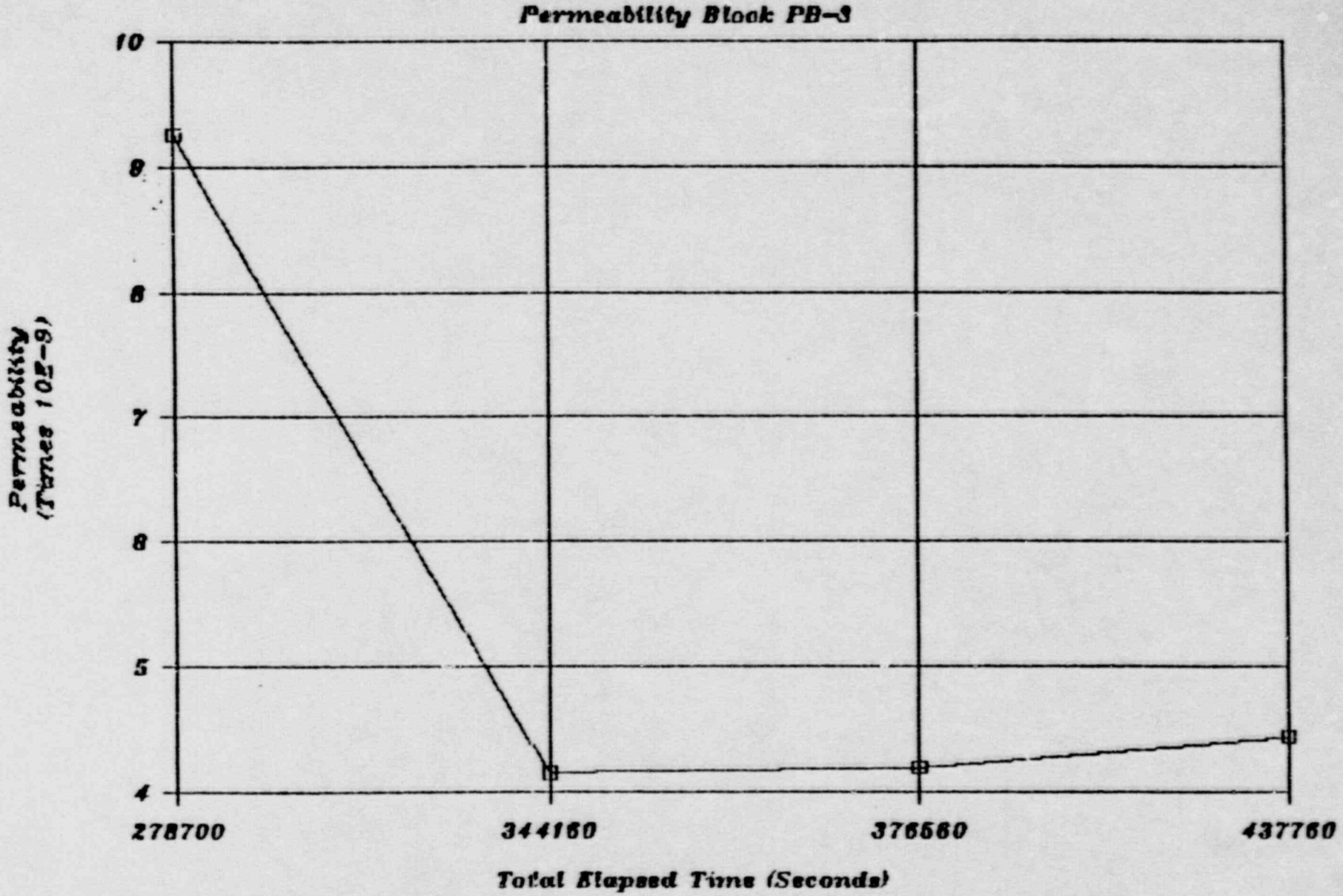


Figure 12

Permeability Work Sheet

Sample No.	PB-1
Location:	Radon Barrier Green River , Utah

Length of sample (cm)	12.289
Area of Burette (cm^2)	1.262
Area of sample (cm^2)	28.509
Head (cm)	352

Elapsed Time Sec.	Total Time Sec.	Burette Reading H cm	Delta H cm	Permeability (cm/sec)
0	0	7.3	0	
28080	28080	7.1	0.2	0.000000011
28800	56880	7	0.1	0.0000000054
57600	114480	6.8	0.2	0.0000000054
32980	147460	6.7	0.1	0.0000000047

Permeability Work Sheet

Sample No.	PB-2
Location:	Radon Barrier Green River , Utah

Length of sample (cm)	12.911
Area of Burette (cm^2)	1.262
Area of sample (cm^2)	28.606
Head (cm)	352

Elapsed Time Sec.	Total Time Sec.	Burette Reading H cm	Delta H cm	Permeability (cm/sec)
0	0	24.6	0	
278940	278940	22.8	1.8	0.0000000104
65400	344400	22.6	0.2	0.0000000049
32400	376800	22.5	0.1	0.0000000065
58320	435120	22.4	0.1	0.0000000028

Permeability Work Sheet

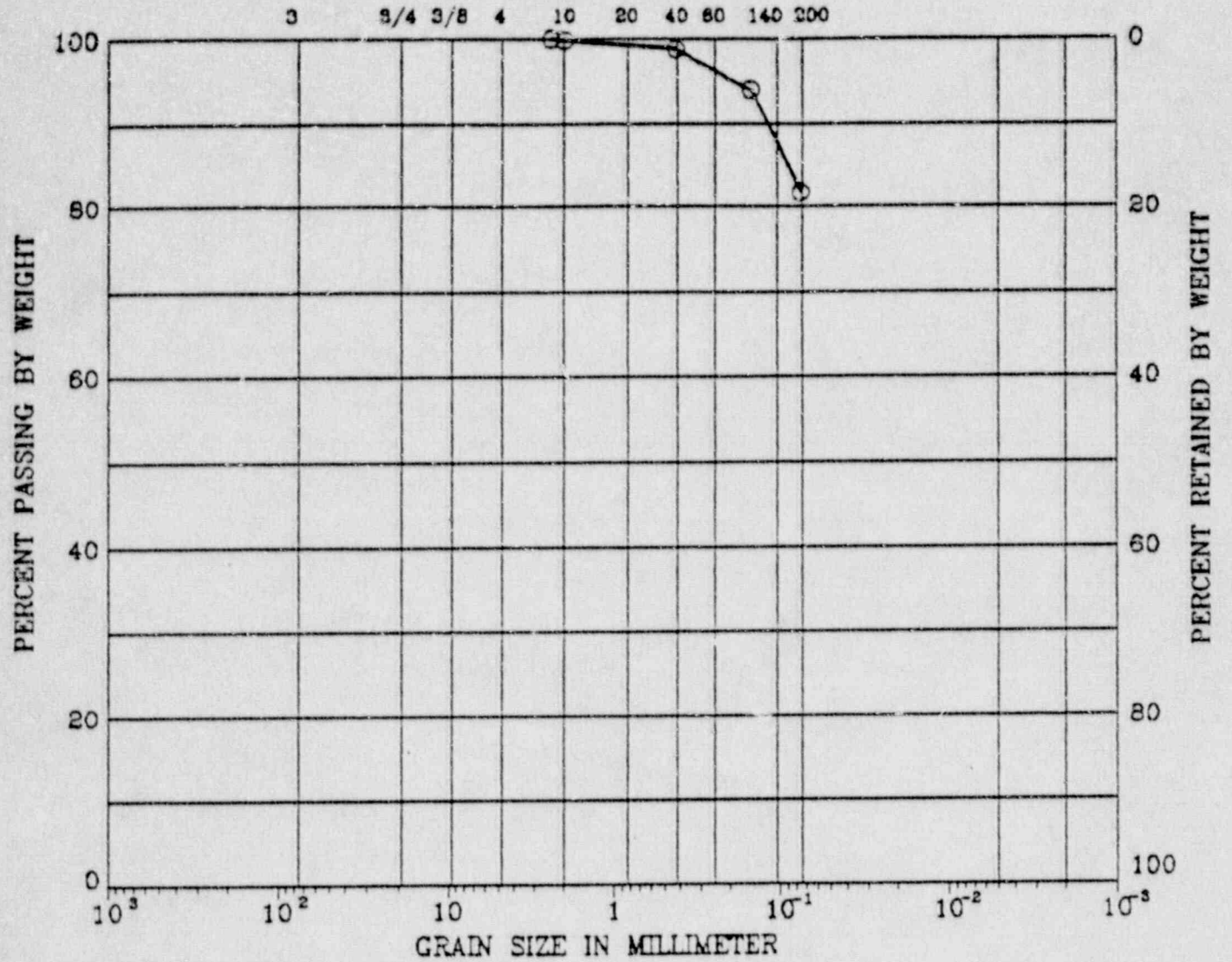
Sample No. PB-3
Location: Radon Barrier
Green River , Utah

Length of sample (cm)	10.744
Area of Burette (cm^2)	1.262
Area of sample (cm^2)	28.389
Head (cm)	352

Elapsed Time Sec.	Total Time Sec.	Burette Reading H cm	Delta H cm	Permeability (cm/sec)
0	0	26.3	0	
278700	278700	24.4	1.9	0.0000000093
65460	344160	24.2	0.2	0.0000000041
32400	376560	24.1	0.1	0.0000000042
61200	437760	23.9	0.2	0.0000000044

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



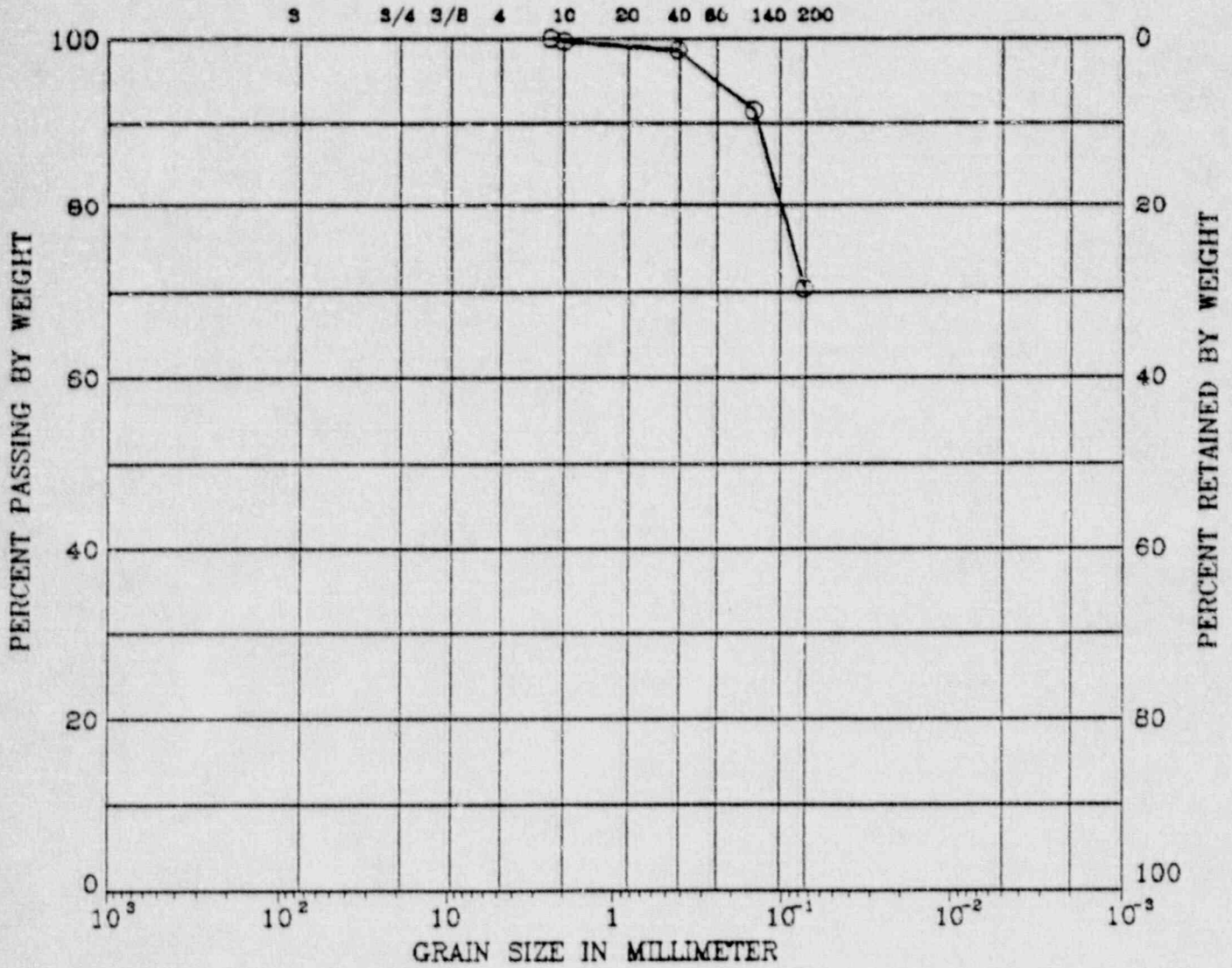
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	PB-1	N/A	34	11	CL A-6(9)

Remark : PERMEABILITY BLOCK SAMPLE PB-1

1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No.13

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



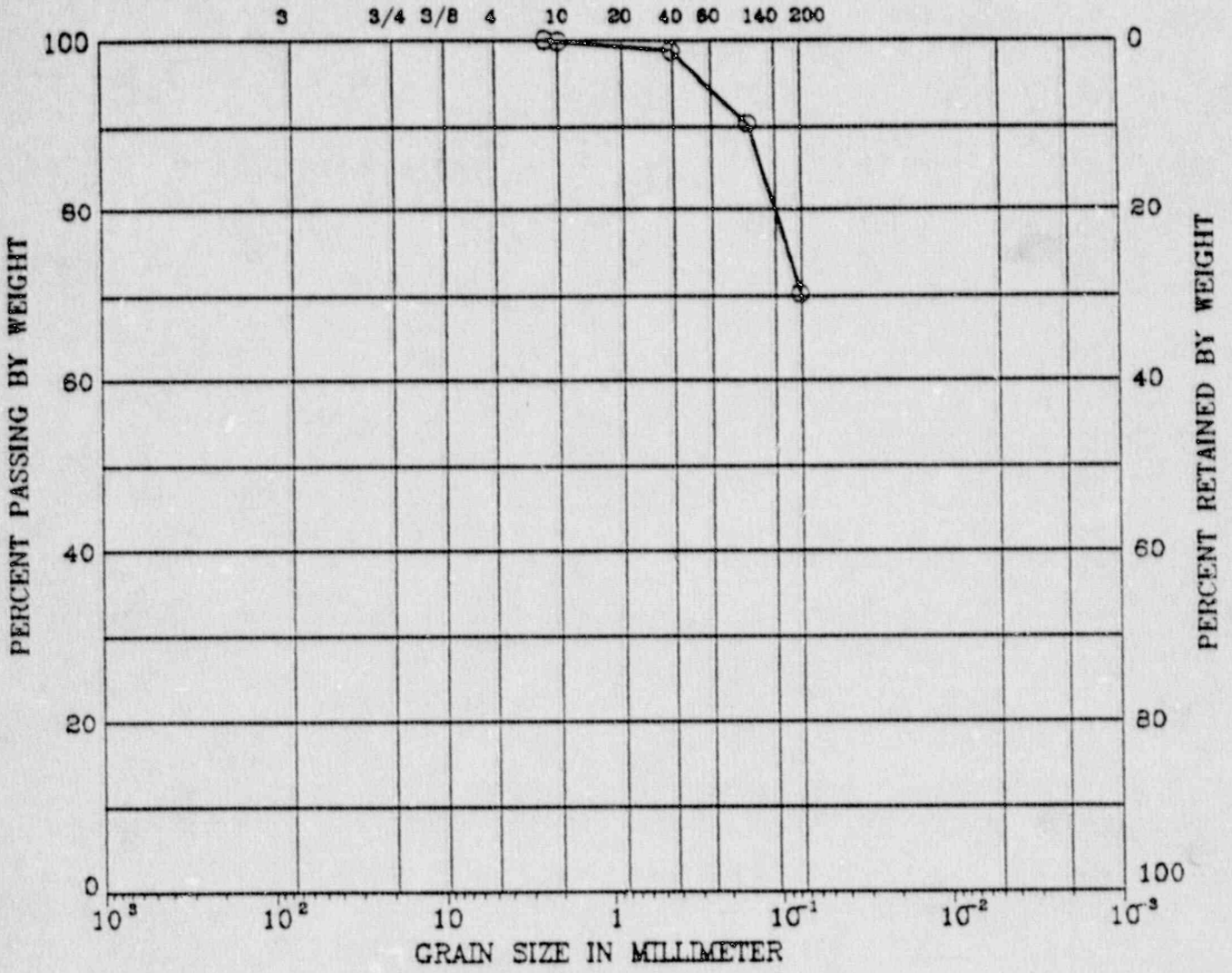
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	PB-2	N/A	28	15	CL A-6(8)

Remark : PERMEABILITY BLOCK SAMPLE PB-2

1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No. 14

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
O	PB-3	N/A	68	51	CH A-7-6(34)

Remark : PERMEABLITY BLOCK SAMPLE PB-3

1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No.15

FOX CONSULTANTS
OF COLORADO, INC.
GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS
DENVER ALBUQUERQUE

September 27, 1989

M-K Ferguson Company
PO Box 361
Green River, Utah 84525

Attention: Mr. John Singleton

Job No. 1-4250-7993-10

Dates of Testing: August 30 through September 26, 1989

Subject: Field Sampling and Laboratory Testing, Radon Barrier, Green River, Utah

Dear Mr. Singleton:

At your request, an engineering technician was provided to obtain samples for laboratory testing at the subject project. The technician obtained permeability block samples PB-9 through 12 and bulk samples GRN-11 through 14 on August 30, 1989. Permeability block samples PB-13 and 14 and bulk samples GRN-15 and 16 were obtained on August 31, 1989. The permeability block samples were obtained in accordance with the Bureau of Reclamation Earth Manual, Des. E-2, Part A. Sample locations are shown on Figure 1. All samples were returned to our laboratory for testing.

The results of moisture-density relations testing performed on bulk samples GRN-11 through 16 are presented on Figures 2 through 7. The results of permeability testing performed on permeability block samples PB-4 through 14 are presented on Figures 8 through 18. The results of specific gravity testing are included on Table 1. The results of sieve analysis testing performed on permeability block samples PB-4 through PB-14 are presented on Figures 19 through 29. Test results have been summarized on Table 1 for your convenience.

