An Evaluation of Phosphorus Contributions to Cherry Creek Reservoir From On-site Sewage Disposal Systems

PHASE II

FINAL REPORT

Prepared for
Cherry Creek Basin Authority

MAY 16, 1991

Prepared By:
Tri-County Health Department
7000 E. Belleview Avenue, Suite 301
Englewood, Colorado 80111-1628
Phone: 220-9200

TABLE OF CONTENTS

INTRODUCTION

BACKGROUND

The Cherry Creek Basin Water Quality Management Plan was adopted in 1985. The plan contains a control program to ensure that the standard for phosphorus in Cherry Creek Reservoir adopted by the Water Quality Control Commission will be maintained. An integral part of this control program is the adoption of Best Management Practices (BMP's) to assist in reducing the contribution of non-point sources of phosphorus to Cherry Creek Reservoir. The plan proposes two non-structural BMP's, erosion control regulations and septic tank regulations.

In relation to the septic tank regulations, the non-point control section of the plan states:

> Septic systems provide another source of phosphorus which is presently unregulated with respect to phosphorus. If the basin must regulate point and non-point phosphorus, it follows that septic systems should also meet certain performance standards. Arapahoe and Douglas counties, in cooperation with Tri-County Health Department, shall develop septic system criteria for meeting phosphorus standards.

To accomplish the objective of developing septic system performance criteria for meeting phosphorus standards, Tri-County Health Department proposed a Four phase study to the Cherry Creek Basin Water Quality Authority. The Authority funded Phase I of this study in 1987. The Phase I study concluded that the existing

3200 onsite sewage disposal systems are a significant source of phosphorus in the Basin. However, the soils and geology of the area in conjunction with Tri-County's existing septic regulations (I-88) are believed to be achieving a high level of phosphorus removal in on-site systems. Based upon the available data, it was concluded that the current load to the reservoir from on-site systems is less than the allocated 450 pounds per year.

Phase I also identified, through its literature research, BMP's that could minimize phosphorus contributions from on-site systems. These practices are currently in various phases of implementation. In addition, several potential BMP's or design criteria were listed that could improve and on-site system's ability to remove or retain phosphorus on a long term basis.

In Phase I it was recommended that sufficient further study be conducted to verify numerous assumptions that were made in completing the initial effort. However this additional study was not intended to include any work associated with developing and calibrating a model to more precisely predict the on-site phosphorus loadings to the reservoir. Based upon the findings of Phase I, the size of the Basin and complexity of the hydrogeology, it is believed that such an effort would not be cost effective or provide additional data with a confidence level any higher than that presented in Phase I.

It was recommended that Phase II emphasize the collection of field and laboratory data which evaluates the effectiveness of BMP's that the Phase I literature research identified as showing potential for improving a systems ability to remove phosphorus from wastewater or retain phosphorus in the soils.

STUDY OBJECTIVES

Phase I of this study utilized information in the available literature to assess the fate of phosphorus in on-site systems. Phase II will emphasize a field and laboratory investigation. One purpose of the field investigation is to specify some of the critical assumptions that were made in Phase I. However, the primary objective of Phase II will be to determine what changes, if any, should be made to enhance the on-site systems capability to remove or retain phosphorus in the Cherry Creek Basin.

Phase I investigation identified several potential BMP's which may improve a systems phosphorus removal or retention capabilities on a long term basis. The potential BMP's that are believed to have the most merit include:

- Require that on-site systems be dosed to provide a more equal distribution of wastewater which will enhance phosphorus removal. (Dosing involves applying wastewater to a leachfield at a high rate and on a periodic basis to spread wastewater over an entire leachfield.)

- Increase the separation distance between the bottom of the leachfield and the maximum seasonal water table to increase the depth of unsaturated flow and thereby enhance phosphorus removal. (Currently 4 feet of separation is required.)

- Preclude the use of conventional on-site systems in course textured soils believed to have "Poor" phosphorus retention capabilities.

- Increase setback requirements from drainage ways and dry gulches since these areas are normally associated with soils having "Poor" phosphorus retention capabilities.

To determine whether these potential BMP's have merit, the following specific Phase II study objectives were developed:

1. Determine whether dosing of septic tank effluent provides significantly greater phosphorus removal than is achieved by conventional distribution methods.

2. Evaluate the effects of depth of unsaturated flow on phosphorus removal in soils beneath an on-site system.

3. Estimate the amount of phosphorus removal achieved in soils with percolation rates less than 20 minutes per inch.

4. Determine the reduction in phosphorus loading that will occur through the use of low phosphate detergents.

WORK PLAN

To accomplish the objectives of this study, two on-site sewage disposals systems were selected for monitoring in the Cherry Creek Basin. The criteria for selecting the sites to be monitored were:

Site 1

- The system should be capable of receiving effluent for disposal by either conventional distribution or dosing.
- Seasonally high groundwater levels are greater than 8 feet below the bottom of the leachfield.
- The system is sited in soil with a percolation rate of 20-40 minutes per inch.
- The system is sited in a soil with a Good Phosphorus Retention Classification as identified in the Phase I study.

Site 2

- The system is sited in soils with a percolation rate of less than 20 minutes per inch.
- Seasonally high groundwater levels are less than 8 feet below the bottom of the leachfield, or a perched water table will develop beneath the system at a depth less than 8 feet.

- o The system is sited in a soil with an intermediate or Poor Phosphorus Retention Classification as identified in the Phase I study.

- o The site should be adjacent to a drainage way with a perched water table.

SAMPLING PLAN

The monitoring system at each site consisted of lysimeters, tensiometers, and moisture blocks installed at three depths below each leachfield. Shallow upgradient and downgradient PVC monitoring wells were installed at Site 2. Two downgradient monitoring wells and one lysimeter were installed at Site 1. Lysimeters were used to obtain soil pore liquid samples at various depths beneath each system. Samples were collected by applying a negative pressure or vacuum to the lysimeter. Tensiometers and moisture blocks were proposed to measure soil suction pressure which could have been utilized to project moisture content. Useful data was only recorded from the septic tank, lysimeters, and the one downgradient well at Site 2. A discussion of the lack of useable / reliable tensiometer and moisture block data is included in Attachment #3.

The sampling program consisted of collecting three (3) lysimeter, one (1) groundwater and one (1) septic tank effluent sample at each site on a regular basis. It was believed that a very high percentage of the phosphorus in the samples would be in the soluble orthophosphate form. Since the phosphorus control program is based on total phosphorus, analysis was performed for both orthophosphate and total phosphorus using EPA Method 365.1.

Sampling occurred from November 1989 through November 1990 at Site 1. This data is listed on Table 1 and Table 2 and displayed on Figure 1. Sampling also occurred from February, 1989 through November 1990 at Site 2 and this data is listed on Tables 4 and 5 and Figure 2. At points where no sample was collected or when no analysis was done, an estimate was made by simply averaging the values obtained at the sampling events before and after that point. Effluent phosphorus removal efficiency or soil phosphorus retention was calculated for each sampling event and at each sampling level under the leachfield. These values are shown in Tables 3 and 6 and are plotted on Figures 2 and 4.

SITE CONDITIONS

SITE 1

A site consistent with the selection criteria for Site 1 was identified and the specified on-site monitoring equipment and wells were installed on Lot 24, Cherry Creek Rancho Subdivision, Arapahoe County (14035 East Progress Court, Aurora), Colorado during the late summer of 1989. This location is in an area of soils that were classified "intermediate" (moderate) phosphorus retention probability in Phase I. The septic system was installed in August 1989 and the home occupied in October, 1989.

The site conditions are generally described below and in more detail in Attachment 1, the completion report prepared by CTL / Thompson, Inc. dated October 26, 1989.

- Moderately low estimated water use in dwelling with two occupants
- The septic system initially received wastewater by conventional gravity distribution then, on 08-01-90 dosing with an electrical pump was started
- Lysimeters were placed at 1', 2.5', and 4' below the bottom of the leachfield and no water samples could be collected from the downgradient piezometers or lysimeter.
- Low / no phosphate laundry detergent used for the duration of the study

Depth to Bedrock	9. feet
Fractured / Weathered Claystone	
Depth to Ground Water	>10. feet
Percent Slope	8.5% to the SW
Average Percolation Rate (25, 29, 40)	32. minutes per inch
Range - from three samples:	
% Sand (Gradation tests)	51 to 86%
Passing # 200 Sieve	14 to 44%

SITE 2

A site consistent with the selection criteria for Site 2, except that no perched water table or drainage way were present, was identified and Phase II of this study was initiated in late 1988 at this site. This site is located in or near an area where the soils were classified with "poor" (low) phosphorus retention probability in Phase I. The septic system was installed in December, 1988 after all specified on-site monitoring equipment and wells were installed on Lot 7, Homestead Hill Subdivision, Douglas County (11007 Cottontail Lane, Parker), Colorado. The septic system was installed in December 1988 and the home was occupied in January 1989. The home was sold during 1989 and the new owner / occupants moved in and sampling resumed during October, 1989.

The site conditions are generally described below and in more detail in Attachment 2, the completion report prepared by CTL / Thompson, Inc. dated December 12, 1988.

- Moderately high estimated water use in dwelling with four (4) occupants
- Septic system was gravity fed throughout the study
- Lysimeters placed a 1', 4', and 7' below the bottom of the leachfield and downgradient groundwater samples were collected from one (1) piezometer
- Laundry detergent changed from standard to low (0.5%) phosphate type on 08-08-90

Depth to Bedrock Claystone	>15. feet (estimate 20')
Depth to Ground Water	15. feet
Percent Slope	4.% to the SE
Average Percolation Rate (10, 10, 20)	13. minutes per inch
Range from three samples:	
% Sand (Gradation tests)	76 to 97%
Passing # 200 Sieve	3.2 to 24%

TABLE 1 - SITE 1
PHOSPHORUS MONITORING DATA
FOR THE
OSORNO RESIDENCE

OCATION	SAMPLE DATE 1989/90									
OTAL PHOSPHORUS (ppm)	11-6-89	12-4-89	4-24-9	5-10-90	5-23-90	6-7-90	6-25-90	7-5-90	7-19-90	8-2-90
ysimeters										
foot	0.800	0.80	0.720	.744	.74	.72	.630	.477	.610	.54
.5 feet	0.389	0.401	0.450	.686	.292	.239	.237	.292	.350	.195
feet	0.385	0.399	0.358	.201	.185	.212	.169	.--	.180	.122
H-1 - See Note 1										
H-2 - See Note 1										
eptic tank	.--	8.6	7.3	7.07	6.60	7.56	7.40	.--	6.45	.--
RTHOPHOSPHORUS (ppm)										
ysimeters										
foot	0.778	.--	0.565	.710	.73	.565	.616	.443	.536	.464
.5 feet	0.370	0.401	0.299	.--	.2	.228	.235	.286	.283	.174
feet	0.350	0.390	0.248	.201	.183	.188	.165	.--	.132	.108
eptic tank	.--	7.1	5.1	6.84	5.69	7.10	6.34	.--	6.32	.--

.-- Indicates that no sample was collected
OTE 1 Indicates that no liquid was collected from any wells or lysimeters

TABLE 2 - SITE 1
PHOSPHORUS MONITOR DATA
FOR THE
OSORNO RESIDENCE

LOCATION	SAMPLE DATE 1990										
TOTAL PHOSPHORUS (ppm)	8-16-90	8-22-90	8-30-90	9-6-90	9-13-90	9-26-90	10-4-90	10-18-90	10-25-90	11-8-90	11-14-90
Lysimeters											
1 foot	1.54	.790	.67	.730	.690	.670	.65	.65	.8*	.607	.61
2.5 feet	.286	.269	.60	.249	.217	.210	.34	.200	.4*	.216	.220
4 feet	.168	.110	.10	.--	.--	.080	.14	.103	.3*	.235	.096
TH-1 - See Note 1											
TH-2 - See Note 1											
Septic tank	17.6	6.1	6.25	6.00	8.1	.--	5.6	.--	2.6*	8.8	9.3
ORTHOPHOSPHORUS (ppm)											
Lysimeters											
1 foot	1.50	.740	.52	.635	.620	.661	.65	.59	.2*	.61	.60
2.5 feet	.262	.24	.25	.184	.150	.17	.34	.130	.4*	.191	.203
4 feet	.140	.070	.10	.--	.--	.08	.19	<0.050	.3*	.106	.097
Septic tank	7.30	5.92	6.16	4.70	6.1	.--	5.6	.--	0.2*	7.6	8.9

.-- Indicates that no sample was collected
* All samples taken on 10-25-90 were analyized by a different lab.
NOTE 1: No liquid was collected from any of the wells or lysimeters.

FIGUR 1

PHOSPHORUS LEVELS - SITE 1

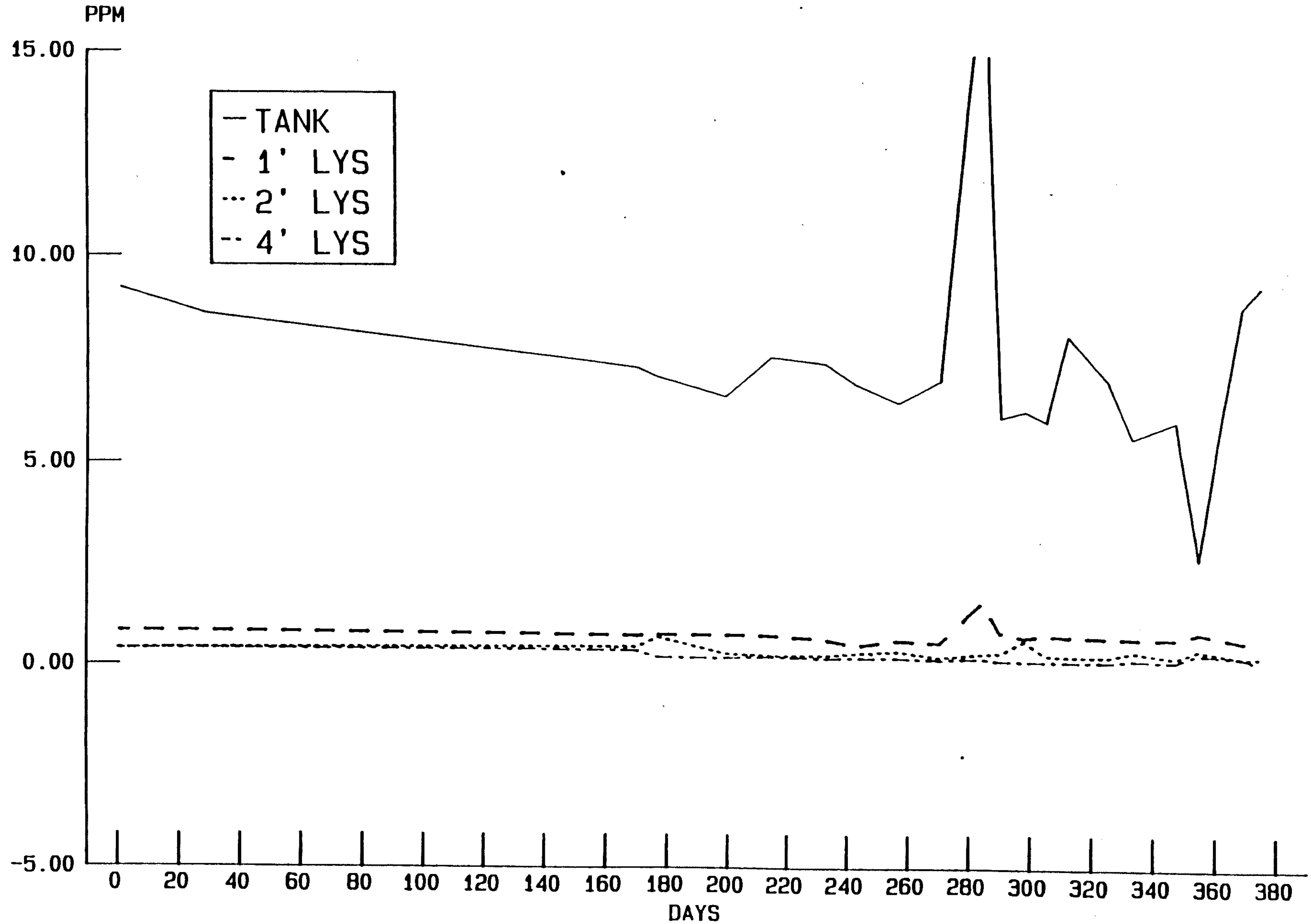


TABLE 3
SITE 1

SAMPLE DATE	DAYS	PHOSPHORUS REMOVAL EFFICIENCY 1 FOOT	2 FEET	4 FEET
11/06/89	1.000	91.30	95.77	95.82
12/04/89	28.00	90.70	95.34	95.36
04/24/90	170.0	90.14	93.84	95.10
05/01/90	177.0	89.48	90.30	97.16
05/23/90	199.0	88.79	95.58	97.20
06/07/90	214.0	90.48	96.84	97.20
06/25/90	232.0	91.49	96.80	97.72
07/05/90 #	242.0	93.09	95.77	97.46 +
07/19/90 *	256.0	90.54	94.57	97.21
08/02/90 #	270.0	92.29	97.21	98.10
08/16/90	284.0	91.25	98.38	99.05
08/22/90	290.0	87.05	95.15	98.20
08/30/90	298.0	89.28	90.40	98.40
09/06/90	305.0	87.83	95.85	98.50 +
09/13/90	312.0	91.48	97.32	98.89 +
09/26/90 #	325.0	90.43	97.00	98.86
10/04/90	333.0	88.39	93.93	97.50
10/18/90 #	347.0	89.17	96.67	98.28
11/08/90	368.0	93.10	97.55	97.33
11/14/90	374.0	93.44	97.63	98.97

* This system was dosed by septic tank effluent starting on 8-1-90.

\# Based on estimated phosphorus levels in septic tank effluent.

\+ Based on estimated phosphorus levels at depth indicated.

FIGURE 2

PHOSPHORUS REMOVAL EFFICIENCY
SITE 1

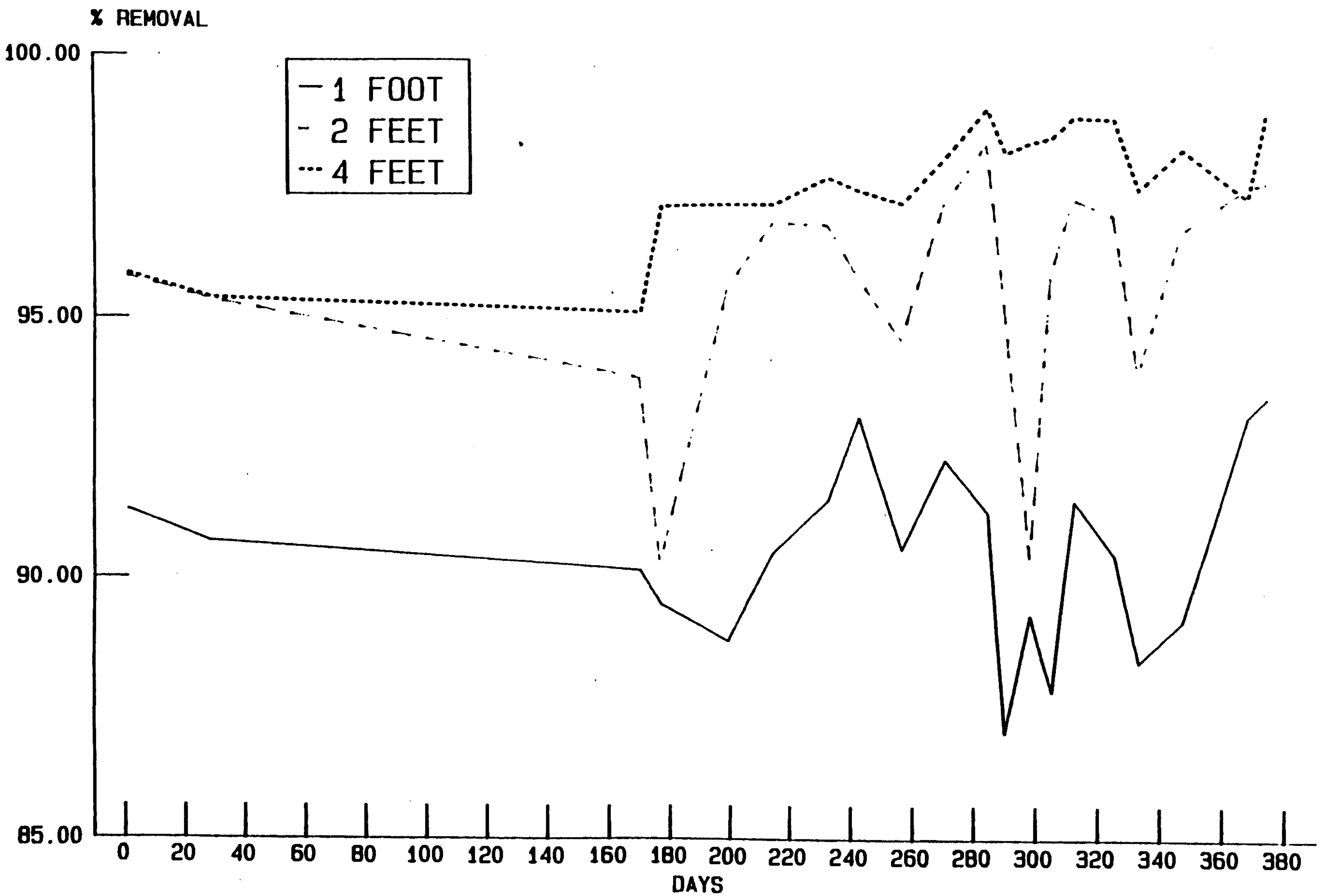


TABLE 4 SITE 2
PHOSPHORUS MONITORING DATA
FOR THE
COOK/MILLET RESIDENCE

LOCATION	SAMPLE DATE 1989										
TOTAL PHOSPHORUS (ppm)	3/6	4/18	5/22	6/13	6/27	7/12	8/2	8/15	8/29	11/6	12/4
Lysimeters											
1 foot	0.710	0.218	0.209	1.200	2.500	2.80	.--	3.140	3.39	2.89	2.39
4 feet	0.204	0.153	0.136	0.140	0.100	0.08	0.081	0.080	0.081	0.082	0.064
7 feet	0.106	0.077	0.072	0.118	0.080	0.059	0.058	0.070	0.067	0.082	0.070
TH-1	0.917	0.428	0.046	0.057	0.024	0.20	0.296	0.03	0.205	0.155	0.039
Septic tank	6.500	6.280	8.470	7.700	5.600	33.5+	6.78	13.10	7.95	20.1	21.8
ORTHOPHOSPHORUS (ppm)											
Lysimeters											
1 foot	0.152	0.205	0.196	1.19	2.6	2.60	.--	3.140	3.34	2.47	2.32
4 feet	0.186	0.152	0.125	0.14	0.1	0.02	0.070	0.075	0.069	0.082	0.064
7 feet	0.1	0.083	0.071	0.118	0.08	0.059	0.060	0.070	0.059	0.080	0.064
TH-1	0.015	0.017	0.034	0.017	0.02	0.018	0.006	0.02	0.014	0.031	0.013
Septic tank	6.76	6.2	9.15	7.7	5.4	5.50	5.10	7.10	6.80	20.2	21.5

.-- Indicates that no sample was collected
\+ Potentially suspect data, (used in calculations)

TABLE 5 ITE 2
PHOSPHORUS MONITORING DATA
FOR THE
COOK/MILLET RESIDENCE

LOCATION	SAMPLE DATE 1990												
TOTAL PHOSPHORUS (ppm)	1/23	2/12	3/15	4/24	5/10	6/7	7/5	8/2	8/22	9/6	9/26	10/18	11/8
Lysimeters													
1 foot	64*	12.8	14.8	16.3	30.0	24.7	22.3	14.7	12.1	12.0	10.1	11.0	11.2
4 feet	0.276	0.578	2.29	.--	9.44	13.5	12.6	12.3	14.6	.--	-	11.8	13.4
7 feet	0.077	0.090	0.055	.--	0.055	.044	.050	.063	.190	.322	.424	8.4	2.63
TH-1	0.90	1.2	1.81	2.31	5.67	6.21	3.43	.241	1.63	2.1	5.80	7.90	8.2
Septic tank	18.6	25	20.7	24.5	.--	-	19.2	15.72	14.5	11.	8.65	8.8	9.8
ORTHOPHOSPHORUS (ppm)													
Lysimeters													
1 foot	44*	12.7	13.3	12.5	17.2	24.1	19.3	14.7	12.0	11.	9.2	10.1	10.7
4 feet	0.157	0.520	2.0	.--	7.80	13.0	12.3	14.0	13.0	.--	-	11.2	12.9
7 feet	0.033	0.049	0.048	.--	0.055	.044	.048	.053	.084	.218	.39	.80	2.08
TH-1	0.83	1.13	0.74	1.96	5.62	5.7	2.72	.206	1.33	1.5	4.24	6.64	7.1
Septic tank	18.6	22.5	15.7	23.1	.--	-	16.0	15.44	14.2	10.	7.52	7.400	8.8

.-- Idicates that no sample was collected
* Suspect data, (not used in calculations)

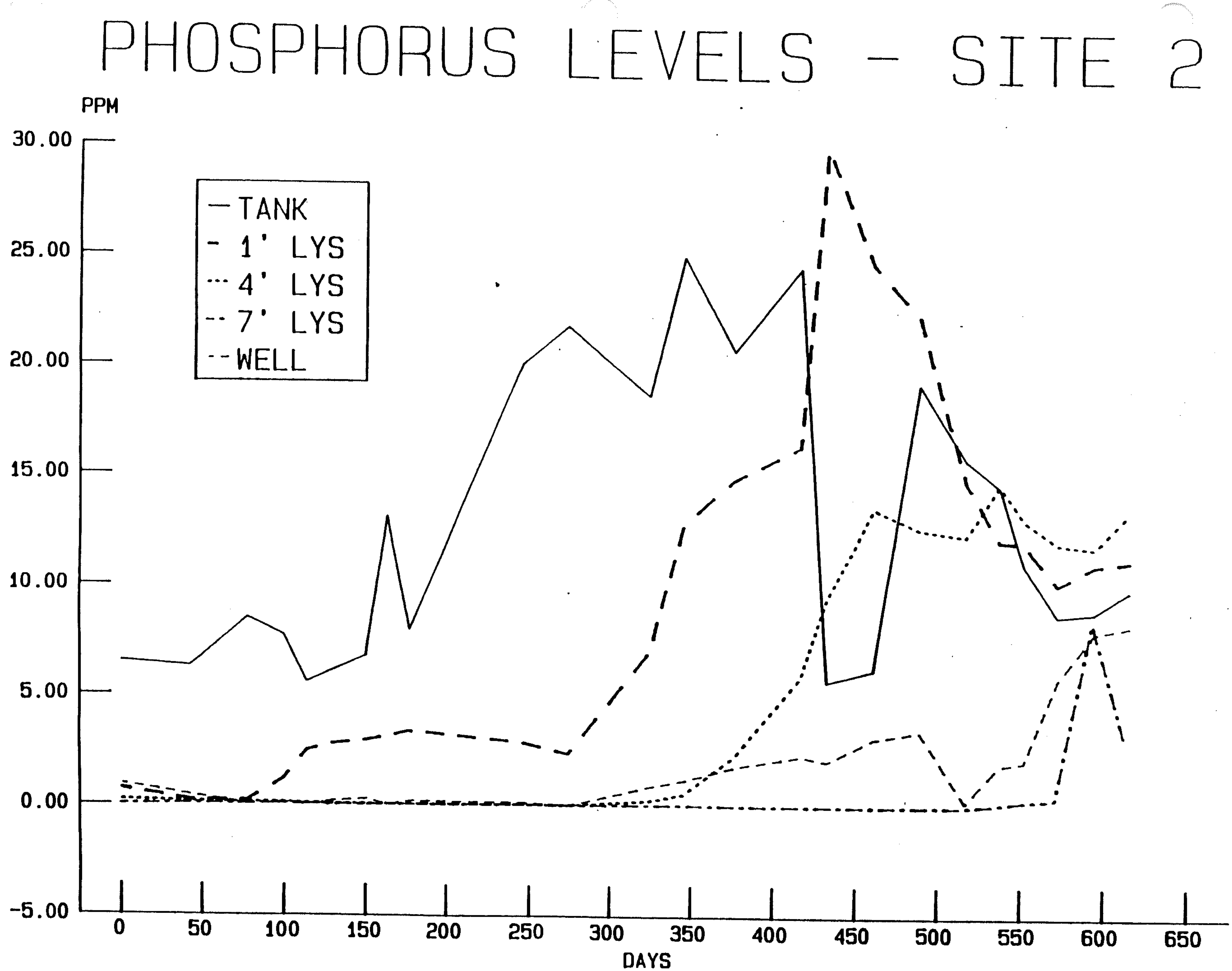

PHOSPHORUS LEVELS - SITE 2
PPM
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
TANK
1' LYS
4' LYS
7' LYS
WELL
0
50
100
150
200
250
300
350
400
450
500
550
600
650
DAYS

TABLE 6
SITE 2

SAMPLE DATE	DAYS	PHOSPHORUS 1 FOOT	REMOVAL 4 FEET	EFFICIENCY 7 FEET
03/06/89	1.000	89.08	96.86	99.75
04/18/89	43.00	96.53	97.56	98.77
05/22/89	78.00	97.53	98.39	99.15
06/13/89	100.0	84.42	98.18	98.47
06/27/89	114.0	55.36	98.21	98.57
07/12/89	129.0	54.10	98.69	99.03
08/02/89	150.0	56.19	98.81	99.14
08/15/89	163.0	76.03	99.39	99.47
08/29/89	177.0	57.36	98.98	99.16
11/06/89	246.0	85.62	99.59	99.59
12/04/89	274.0	89.04	99.71	99.68
01/23/90	324.0	62.36	98.52	99.59
02/12/90	345.0	48.80	97.69	99.64
03/15/90	376.0	28.50	88.94	99.73
04/24/90	416.0	33.47	76.08	99.78
05/10/90	432.0	0.000	0.000	99.03
06/07/90	460.0	0.000	0.000	99.29
07/05/90	488.0	0.000	34.38	99.74
08/02/90 *	516.0	6.489	21.76	99.60
08/22/90	536.0	16.55	0.000	98.69
09/06/90	551.0	0.000	0.000	97.07
09/26/90	571.0	0.000	0.000	95.10
10/18/90	593.0	0.000	0.000	4.545
11/08/90	614.0	0.000	0.000	70.10

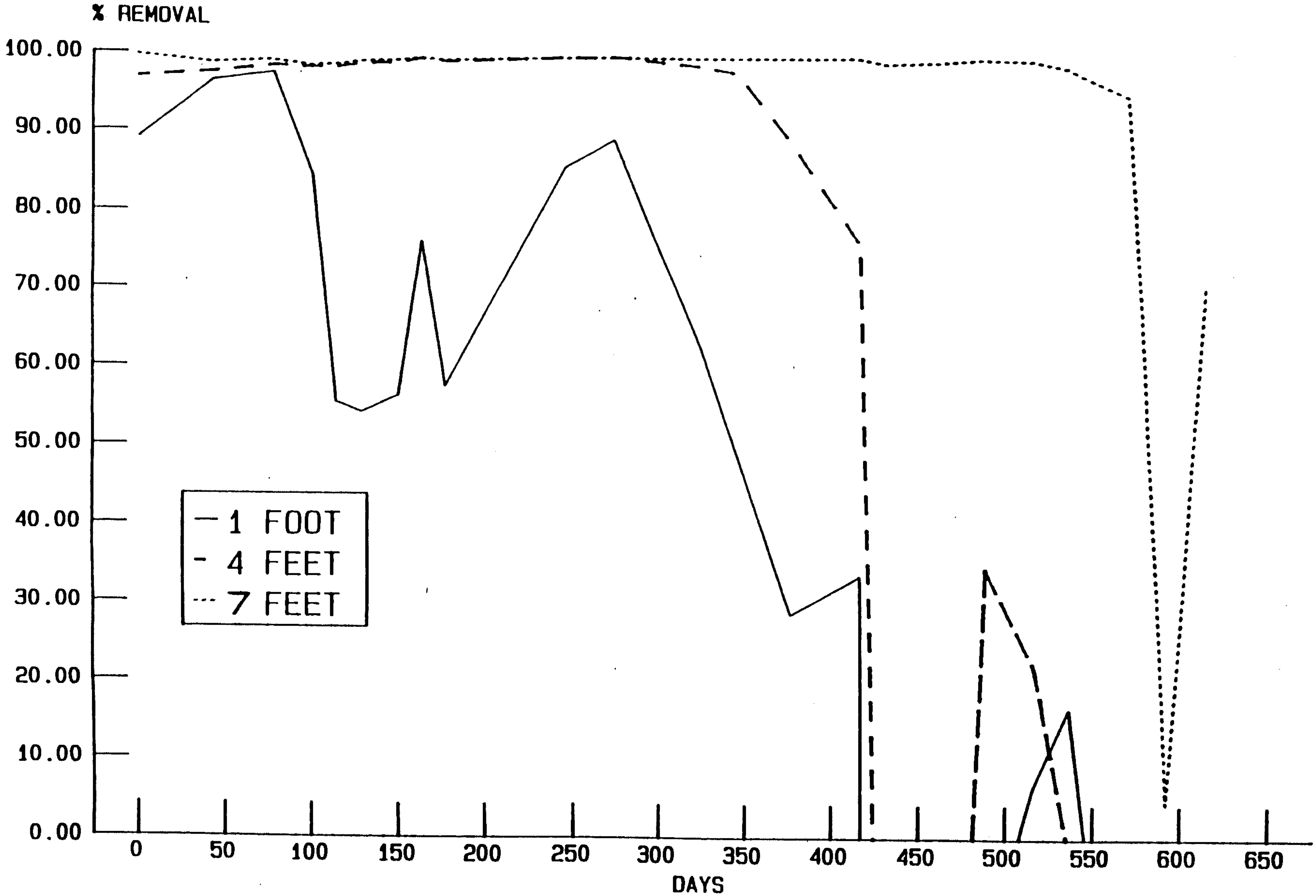
* The use of low phosphate laundry detergent occurred several times during early 1990 and was used excusively after 8-8-90.

Based on estimated phosphorus levels in septic tank effluent.

+ Based on estimated phosphorus levels at depth indicated.

FIGURE 4

PHOSPHORUS REMOVAL EFFICIENCY
SITE 2



DISCUSSION

Phosphorus retention in soil and / or removal from septic tank effluent is influenced by processes or factors that may be grouped into three general categories; chemical, physical, and biological. These factors were discussed in detail in Phase I of this study.

SITE 1

The septic system installed on this site appeared to function consistently at between 95 and 97% reduction of septic tank effluent phosphorus levels at four (4) feet below the leachfield throughout the study period. The actual levels of total phosphorus measured at this depth ranged from 0.08 to 0.4 mg/l, with an average of about 0.18 mg/l. At the one (1) foot and two and one half (2.5) foot depths the phosphorus levels were higher and reduction rates were lower, but they remained consistent throughout the study period. There was no observable / significant change in the effluent phosphorus or the soil phosphorus retention when the system was dosed. This is illustrated on Figures 1 and 2.

The average septic tank effluent total phosphorus level measured during this study was about 7.9 mg/l. This is about half of the average total effluent phosphorus of 15 mg/l identified in Phase I, Canter and Knox (1985). The primary factor influencing this is the phosphate content of detergents. The residents used a no / low phosphate laundry detergent for the duration of the study.

Orthophosphate accounted for between 75 and 100 percent of the total phosphorus measured in the septic tank effluent with an average of 89%. This compares with the 85% value identified by Magdoff et al. (1974) and Otis et al. (1975) cited in Phase I.

Based on the average percolation rate of 32 minutes per inch, at this site the septic tank effluent applied to the leachfield would have taken about 25 1/2 hours to reach the claystone bedrock 4 feet below the leachfield. This reduced porewater velocity encourages solute interaction with the soil, as indicated by Selim et al. (1975) and Carargo et al. (1979) cited in Phase I.

Soil gradation analysis showed a moderate amount of clay and silt size material, 14 to 44%, in the soil column below the leachfield. As the amount of clay and silt size material increases so does the surface area of the soil available for sorption. It should be noted that clay and silt sized material may or may not contain a significant amount of clay minerals which also affect phosphorus sorption and slow mineralization.

Two downgradient piezometers were installed at the time the system was installed. These were designed to allow for sampling of the treated wastewater that would have traveled downgradient when a groundwater mound had established itself under the leachfield. However, at no time during the study was any water recoverable from the two piezometers or from the lysimeter installed later to the southwest of the leachfield. The migration path of the wastewater could not be determined at this site.

SITE 2

Initially, the system appeared to achieve greater than 98% reduction of the septic tank effluent total phosphorus in the seven (7) feet of soil located beneath the leachfield. After several months the total phosphorus concentrations, measured at the 1 foot lysimeter, began to increase possibly indicating the sorptive capacity of the soil underlying the leachfield was being exhausted. Similar conditions appeared later at the four (4) foot and eventually at the seven (7) foot lysimeters. This is illustrated on Figure 4.

The total phosphorus level in septic tank effluent averaged 20.7 mg/l during the periods when average (about 8%) phosphate laundry detergents were used and 10.5 mg/l when 0.5% phosphate laundry detergent was used. This drop is discernible on Figure 3. The range of phosphorus in effluent identified by several sources in Phase I was 11 to 31 mg/l.

Orthophosphate accounted for between 54 and 100 percent of the total phosphorus measured in the septic tank effluent with an average of 90%. This compares with the 85% value identified in Phase I.

Based on the average percolation rate of 13 minutes per inch at this site, the septic tank effluent applied to the leachfield would take about 19 hours to reach the 7 foot level and about 33 hours to reach ground water at about 15′ below the surface (12′ below the leachfield). Soil gradation analysis showed relatively small amount of clay and silt size material, 3.2 to 24%, in the soil column. The effect of this lack of fines is illustrated in the fast porewater velocity (percolation rate).

In the downgradient groundwater, orthophosphate initially accounted for less than 30 percent of total phosphorus measured. However this level increased and appeared to stabilize near 85% of the total phosphorus as the wastewater from the septic system appeared to impact the groundwater phosphorus content and this ratio.

GENERAL OBSERVATIONS

Information regarding the interrelation of surface waters, shallow ground waters or perched water tables and deeper, drinking water aquifers in the Cherry Creek Basin is limited and therefore an issue of concern. To help in evaluating the impacts of all non point sources of phosphorus the clarification of the Basin hydrogeology would be helpful.