M-K Ferguson Company
Attention: Mr. John Singleton
Job No. 1-4250-7993-10
September 27, 1989

All laboratory testing scheduled has been completed. If we may be of further assistance in evaluating these data, please contact us at your convenience.

Respectfully submitted,

FOX CONSULTANTS OF COLORADO, INC.

Mary H. Broncucia

Mary H. Broncucia, C.E.T.

REGISTERED PROFESSIONAL ENGINEER
DONALD R. CLARK
5280
STATE OF UTAH

Reviewed by:

Donald R. Clark

Donald R. Clark, P.E.
Principal Engineer

MHB/nh

Copies: 3

Attached: Location Map, Figure 1
Moisture-Density Curves, Figures 2-7
Permeability Results, Figures 8-18
Sieve Analysis/Plasticity Index, Figures 19-29
Summary, Table 1

DAILY DIARY

PROJECT: GREEN RIVER RADON BARRIER

LOCATION: GREEN RIVER, UTAH

SOURCE: RADON BARRIER

PROJECT NO: 1-4250-7993-10 **REPORT NO:** N/A **DATE:** 8/30/89

PROCTOR NO: N/A **TIME:** N/A

SAMPLE NO: N/A **ENGINEERING TECHNICIAN:** BASHAM

WORK PERFORMED:

Four permeability block samples and four bulk soil samples were obtained at the given locations and elevations. All samples were transported to our laboratory for Proctor determination, permeability testing, sieve analysis, and specific gravity determination.

REMARKS:

Samples from locations PB-11 and PB-12 were obtained from the third lift before the fourth lift was placed and compacted.

DAILY DIARY

PROJECT: GREEN RIVER RADON BARRIER

LOCATION: GREEN RIVER, UTAH

SOURCE: RADON BARRIER

PROJECT NO: 1-4250-7993-10 **REPORT NO:** N/A **DATE:** 8/31/89

PROCTOR NO: N/A **TIME:** N/A

SAMPLE NO: N/A **ENGINEERING TECHNICIAN:** BASHAM

WORK PERFORMED:

Two permeability block samples and two bulk soil samples were obtained at the given locations and elevations. All samples were transported to our laboratory for Proctor determination, permeability testing, sieve analysis and specific gravity determination.

REMARKS:

Fox Consultants of Colorado, Inc.

Green River Radon Barrier
Job No. 1-4250-7993-10
September 27, 1989

LABORATORY TESTING SUMMARY

SAMPLE I.D.	MAX.DRY PCF	OPTIMUM M.C.%	PERM. CM/SEC.	NATURAL DRY PCF	NATURAL M.C.%	SPECIFIC GRAVITY
GRN-11	116.0	15.0				
GRN-12	115.5	14.5				
GRN-13	114.5	14.5				
GRN-14	113.0	15.0				
GRN-15	110.0	17.0				
GRN-16	116.0	12.5				
PB-4			3.8X10E-9	112.5	16.8	2.70
PB-5			3.4X10E-9	118.5	14.9	2.68
PB-6			7.8X10E-9	111.9	15.0	2.71
PB-7			1.5X10E-8	120.8	16.6	2.70
PB-8			2.6X10E-9	116.1	16.6	2.67
PB-9			1.3X10E-8	114.6	17.3	2.65
PB-10			1.3X10E-8	118.1	16.1	2.68
PB-11			2.0X10E-9	115.7	17.7	2.72
PB-12			1.7X10E-9	112.6	17.3	2.70
PB-13			2.4X10E-9	109.8	18.5	2.66
PB-14			2.9X10E-9	115.9	17.5	2.67

Table 1

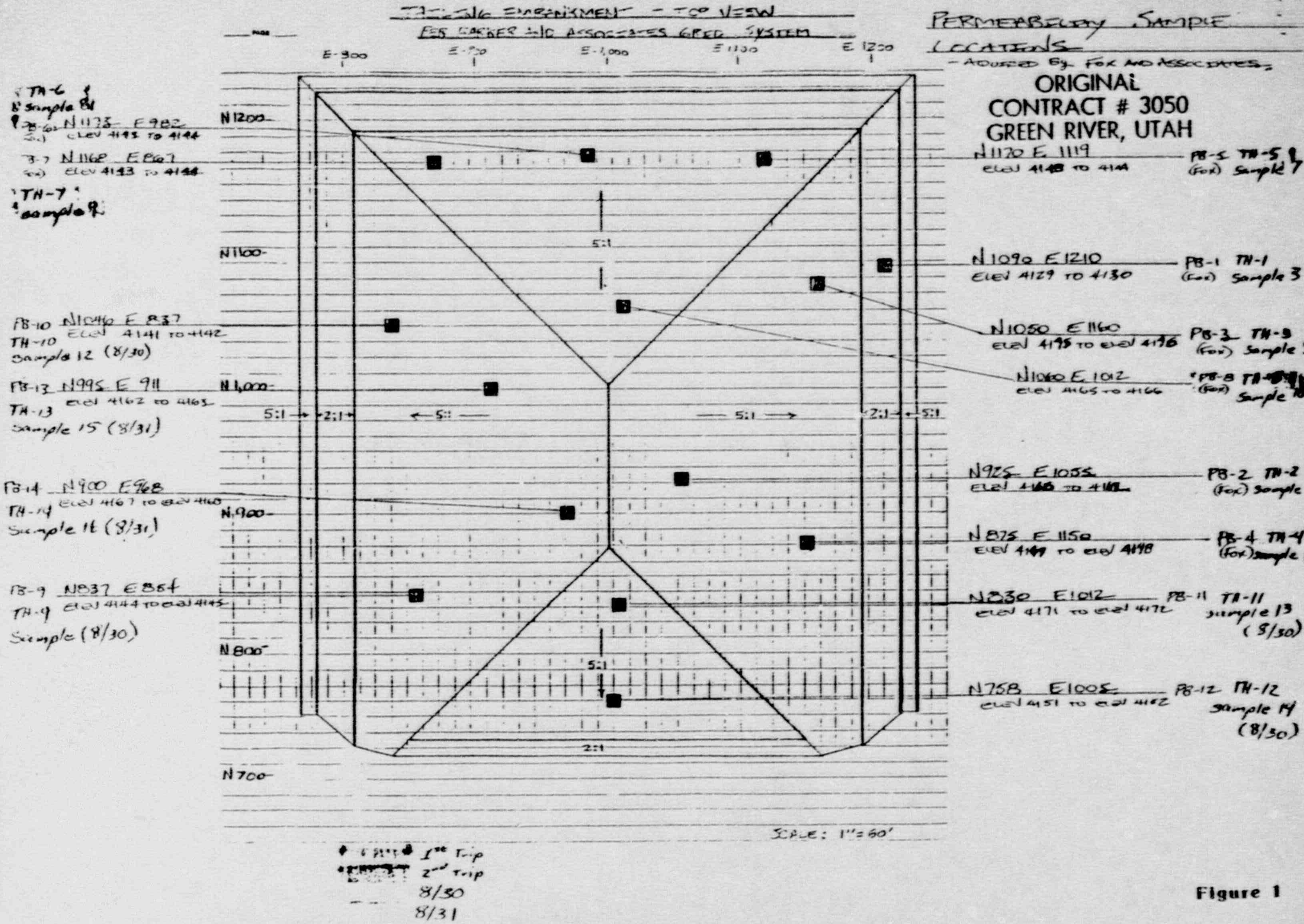
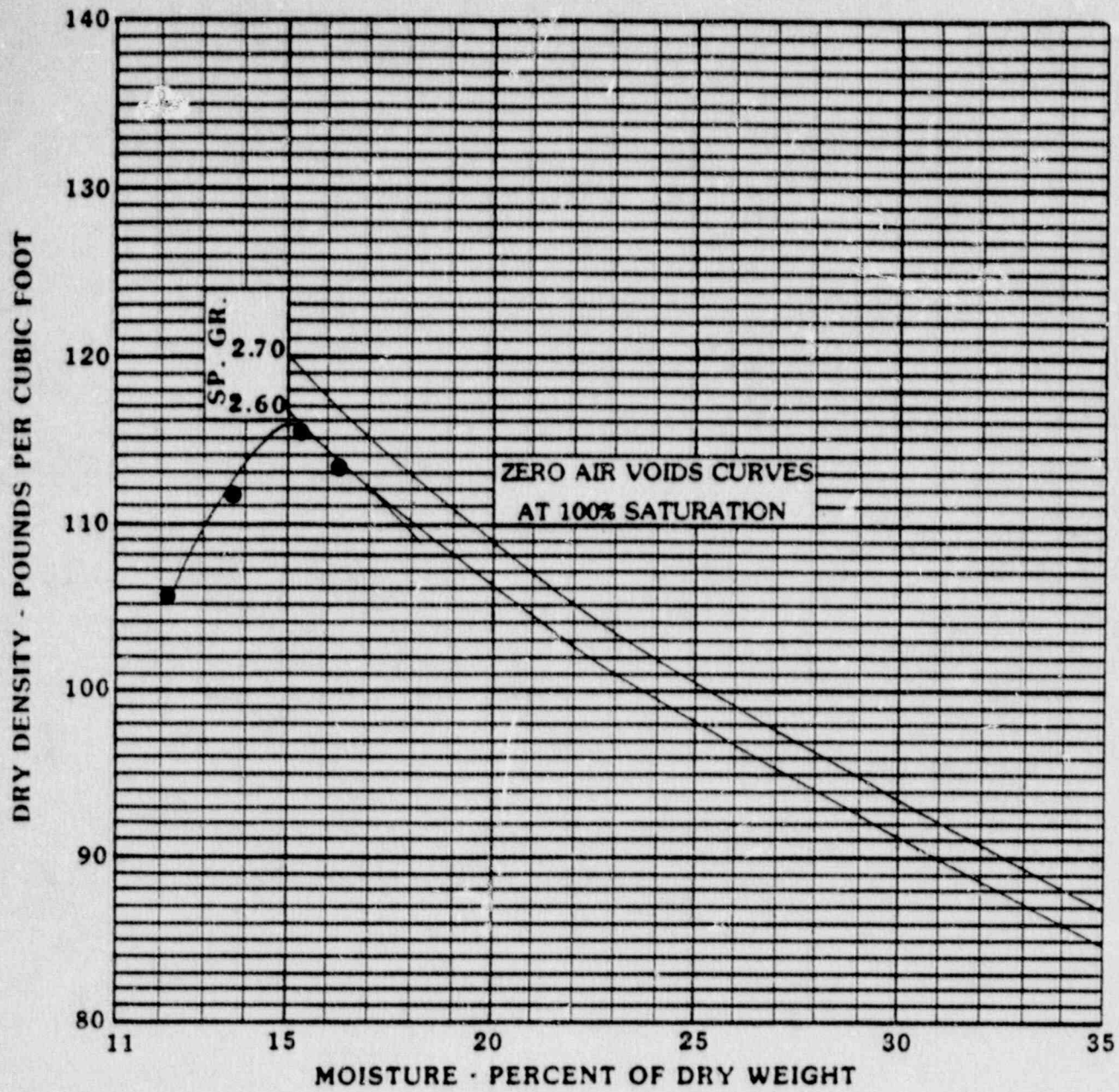

TAILING EMBANKMENT - TOP VIEW
PER BARKER AND ASSOCIATES GRID SYSTEM
PERMEABILITY SAMPLE LOCATIONS
- ADVISED BY FOX AND ASSOCIATES
ORIGINAL
CONTRACT # 3050
GREEN RIVER, UTAH
E 900
E 950
E 1,000
E 1100
E 1200
N1200
N1100
N1,000
N900
N800
N700
5:1
2:1
TH-6 Sample 8
PB-6 N1173 E982
ELEV 4143 TO 4144
PB-7 N1168 E867
ELEV 4143 TO 4144
TH-7 Sample 9
PB-10 N1040 E837
ELEV 4141 TO 4142
TH-10
Sample 12 (8/30)
PB-13 N995 E911
ELEV 4162 TO 4163
TH-13
Sample 15 (8/31)
PB-14 N900 E968
ELEV 4167 TO ELEV 4168
TH-14
Sample 16 (8/31)
PB-9 N837 E884
ELEV 4144 TO ELEV 4145
TH-9
Sample (8/30)
N1120 E1119
ELEV 4148 TO 4144
PB-5 TH-5 (Fox) Sample 7
N1090 E1210
ELEV 4129 TO 4130
PB-1 TH-1 (Fox) Sample 3
N1050 E1160
ELEV 4195 TO ELEV 4196
PB-3 TH-3 (Fox) Sample 5
N1060 E1012
ELEV 4165 TO 4166
PB-8 TH-8 (Fox) Sample 10
N925 E1055
ELEV 4166 TO 4168
PB-2 TH-2 (Fox) Sample 4
N875 E1150
ELEV 4149 TO ELEV 4148
PB-4 TH-4 (Fox) Sample 6
N830 E1012
ELEV 4171 TO ELEV 4172
PB-11 TH-11 Sample 13 (8/30)
N758 E1005
ELEV 4151 TO ELEV 4152
PB-12 TH-12 Sample 14 (8/30)
SCALE: 1"=60'
1st Trip
2nd Trip
8/30
8/31

Figure 1

LABORATORY MOISTURE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 116.0 pcf **OPTIMUM MOISTURE CONTENT :** 15.0%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-11 PB-9

AMT. OF MAT'L FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PL : PI :

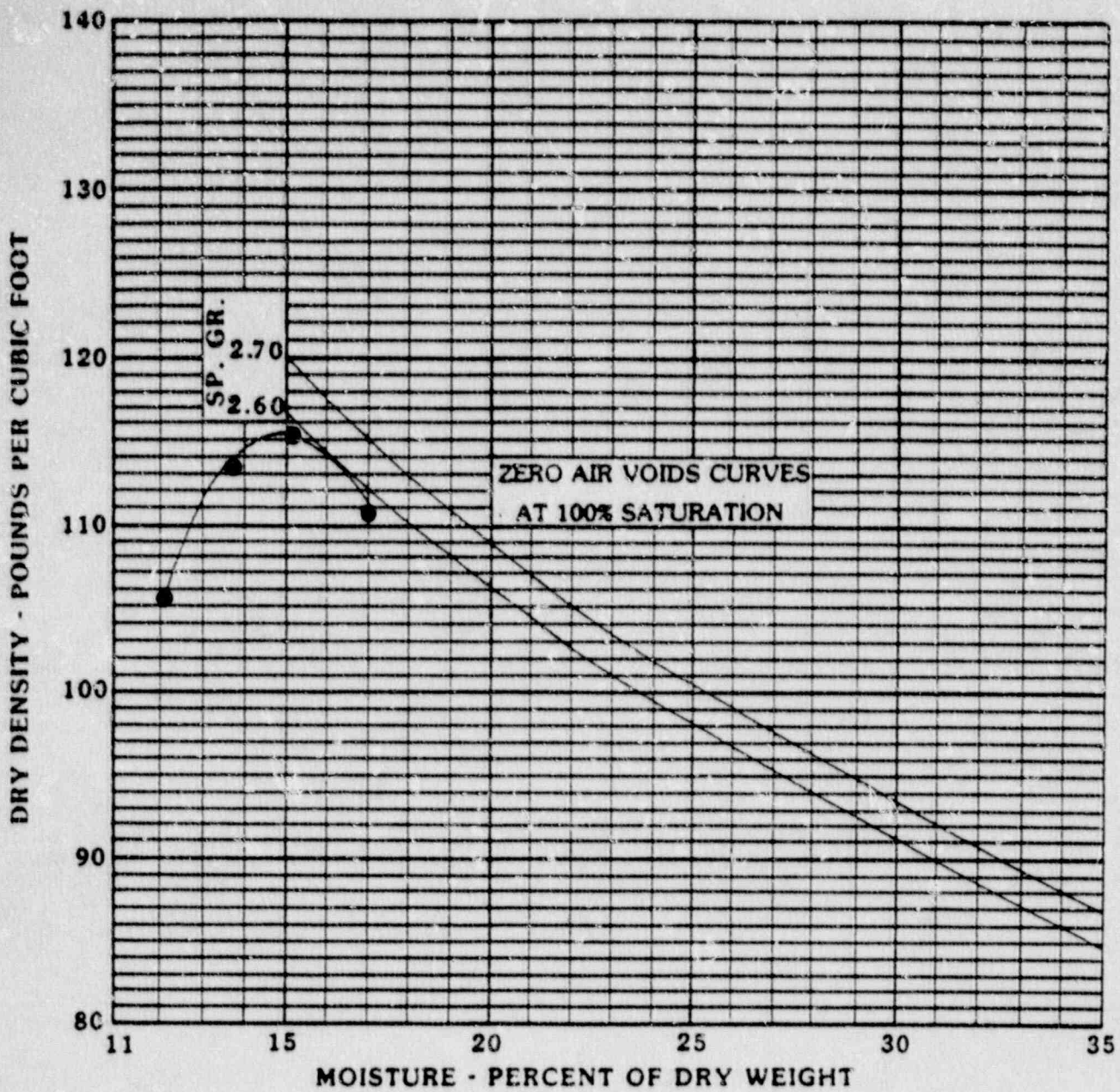
SWELL/CONSOLIDATION RESULTS

UNCONFINED COMPRESSIVE STRENGTH :

CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOX GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 2

LABORATORY MOISTURE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 115.5 pcf **OPTIMUM MOISTURE CONTENT :** 14.5%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-12 PB-10

AMT. OF MAT'L FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PI. : PI :

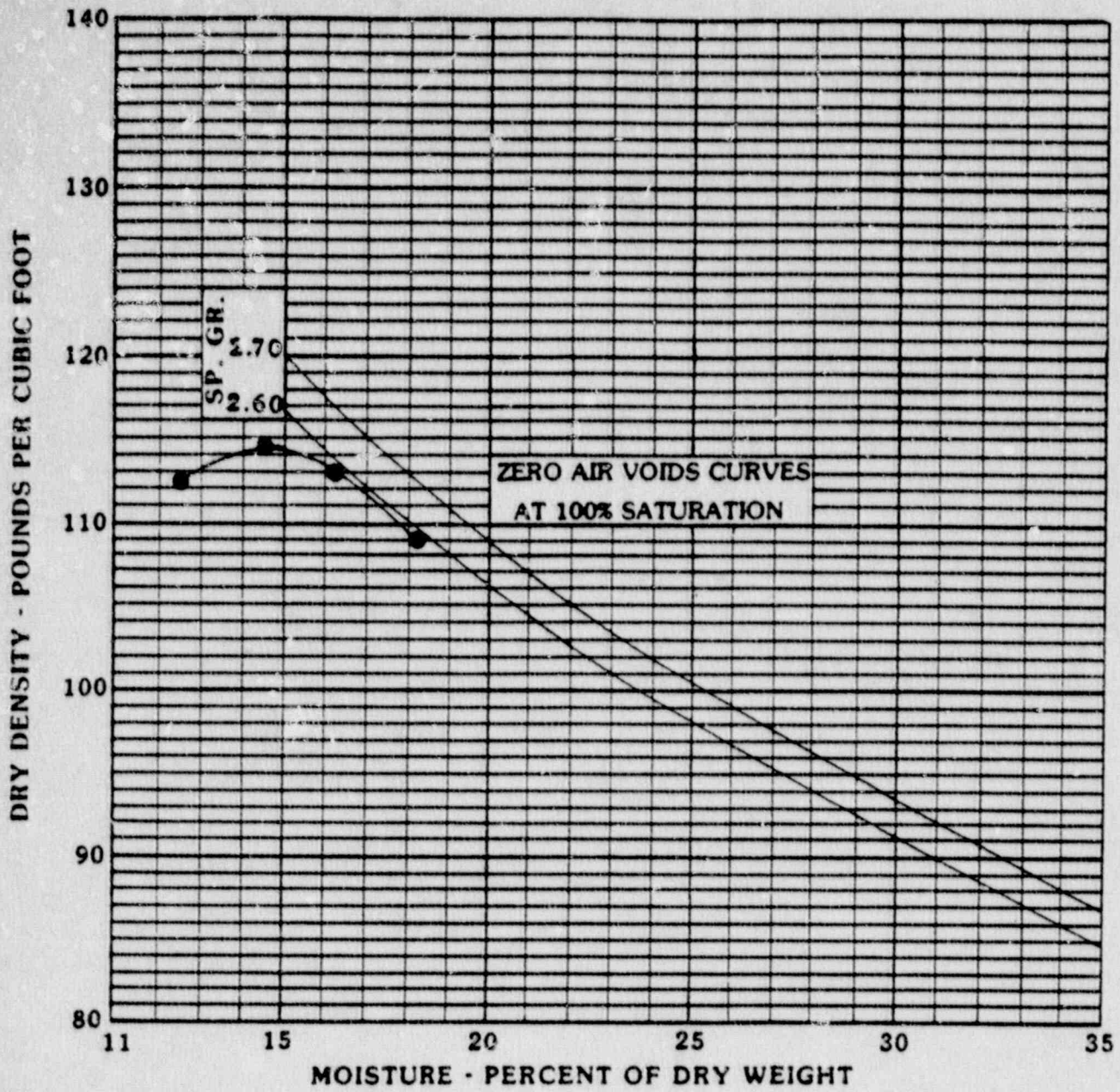
SWELL/CONSOLIDATION RESULTS

UNCONFINED COMPRESSIVE STRENGTH :

CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOX GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 3

LABORATORY MOISTURE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 114.5 pcf **OPTIMUM MOISTURE CONTENT :** 14.5%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-13 PB-11

AMT. OF MAT'L FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PL : PI :

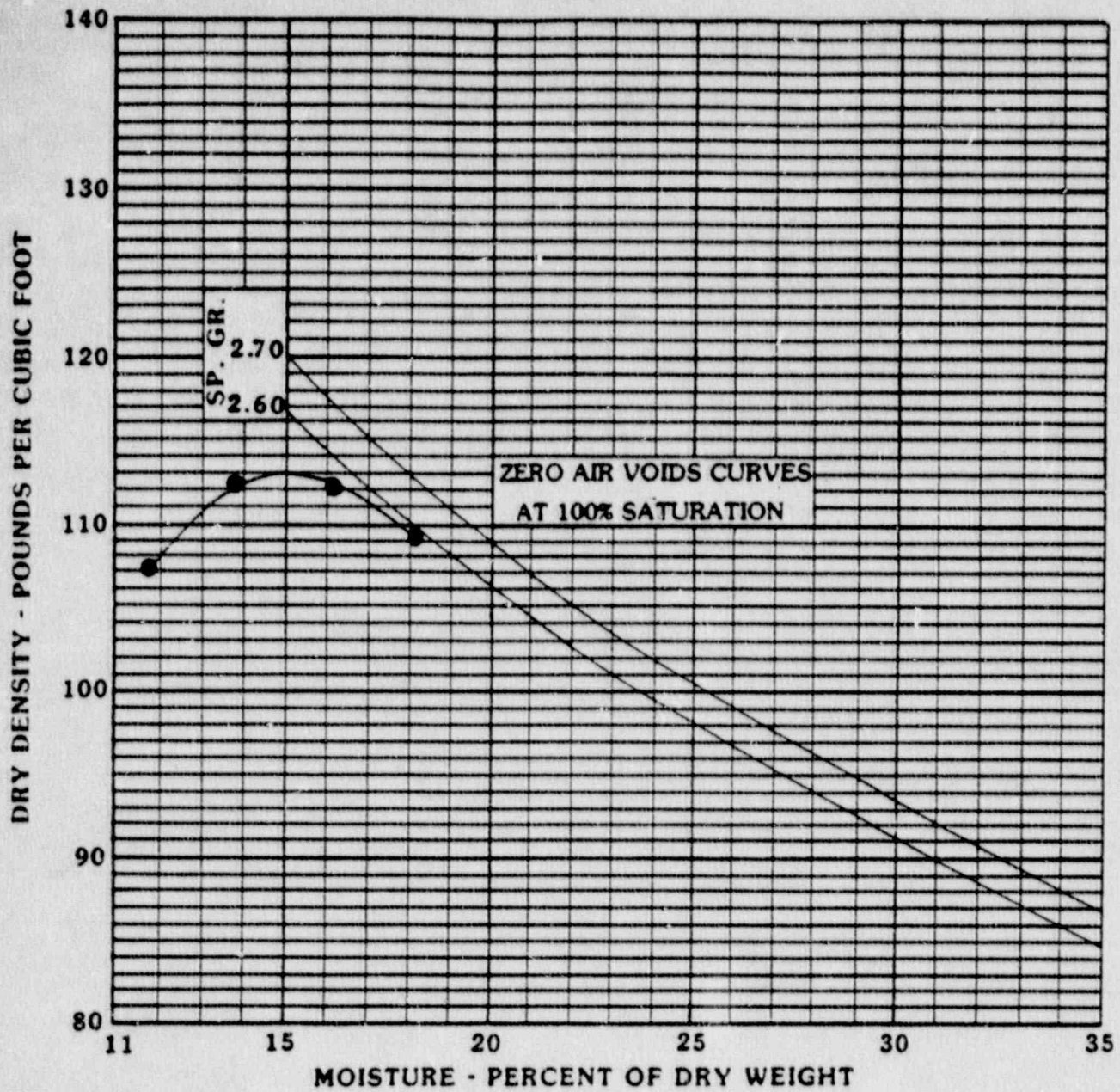
SWELL/CONSOLIDATION RESULTS

UNCONFINED COMPRESSIVE STRENGTH :

CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOX GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 4

LABORATORY MOISTURE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 113.0 pcf **OPTIMUM MOISTURE CONTENT :** 15.0%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-14 PB-12

AMT. OF MAT'L FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PL : PI :

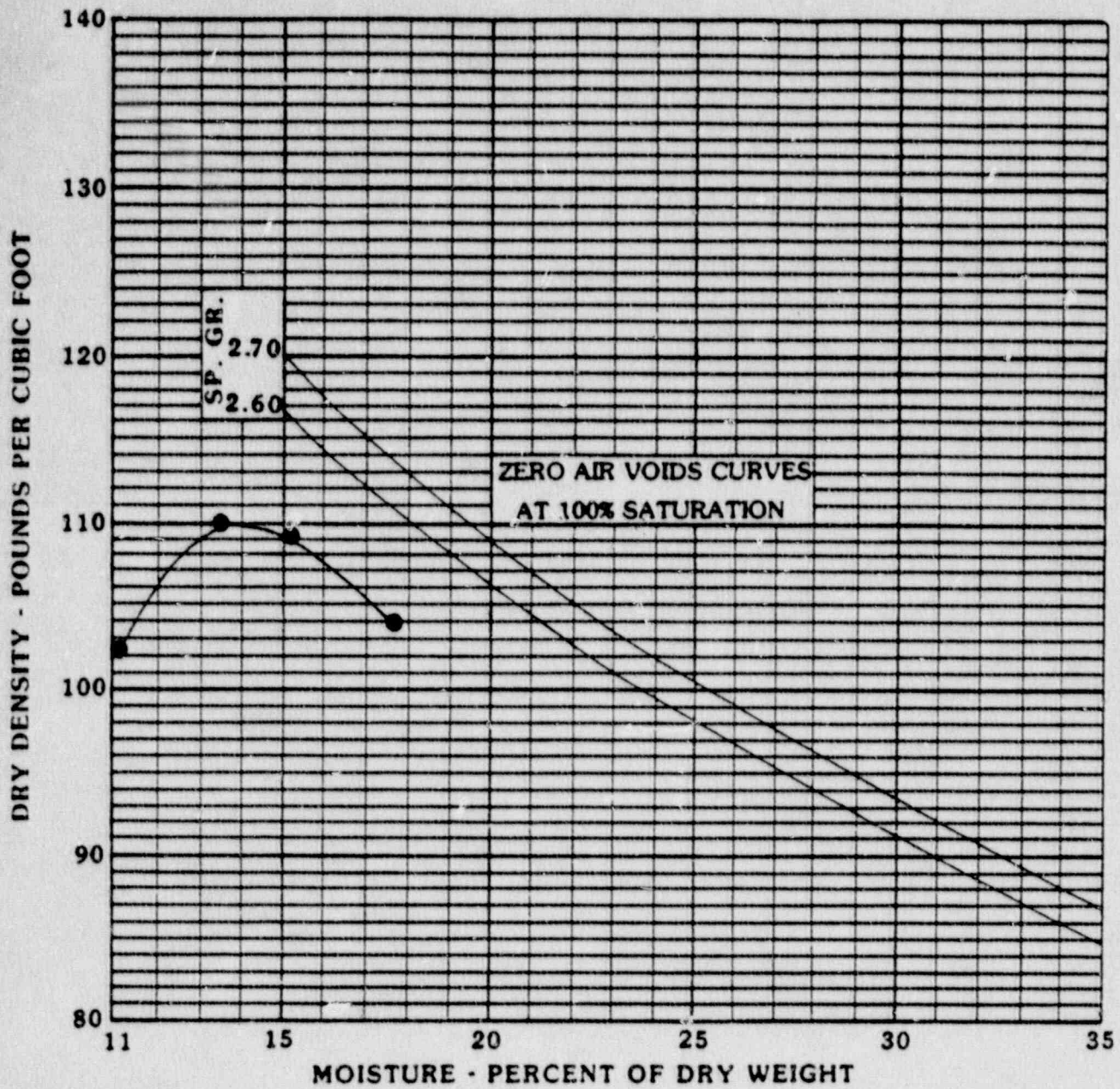
SWELL/CONSOLIDATION RESULTS

UNCONFINED COMPRESSIVE STRENGTH :

CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOX GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 5

LABORATORY MOISTURE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 110.0 pcf **OPTIMUM MOISTURE CONTENT :** 13.0%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-15 PB-13

AMT. OF MAT'L FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PL : PI :

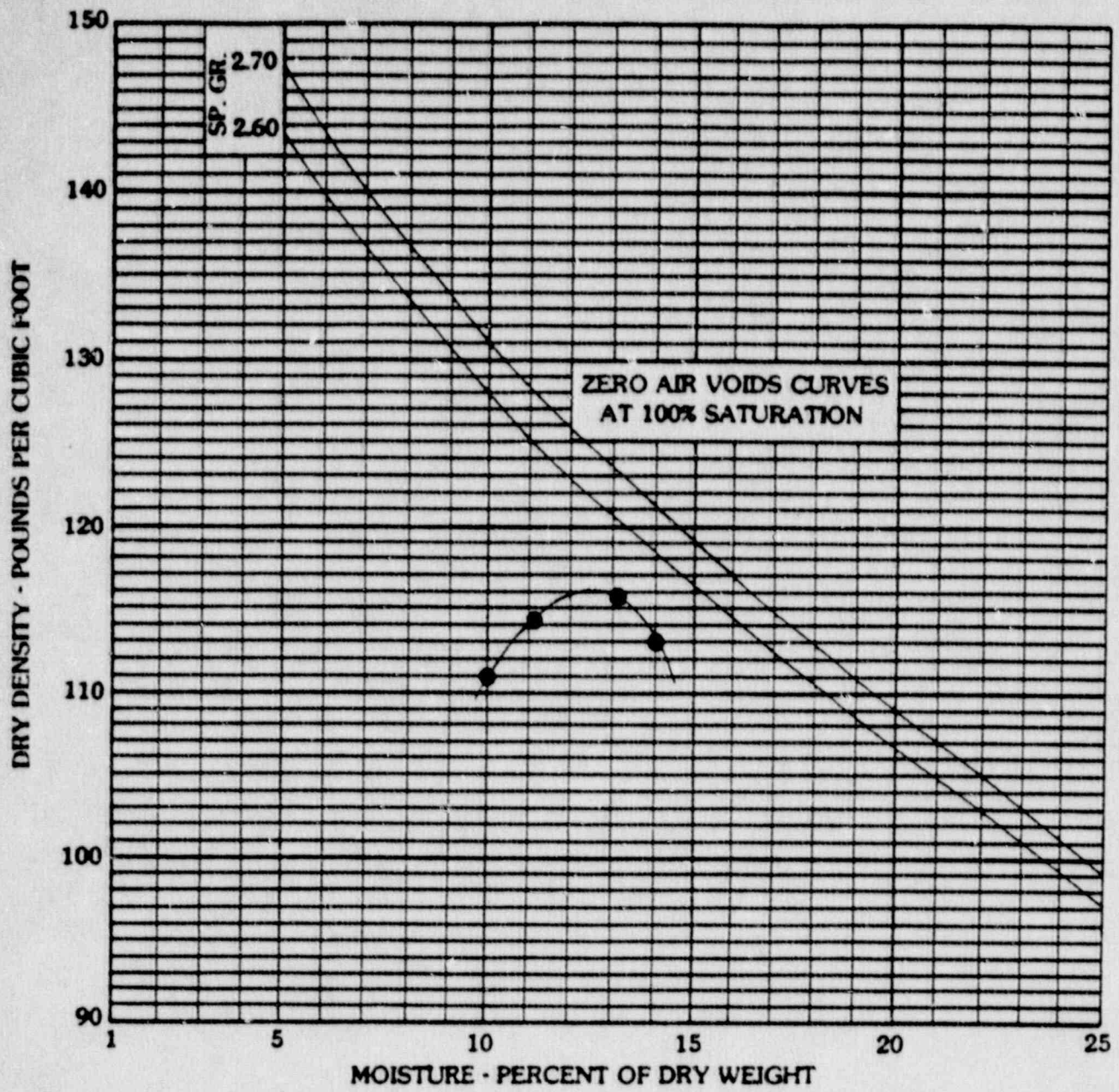
SWELL/CONSOLIDATION RESULTS

UNCONFINED COMPRESSIVE STRENGTH :

CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOX GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 6

LABORATORY MOISTURE DENSITY TEST RESULTS



MAXIMUM DRY DENSITY : 116.0 pcf OPTIMUM MOISTURE CONTENT : 12.5%

SAMPLE DESCRIPTION : Bentonite Mix

LOCATION : Bulk Sample GRN-16 PB-14

AMT. OF MAT'L. FINER THAN : #4 SIEVE #10 #40 #200

ATTERBERG LIMITS : LL : PL : PI :

SWELL/CONSOLIDATION RESULTS :

UNCONFINED COMPRESSIVE STRENGTH :

CHECK POINTS :

LABORATORY MOISTURE DENSITY TEST RESULTS	Proctor No.
FOX GEOTECHNICAL, MATERIALS & ENVIRONMENTAL CONSULTANTS	Comp. Test Proc.
	Figure 7

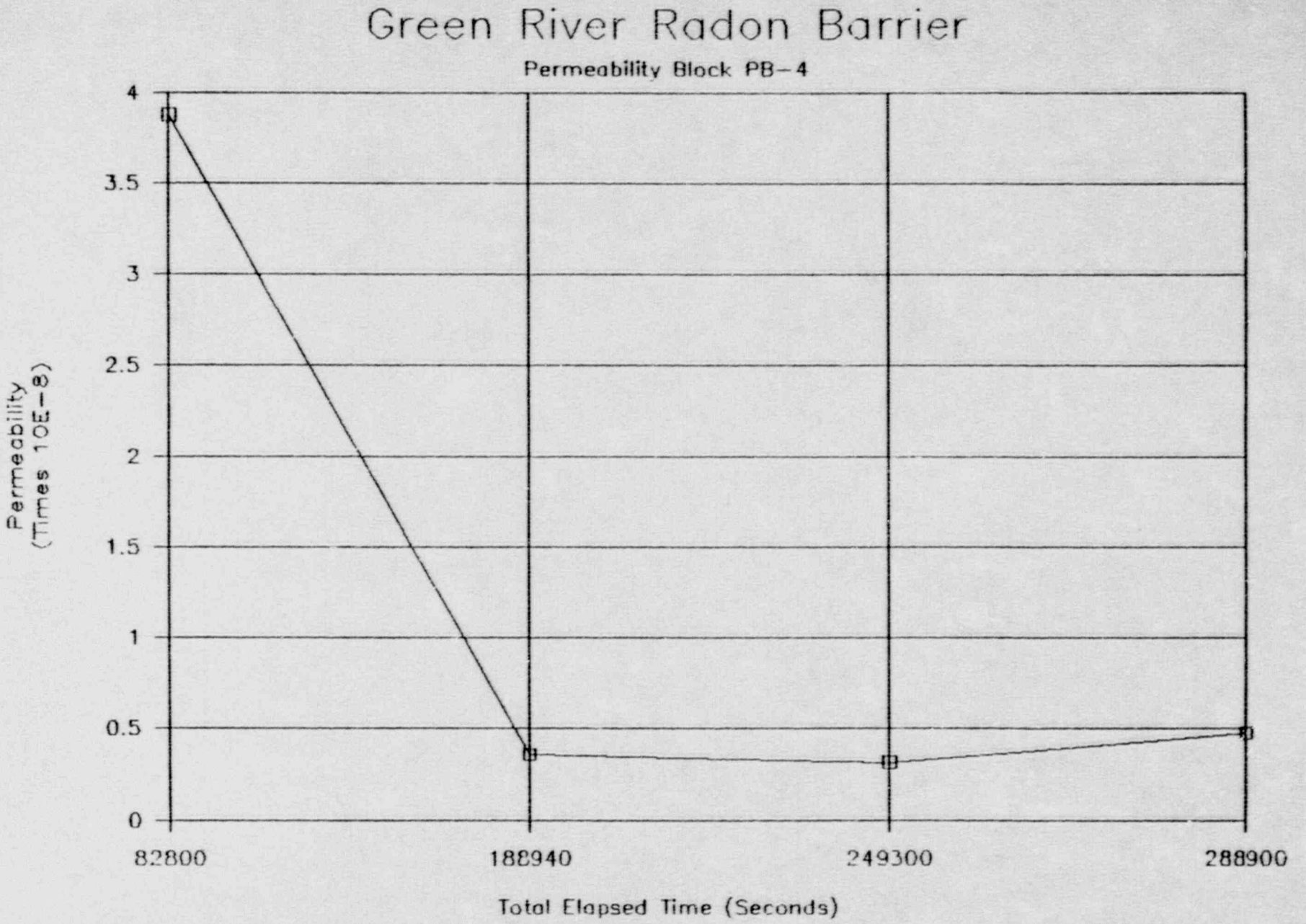

Green River Radon Barrier
Permeability Block PB-4
Permeability (Times 10E-8)
4
3.5
3
2.5
2
1.5
1
0.5
0
82800
188940
249300
288900
Total Elapsed Time (Seconds)