The levels of unretained phosphorus measured in the ground water at Site 2 ranged from 0.8 up to 7.0 mg/l. At Site 1, at four (4) feet below the leachfield (about the depth of bedrock in the area) they ranged from 0.08 up to 0.39 mg/l. These levels are comparable to those listed in Table 6 of Phase I. Wastewater generation rates were not measured at these sites. If this piece of information could be obtained and if the phosphorus levels measured at these two sites were confirmed at other sites in the Cherry Creek Basin, then the accuracy of the values used to make this estimate could be confirmed or modified. The average level used to previously calculate phosphorus contributions from septic systems in Cherry Creek Basin was 0.058 mg/l.

The relationship between soil chemistry / mineralogy and retention of phosphorus should be evaluated in detail to determine if its' potential impact on phosphorus removal is significant. The presence of aluminum, calcium and iron compounds was identified in Phase I, as having a possible favorable affect on phosphorus retention in soils. This information could be obtained for soils in the area of the two systems evaluated in this phase of the study, and used to further evaluate the data collected.

If soil mineralogy does have a significant impact on phosphorus sorption and slow mineralization then soil chemistry /mineralogy analysis could become part of the septic system design criteria and a permit condition. This may be particularly useful in marginal soils where soil amendments could be added to increase phosphorus retention. The impact of such an analysis requirement and potential soil amendments should be evaluated.

Another area where additional information is still needed is in or near drainage ways. Many of these drainage ways appear to have "poor" phosphate retention probability. In some areas of the Basin these areas are even wet. It is possible that the moisture observed is generated by individual sewage disposal systems. A project to evaluate some of these areas and the nearby septic systems should also be considered.

CONCLUSIONS

Dosing:

The system at Site 1 was operated for about two-thirds of the study duration as a gravity fed system and then dosed for the final four (4) months. There did not appear to be a significant change in the effluent phosphorus levels or soil retention when the application method changed. From this information alone, it is unclear whether dosing would extend the phosphorus removal life or increase the phosphorus retention capacity of a system. However, one possible explanation for the rapid nature of the decrease in phosphorus removal measured at Site 2 would be that the wastewater discharge into the leachfield, found the lowest point and continued to infiltrate at that point exhausting the phosphorus capacity of that portion of the soil column. This would explain the conditions observed at Site 2 when higher levels of phosphorus were observed in the downgradient piezometer than at the 7 foot lysimeter. Although not demonstrated in this study, the majority of references identified in Phase I appear to agree, in concept, that dosing does increase soil phosphorus sorption capacity.

Depth of Unsaturated Flow:

At Site 2 the depth of unsaturated flow was about 12 feet. This is three (3) times the minimum currently required by Tri-County Health Department's Regulation I-88 (Individual Sewage Disposal Systems). Phosphorus levels and removal efficiencies were measured at 1, 4, and 7 feet below the leachfield level and in a ground water monitoring well. Even with this long unsaturated flow length, this type of soil's phosphorus removal capacity appeared to be exhausted rapidly and if there had been only four (4) feet of soil there would be an even greater impact from phosphorus to the groundwater. This level of phosphorus removal may be as much or more related to soil type, which is "poor" (low) according to Phase I, rather than the depth of unsaturated flow. At Site 1, where there was only 4 feet of unsaturated flow through soils with a significantly greater amount of clay and silt size particles, we observed that phosphorus levels in waste water decreased as the depth of measurement increased and removal efficiencies remained fairly constant for the duration of the study. References identified is Phase I strongly support the concept that increased depth of unsaturated flow increases the potential for phosphorus sorption and / or slow mineralization. The data gathered in this phase of the study is inadequate to question that concept.

Phosphorus Removal in Soils with Percolation Rates less than 20 Minutes per Inch:

At Site 2 the percolation rate was 13 minutes per inch. This rate is consistent with the sandy soils encountered in the leachfield area. The site is in or near an area where the soil was classified as "poor" (low) phosphate retention probability in Phase I. The lack of clay and silt size particles may have been largely responsible for the low levels of phosphorus retention. This could be related to both a porewater velocity that prevented adequate contact time with soil particle surfaces and / or the lack of soil surface area available for adsorption due to the lack of small silt and clay size soil particles. Soil chemistry and mineralogy must also be evaluated with percolation rate data to adequately correlate phosphorus removal with percolation rate in a variety of soils.

Low Phosphate Detergents:

The average phosphorus levels measured in the septic tank effluent samples at Site 1, where low phosphate detergent was used for the duration of the study, were significantly lower that the range identified in Phase I. Also, there was a significant drop in the effluent phosphorus levels at Site 2 when the residents changed from standard, 8%, to 0.5% phosphate laundry detergent. This clearly indicates a phosphorus source that has been identified and could be controlled.

RECOMMENDATIONS

The information gathered about dosing during this phase of the study was inconclusive, primarily due to the limited duration of system monitoring at Site 1. Therefore, the impact of a dosing requirement should be evaluated further, prior to implementation of this potential BMP. The issues of additional system cost for either passive or active dosing system installation and additional maintenance must be addressed as part of this evaluation.

It appears that the depth of unsaturated flow alone has little effect on phosphorus removal if the soil has a fast percolation rate, i.e., less than 20 minutes per inch. At Site 2, where there was 12 feet of unsaturated flow through soil with a percolation rate of 13 minutes per inch we observed a fairly rapid loss of phosphorus retention in the soil column and an increase in the groundwater phosphorus level. However, at Site 1 where there was only 4 feet of soil (with a percolation rate of 32 minutes per inch), the potential impact of phosphorus on the groundwater would be estimated to be minimal. Based on this information implementation of a BMP related solely to depth of unsaturated flow is not warranted.

Based on the information outlined above, the percolation rate appears to be directly related to phosphorus removal capacity of soils. The faster the percolation rate the less the contact time and therefore the less phosphorus removal that occurs in the soil column. Soil mineralogy, discussed previously, also effects phosphorus adsorption and slow mineralization. There are several potential options to address system modification or alternative design in fast percolating soils. (1) The first is to require a type of septic system that would rely on a lined evapotranspiration system or other processes; as opposed to infiltration in poor soil types. This may be possible to require through a change in county regulation. However, the additional costs and the potential drawbacks would need to be evaluated. (2) A second option would be to require soil amendments in the leach field area to decrease the percolation rate and / or change the soil mineralogy. Again this would increase system installation costs. Also, sanitation districts could be encouraged to extend service lines, then developments could be required to connect with public sewer systems where feasible through the planning and development process at the county or city level.

The information from this study clearly indicates that the phosphate content of detergents has a significant impact on effluent phosphorus content. A program to encourage the use of low / no phosphate detergents through a change in Tri-County's onsite sewage disposal regulations should proceed to be implemented with the next revision of these regulations. The counties may have the ability to require the use of these types of readily available detergents. A drawback to this approach may be the limited ability to enforce such a regulation.

ATTACHMENT 1

Completion Report Site 1

CTL/THOMPSON, INC.
CONSULTING GEOTECHNICAL AND MATERIALS ENGINEERS

October 26, 1989

Tri-County Health Department
7000 E. Belleview Avenue, Suite 301
Englewood, Colorado 80111-1628

Attention: Mr. Rick Kinshella, P.E.

Subject: Phosphorus Monitoring Program
Osorno Residence Percolation Field
14035 E. Progress Court
Aurora, Colorado
Job No. 15,346

Gentlemen:

We were requested to install sampling and monitoring instrumentation below and nearby the percolation field at the Osorno residence, 14035 East Progress Court in the Cherry Creek Rancho Subdivision, Aurora, Colorado (Fig. 1). The scope of our work included acquisition and installation of groundwater monitoring and sampling equipment, drilling of two exploratory borings and developing these borings as groundwater monitor piezometers. This letter provides a summary of our field installation procedures, a site plan showing the location of exploratory borings and instrumentation installation, and laboratory data.

Instrumentation Installation

On July 27, 1989 our representatives installed the monitoring and sampling equipment in the percolation field south of the Osorno residence as shown on Fig. 1. The field had been excavated by the contractor to a depth of 3 to 3.5 feet prior to our visit. We used hand augers to excavate 6 inch diameter holes to depths of 1, 3 and 5 feet below the bottom of the leach field. Soils found in our auger holes consisted of 2 feet of medium dense dry silty sand underlain by moist silty sands. Claystone bedrock was at 5 feet. Soils samples were obtained at 1-foot intervals from 0 to 4 feet, and returned to our laboratory for classification and analyses. Tests performed on the samples included natural moisture content, dry density, grain size analyses and specific gravity. Summary test results are showed in Table I.

We installed one lysimeter, one moisture block and one tensiometer in the bottom of each of the three auger holes. The devices were installed in the native subsoils to simulate natural conditions. Each lysimeter was installed with approximately 2 inches of silica flour packing around the porous cup at the bottom of the lysimeter. Wires from the moisture blocks, the tensiometer extensions and dial gages, and the sampling tubes from the lysimeters were installed to extend to approximately one foot below proposed finished grade. Following the installation of the instrumentation, a plywood box 2 feet wide, 4 feet long and 4 feet high was constructed over the top of the instrumentation and secured with chain and a padlock. We then placed 2-inch gravel over the ground in the bottom of the box.

1971 WEST 12TH AVENUE • DENVER, COLORADO 80204 • (303) 825-0777

The week following our equipment installation, the contractor returned to the site and completed the construction of the percolation field. We understand a one foot layer of 2-inch fractured rock was placed around the leach field distribution pipes and covered by 2 to 2.5 feet of native soil.

Piezometer Installation

On September 8, 1989 we returned to the site and drilled two exploratory borings at the locations shown on Fig. 1. Logs of the subsoils found in the exploratory borings are shown on Fig. 2. Soils found in our borings consisted of four and five feet of sandy, silty clay underlain by silty sand. Bedrock was encountered at 9.5 and 8.5 feet. The sands were medium dense and the bedrock was hard. No free groundwater was found in the borings at the time of drilling.

We developed the borings as groundwater monitor piezometers. Factory slotted PVC pipe was installed and the holes were backfilled with silica sand, a bentonite plug and grout. Ten inch diameter limited access man-hole covers were installed over the piezometers according to the schematic diagram shown on Fig. 2. We then installed a 2-inch diameter aluminum casing adjacent to the instrumentation access box. This pipe will be used in conjunction with a down-hole densiometer (moisture-density gauge) to measure the soil moisture profile of the percolation field through the project time.

We appreciate working with you on this project. If you have questions, please call.

Very truly yours,

CTL/THOMPSON, INC.

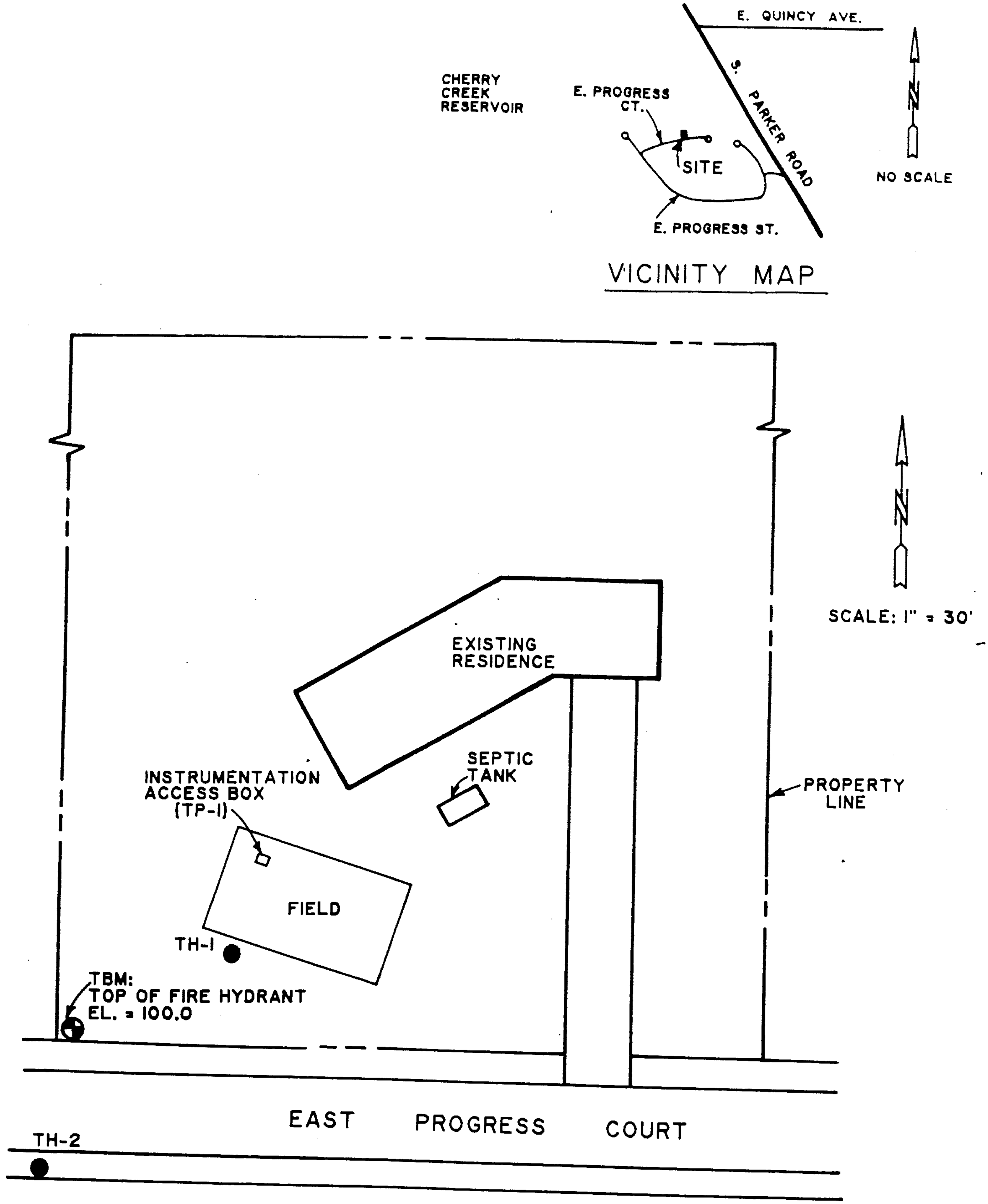
Mike Schneider
Environmental Staff Engineer

Reviewed by:

Ronald M. McOmber, P.E.
Associate

COLORADO REGISTERED RONALD M. McOMBER 20243 PROFESSIONAL ENGINEER

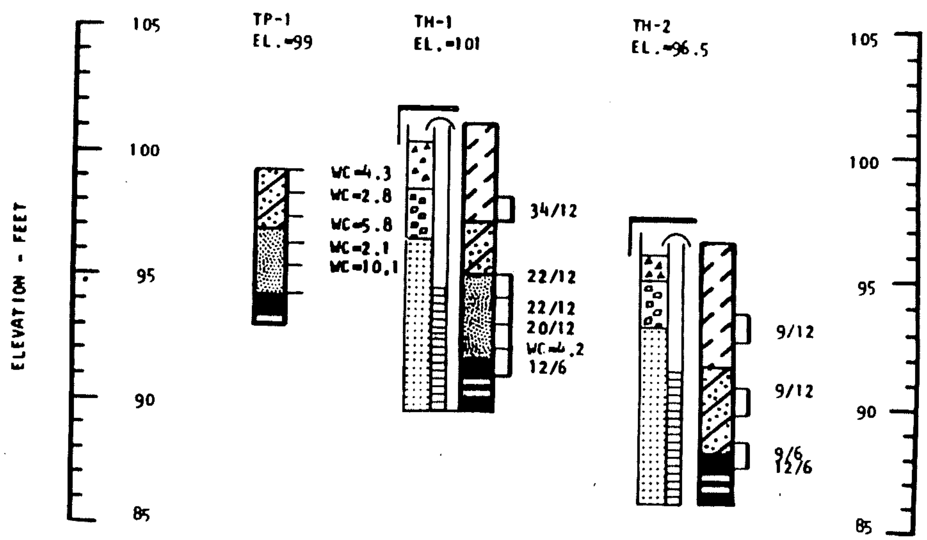
MS:RMM:am
(3 copies sent)



LOCATIONS OF EXPLORATORY BORINGS

JOB NO. 15,346

FIG. 1



NOTES:

1. TP-1 WAS EXCAVATED JULY 27, 1989 WITH HAND AUGERS. TH-1 AND TH-2 WERE DRILLED SEPTEMBER 8, 1989 WITH A TRUCK-MOUNTED, 4-INCH DIAMETER CONTINUOUS FLIGHT POWER AUGER.