Figure 8

Green River Radon Barrier

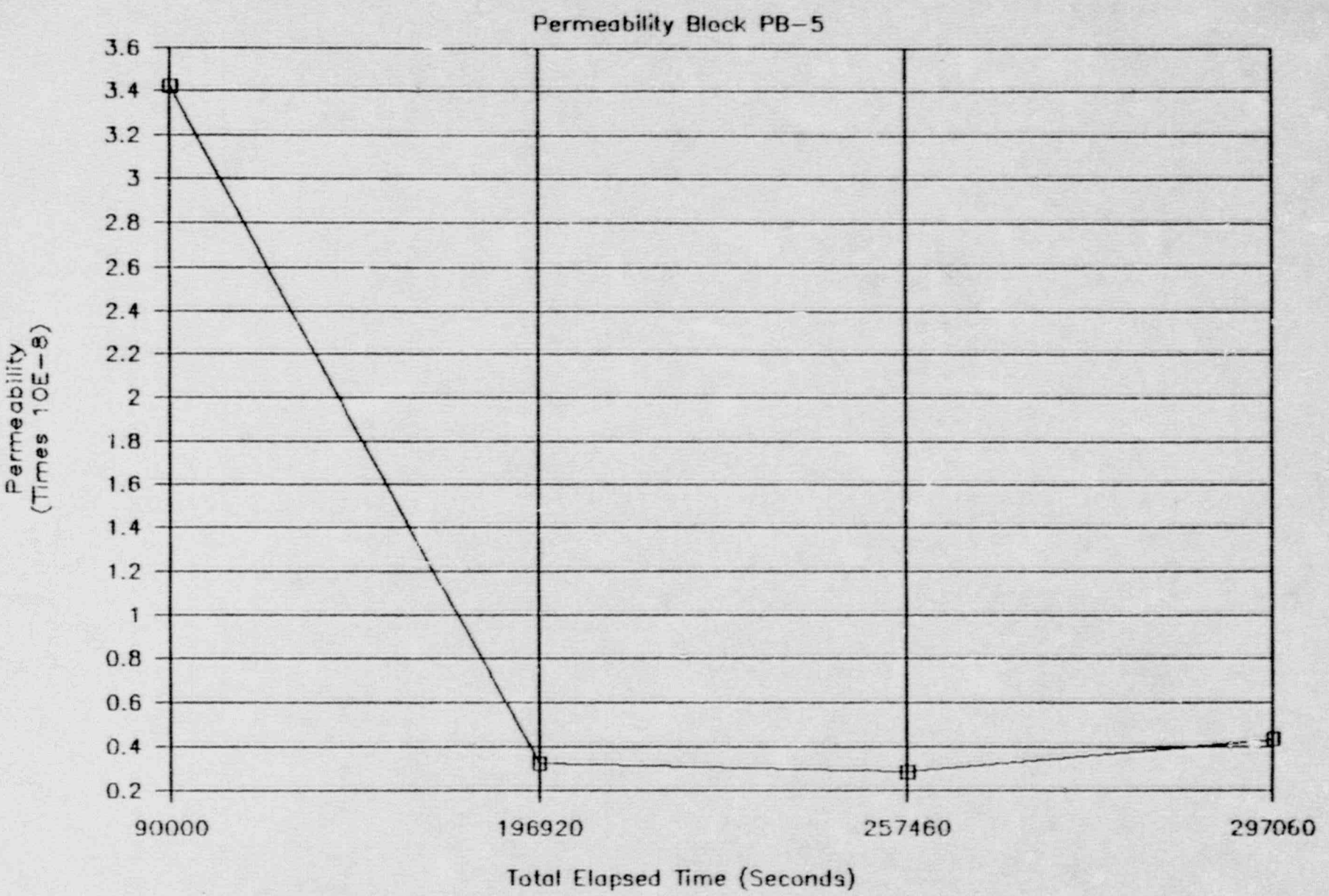


Figure 9

Green River Radon Barrier

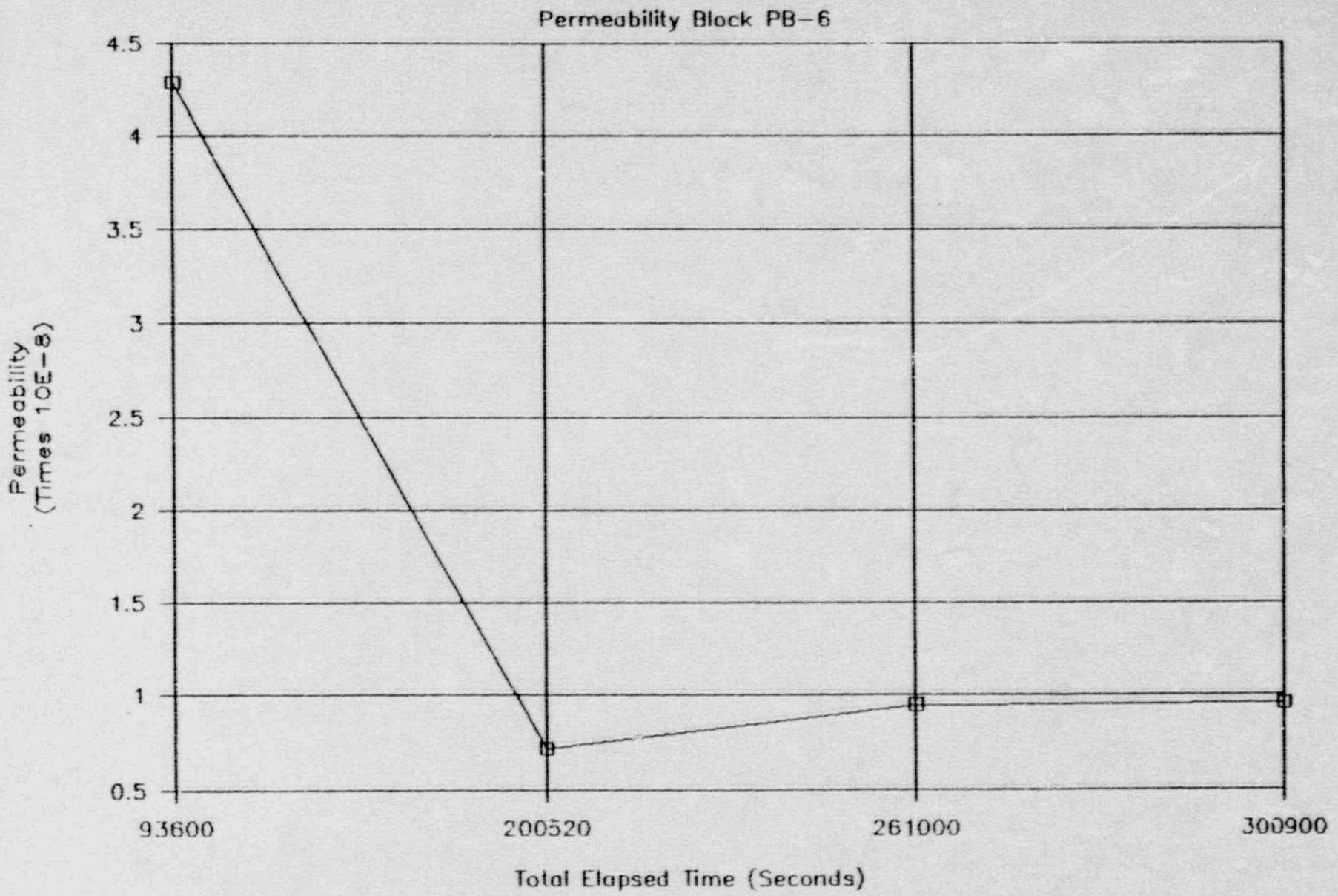


Figure 10

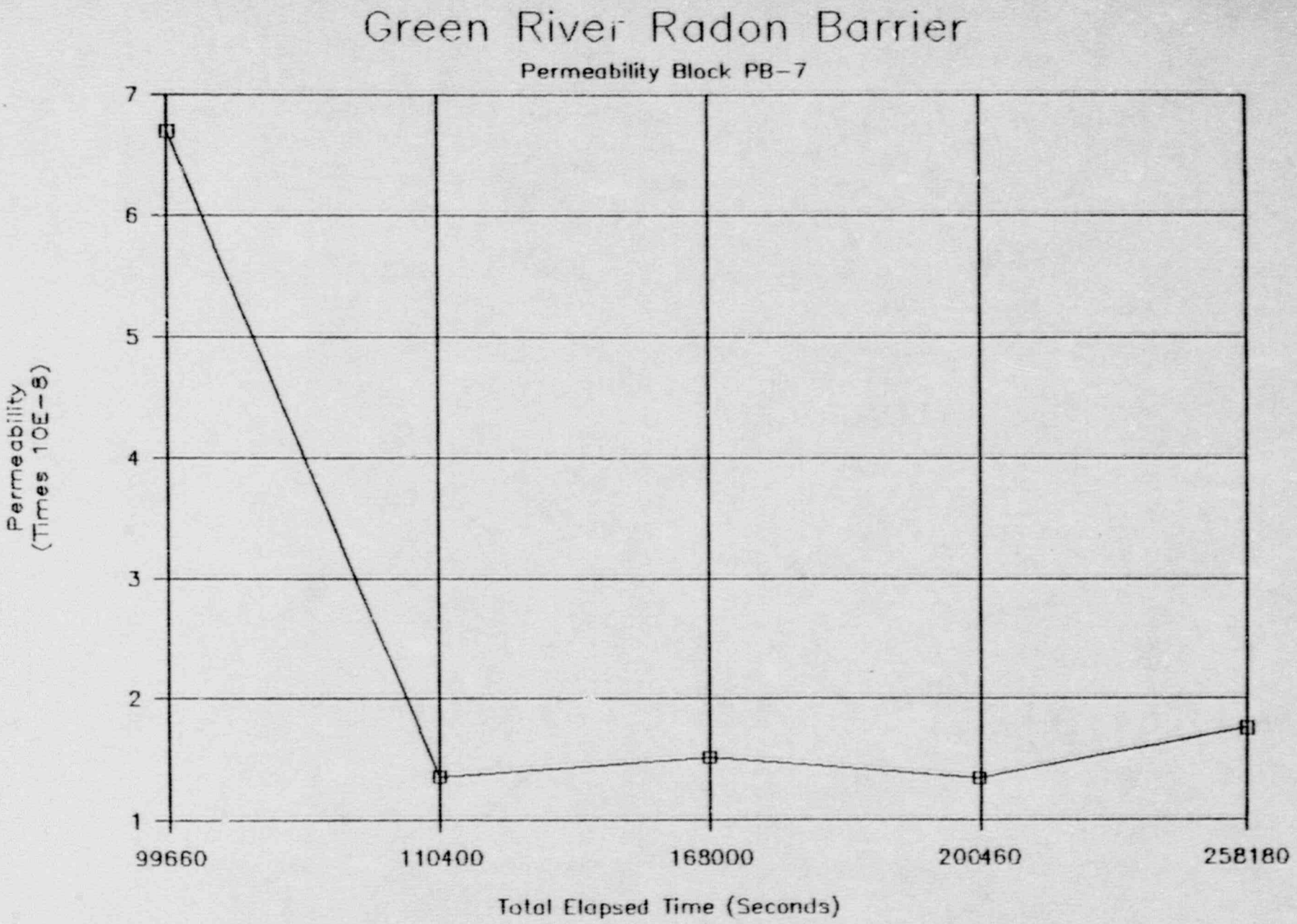

Green River Radon Barrier
Permeability Block PB-7
Permeability (Times 10E-8)
7
6
5
4
3
2
1
99660
110400
168000
200460
258180
Total Elapsed Time (Seconds)

Figure 11

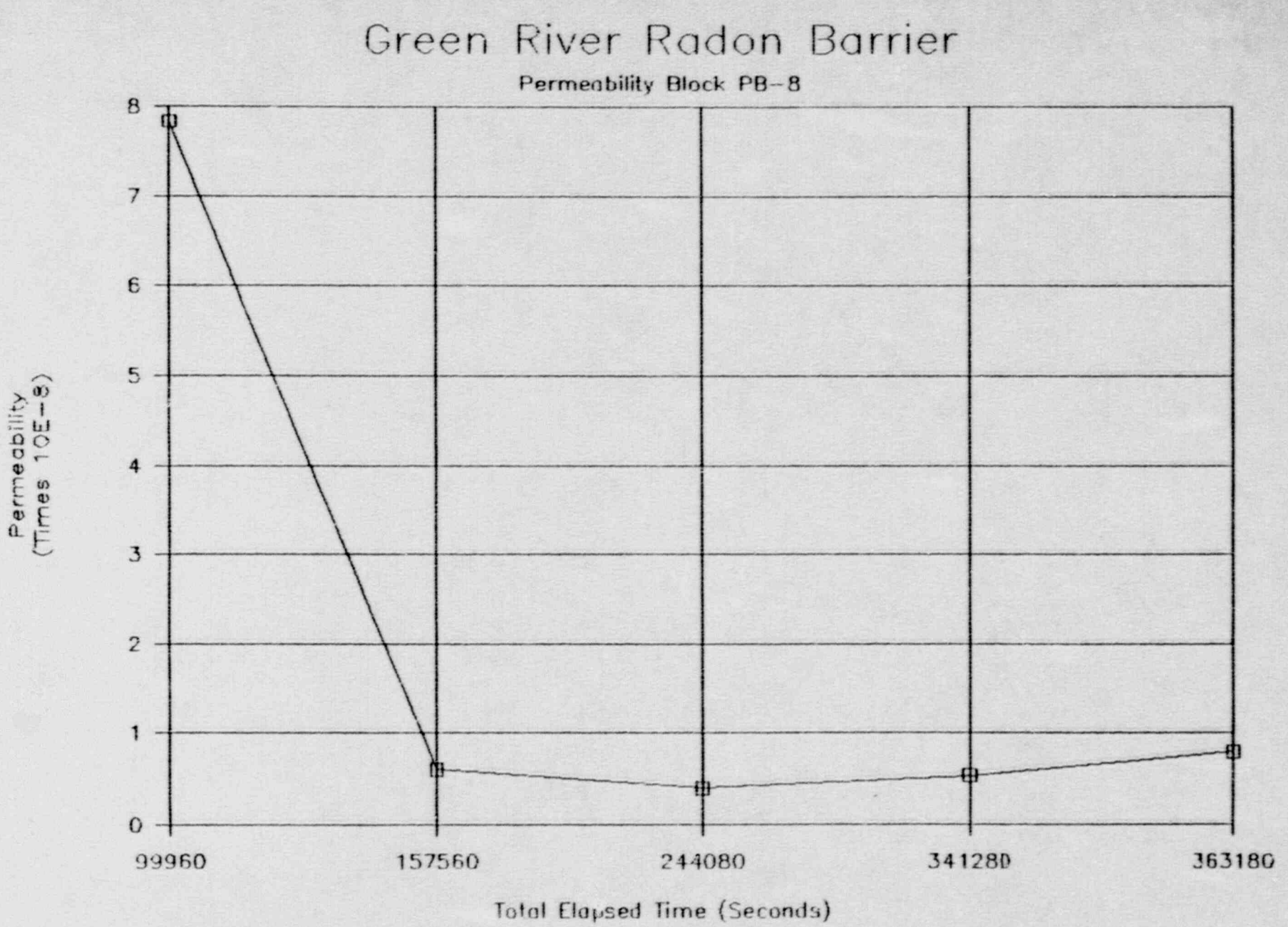

Green River Radon Barrier
Permeability Block PB-8
Permeability (Times 10E-8)
8
7
6
5
4
3
2
1
0
99960
157560
244080
341280
363180
Total Elapsed Time (Seconds)

Figure 12

Green River Radon Barrier

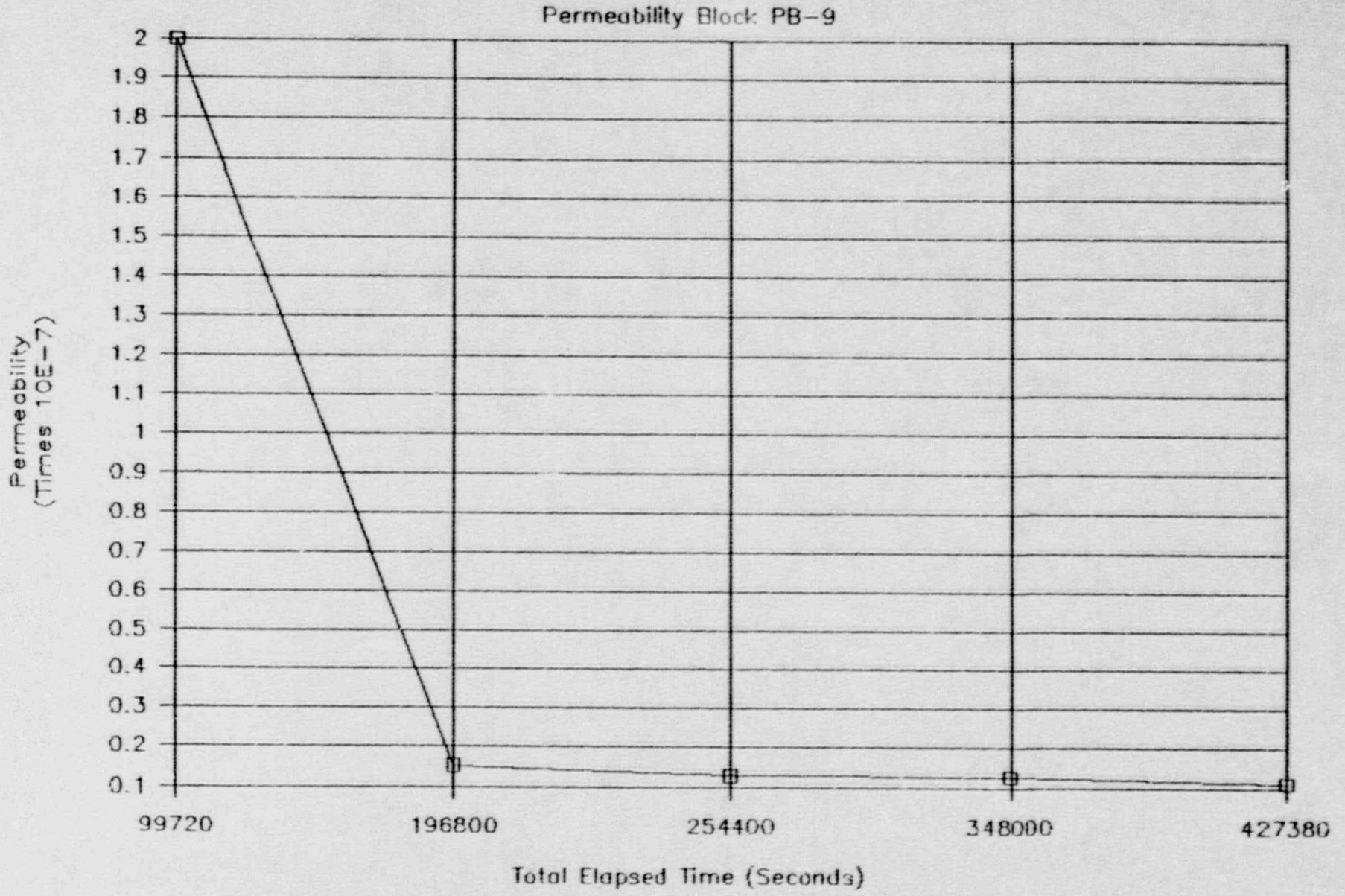


Figure 13

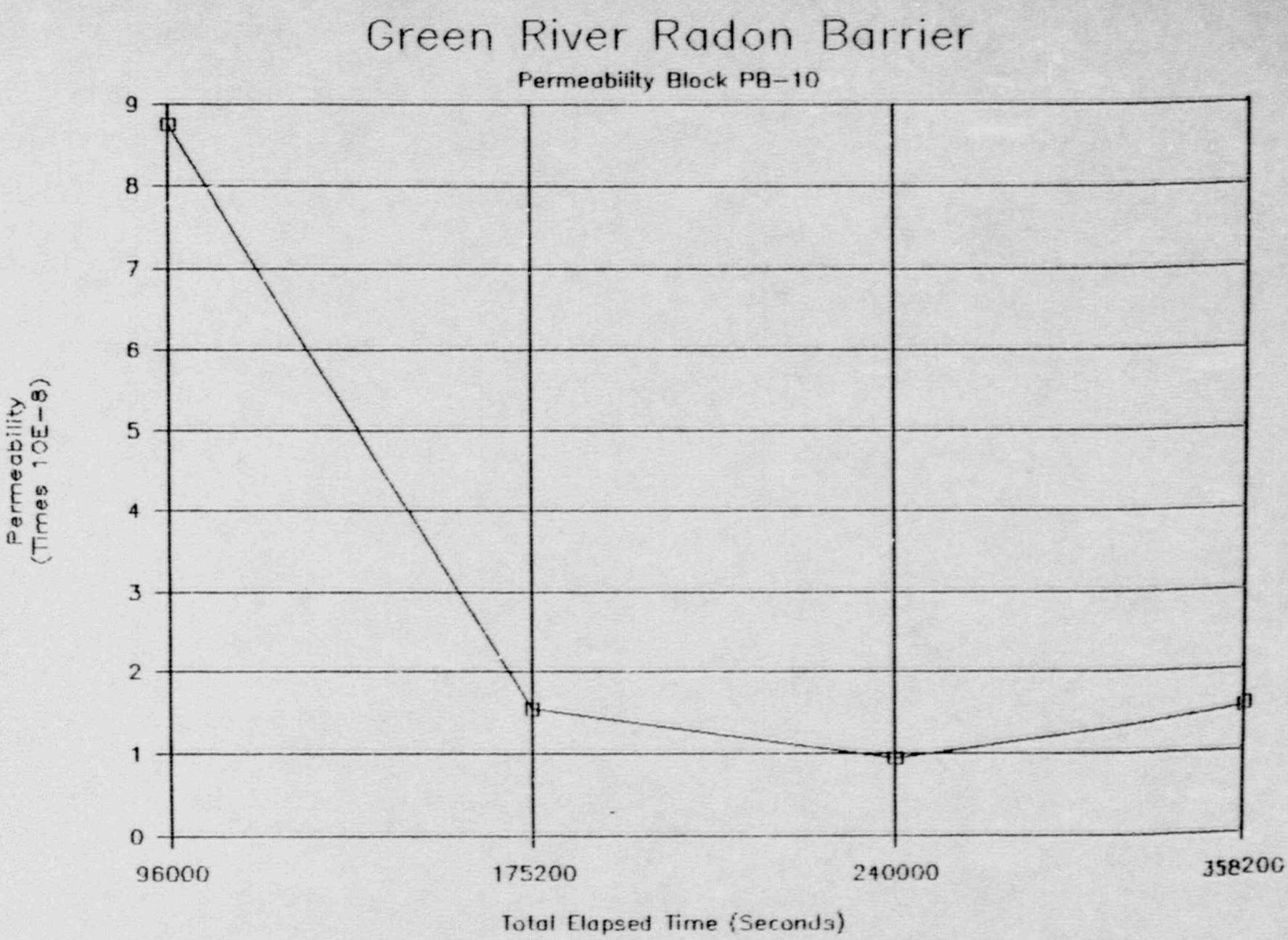

Green River Radon Barrier
Permeability Block PB-10
Permeability (Times 10E-8)
9
8
7
6
5
4
3
2
1
0
96000
175200
240000
358200
Total Elapsed Time (Seconds)

Figure 14

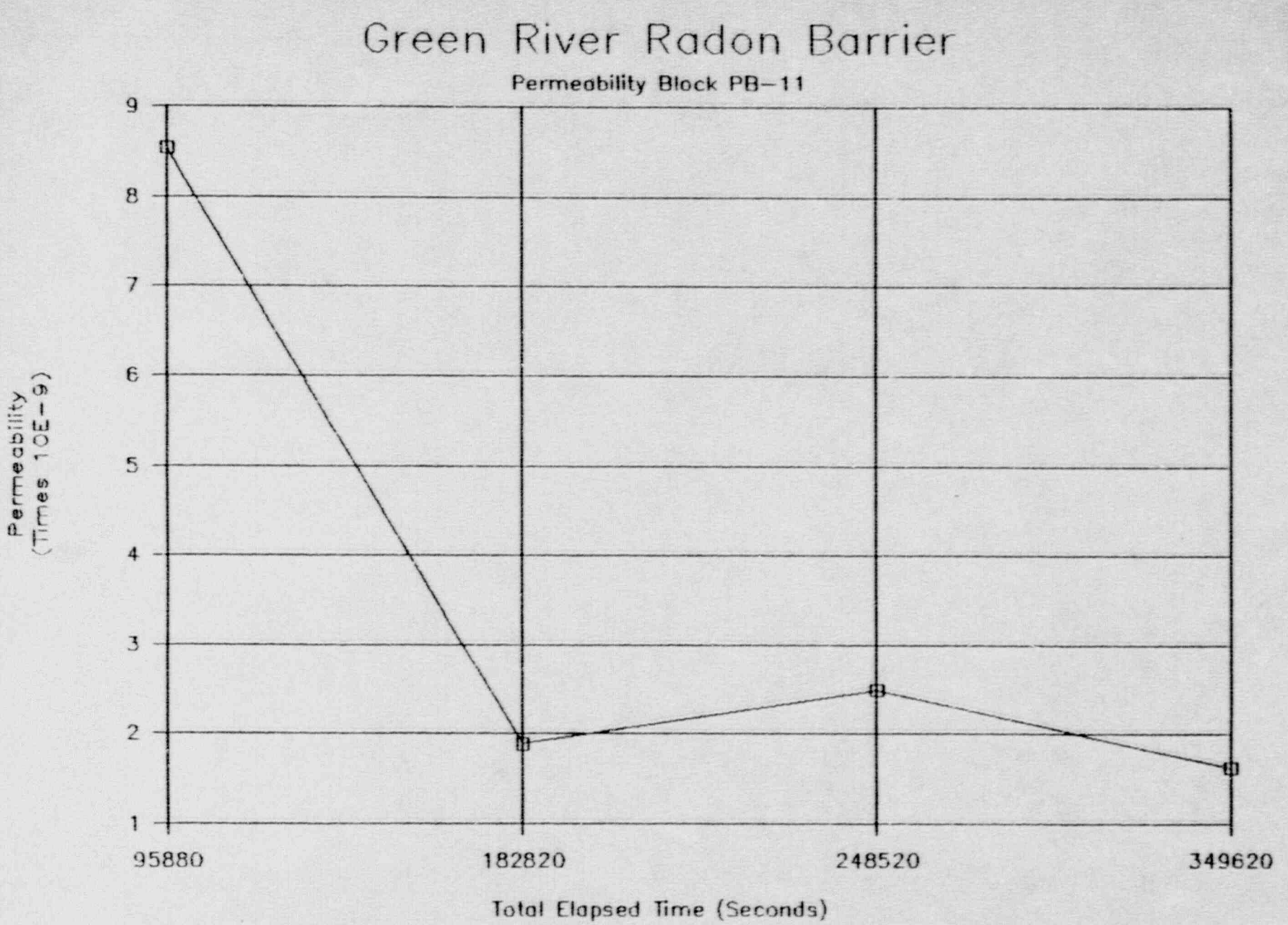

Green River Radon Barrier
Permeability Block PB-11
Permeability (Times 10E-9)
9
8
7
6
5
4
3
2
1
95880
182820
248520
349620
Total Elapsed Time (Seconds)