2. THESE LOGS ARE SUBJECT TO THE EXPLANATIONS, LIMITATIONS AND CONCLUSIONS AS CONTAINED IN THIS LETTER.

3. WC-INDICATES NATURAL MOISTURE CONTENT (%)
-200-INDICATES PERCENT PASSING THE NO. 200 SIEVE

LEGEND:

CLAY, VERY SANDY, SILTY, STIFF TO VERY STIFF, DRY, BROWN (CL)

SAND, SILTY, MEDIUM DENSE, DRY TO MOIST, TAN, BROWN (SM)

SAND, SLIGHTLY SILTY, MEDIUM DENSE, TAN (SP)

BEDROCK, CLAYSTONE, MEDIUM, HARD, DRY, GRAY, TAN, RUST

DRIVE SAMPLE. THE SYMBOL 16/12 INDICATES THAT 16 BLOWS OF A 140 POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE A 2.5 INCH O.D. SAMPLER 12 INCHES

GRAB SAMPLE OBTAINED FROM AUGER CUTTINGS DURING TEST PIT EXCAVATION OR HAND DRIVE OBTAINED BY PUSHING A THIN-WALLED LINER INTO THE NATIVE SOILS

LIMITED ACCESS MONITOR WELL COVER

2 INCH, SOLID FLUSH JOINT THREATED PVC PIPE WITH LOCKING CAP

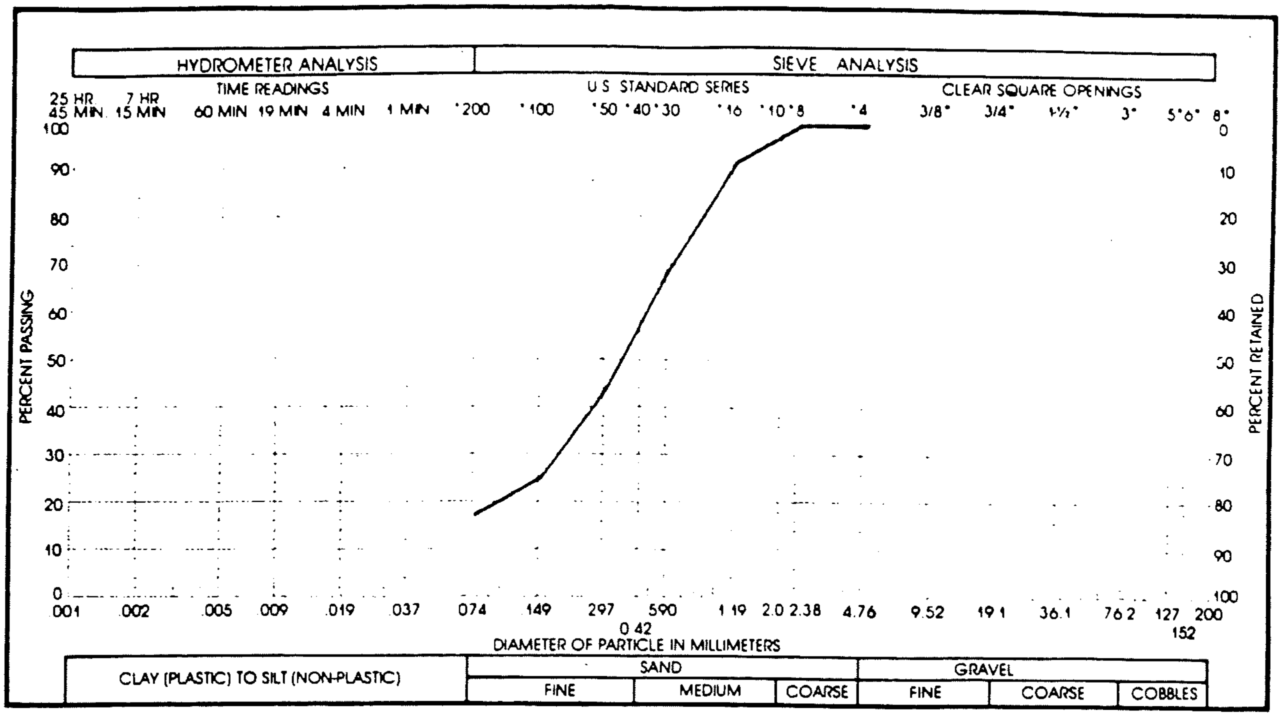
2 INCH, SLOTTED FLUSH JOINT THREADED PVC PIPE

CONCRETE

BENTONITE

SILICA SAND

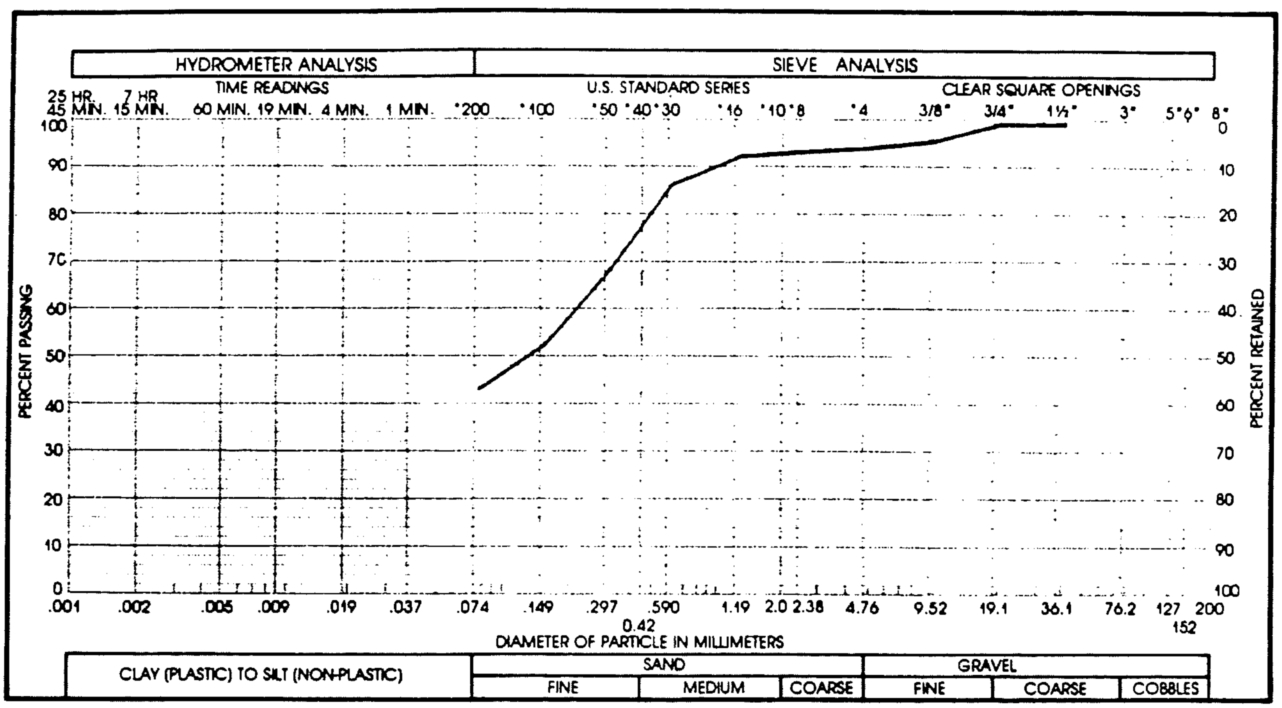
LOGS OF EXPLORATORY BORINGS



Sample of SAND, SILTY, MEDIUM MOIST, BROWN GRAVEL 0 % SAND 81 %

From TP-1 AT 1 FOOT SILT & CLAY 19 % LIQUID LIMIT ____ %

PLASTICITY INDEX ____ %



Sample of SAND, SILTY, MEDIUM MOIST, BROWN GRAVEL 5 % SAND 51 %

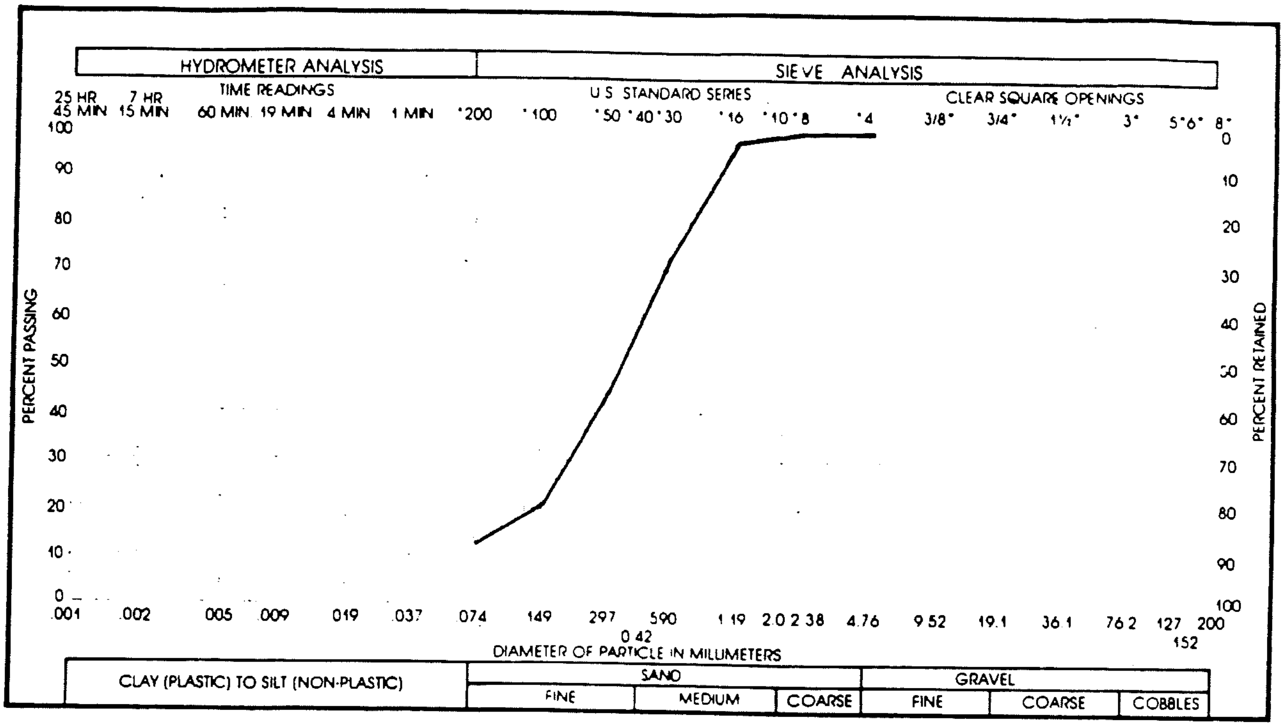
From TP-1 AT 4 FEET SILT & CLAY 44 % LIQUID LIMIT ____ %

PLASTICITY INDEX ____ %

Gradation Test Results

JOB NO. 15,346

FIG. 3



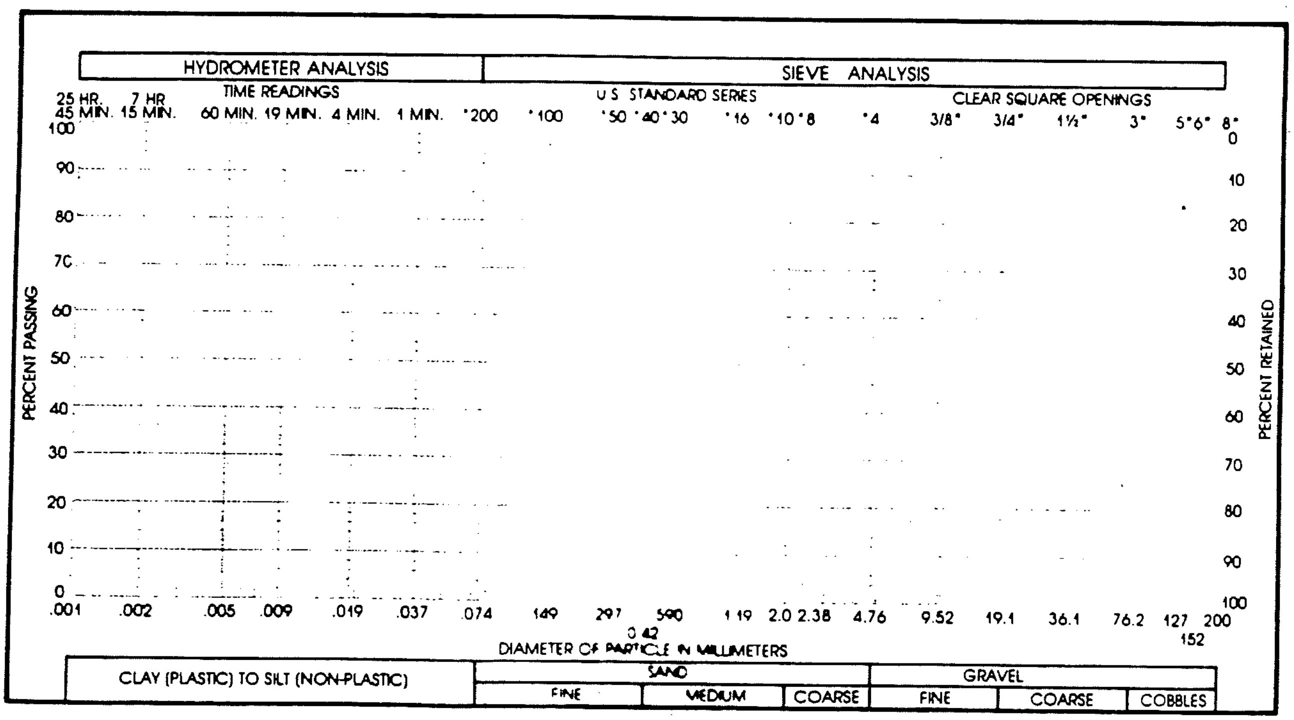
Sample of SAND, SLIGHTLY SILTY, MOIST, BROWN

From TH-1 AT 8 FEET

GRAVEL 0 % SAND 86 %

SILT & CLAY 14 % LIQUID LIMIT ____ %

PLASTICITY INDEX ____ %



Sample of ____

From ____

GRAVEL ____ % SAND ____ %

SILT & CLAY ____ % LIQUID LIMIT ____ %

PLASTICITY INDEX ____ %

Gradation Test Results

JOB NO. 15,436

FIG. 4

Form 10

JOB NO. ,346

TABLE 1
SUMMARY OF LABORATORY TEST RESULTS

HOLE	DEPTH (FEET)	NATURAL MOISTURE (%)	NATURAL DRY DENSITY (PCF)	ATTERBERG LIMITS		PASSING NO. 200 SIEVE (%)	TRIAXIAL SHEAR TESTS		SPECIFIC GRAVITY AT 200C	SOIL TYPE
				LIQUID LIMIT (%)	PLASTICITY INDEX (%)		DEVIATOR STRESS (PSF)	CONFINING PRESSURE (PSF)		
TH-1	8	4.2	110			14			2.60	SAND, SILTY
TP-1	0	4.3	98							SAND, SLIGHTLY CLAYEY
	1	2.8	92			19			2.62	SAND, SILTY
	2	5.8								SAND, SILTY
	3	2.1	123							SAND, SLIGHTLY SILTY
	4	10.1				44				SAND, CLAYEY

ATTACHMENT 2

Completion Report Site 2

CTL/THOMPSON, INC.
CONSULTING GEOTECHNICAL AND MATERIALS ENGINEERS

December 12, 1988

Tri-County Health Department
Administrative Office
7000 East Belleview Avenue
Suite 301
Englewood, Colorado 80111-1628

Attention: Mr. Rick Kinshella, P.E.

Subject: Phosphorus Monitoring Program
Cook Residence Percolation Field
11007 Cottontail
Parker, Colorado
Job No. 15,346

Gentlemen:

We were requested to install sampling and monitoring instrumentation below the percolation field at the Cook residence at 11007 Cottontail in the Homestead Hills Subdivision in Parker, Colorado (Fig. 1). The scope of our work included acquisition and installation of ground water monitoring and sampling equipment, drilling of two exploratory borings and developing these borings as ground water monitor piezometers. This letter provides a summary of our field installation procedures, and a site plan showing the location of exploratory borings and instrumentation installation.

Instrumentation Installation

On November 2, 1988 our Messrs. Clyde Anderson and Mike Schneider installed the monitoring and sampling equipment in the percolation field south of the Cook residence as shown on Fig. 1. The field had been excavated by the contractor to a depth of 2.5 to 3 feet prior to our visit. We used hand augers to excavate 6-inch diameter holes to depths of 1, 4 and 7 feet below the bottom of the leach field. Soils found in our auger holes consisted of 0.5 to 1.5 feet of medium dense, dry, silty sand underlain by slightly silty sands. Soil samples were obtained from depths of 1, 4 and 6.5 feet and returned to our laboratory for classification and analysis. Tests performed on the samples included natural moisture content, dry density, grain size analysis and specific gravity. Summary test results are in Table I.

We installed one lysimeter, one moisture block and one tensiometer in the bottom of each of the three auger holes. The devices were installed in the native subsoils to simulate natural conditions. Each lysimeter was installed with approximately 2 inches of silica flour packing around the porous cup at the bottom of the lysimeter. Wires from the moisture blocks, the tensiometer extensions and dial gages, and the sampling tubes from the lysimeters were installed to extend to approximately one foot below proposed finished grade. Following the installation of the instrumentation, a plywood box 2 feet wide, 4 feet long and 4 feet high was constructed and installed over the top of the instrumentation and secured with 3/8-inch chain and a padlock.

The day following our equipment installation, the contractor returned to the site and completed the construction of the percolation field. We understand a one foot thick layer of 2-inch fractured rock was placed around the leach field distribution pipes and covered by 2 feet of soil. Our representative returned to the site and installed 2-inch fractured gravel at the bottom of the instrumentation access box, at the request of Mr. Kinshella.

Piezometer Installation

Several days following the completion of the leach field installation, we returned to the site and drilled two exploratory borings at the locations shown on Fig. 1. Logs of the subsoils found in our exploratory borings can be found on Fig. 2. We developed the borings as ground water monitor piezometers. Factory slotted PVC pipe was installed and they were backfilled with silica sand, a bentonite plug and grout. Protective steel casing and a locking well cap were installed over the piezometers according to the schematic shown on Fig. 5. The soils found in our borings consisted of 10 and 16 feet of silty sands underlain by sandstone and claystone bedrock to 20 feet. The sands were medium dense and the bedrock was hard. No free ground water was found in the borings at the time of drilling.

Monitoring

We obtained initial tensiometer readings of 22, 40 and 38 centibars for the 1, 4 and 7 foot instrument depths. Following the readings, we emptied the water from the tensiometers for winter frost protection. We anticipate sampling discharge water and ground water twice during the month following occupancy of the residence. We will then allow the leach field system to stabilize for the following five months and sample the discharge water and ground water for the following 11 months at a rate of two events per month.

We appreciate working with you on this project. If you have any questions, please call.

Very truly yours,

CTL/THOMPSON, INC.

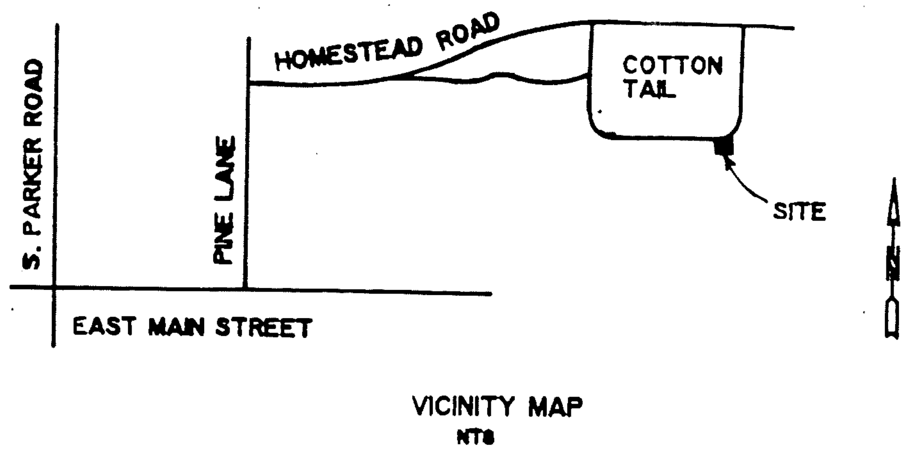
Mike Schneider
Project Engineer

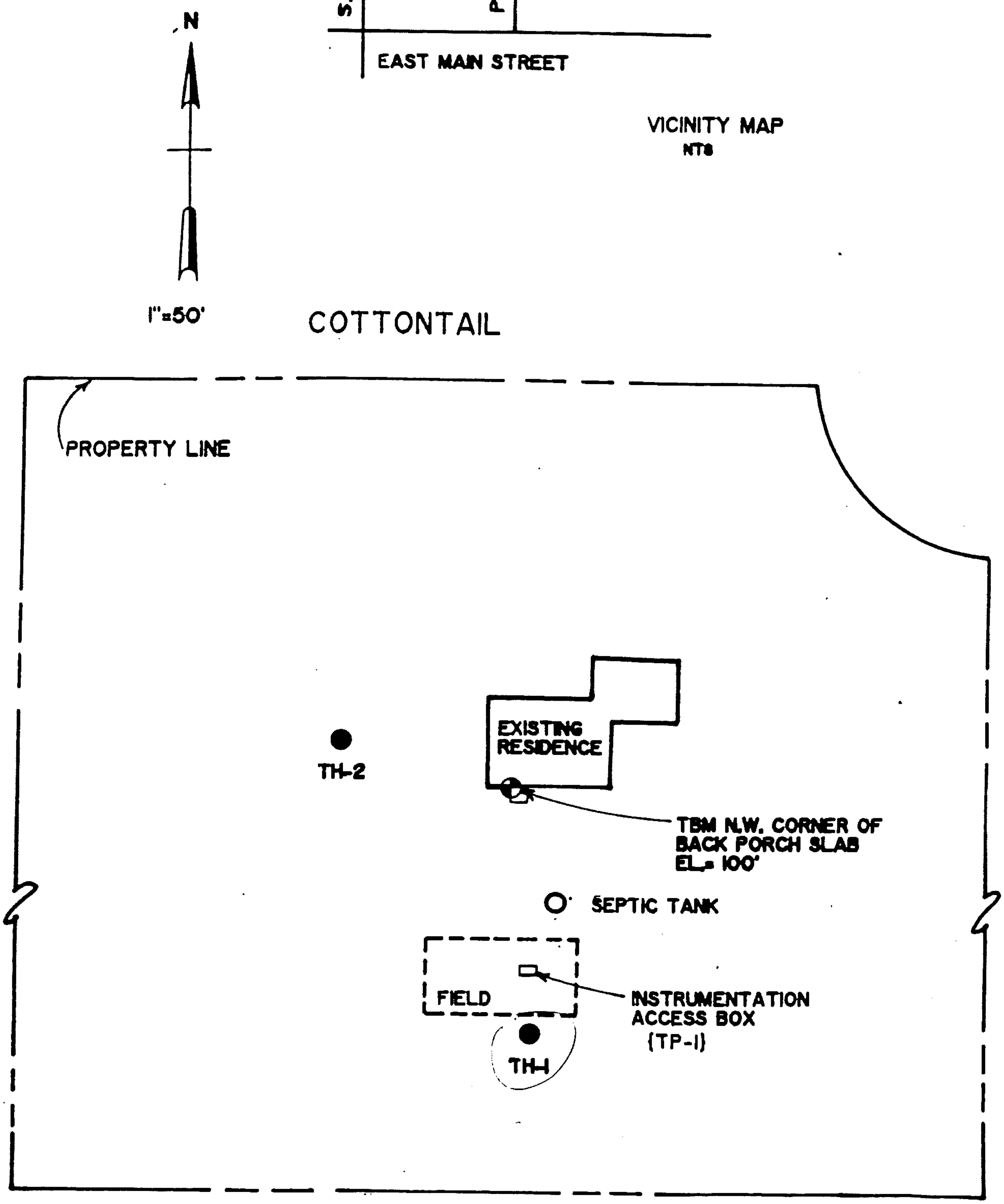
Reviewed By:

Ronald M. McOmber, P.E.
Principal, Senior Engineer

COLORADO REGISTERED PROFESSIONAL ENGINEER RONALD M. McOMBER 20243

MS:RMM:gl
(3 copies sent)

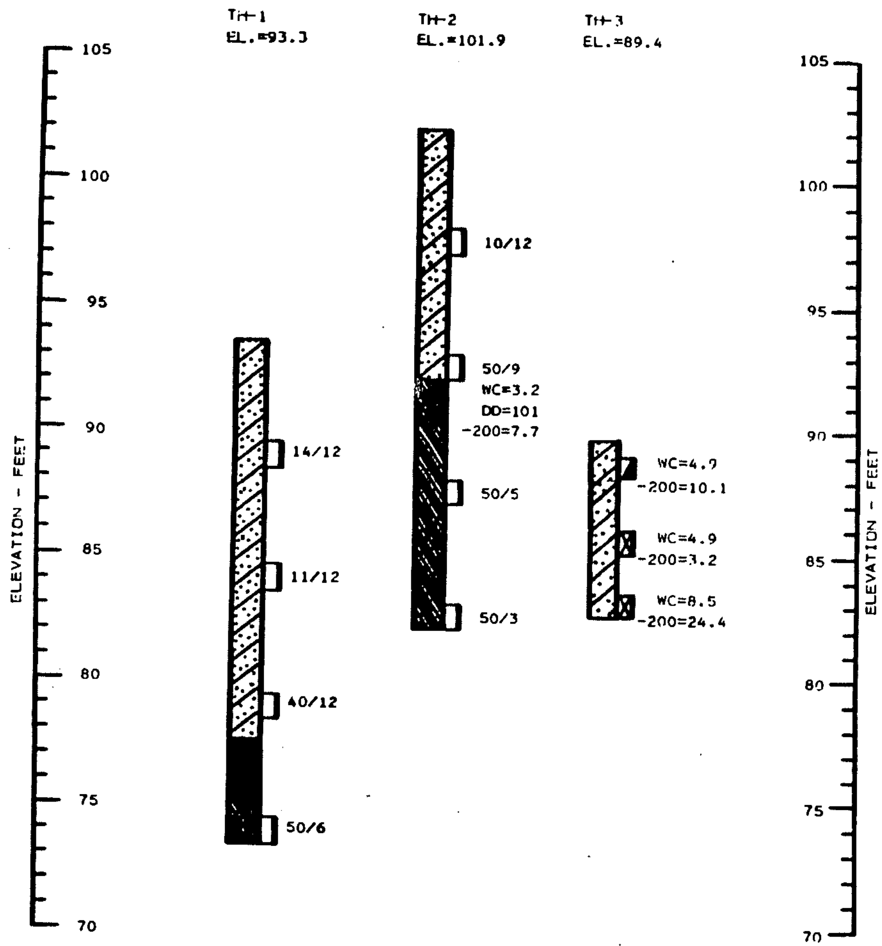




LOCATION OF EXPLORATORY BORINGS

JOB NO. 15,346

FIG. 1



LEGEND:

SAND, SILTY, MEDIUM DENSE, DRY TO MOIST, BROWN (SM, SP-SM)

BEDROCK, INTERBEDDED SANDSTONE, CLAYSTONE, HARD, DRY, GRAY, GREEN

DRIVE SAMPLE. THE SYMBOL 14/12 INDICATES THAT 14 BLOWS OF A 140 POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE A 2.5 INCH O.D. SAMPLER 12 INCHES.

HAND DRIVE SAMPLE USING A 2.0 INCH O.D. SAMPLER

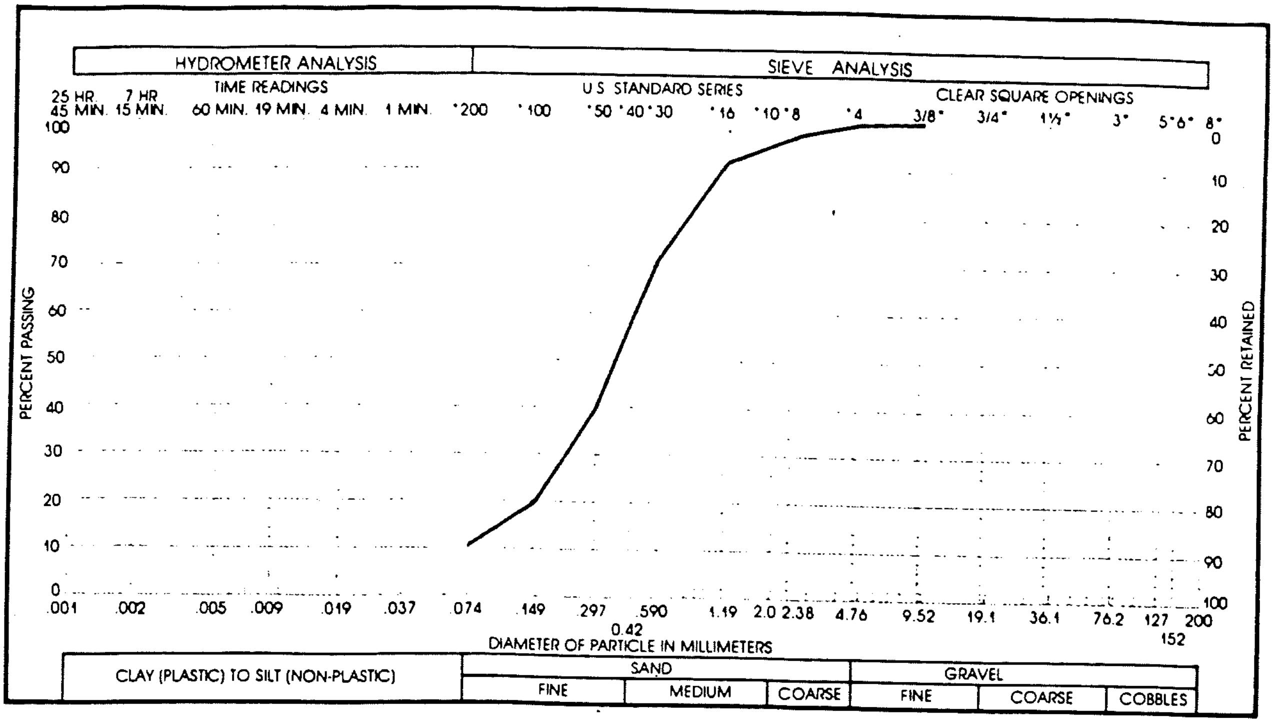
CUP SAMPLE COLLECTED FROM AUGER CUTTINGS.

NOTES:

1. THE BORINGS WERE DRILLED NOVEMBER 8, 1988 USING A 4-INCH DIAMETER CONTINUOUS FLIGHT POWER AUGER.
2. ELEVATIONS WERE OBTAINED RELATIVE TO TBM (EL.=100.0) SHOWN ON FIG. 1.
3. THESE LOGS ARE SUBJECT TO THE EXPLANATIONS, LIMITATIONS AND CONCLUSIONS CONTAINED IN THIS LETTER.
4. WC - INDICATES NATURAL MOISTURE CONTENT (%)
   DD - INDICATES DRY DENSITY (PCF)
   -200 - INDICATES PERCENT PASSING THE NO. 200 SIEVE

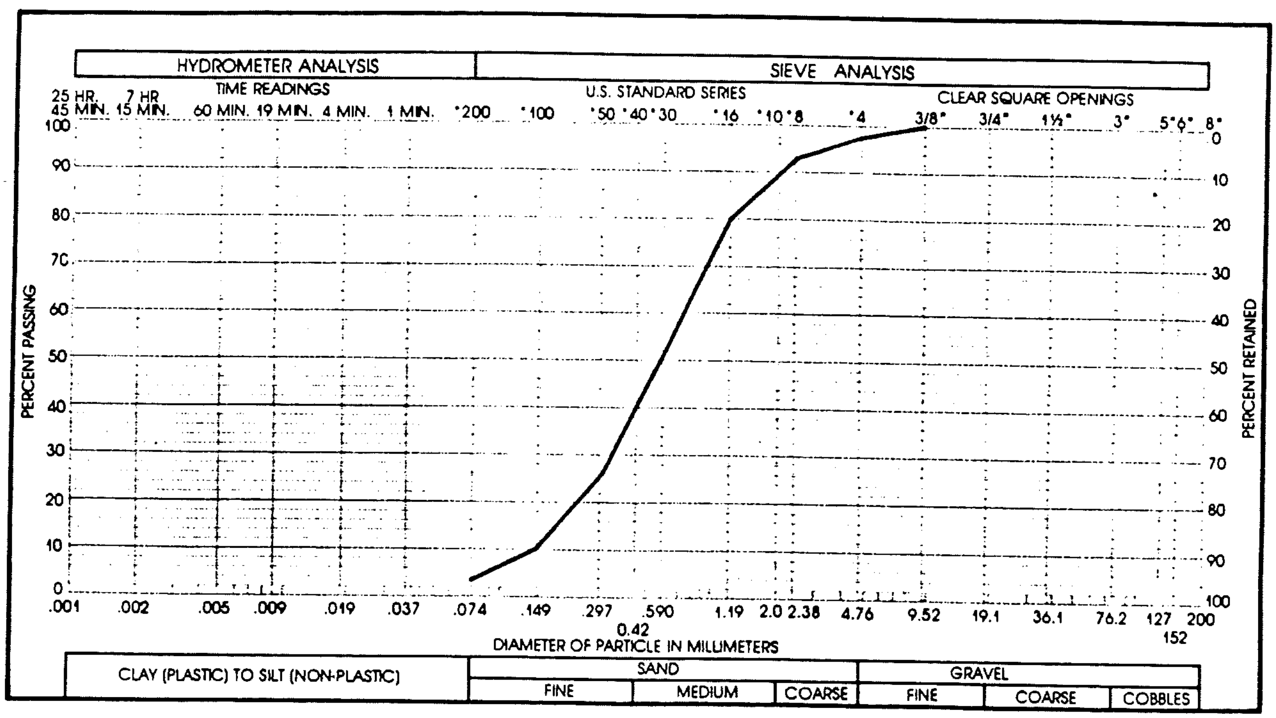
LOGS OF EXPLORATORY BORINGS

[redacted]



Sample of SAND, SILTY, BROWN (SM)
From TP-1 AT 1 FOOT

GRAVEL 0 % SAND 90 %
SILT & CLAY 10 % LIQUID LIMIT – %
PLASTICITY INDEX – %



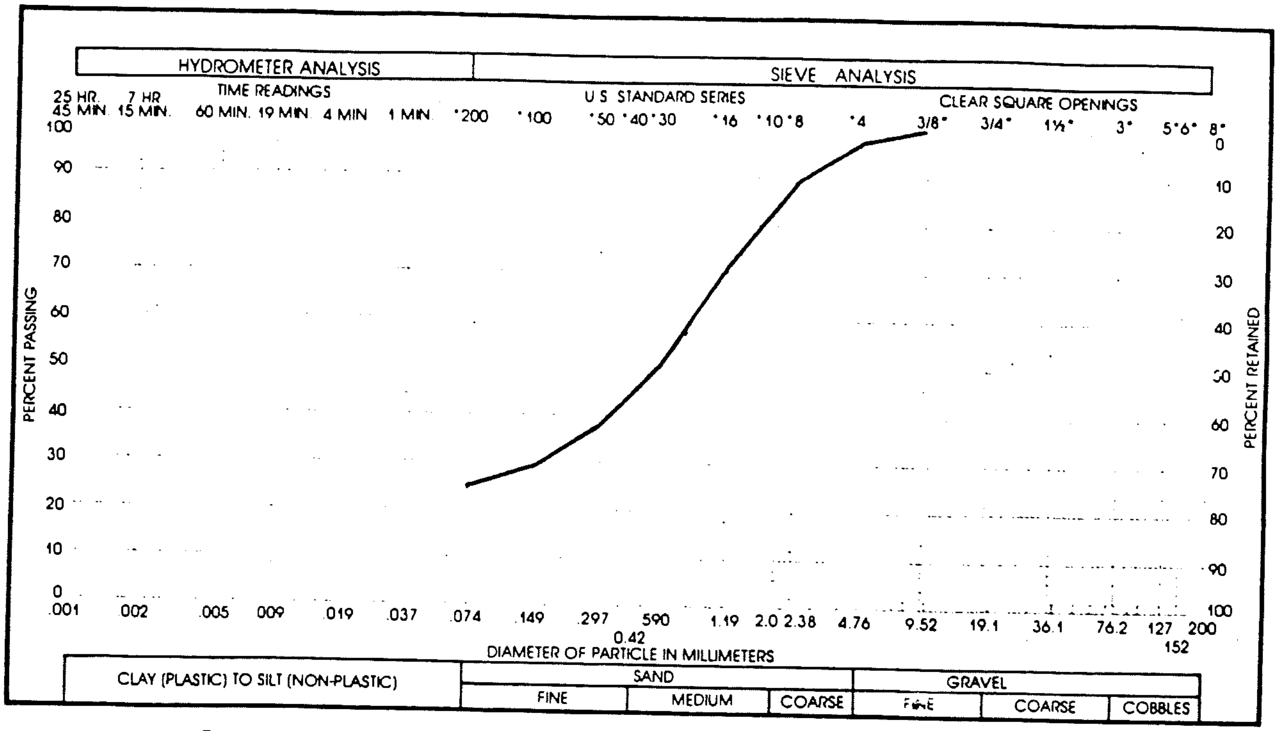
Sample of SAND, BROWN (SP)
From TP-1 AT 4 FEET