Figure 15

Green River Radon Barrier

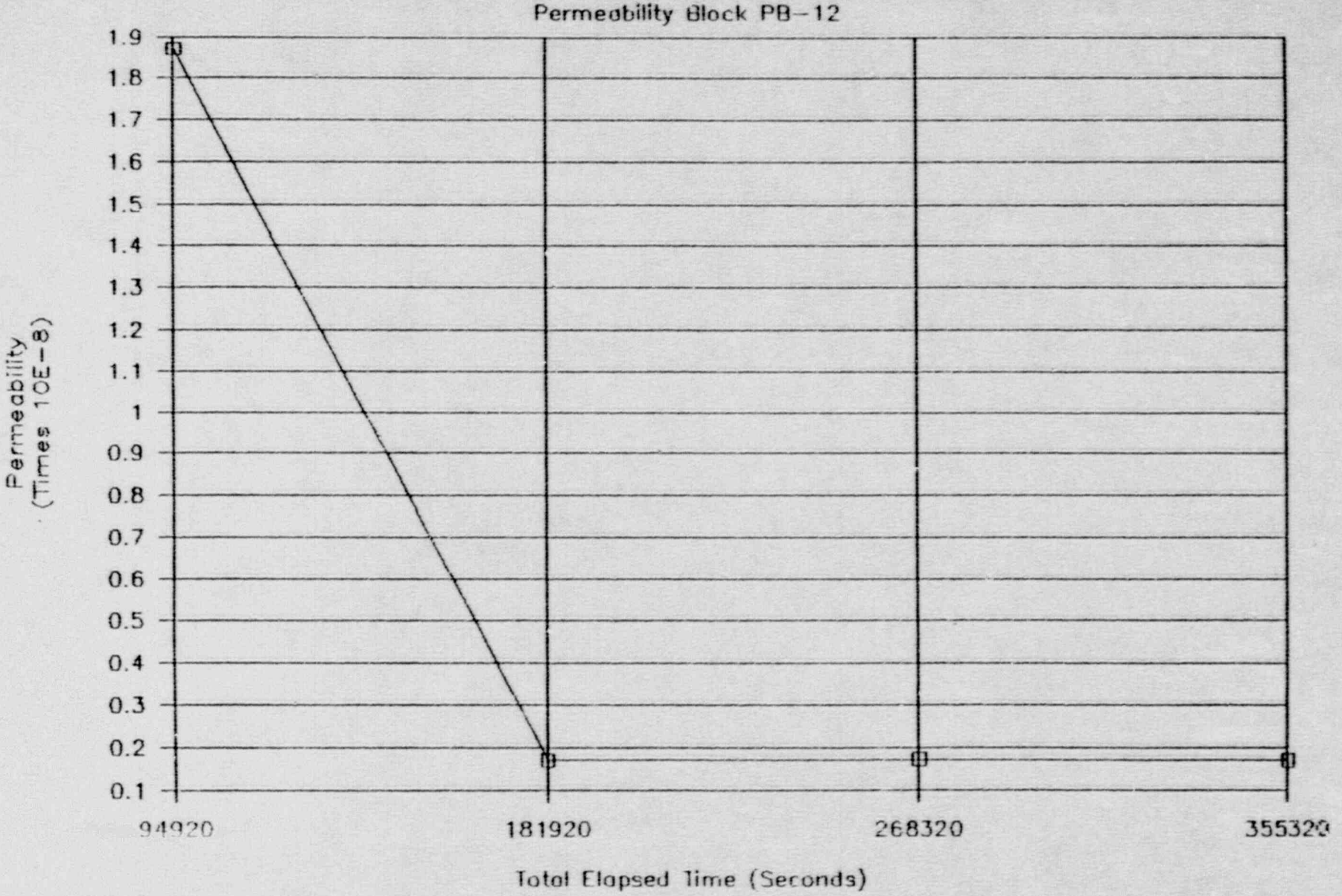


Figure 16

Green River Radon Barrier

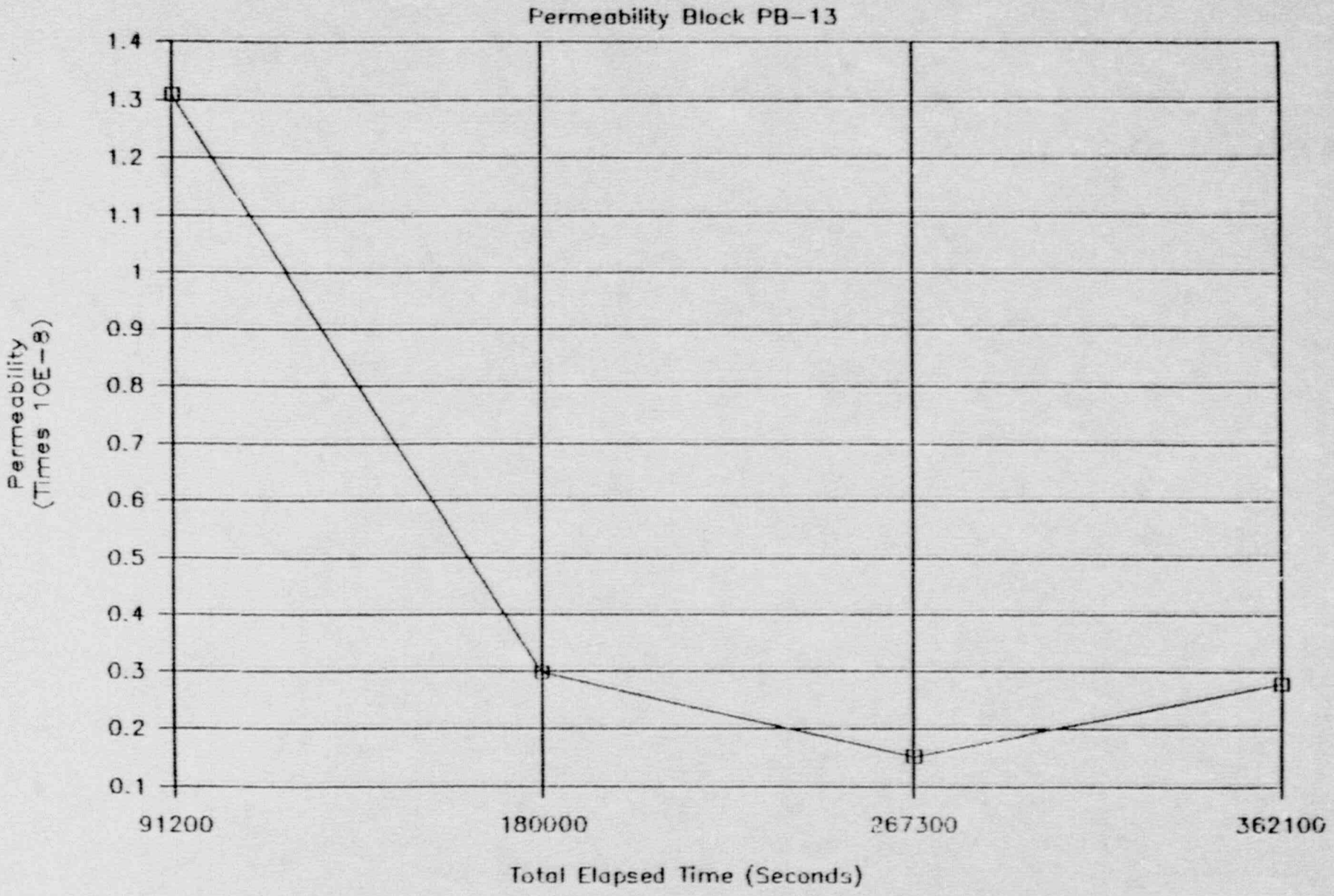


Figure 17

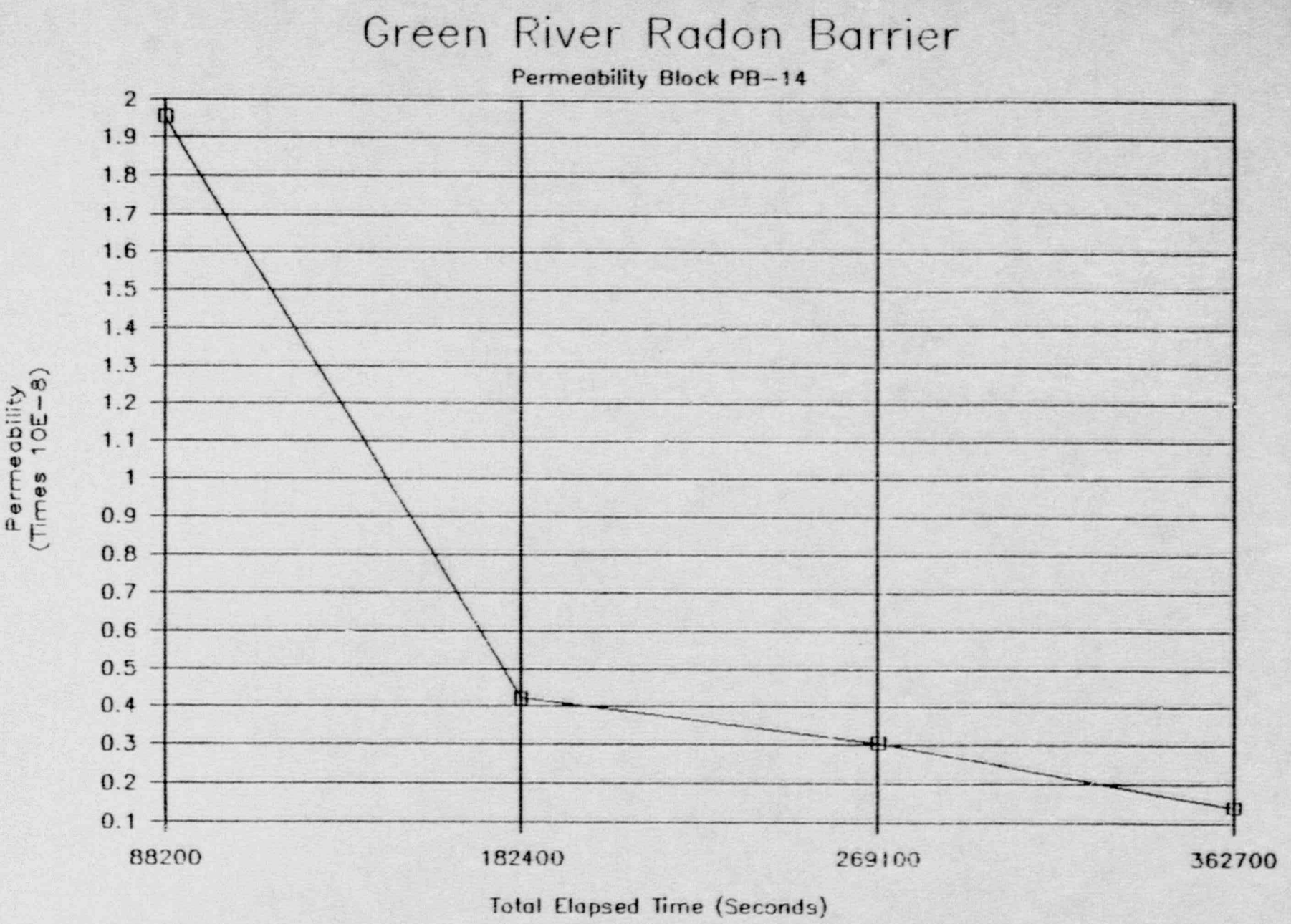
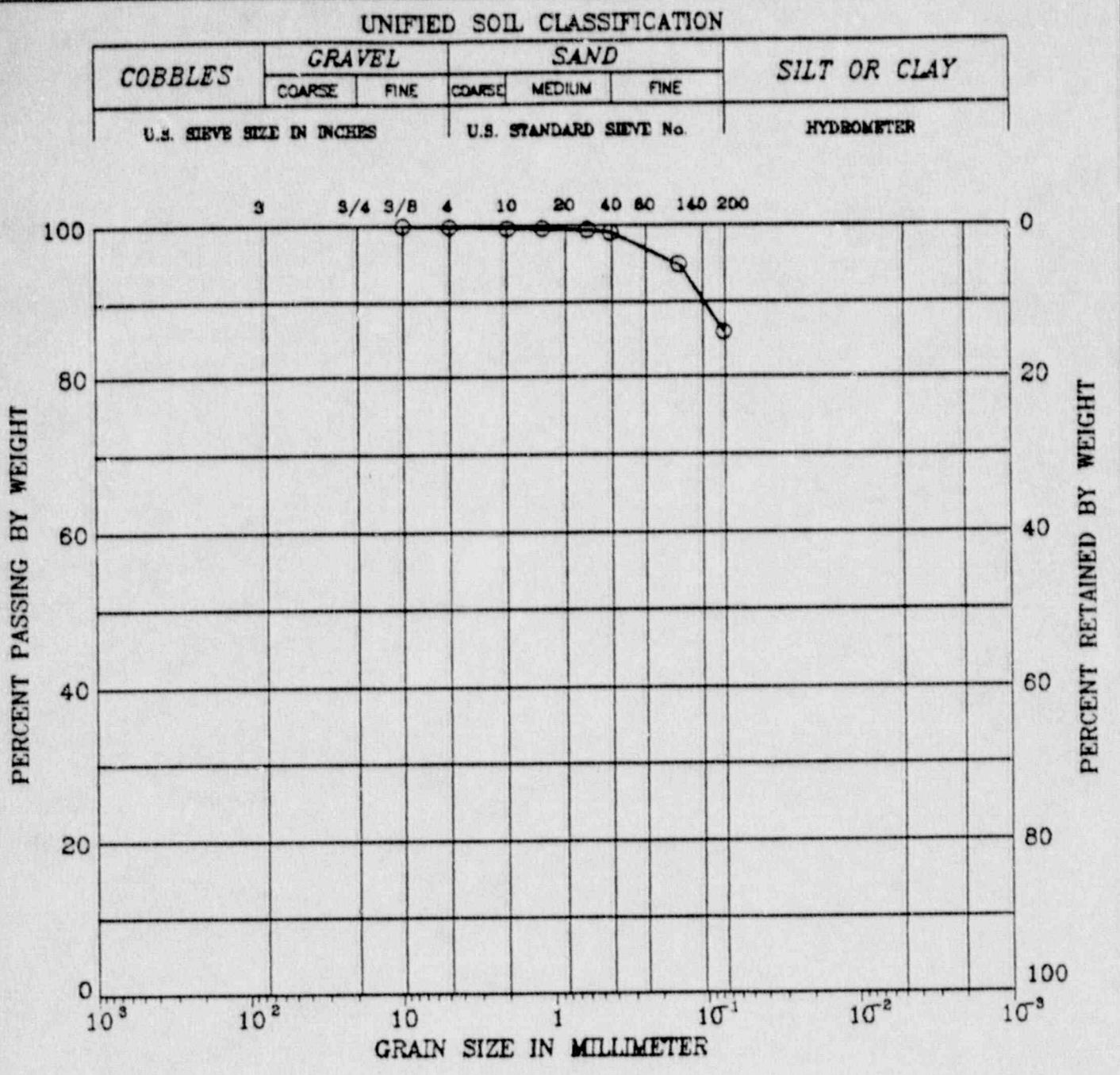

Green River Radon Barrier
Permeability Block PB-14
Permeability (Times 10E-8)
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
88200
182400
269100
362700
Total Elapsed Time (Seconds)

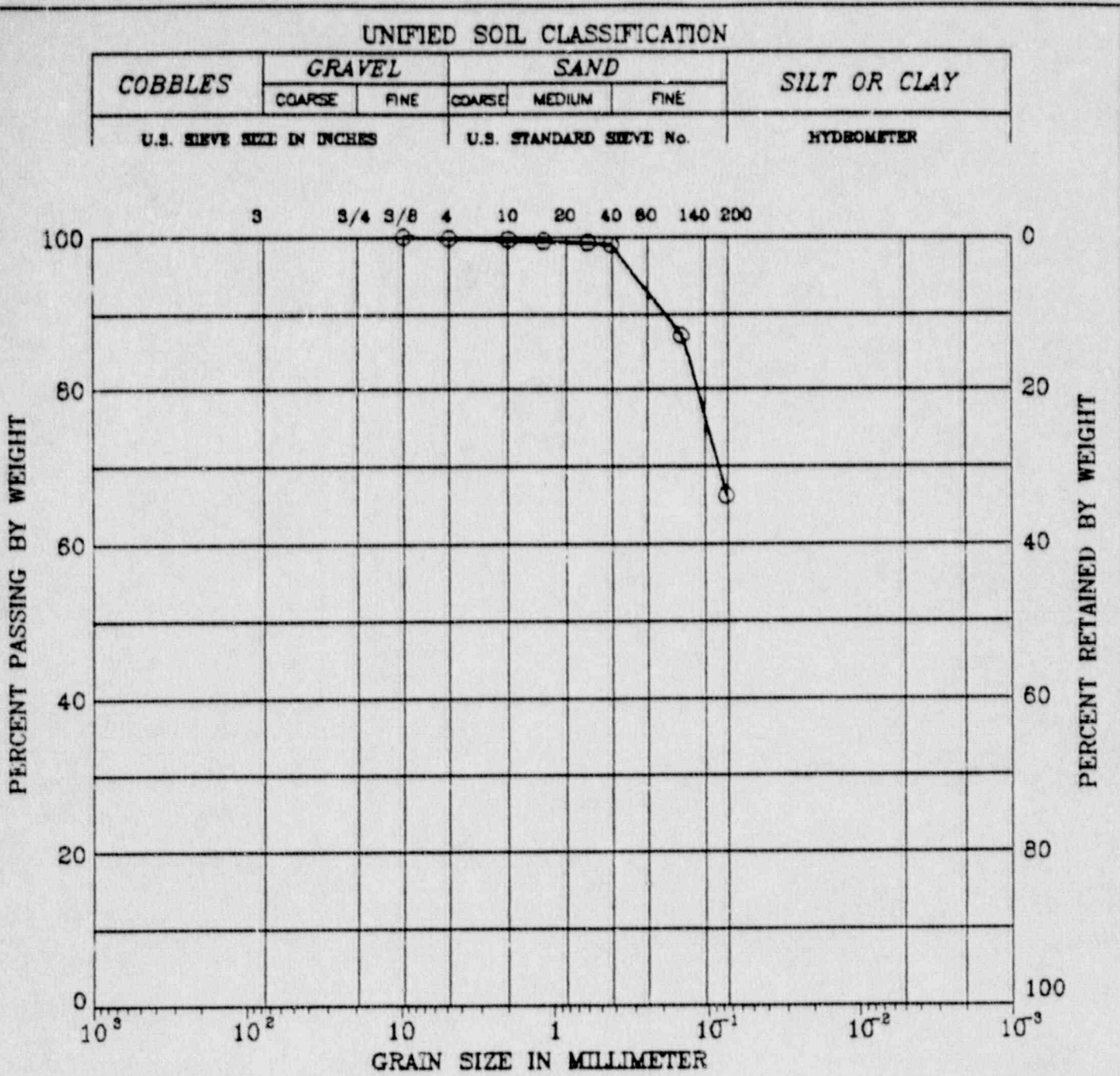
Figure 18



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	PB-4	N/A			CL

Remark : PERMEABILITY BLOCK SAMPLE PB-4

1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No. 19



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	PB-5	N/A			CL

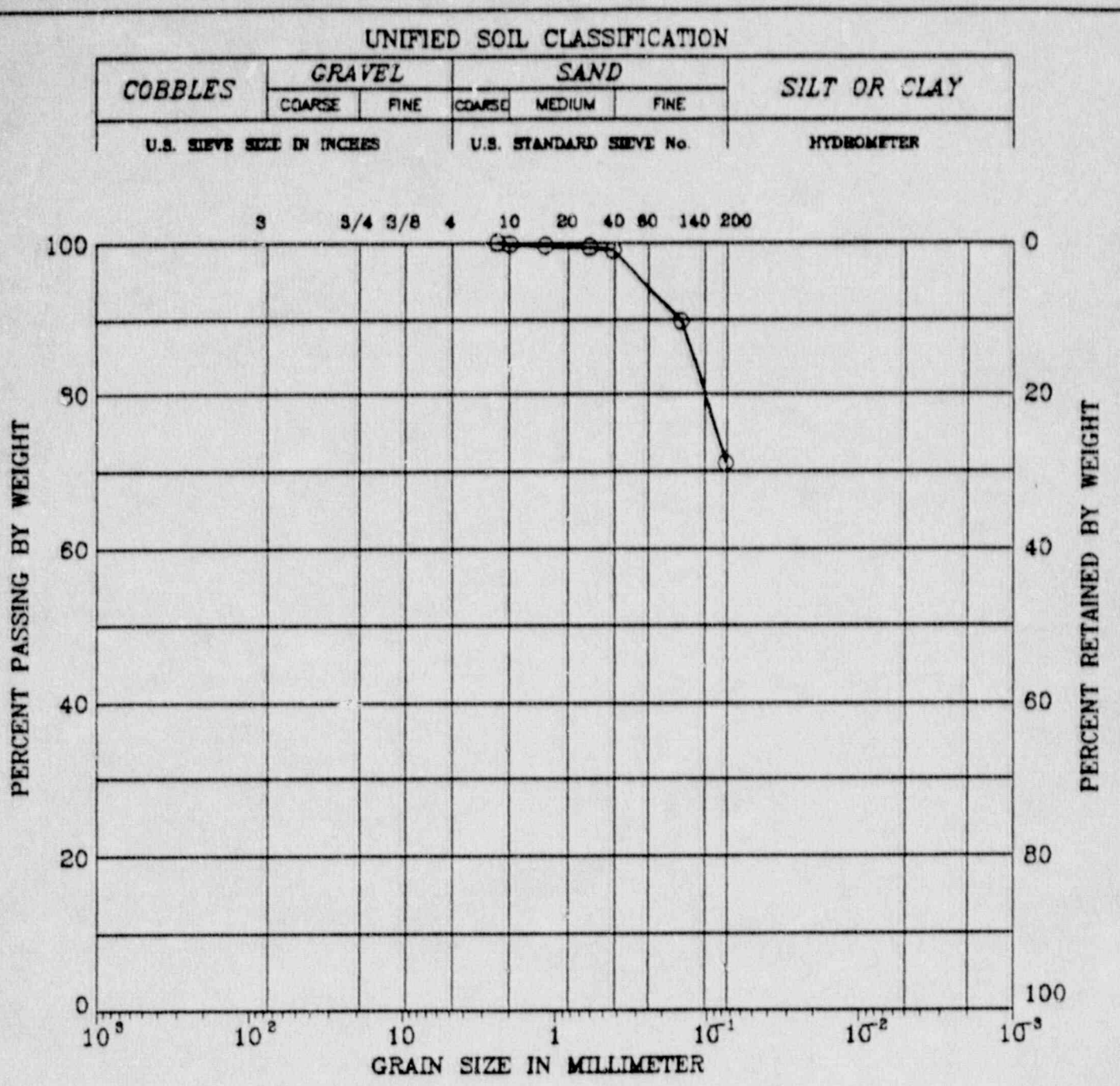
Remark : PERMEABILITY BLOCK SAMPLE PB-5

1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No. 20

C22: READY

	A	B	C	D	E	F
4	Sample No.		PB-14			
5	Location:		Radon Barrier			
6			Green River , Utah			
7						
8	----------					
9	Length of sample (cm)				10.635	
10	Area of Burette (cm^2)				1.262	
11	Area of sample (cm^2)				28.75	
12	Head (cm)				352	
13	----------					
14	Elapsed	Total	Burette			
15	Time	Time	Reading	Delta	Permeability	
16	Sec.	Sec.	H cm	H cm	(cm/sec)	
17	0	0	26.8	0		
18	88200	88200	25.5	1.3	0.0000000195	
19	94200	182400	25.2	0.3	0.0000000042	
20	86700	269100	25	0.2	0.0000000031	
21	93600	362700	24.9	0.1	0.0000000014	
22						
23						

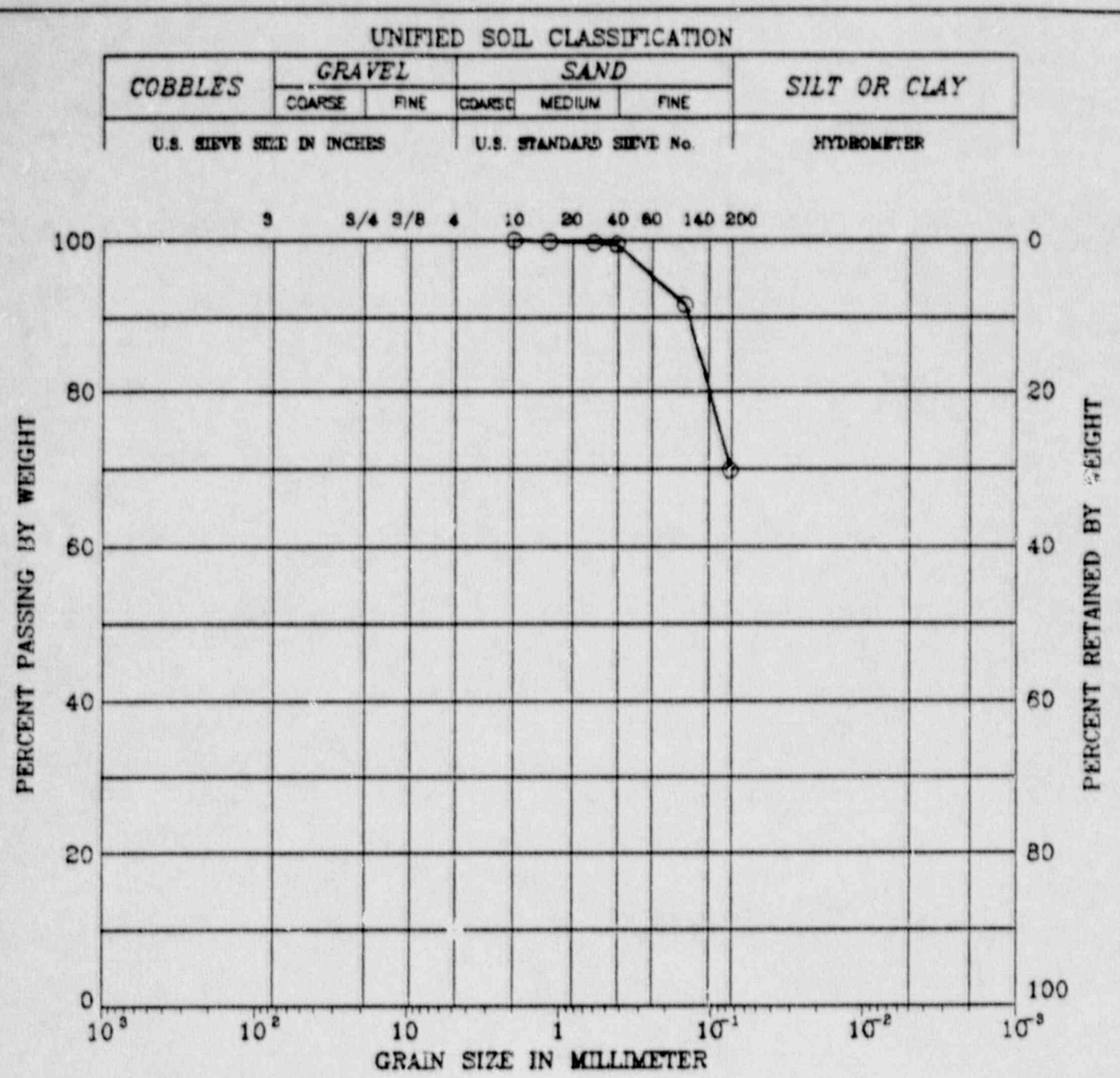
01-Jan-80 12:24 AM CAPS



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	PB-6	N/A			CL

Remark : PERMEABILITY BLOCK SAMPLE PB-6

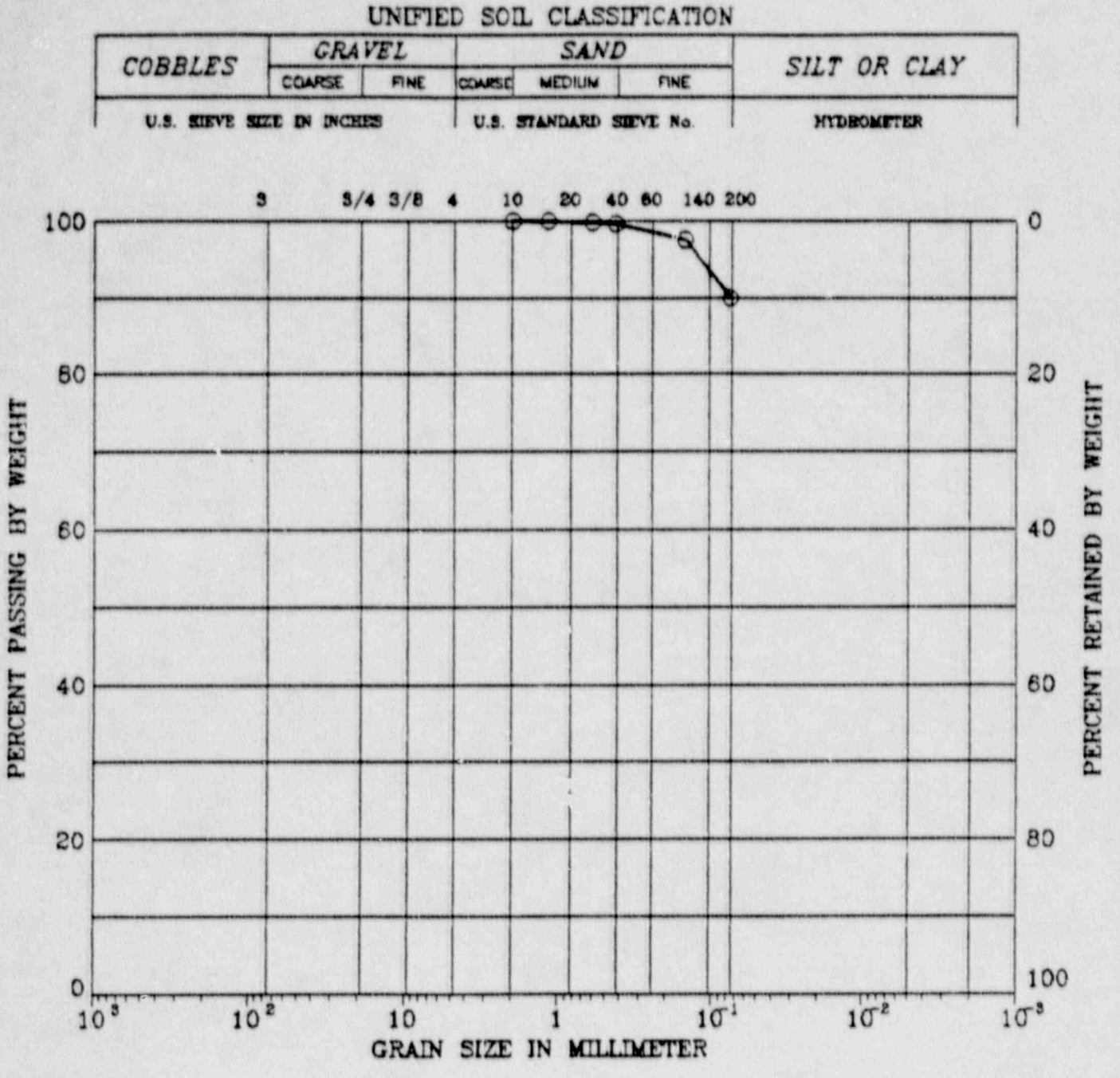
1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No. 21



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	PB-7	N/A			CL

Remark : PERMEABILITY BLOCK SAMPLE PB-7

1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No. 22



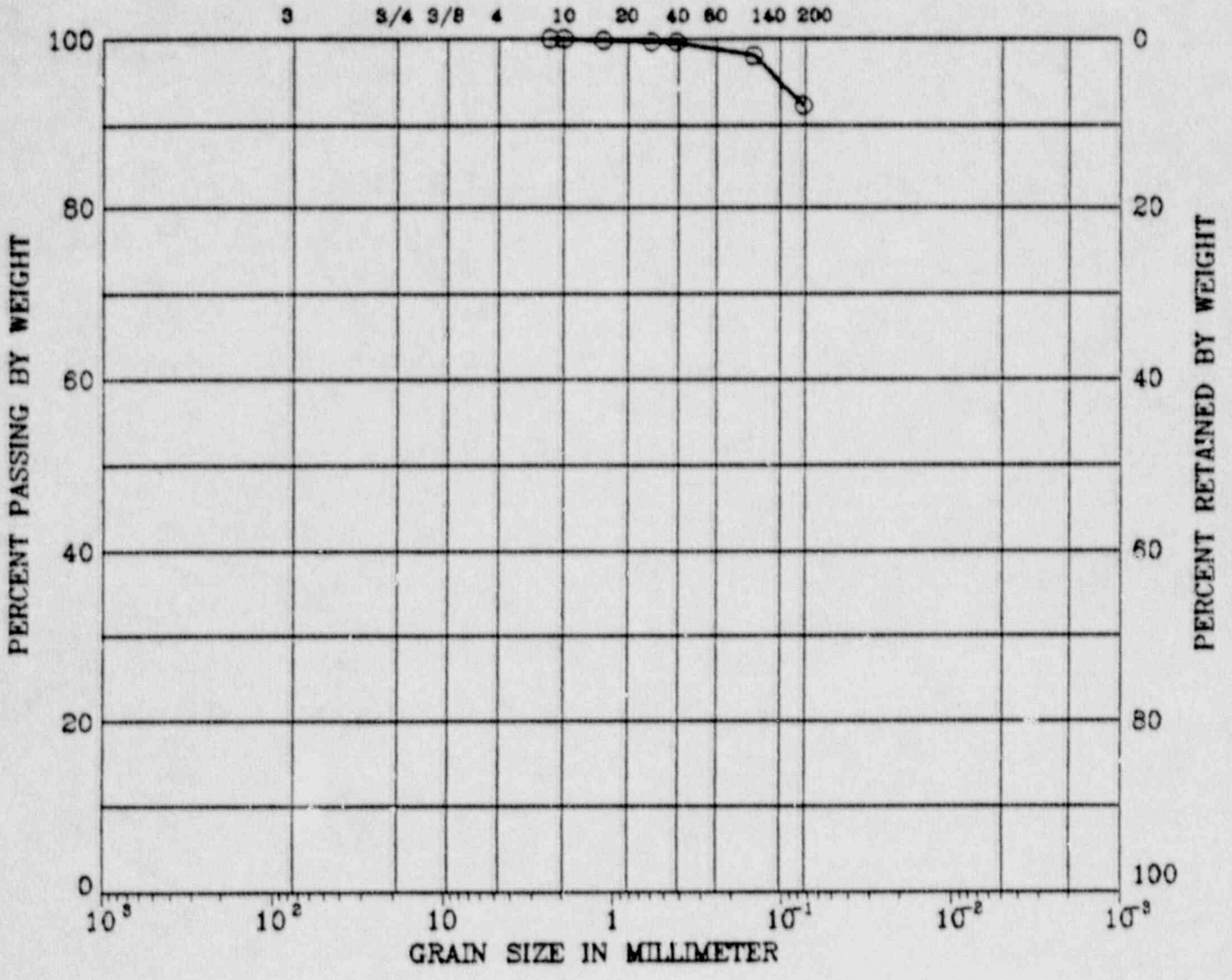
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	PB-8	N/A			CL

Remark : PERMEABILITY BLOCK SAMPLE PB-8

1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No. 23

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



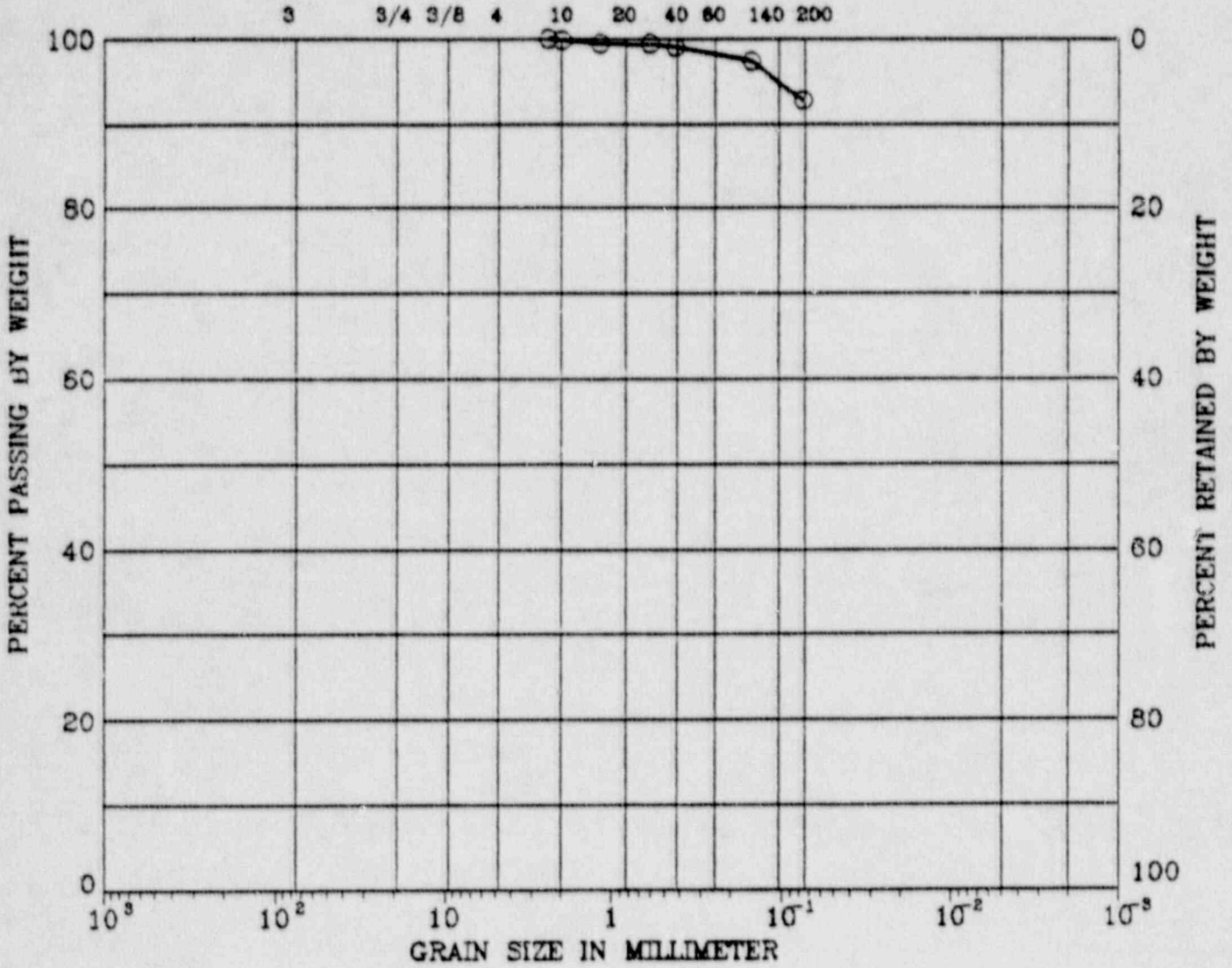
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	PB-9	N/A			CL

Remark : PERMEABILITY BLOCK SAMPLE PB-9

1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No. 24

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



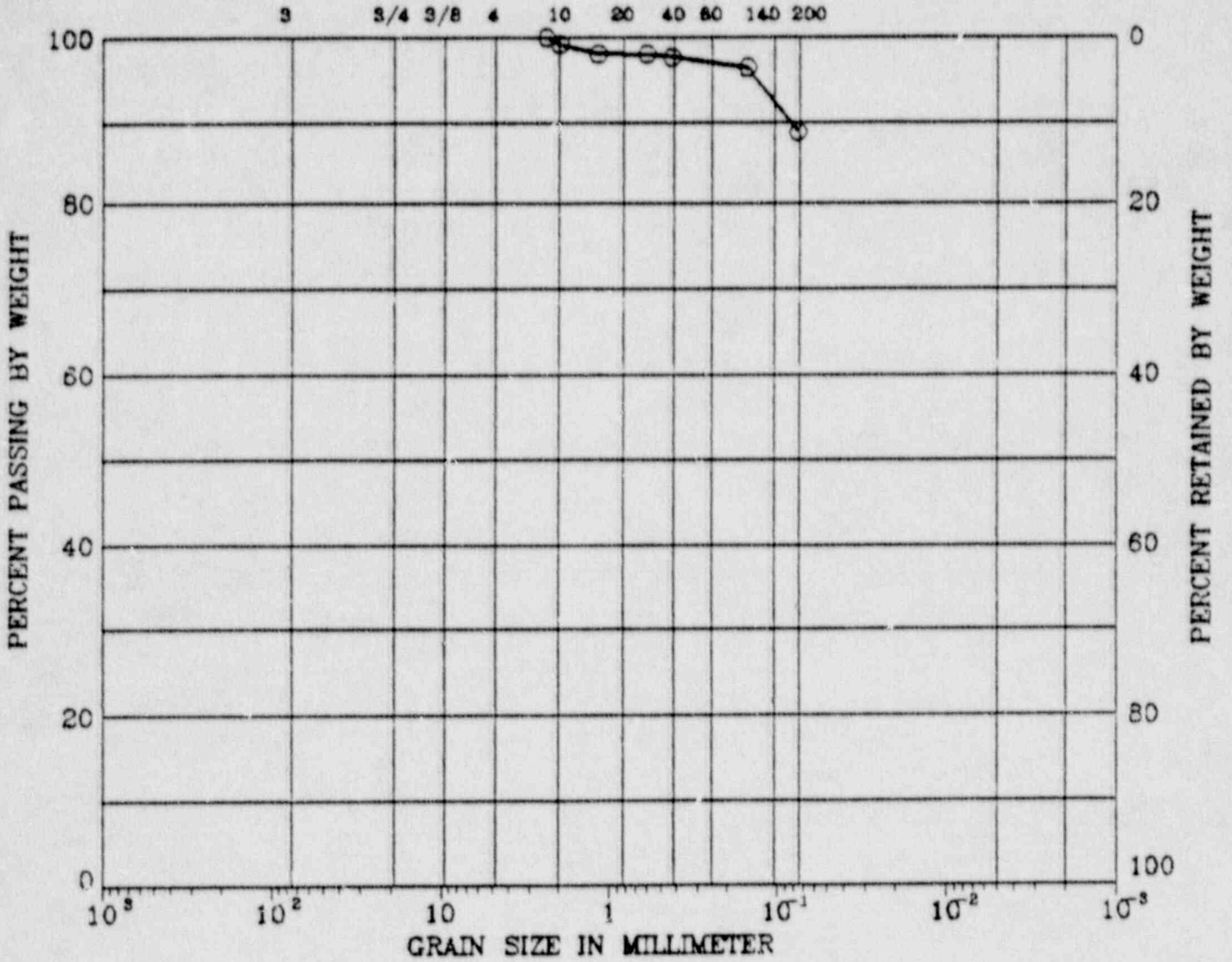
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	PB-10	N/A			CL