GRAVEL 0 % SAND 97 %
SILT & CLAY 3 % LIQUID LIMIT – %
PLASTICITY INDEX – %

JOB NO. 15,346

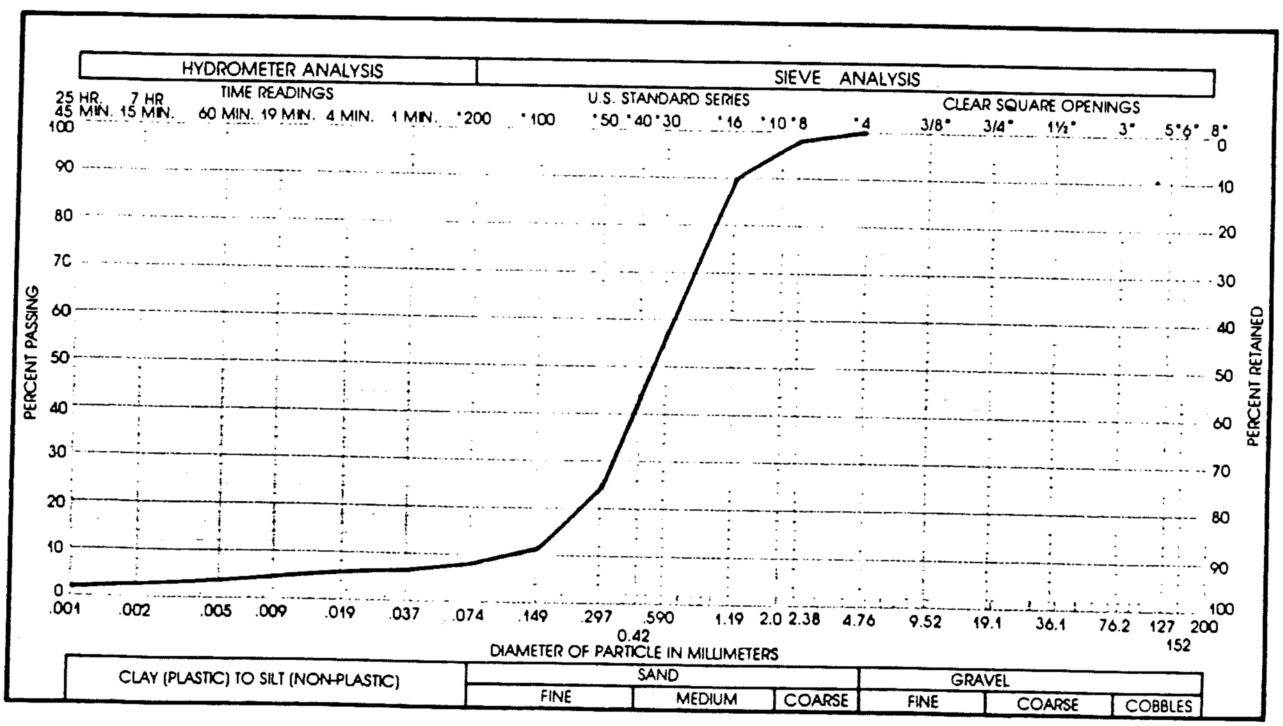
Gradation Test Results

FIG. 3



Sample of SAND, SILTY, BROWN (SM)
From TP-1 AT 6.5 FEET

GRAVEL 0 % SAND 76 %
SILT & CLAY 24 % LIQUID LIMIT – %
PLASTICITY INDEX – %



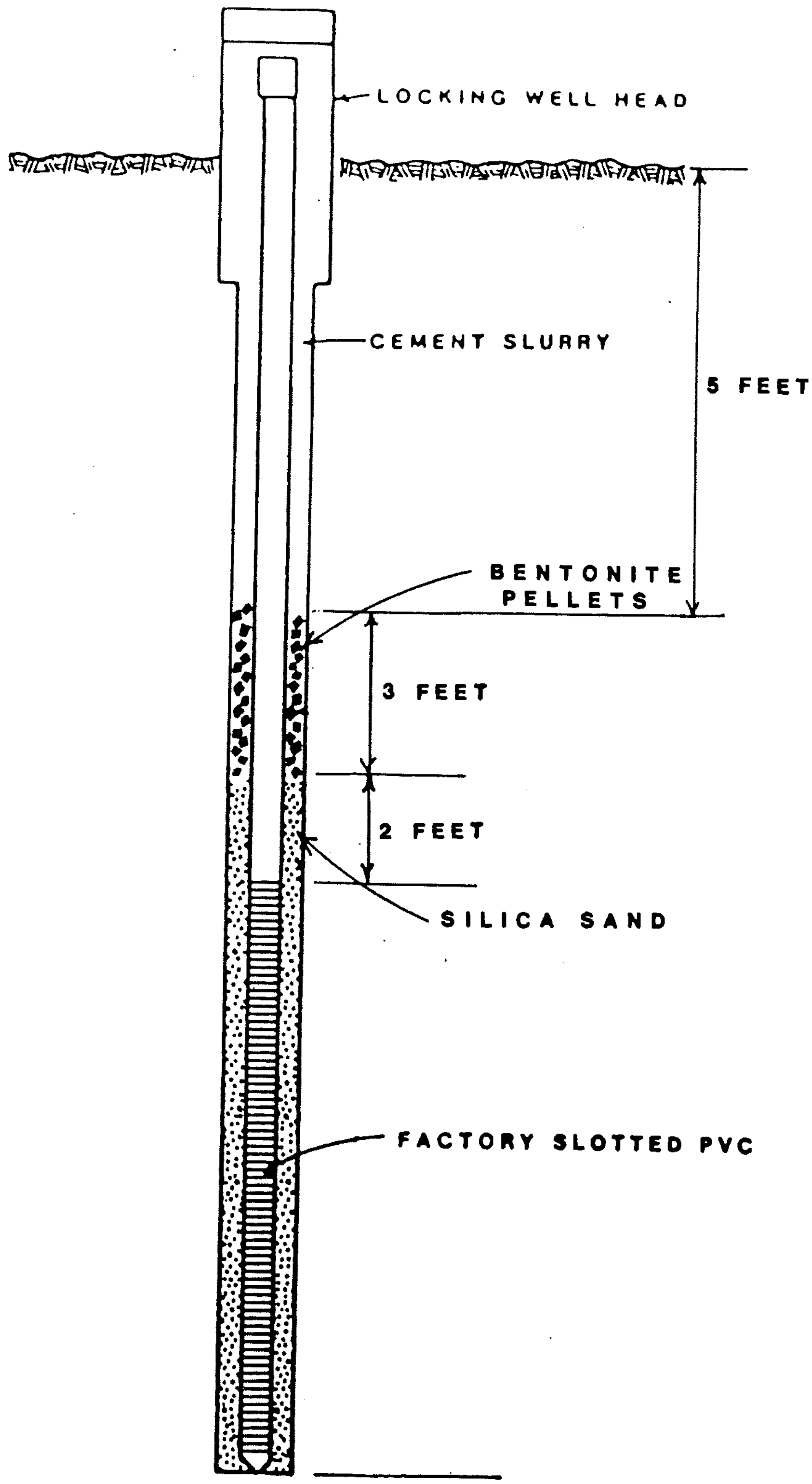
Sample of SAND, SILTY, BROWN (SM, SP-SM)
From TH-1 AT 9 FEET

GRAVEL 0 % SAND 92 %
SILT & CLAY 7 % LIQUID LIMIT – %
PLASTICITY INDEX – %

JOB NO. 15,346

Gradation Test Results

FIG. 4



GROUND WATER PIEZOMETER SCHEMATIC

JOB NO. 15,346

FIG. 5

Form 10

JOB NO. 1[illegible]346

TABLE I
SUMMARY OF LABORATORY TEST RESULTS

HOLE	DEPTH (FEET)	NATURAL MOISTURE (%)	NATURAL DRY DENSITY (PCF)	ATTERBERG LIMITS		PASSING NO. 200 SIEVE (%)	TRIAXIAL SHEAR TESTS		SPECIFIC GRAVITY AT 20°C	SOIL TYPE
				LIQUID LIMIT (%)	PLASTICITY INDEX (%)		DEVIATOR STRESS (PSF)	CONFINING PRESSURE (PSF)		
TP-1	1	4.9				10.1			2.54	SAND
	4	4.9				3.2			2.59	SAND
	6.5	8.5				24.4			2.53	SAND, CLAYEY, SLIGHTLY SILTY
TH-1	9	3.2	101			7.7				SAND

ATTACHEMENT 3

Discussion of Tensiometer
and
Moisture Block Measurements

CTL/THOMPSON, INC.
CONSULTING GEOTECHNICAL AND MATERIALS ENGINEERS

January 30, 1991

Tri-County Health Department
7000 East Belleview Avenue
Suite 301
Englewood, Colorado 80111

Attention: Mr. Tom Butts

Subject: Discussion of Instrumentation
Phosphorus Monitoring Program
Osorno Residence and Millet Residence
Douglas County, Colorado
Job No. 15,346

Gentlemen:

CTL/Thompson, Inc. was retained by the Tri-County Health Department in August of 1988 to assist with a Phosphorus Monitoring Study in the Cherry Creek Basin. The purpose of the study was to obtain phosphorus loading data for two residential percolation fields in the Basin. Our scope began with the installation of tensiometers, lysimeters and soil moisture blocks below the fields and groundwater sampling wells adjacent to or down gradient from the fields. The subsequent monitoring program involved sampling events. A sampling event consisted of a CTL/Thompson representative obtaining water samples from three lysimeters below the percolation field, septic tank effluent and the groundwater sampling wells, as well as reading the dial gauges on the tensiometers and obtaining a meter reading from the moisture blocks. After installation of the equipment at the first (Cook) residence in November of 1988, we discovered the tensiometer and moisture block data were not useful for the purposes of this project. This letter discusses the data from field and laboratory work performed by CTL/Thompson, Inc. on the tensiometers and the moisture blocks, and our opinions of why field instrument readings were not meaningful over the duration of the project.

Manaufacturers data on the tensiometers and soil moisture blocks indicated the instruments can be calibrated for a certain soil by obtaining readings at varying moisture contents. (Copies of the manufacturers literature for the tensiometer and the moisture block are presented in Appendix A) We obtained approximately 60 pounds of soil from the Cook residence site at the time of the instrumentation installation. We calibrated the 1 foot tensiometer and a moisture block in our laboratory. Calibration was performed by compacting the soil samples into barrels at densities similar to those measured from field samples at varying moisture contents and installing the the instruments. We plotted the data points on a graph showing soil moisture content versus soil suction and moisture block readings provided in the manufacturers literature (Fig. 1).

1971 WEST 12TH AVENUE • DENVER, COLORADO 80204 • (303) 825-0777

The data obtained in our laboratory indicated the instruments provided relative moisture data for the soil tested in the range of 1 percent to about 9 percent moisture for the moisture block, and 1 percent to about 20 percent for the 1 foot tensiometer. The 4 foot and 7 foot tensiometers were not laboratory calibrated.

This monitoring program was established by Tri-County Health. After installation and inital measurments, each percolation system was allowed to load for approximately 2 months after occupancy before the second sampling occurred. Initial tensiometer measurements were performed prior to loading and laboratory testing of soil samples obtained during drilling. The readings were of the same magnitude but did not match moisture contents measured from field soil samples. After the "loading" period, no change in moisture was indicated by tensiometer and moisture blcoks through the project duration. We believe the moisture content of the soils below the percolation field after the loading period was higher than the range of sensitivity for these instruments. Instrument readings from the first five sampling events are presented on Exhibit A. Based on the data obtained from our laboratory and field monitoring program we believe data obtained from the tensiometers and moisture blocks was "endpoint" data for the soils at the test sites.

When we discovered the instrument readings were not meaningful for this project, we installed an aluminum tube at the Osorno residence for "down-hole" moisture readings. CTL/Thompson, Inc. has a Campbell Pacific Nuclear down-hole moisture density gauge. It is operated by lowering a nuclear source probe into a 2-inch diameter aluminum tube installed in the soil. We intended to use the down-hole gauge to obtain moisture data at the Orsono residence. However, the aluminum tube was destroyed during landscaping repairs by others and moisture contents were not measured.

We appreciated the opportunity to work with Tri-County Health Department on this project. If you have questions regarding the contents of this letter or the monitoring program in general, please call.

Very truly yours,

CTL/THOMPSON, INC.

Mike Schneider
Environmental Staff Engineer

Reviewed by:

COLORADO REGISTERED PROFESSIONAL ENGINEER RONALD M. McOMBER 20?43

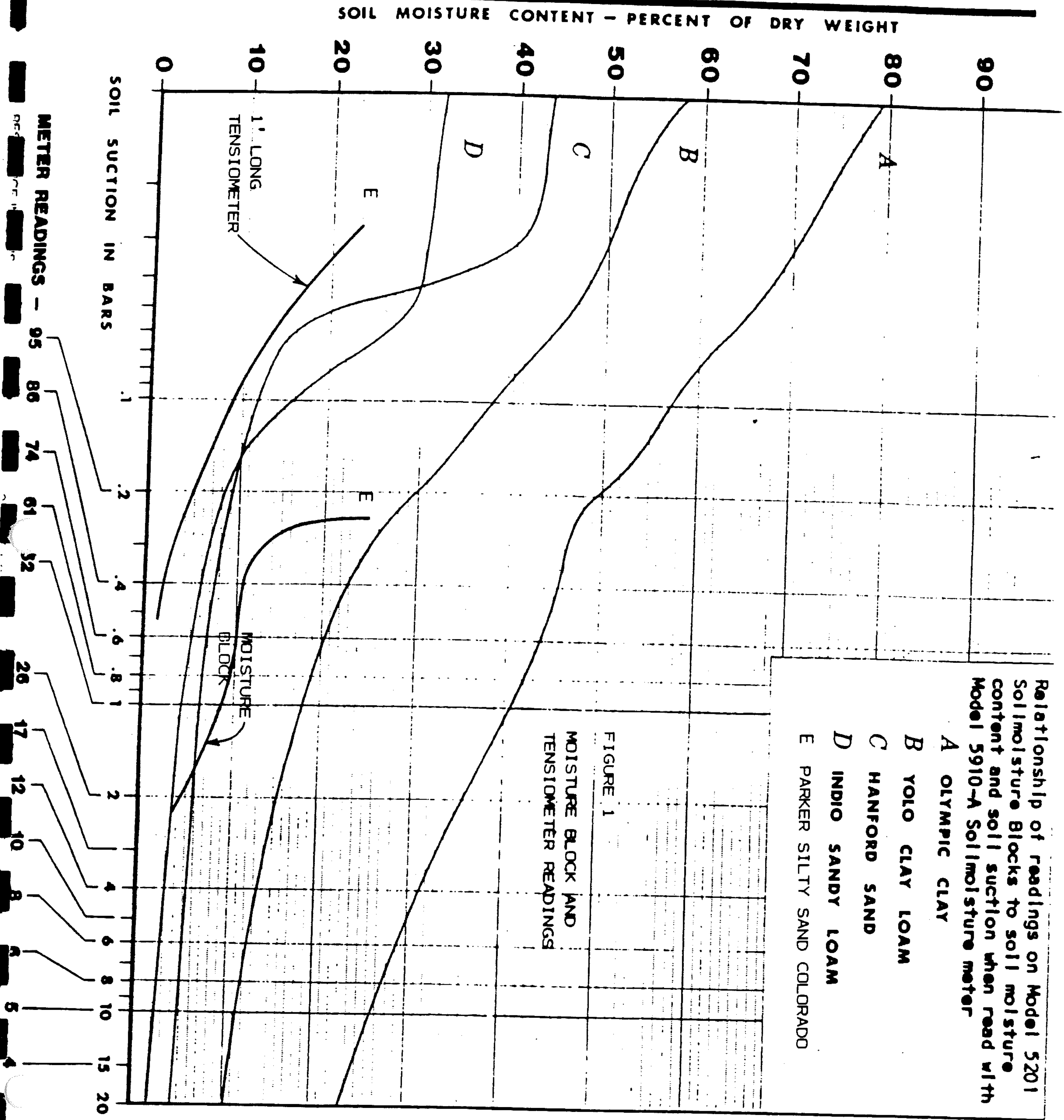
Ronald M. McOmber, P.E.
Associate

MS:RMM:kp

MARCH 1983

ENGINEERING DETAILS

MODEL 5201 AND MODEL 5910-A SOIL MOISTURE RELATIONSHIPS



SOILMOISTURE EQUIPMENT CORP.
P. O. Box 30025
Santa Barbara, CA 93105
U.S.A.

Telephone No. (805) 964-3525
Telex No. 65-8424
Cable Address: SOILCORP

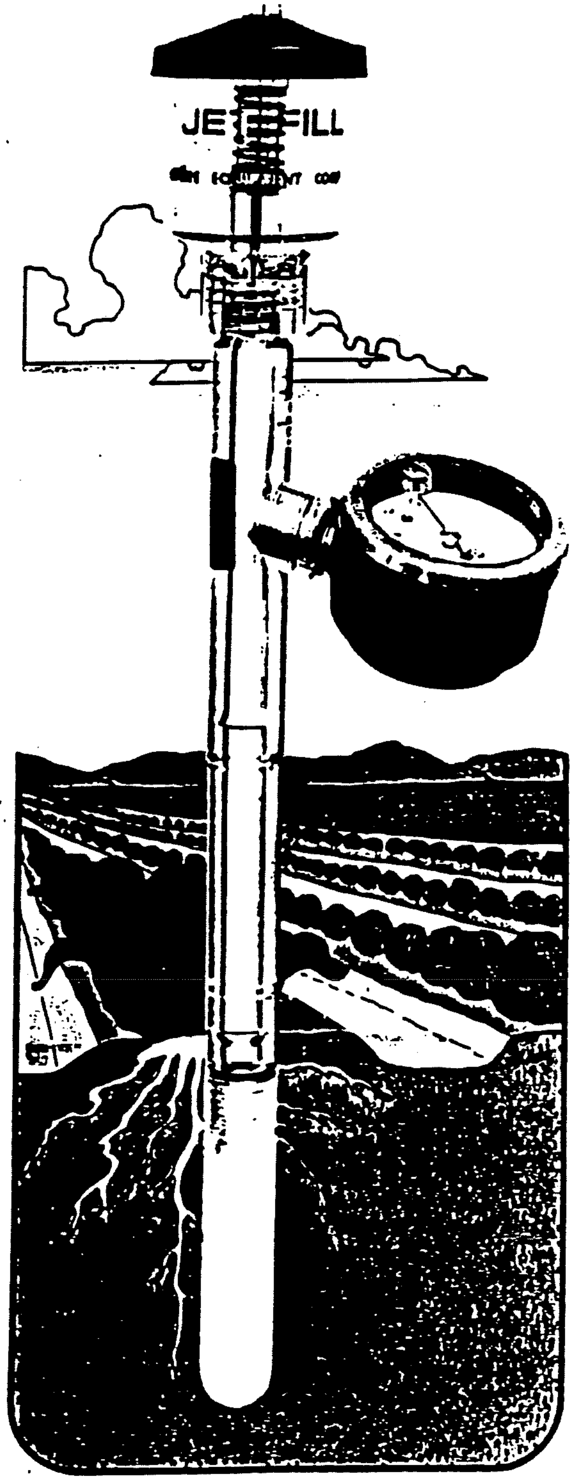
SOILMOISTURE

EXHIBIT A
PHOSPHORUS MONITORING DATA FOR THE
COOK RESIDENCE, TRI-COUNTY HEALTH DEPARTMENT PROJECT
JOB NO. 15,346

LOCATION	SAMPLE DATE				
	3/6/89	4/18/89	5/22/89	6/13/89	6/27/89
TOTAL PHOSPHORUS (ppm)					
Lysimeters					
1 foot	0.710	0.218	0.209	1.200	2.500
4 feet	0.204	0.153	0.136	0.140	0.100
7 feet	0.106	0.077	0.072	0.118	0.080
TH-1	0.917	0.428	0.046	0.057	0.024
Septic tank	6.500	6.280	8.470	7.700	5.600
ORTHOPHOSPHORUS (ppm)					
Lysimeters					
1 foot	0.152	0.205	0.196	1.19	2.6
4 feet	0.186	0.152	0.125	0.14	0.1
7 feet	0.1	0.083	0.071	0.118	0.08
TH-1	0.015	0.017	0.034	0.017	0.02
Septic tank	6.76	6.2	9.15	7.7	5.4
MOISTURE BLOCK READINGS (no scale)					
1 foot	89	91	92	94	94
4 feet	92	92	92	94	94
7 feet	92	92	93	94	94
TENSIOMETER READINGS (centibars)					
1 foot	n/a	n/a	5.5	6.0	5.5
4 feet	n/a	n/a	8.5	10.0	10.5
7 feet	n/a	n/a	9.5	11.5	11.5
DEPTH TO GROUNDWATER (feet)					
TH-1	16.5	15.5	15.4	16.1	15.7
TH-2	>18.5	>18.5	>18.5	>18.5	>18.5

APPENDIX A

MOISTURE BLOCK AND TENSIOMETER MANUFACTURES LITERATURE



2725 SERIES

JET FILL TENSIOMETERS

THE MOST ADVANCED, MOST SENSITIVE INSTRUMENTS AVAILABLE FOR THE FIELD MEASUREMENT OF SOIL MOISTURE.

USE THEM IN:

AGRICULTURE

- to tell you when to start irrigating
- to tell you when to stop irrigating
- to save expensive water, fertilizer, power, and labor costs
- to improve crop yields
- to make profits for you!

AGRONOMY RESEARCH

- to maintain accurate control of soil moisture during plant growth experiments in the development of superior varieties
- to correlate physiological plant changes with surrounding soil moisture values
- to develop effective irrigation practices for crop production

HYDROLOGY

- to measure soil moisture potential to determine subsurface moisture flow
- to verify proper moisture conditions for vadose zone soil water sampling—vital in pollution control
- to provide essential data to relate computer modelling to actual field conditions

Engineered and produced by the foremost manufacturers of soil moisture measuring equipment for over 30 years.

THE MODEL 2725 JET FILL

IS THE BEST TENSIOMETER IN THE WORLD

The flexible reservoir cover allows for convenient filling and sealing of stored water.

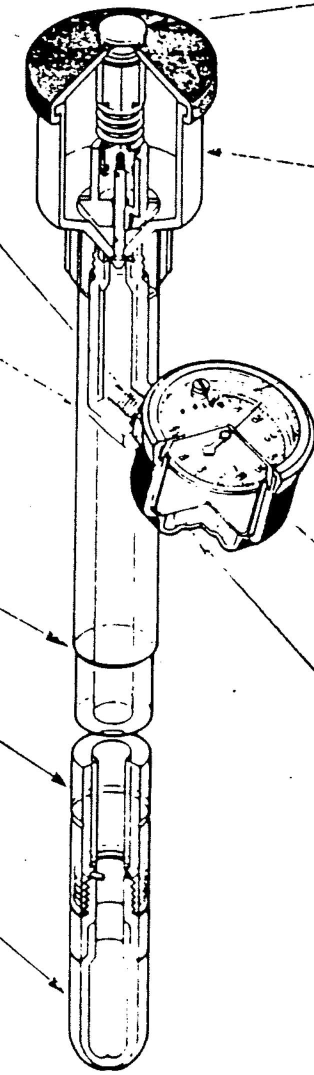
Time proven "O" ring seals throughout assure leak proof vacuum joints while allowing easy removal or replacement of critical components.