Remark : PERMEABILITY BLOCK SAMPLE PB-10

1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No. 25

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



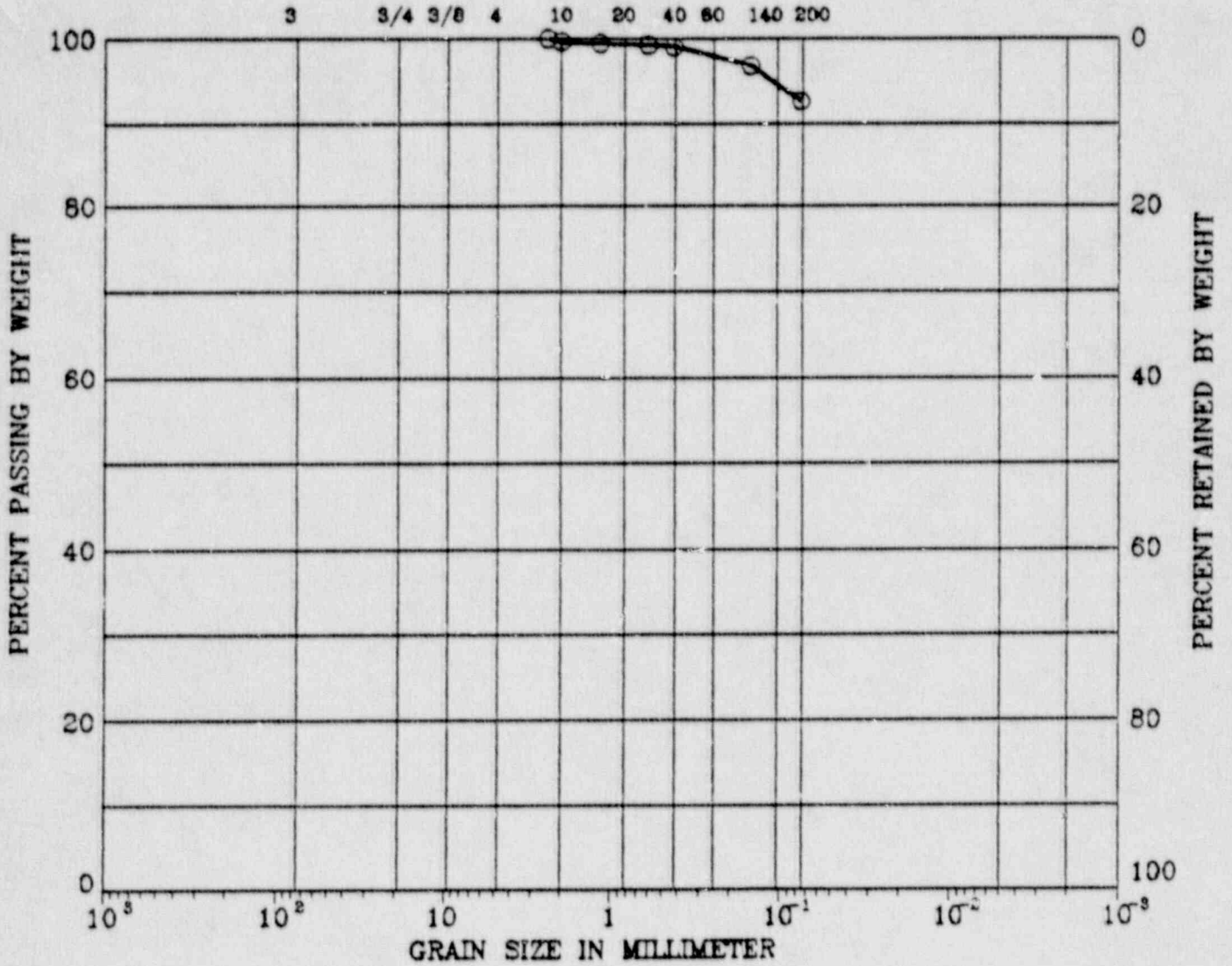
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	PB-11	N/A			CL

Remark : PERMEABILITY BLOCK SAMPLE PB-11

1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No. 26

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



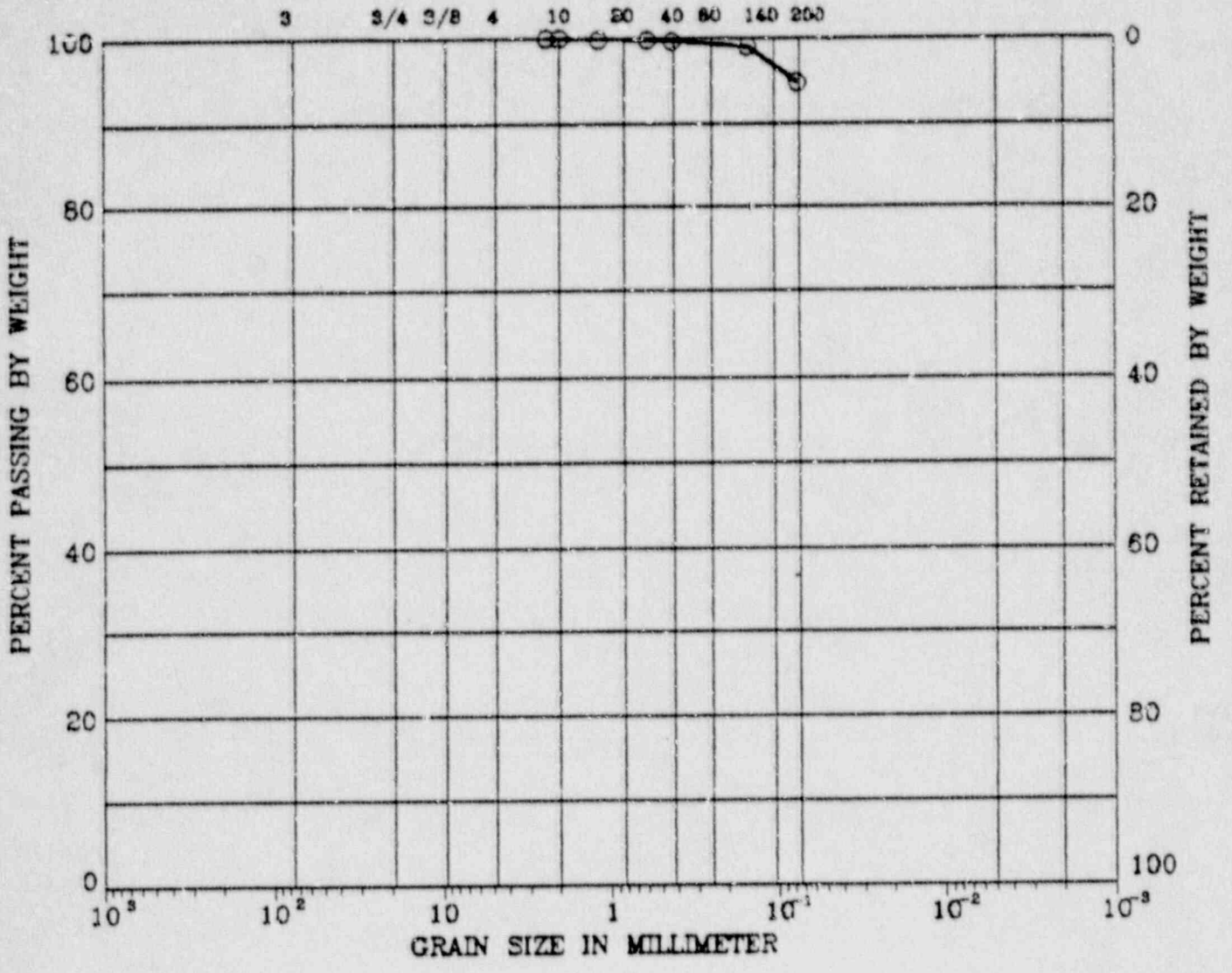
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	PB-12	N/A			CL

Remark : PERMEABILITY BLOCK SAMPLE PB-12

1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No. 27

UNIFIED SOIL CLASSIFICATION

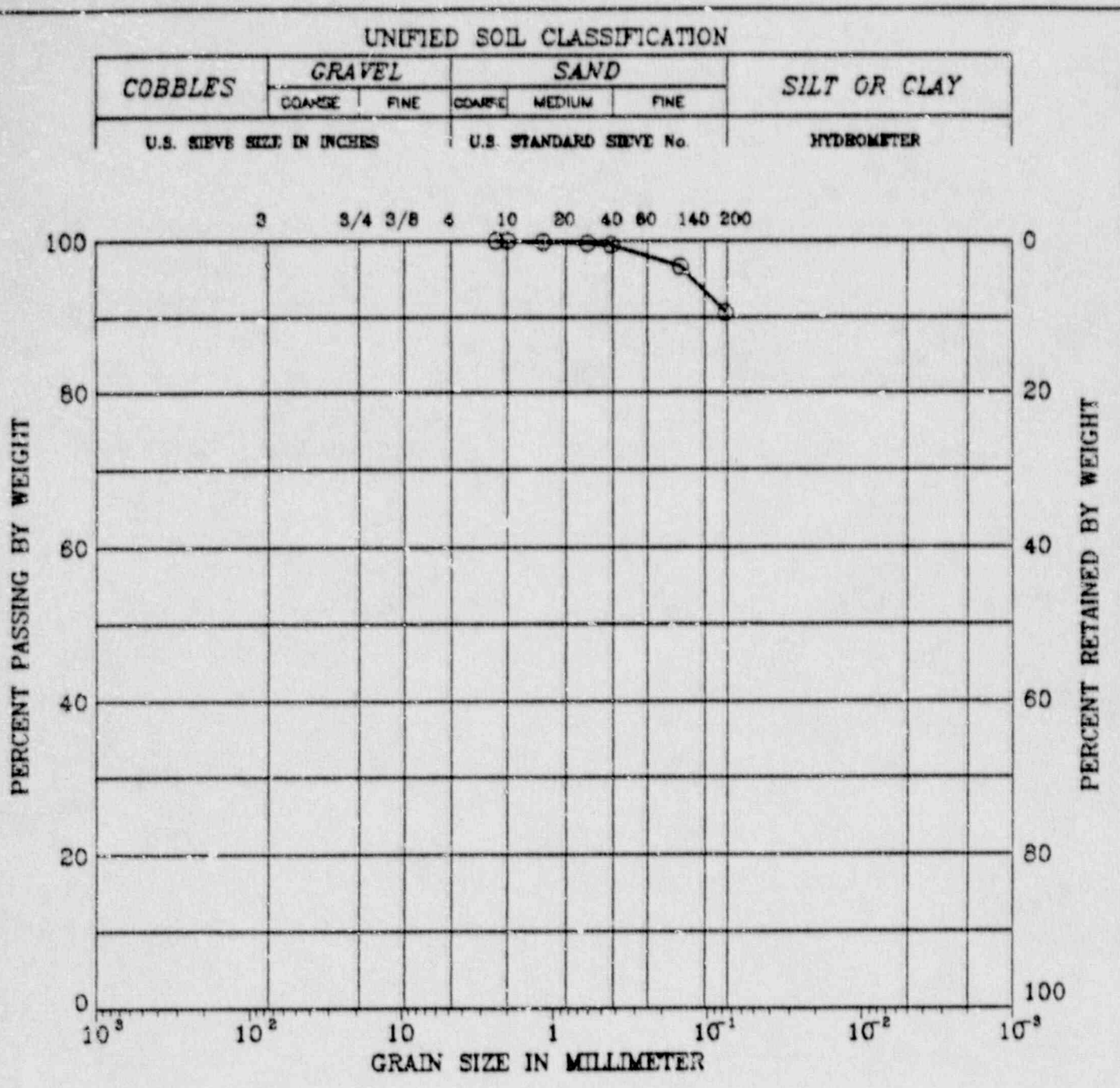
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	PB-13	N/A			CL

Remark : PERMEABILITY BLOCK SAMPLE PB-13

1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No. 28



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	PB-14	N/A			CL

Remark : PERMEABILITY BLOCK SAMPLE PB-14

1-4250-7993-10	GREEN RIVER RADON BARRIER
FOX AND ASSOCIATES	GRAIN SIZE DISTRIBUTION Figure No. 29

```
CCC:                                                          READY

     A          B          C          D          E          F
4    Sample No.            PB-4
5    Location:             Radon Barrier
6                          Green River , Utah
7
8    ---------------------------------------------------------
9    Length of sample (cm)                              15.128
10   Area of Burette (cm^2)                              1.262
11   Area of sample (cm^2)                              28.702
12   Head (cm)                                             352
13   ---------------------------------------------------------
14    Elapsed    Total    Burette
15     Time       Time     Reading    Delta    Permeability
16     Sec.       Sec.       H cm     H cm      (cm/sec)
17          0          0       27.3        0
18      82800      82800       25.6      1.7   0.0000000388
19     106140     188940       25.4      0.2   0.0000000036
20      60060     249000       25.3      0.1   0.0000000031
21      39600     288900       25.2      0.1   0.0000000043
22
23
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```

EDT: [W19] READY

	A	B	C	D	E	F
4	Sample No.		PB-5			
5	Location:		Radon Barrier			
6			Green River , Utah			
7						
8	----------					
9	Length of sample (cm)				13.688	
10	Area of Burette (cm^2)				1.262	
11	Area of sample (cm^2)				26.678	
12	Head (cm)				352	
13	----------					
14	Elapsed	Total	Burette			
15	Time	Time	Reading	Delta	Permeability	
16	Sec.	Sec.	H cm	H cm	(cm/sec)	
17	0	0	20.3	0		
18	90000	90000	18.5	1.8	0.0000000342	
19	106920	196920	18.3	0.2	0.0000000032	
20	60540	257460	18.2	0.1	0.0000000028	
21	39600	297060	18.1	0.1	0.0000000043	
22						
23						

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C22:

READY

	A	B	C	D	E	F
4	Sample No.		PB-6			
5	Location:		Radon Barrier			
6			Green River , Utah			
7						
8	----------					
9	Length of sample (cm)				15.253	
10	Area of Burette (cm^2)				1.262	
11	Area of sample (cm^2)				28.606	
12	Head (cm)				352	
13	----------					
14	Elapsed	Total	Burette			
15	Time	Time	Reading	Delta	Permeability	
16	Sec.	Sec.	H cm	H cm	(cm/sec)	
17	0	0	30	0		
18	93600	93600	27.9	2.1	0.0000000429	
19	106920	200520	27.5	0.4	0.0000000072	
20	60480	261000	27.2	0.3	0.0000000095	
21	39900	300900	27	0.2	0.0000000096	
22		ERR		ERR	ERR	
23		ERR		ERR	ERR	

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CAPS

CAT:

READY

	A	B	C	D	E	F
4	Sample No.		PB-7			
5	Location:		Radon Barrier			
6			Green River , Utah			
7						
8	----------					
9	Length of sample (cm)				11.336	
10	Area of Burette (cm^2)				1.262	
11	Area of sample (cm^2)				28.006	
12	Head (cm)				352	
13	----------					
14	Elapsed Time Sec.	Total Time Sec.	Burette Reading H cm	Delta H cm	Permeability (cm/sec)	
15	0	0	23.5	0		
16	99660	99660	18.9	4.6	0.0000000067	
17	10740	110400	18.8	0.1	0.0000000135	
18	57600	168000	18.2	0.6	0.0000000151	
19	32460	200460	17.9	0.3	0.0000000134	
20	57720	258180	17.2	0.7	0.0000000176	
21		ERR		ERR	ERR	

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CAPS

C23:

READY

	A	B	C	D	E	F
4	Sample No.		PB-8			
5	Location:		Radon Barrier			
6			Green River , Utah			
7						
8	----------					
9	Length of sample (cm)				13.688	
10	Area of Burette (cm^2)				1.262	
11	Area of sample (cm^2)				28.222	
12	Head (cm)				352	
13	----------					
14	Elapsed Time Sec.	Total Time Sec.	Burette Reading H cm	Delta H cm	Permeability (cm/sec)	
15	0	0	22.2	0		
16	99960	99960	17.7	4.5	0.0000000783	
17	37600	137560	17.5	0.2	0.000000006	
18	86520	244080	17.3	0.2	0.000000004	
19	97200	341280	17	0.3	0.0000000054	
20	21900	363180	16.9	0.1	0.0000000079	
21		ERR		ERR	ERR	

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9: 10.8

	A	B	C	D	E	F
4	Sample No.		PB-9			
5	Location:		Radon Barrier			
6			Green River, Utah			
7						
8	---	---	---	---	---	---
9	Length of sample (cm)					11.508
10	Area of Burette (cm02)					1.262
11	Area of sample (cm02)					28.15
12	Head (cm)					352
13	---	---	---	---	---	---
14	Elapsed	Total	Burette			
15	Time	Time	Reading	Delta	Permeability	
16	Sec.	Sec.	H cm	H cm	(cm/sec)	
17	0	0	25.4	0		
18	99720	99720	11.8	13.6	0.0000001999	
19	97080	196800	10.8	1	0.0000000151	
20	57600	254400	10.3	0.5	0.0000000127	
21	93600	348000	9.5	0.8	0.0000000125	
22	79380	427380	8.9	0.6	0.0000000111	
23		ERR		ERR	ERR	

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222:

READY

	A	B	C	D	E	F
4	Sample No.		PB-10			
5	Location:		Radon Barrier			
6			Green River , Utah			
7						
8	----------					
9	Length of sample (cm)				12.017	
10	Area of Burette (cm^2)				1.262	
11	Area of sample (cm^2)				28.198	
12	Head (cm)				352	
13	----------					
14	Elapsed	Total	Burette			
15	Time	Time	Reading	Delta	Permeability	
16	Sec.	Sec.	H cm	H cm	(cm/sec)	
17	0	0	26.2	0		
18	96000	96000	20.7	5.5	0.0000000875	
19	79200	175200	19.9	0.8	0.0000000154	
20	64800	240000	19.5	0.4	0.0000000094	
21	118200	358200	18.3	1.2	0.0000000155	
22						
23						

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CAPS

C22:

READY

	A	B	C	D	E	F
4	Sample No.		PB-11			
5	Location:		Radon Barrier			
6			Green River , Utah			
7						
8	----------					
9	Length of sample (cm)				12.822	
10	Area of Burette (cm^2)				1.262	
11	Area of sample (cm^2)				28.077	
12	Head (cm)				352	
13	----------					
14	Elapsed	Total	Burette			
15	Time	Time	Reading	Delta	Permeability	
16	Sec.	Sec.	H cm	H cm	(cm/sec)	
17	0	0	28.6	0		
18	95880	95880	28.1	0.5	0.0000000085	
19	86940	182820	28	0.1	0.0000000019	
20	65700	248520	27.9	0.1	0.0000000025	
21	101100	349620	27.8	0.1	0.0000000016	
22						
23						

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CAPS

C21: 12.5 MENU

	A	B	C	D	E	F
4	Sample No.		PB-12			
5	Location:		Radon Barrier			
6			Green River , Utah			
7						
8	---					
9	Length of sample (cm)				11.709	
10	Area of Burette (cm^2)				1.262	
11	Area of sample (cm^2)				28.365	
12	Head (cm)				352	
13	---					
14	Elapsed Time Sec.	Total Time Sec.	Burette Reading H cm	Delta H cm	Permeability (cm/sec)	
17	0	0	14	0		
18	94920	94920	12.8	1.2	0.000000187	
19	87000	181920	12.7	0.1	0.0000000017	
20	86400	268320	12.6	0.1	0.0000000017	
21	87000	355320	12.5	0.1	0.0000000017	
22						
23						

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READY

	A	B	C	D	E	F
4	Sample No.		FB-13			
5	Location:		Radon Barrier			
6			Green River , Utah			
7						
8	----------					
9	Length of sample (cm)				10.629	
10	Area of Burette (cm^2)				1.262	
11	Area of sample (cm^2)				28.726	
12	Head (cm)				352	
13	----------					
14	Elapsed	Total	Burette			
15	Time	Time	Reading	Delta	Permeability	
16	Sec.	Sec.	H cm	H cm	(cm/sec)	
17	0	0	27.8	0		
18	91200	91200	26.9	0.9	0.0000000131	
19	88800	180000	26.7	0.2	0.000000003	
20	87300	267300	26.6	0.1	0.0000000015	
21	94800	362100	26.4	0.2	0.0000000028	
22						
23						

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CAPS