Angle molded port in the sidewall provides a strong connection, keeping the dial gauge continuously filled with water and easy to view. The Vacuum Dial Gauge is readily replaceable in the field and can be oriented in any position for reading convenience. Port also accepts Electrical Switching Gauge and Pressure Transducers.

Convenient molded shoulder indicates soil surface position for easy, accurate depth placement.

Heavy walled tube constructed of rigid, clear plastic assures accurate readings at high soil suction values, and is completely immune to damage by sun, water, or soil conditions.

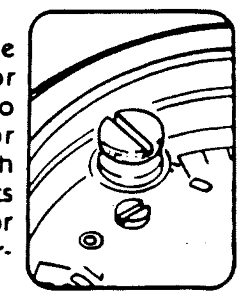
Unique superporous ceramic tip has 10 times the water conductivity of comparable units, providing the ultimate in sensitivity and long life. Convenient thread adaptor design allows the ceramic tip to be readily removed or replaced, as well as permitting the addition of extension tubes to vary the placement depth of the tensiometer.



At a push of the button, patented Jet Fill action instantly injects water into the body of the tensiometer and removes accumulated air with no disturbance to the soil. Recovery is in minutes—not hours!

Large volume, detachable reservoir holds sufficient water for months of servicing. All materials are completely weatherproof for years of use.

Optional recalibrator style gauge allows for adjustment of zero point setting for careful research work. Also permits compensation for water table reference point.



The large 2 inch diameter easy-to-read dial face has a fixed pointer and is graduated from 0 to 100 centibars (Kpa) of soil suction.

A flexible temperature adjusting outer jacket interlocks with the unbreakable, clear plastic coverplate to hermetically seal the gauge, protecting against weather and shock. Complete with vent screw to compensate for altitude variations.

Superior Features Protected by Patent No. 3898872

JET FILL TENSIOMETERS

Are more precise than any other method of measuring soil moisture conditions in the field.

Do not require calibration.

Do not require transporting bulky measuring equipment into the field.

Do not require attaching electrical leads to make a measurement—simply look at the dial gauge.

Do not require any power source.

Can be read instantly—simply look at the dial gauge.

Available in nine stock lengths from 6" (15 cm) to 60" (150 cm) to meet varying installation requirements.

Extra long lengths, extension tubes and special modification supplied on short notice.

Simple "field replaceable" parts assure years of service.

The single most inexpensive instrument to give precise, direct, continuous measurement of soil moisture conditions.

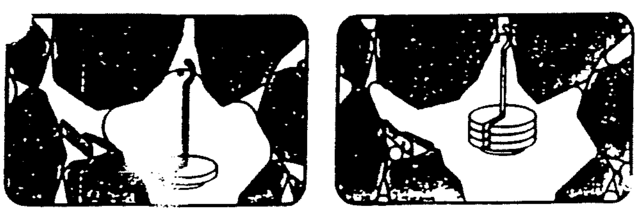
Available throughout the world.

HOW IT WORKS

Beneath the soil surface, soil particles, water, air, and plant roots share the same space. In this environment water does not move freely as it does above the surface, but is held in the grasp of the soil which determines how it will move and how plant roots can withdraw it.

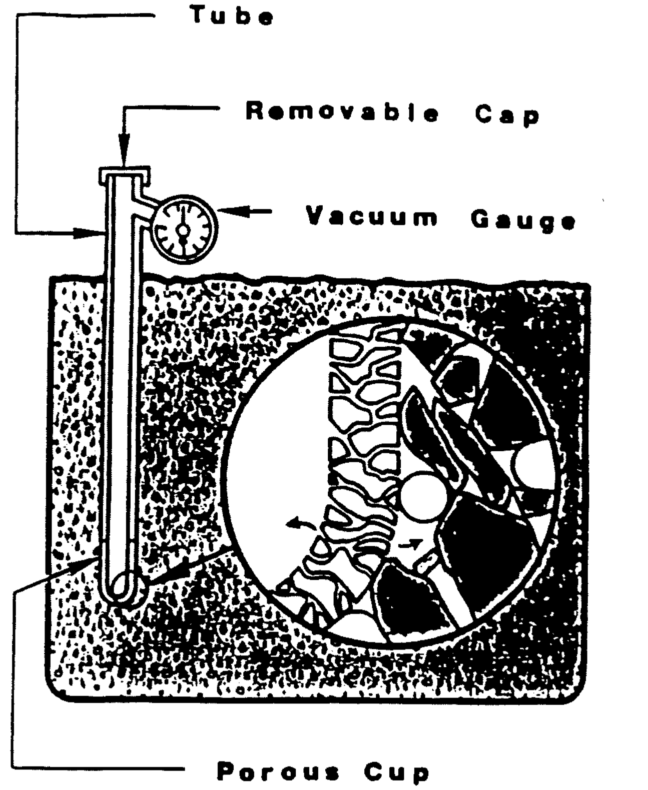
The illustration above shows how the soil particles, water, air, and roots intermingle. The water is naturally attracted to the soil particles and it sticks on the surface of each particle and in the various sized "capillary" spaces or "pores" between the soil particles. When the soil is very wet, most all the large pores are filled with water, and the water can move quite freely and can be easily removed by the plant root. As the soil dries out, the water remaining is held more tightly in the smaller sized capillary spaces.

The picture below illustrates the increasing force required to remove the water from the small sized pores compared to the large pores, as the soil dries out. Because of this, plants find it increasingly difficult to get adequate water as the soil



dries. When remaining water is held only in extremely small pore spaces, the plants cannot exert enough force to withdraw it, and the plants wilt and die. Even though there may be a considerable volume of water in the soil, the plants can't pull it out.

Tensiometers are the only instruments [illegible] direct measurement of "Soil Suction" the force that plants have to overcome to get needed water, and the force that determines which way moisture will move in the soil. A tensiometer consists of a tube with a porous ceramic tip on the bottom, a vacuum gauge near the top, and a sealing cap. When it is filled with water and inserted into the soil, water can move into and out of the tensiometer through the connecting pores in the tip, as shown in the illustration. As the soil dries and water moves out of the tensiometer, it creates a vacuum inside the tensiometer which is indicated on the gauge. When the vacuum created just equals the "Soil Suction", water stops flowing out of the tensiometer. The dial gauge reading is then a direct measure of the force required to remove water from the soil. If the soil dries further, additional water moves out until a higher vacuum level is reached. When moisture is added to the soil, the reverse process takes place. Moisture from the soil moves back into the tensiometer through the porous tip until the vacuum level is reduced to equal the lower Soil Suction value, then water movement stops. If enough water is added to the soil so that it is completely saturated, the gauge reading on the tensiometer will drop to zero. Because water can move back and forth through the pores in the porous ceramic tip, the gauge reading is always in "balance" with the Soil Suction.

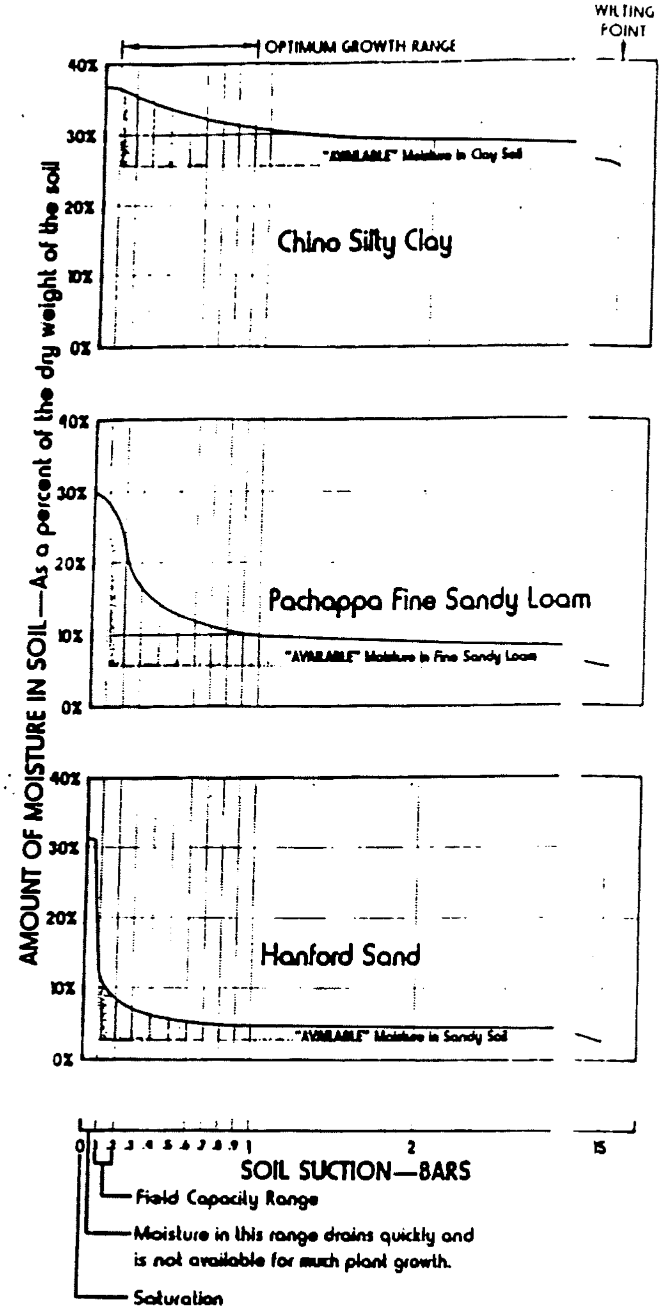


[illegible] Plant Growth Range is within the operating range of tensiometers. Plants will live until the soil is so dry that the soil suction value reaches 15 Bars—referred to as the "Wilting Point." It is within the 0-.85 Bar soil suction operating range of tensiometers, however, where most all movement of moisture takes place and where the important moisture is stored for plant growth.

A "bar" is the unit of pressure that has been adopted for the expression of soil suction. The bar is an international unit of pressure, either positive or negative, in the metric system. A bar is equivalent to 14.5 lb/in^2 or .897 atmospheres. It is also equivalent to the pressure exerted by a height of 750 millimeters of mercury or the height of 1,020 cm of water or the height of 33.5 ft. of water. Scientifically it is defined as 10^6 dynes/cm^2.

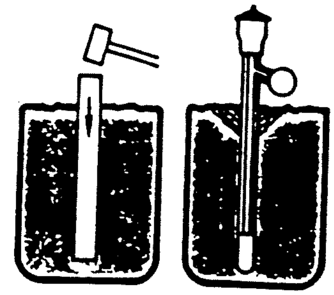
Tensiometer measurements are always less than 1 bar and for convenience the tensiometer scale has been divided into 100 divisions so that each division is 1/100 of a bar or "1 centibar." This is usually abbreviated as 1 cb. 1 centibar is also equal to 1 Kpa (kilopascal). The full dial gauge reading on our Jet Fill Tensiometer is 100 centibars of negative pressure or vacuum.

The graph below developed through the use of our Pressure Membrane Extractors shows the percent of moisture in the soil compared to the force of soil suction with which it is held, for three different types of soils.



The "available" moisture for plant growth lies between the "Field Capacity" and the "Wilting Point." In general when 50 percent of the available moisture is used up, irrigation should be started. With the exception of heavy clay soils, tensiometers measure the soil suction value at which 50 percent of the available moisture is used up. In virtually all types of soils and for virtually all commercial crops, if the soil moisture is kept within the operating range of tensiometers, there will be optimum growth conditions and crop yields.

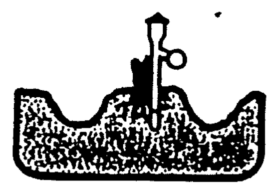
JET FILLS ARE EASY TO INSTALL

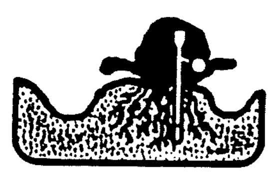


Jet Fill Tensiometers are readily installed in the soil by using conventional soil sampling tools. The body tube and porous sensing tip of the tensiometer are ⅞" (2.2 cm) in diameter. Installation must be made so that the porous ceramic sensing tip is in tight contact with the soil. The Model 240 Insertion Tools can be used in rock free soils. Standard ½" (U.S.) steel pipe can also be used to drive a hole into the soil to accept the tensiometer. In rocky soils a soil auger can be used to core a larger hole and then the soil is sifted and packed around the porous ceramic tip to make good contact before the hole is back filled. The surface soil is tightly tamped around the body tube to seal surface water from entering.

SELECT THE PROPER LENGTH SO THAT THE POROUS CERAMIC SENSING TIP WILL BE IN THE ACTIVE ROOT ZONE.

FOR SHALLOW ROOTED PLANTS





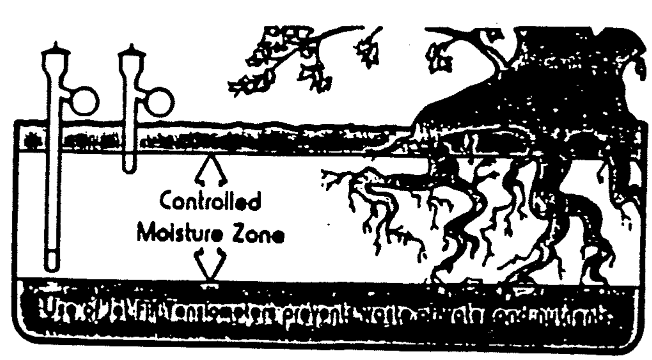
For plants with shallow root systems of less than 18" in depth, such as certain row crops, a single tensiometer with porous ceramic tip located ¾ of the way down the root zone can give adequate information. The tensiometer tip can be located near the surface when the plant is young and then lowered as the root system develops.

FOR DEEP ROOTED PLANTS

For deep rooted plants and trees with large root systems, two tensiometers are installed at the same location. The shallow unit has the sensing tip about ¼ of the way down the root zone. The deep unit is ¾ of the way down into the root zone.

The shallow unit indicates when to start irrigation.

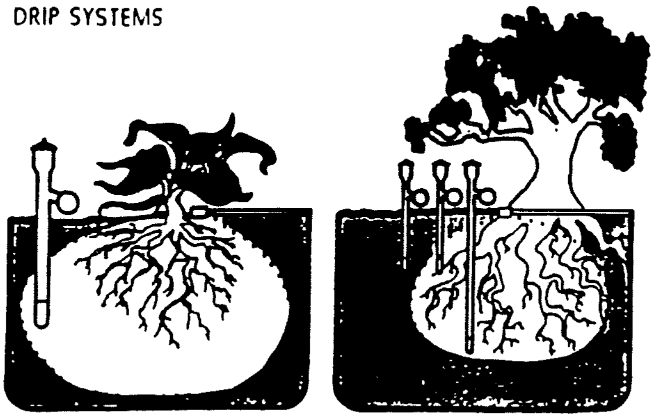
The deep unit evaluates water penetration and moisture conditions at the bottom of the root zone.



JET FILLS ARE USED TO PROGRAM IRRIGATION WITH ALL TYPES OF IRRIGATION SYSTEMS, WITH ALL TYPES OF CROPS IN ALL TYPES OF SOILS.

"TENSIOMETER STATION" is the name given to a tensiometer installation consisting of one or more tensiometers at one place. To monitor moisture conditions in the field, tensiometer stations are located in critical places, required by the irrigation system.

DRIP SYSTEMS

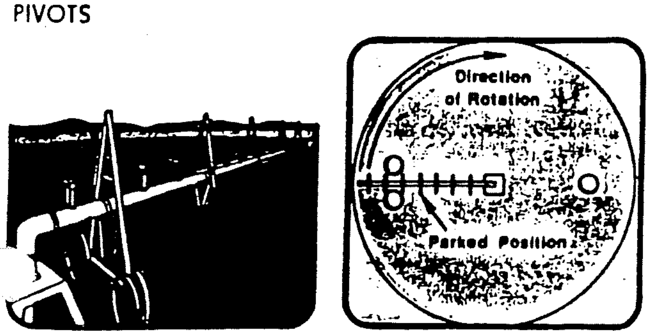


The great variety of drip emitters and bi-wall type tubing lend themselves to a wide range of application, from vast fields of sugarcane and cotton to orchards, landscaped areas, and the growing of nursery stock. This "point source" application of irrigation water, where most of the flow is underground, makes it particularly difficult to judge soil moisture conditions by surface observations. Jet Fill Stations can reveal the irrigation wetting pattern in the hidden root zone.

The station is located within the wetting pattern of a typical emitter. One tensiometer placed near the emitter and down near the maximum rooting depth of the plant will provide information on penetration and when to stop the irrigation cycle. A second tensiometer placed near the lateral extent of the wetting pattern, usually 12" to 18" from the emitter and in the upper root zone will indicate when to start the irrigation cycle. The frequency of the irrigation cycle and length of irrigation can then be adjusted to keep a uniform wetting pattern with good moisture conditions throughout the pattern.

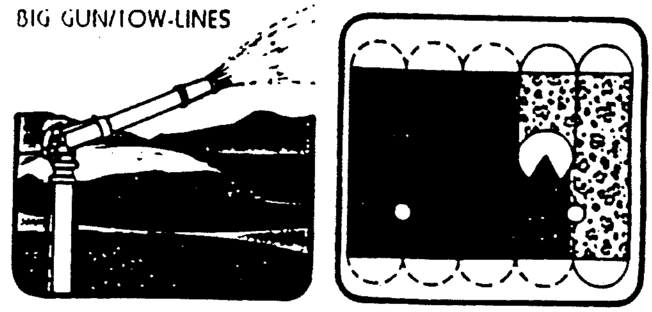
In new installations, several tensiometers placed at various depths and distances from the emitter will give definite information on the size and shape of the wetting zone.

PIVOTS



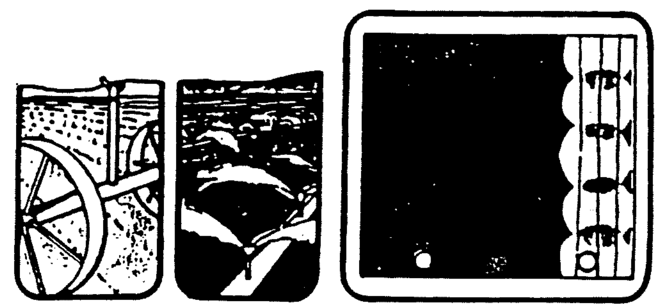
For pivots, three tensiometer stations should be used for each pivot. One station is located in front of the parked position of the pivot and between the second and third towers from the outside. A second station is located in the same position but 180 degrees away. The third station is located behind the parked position and also between second and third towers. This arrangement provides moisture information typical of the field and is ideal for determining when to start the next irrigation cycle.

BIG GUN/TOW-LINES



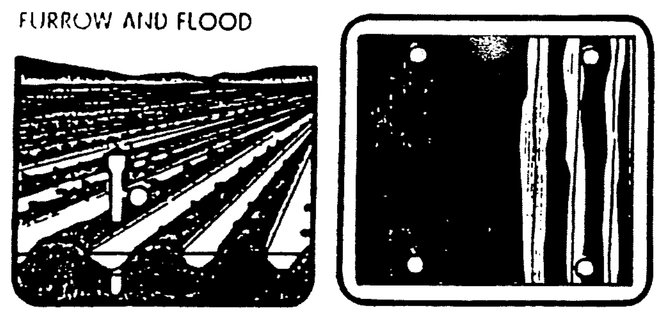
For tow lines, a station is located between the first and second sets on a field and between the next-to-last and last sets.

WHEEL AND HAND MOVE LATERALS



A station is located between the first and second sets on the field and between the next-to-last and last sets.

FURROW AND FLOOD



One station is located near the upper end and one near the lower end of the run for each field or portion of the field irrigated at the same time. Head of water and timing are adjusted in successive irrigations to get as uniform a distribution as possible, using the tensiometer readings as a guide.

SOLID SET SYSTEMS

Solid set irrigation systems can provide great uniformity in the application of irrigation water. A single tensiometer station located where spray is received from a full group of adjacent sprinklers, away from the periphery of the field, can be used to schedule irrigation for each separately irrigated section.

SUBSURFACE IRRIGATION SYSTEMS

In some areas, a high water table during much of the year often combined with a need for irrigation during some of the summer months, makes tile drains a desirable investment. During wet periods, the system provides drainage to remove excess water. In the irrigation mode, water is fed back into the drains and up into the root zone by capillary action through the soil.

Jet Fill stations located in typical areas of the field provide the critical information to rigidly control the water table height. If the water table is too high, plant growth will be retarded or stopped completely.

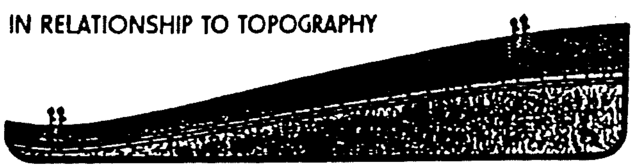
OTHER CONSIDERATIONS IN LOCATING TENSIOMETER STATIONS

IN RELATIONSHIP TO PLANTS

For row crops, the tensiometer station is located directly in the row. A place is chosen where plant population is typical of the field.

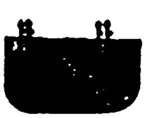
For orchards, the tensiometer station is located just inside the drip line of the tree, preferably on the side receiving the most sun, since water will be depleted faster there.

IN RELATIONSHIP TO TOPOGRAPHY



On hilly fields, tensiometer stations are located in the high and low areas, where drainage conditions may be different. Irrigation practices can be modified to keep moisture levels as uniform as possible.

IN RELATIONSHIP TO SOIL TYPE



Rates of penetration and storage capacity vary greatly between various soil types. Therefore, tensiometer stations should be located where the soil is most representative of the field to be irrigated. Additional stations should be located where soil type is radically different in order to provide full information for irrigation timing in those areas.

GOOD AND POOR GROWTH AREAS

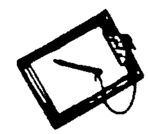
Tensiometer stations located in the good and poor growth areas of a field will quickly reveal whether moisture conditions are the major contributing factor. If so, they will indicate the changing moisture conditions as corrections in irrigation procedures are made.

UNEVEN IRRIGATION DISTRIBUTION

Variations in sprinkler head output, water pressure, wind action, and other factors can result in uneven distribution of irrigation water. Tensiometer stations located in suspected areas can provide positive data on which to base corrective action.

JET FILL TENSIOMETERS ALONE WILL PROVIDE THE INFORMATION YOU NEED FOR A COMPREHENSIVE IRRIGATION SCHEDULING PROGRAM

WITHOUT THE NEED FOR INVOLVED WATER DEPLETION CALCULATIONS, THE TENSIOMETER READING GIVES INSTANTLY THE CURRENT STATUS OF THE VITAL SOIL MOISTURE, AUTOMATICALLY SHOWING THE RESULTANT EFFECT OF CHANGING WEATHER CONDITIONS, CONSUMPTIVE USE, IRRIGATION AND RAINFALL.

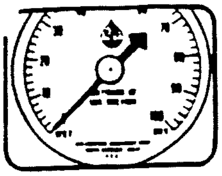


RECORDING THE TENSIOMETER READINGS GIVES YOU A VISUAL PICTURE OF THE RATE AT WHICH PLANTS ARE WITHDRAWING MOISTURE FROM THE SOIL—TO PLAN WHEN THE NEXT IRRIGATION CYCLE SHOULD START.

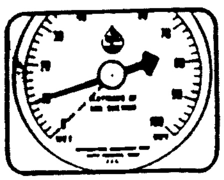
WITH SHALLOW AND DEEP JET FILL TENSIOMETERS SPANNING THE ACTIVE ROOT ZONE, AND BY KNOWING THE AMOUNT OF IRRIGATION WATER APPLIED, OR THE LENGTH OF THE CYCLE, YOU CAN QUICKLY DETERMINE DURING SUCCESSIVE CYCLES THE AMOUNT OF IRRIGATION REQUIRED TO REPLENISH THE ACTIVE ROOT ZONE.

FOR ALL OTHER SCHEDULING SYSTEMS, JET FILL TENSIOMETERS CAN PROVIDE THE LINK BETWEEN THE PROJECTION THEORY AND ACTUAL FIELD CONDITIONS.

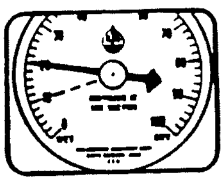
WHAT DO THE JET FILL READINGS TELL YOU ABOUT IRRIGATION SCHEDULING?



ZERO: A gauge reading of zero means the surrounding soil is completely saturated with water, regardless of the type of soil. Zero readings can be expected after a heavy rain or deep irrigation. If the zero reading persists after a long period of time, there will be oxygen starvation to plant roots and development of diseases. A persistent zero reading after irrigation indicates poor drainage conditions which should be investigated and corrected.



0-10 CENTIBARS: Gauge readings in the range of 0-10 cb indicate a surplus of water for plant growth. Water held by the soil in this range drains off within a few days. Persistent readings in this range indicate poor drainage conditions which should be corrected to obtain healthy plant growth.



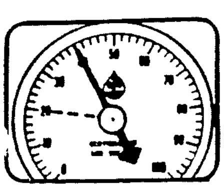
10-20 CENTIBARS: Gauge readings in the range of 10-20 cb indicate that there is ample moisture and also air in the soil for healthy plant growth in all types of soils. This range is often referred to as the "Field Capacity" range for soils, which means that the soil has reached its "capacity" and cannot hold any more water for future plant growth. When soils are at "Field Capacity," any additional water that is added drains out of the root zone within a day or two—before it can be used by the growing plant.

If irrigation has been in process, it should be stopped when gauge drops to this level, since any further additional water will be quickly drained from the root zone and wasted, carrying with it valuable fertilizer.

HEAVY CLAY SOILS: No irrigation required at this time.

MEDIUM TEXTURED SOILS: No irrigation required at this time.

SANDY SOILS: No irrigation is usually required. These soils, however, have a very limited water storage capacity and therefore soil suction values increase very rapidly as moisture is removed by the plant after soil suction values reach 15-20 cb (see chart on Page 5). If water-sensitive plants, such as potatoes, are planted in coarse, sandy soils, irrigation may need to be started between 15-20 cb to allow time to apply the irrigation water before damaging stress conditions develop.

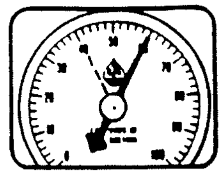


20-40 CENTIBARS: Available moisture and aeration good for plant growth.

HEAVY CLAY SOILS: No irrigation required.

MEDIUM TEXTURED SOILS: No irrigation required.

SANDY SOILS: Irrigation started for coarser sandy soils in the 20-30 cb range. For finer sandy soils in the 30-40 cb range.

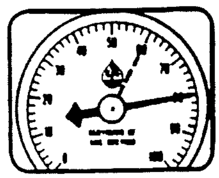


40-60 CENTIBARS: Available moisture and aeration are good for plant growth in finer textured soils.

HEAVY CLAY SOILS: No irrigation required.

MEDIUM TEXTURED SOILS: Irrigation started in this range. The finer the texture the higher the reading before start of irrigation.

SANDY SOILS: Too dry. Hot windy conditions can force soil suction to high reading quickly and damage plants.



60-80 CENTIBARS: Readily available moisture scarce, except in heavy clay soils.

HEAVY CLAY SOILS: Start of irrigation desirable as soil suction values reach 70-80 cb.

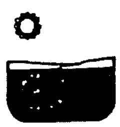
MEDIUM TEXTURED SOILS: Too dry. Hot, windy conditions can force soils suction to high reading quickly and damage plants.

SANDY SOILS: Too dry. Damage to plants will occur before irrigation can be applied.

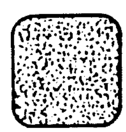
IRRIGATION TIMING

IS INFLUENCED BY A NUMBER OF FACTORS IN ADDITION TO THE JET FILL TENSIOMETER READING.

In cooler, moister climates, irrigation can be somewhat delayed beyond normal without damage to the plant.

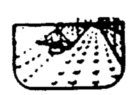


In hot dry climates where evapotranspiration is high, and there could be a time lag in applying water, the irrigation cycle should be started early.



In heavy textured soils, irrigations can be started later because water is depleted more slowly.

In sandy soils which dry out quickly because of their limited storage capacity, it is critical to closely watch Jet Fill readings and start irrigation on time.



Practical consideration concerning the length of time it takes to complete an irrigation cycle with your system will determine when to start the cycle—so that soil suction values will not get too high before the irrigation water reaches the root zone.

PLOTTING THE JET FILL TENSIOMETER READINGS

Gives you the full picture you need to [illegible] will be [illegible], taking into account the varying [illegible] type, [illegible] and climate

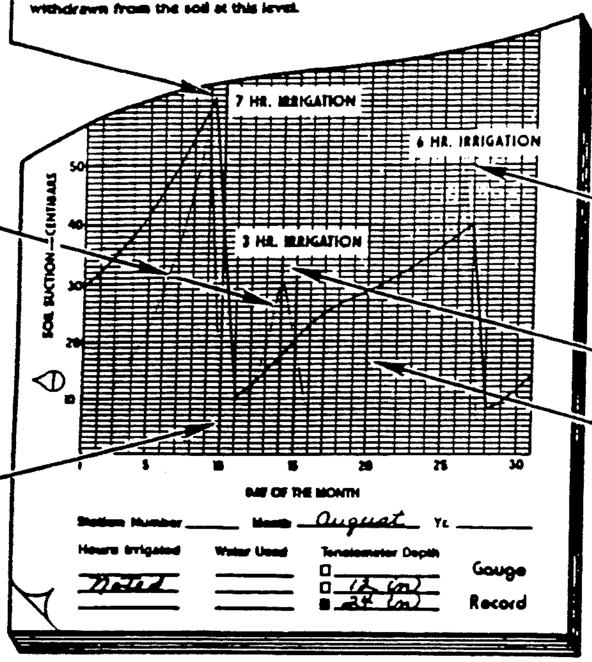
The charts below show typical changes in Jet Fill Tensiometer readings plotted on our chart form.

By observing the slope of the curve, and referring to earlier irrigation cycles, it is quite easy to project the number of days until irrigation will again be required.

Tensiometer reading when irrigation was started. Note how quickly the readings fell when irrigation water reached the porous tip of the tensiometer.

A short irrigation was applied to re-wet the upper root zone, but not the 24" depth, which was still wet enough.

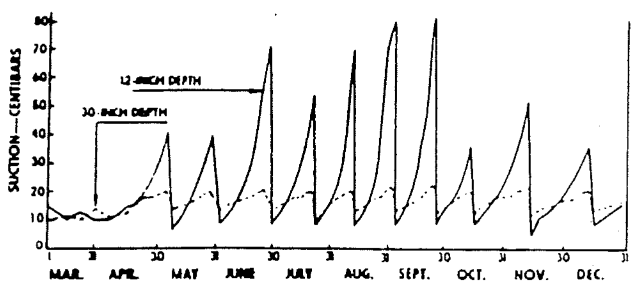
Shallow tensiometer reaches higher value than deep unit since more water is withdrawn from the soil at this level.



Light rain at this time reduced soil suction values and delayed need for irrigation.

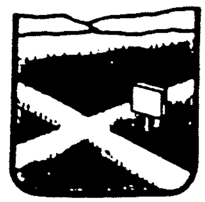
Tensiometer reading after irrigation is completed. Amount of irrigation is correct, since soil profile was filled to capacity, tensiometer readings in the range of 10-20 cb. Saturation and waste of water was avoided since lower tensiometer did not drop to zero.

The chart below, covering a 10 month period, records the soil suction value at two levels in a Valencia orange orchard in Southern California. Rainfall during the first part of the year, including March and April made irrigation unnecessary. Irrigation on approximately 3 week cycles was necessary to maintain proper moisture. It is evident that irrigation water was not wasted because at no time did the soil in the lower root zone reach the saturation level, zero centibars. This also means that fertilizer was not carried beyond the root zone and would have been fully utilized by the plants.

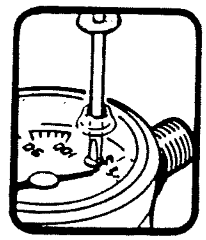


IN AGRONOMY RESEARCH

JET FILL TENSIOMETERS ARE ESSENTIAL

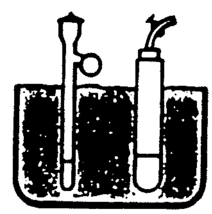


Growing plants involved in research projects require the same careful evaluation of moisture conditions that Jet Fill Tensiometers provide for commercial agriculture. Additionally, research requires the ultimate in accuracy and consistency of measurement. Only the Jet Fill Tensiometer with its unequaled superporous ceramic tip and the unique Jet Fill mechanism to easily and quickly remove air, can provide the sensitivity of response that you need.



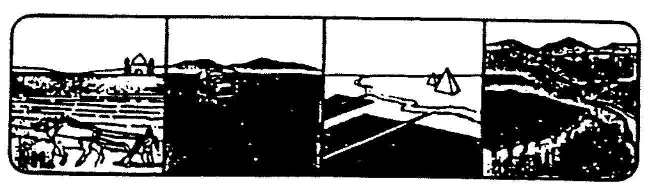
The Model 2725 AR Series Jet Fill Tensiometer with the recalibrator style vacuum gauge allows accurate setting of the zero position—also adjustment of the pointer to set the water table reference point at the center line of the sensing tip or at the soil surface, required for accurate research data.

The Jet Fill Tensiometer is an excellent diagnostic tool providing pinpoint accuracy of measurement when investigating unusual moisture conditions.



If you are involved with nutrients in the soil, the Jet Fill Tensiometer can be used to indicate when soil suction values are suitable for extraction of soil water samples with suction lysimeters for chemical analysis.

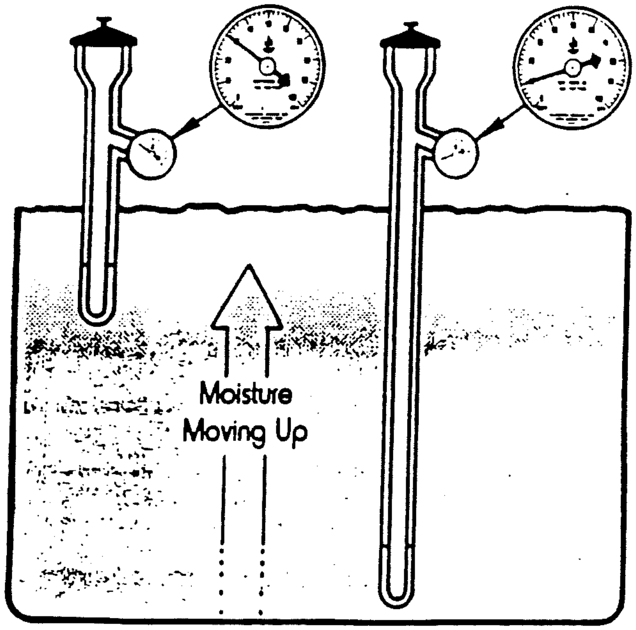
As experiments are completed the Jet Fill Tensiometers can be easily moved to new test plots.



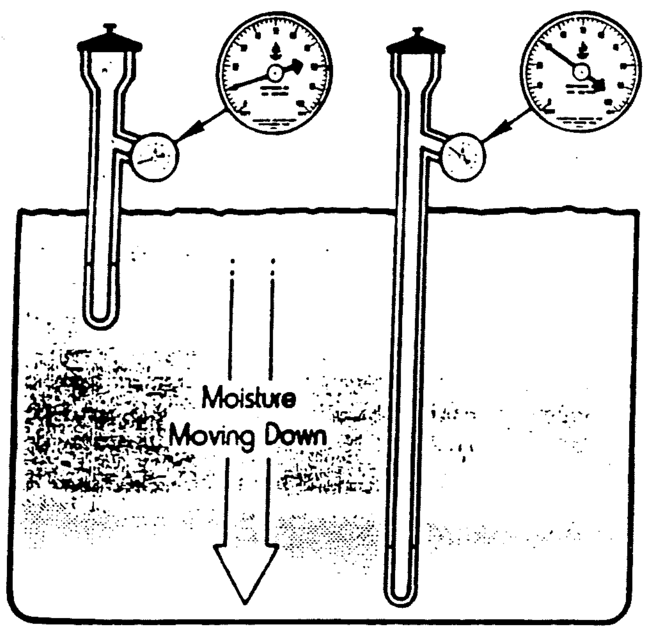
[illegible]

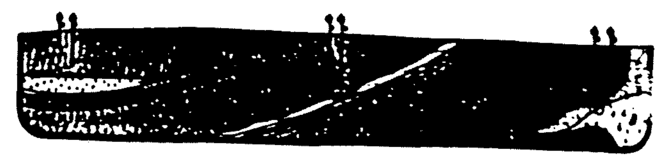
IN HYDROLOGY

JET FILL TENSIOMETERS FIND MANY APPLICATIONS



In the vadose zone, the unsaturated zone between soil surface and the ground water, the soil suction in different areas determines the direction in which unsaturated flow of water will take place. Water held at low soil suction values in the soil will move to adjacent areas which have a higher soil suction value. This movement can be in any direction depending upon the relative soil suction values. Jet Fill Tensiometers provide a simple tool to reveal underground flow patterns.





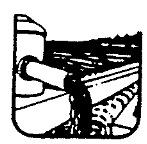
They can reveal the presence of perched water tables, aquifers, and unusual moisture conditions near changing strata in the soil profile.

They can reveal the presence of subsurface seepage below water or waste storage areas.

Jet Fill Tensiometers provide a means of verifying proper moisture conditions for sampling of the soil solution through the use of vacuum lysimeters.

JET FILL TENSIOMETERS QUICKLY PAY FOR THEMSELVES.

PROFITS AND SAVINGS COME FROM MANY SOURCES



WATER is becoming a scarce commodity in many parts of the world, and crop irrigation is one of the largest water uses. Jet Fill Tensiometers assure that you are applying a minimum amount of water—conserving water and lowering your water use costs.

ENERGY costs have sky rocketed as basic fuels have become scarce and demand has overtaken supply. Jet Fill Tensiometers allow you to reduce expensive energy-consuming pumping costs as you reduce your water requirements.

FERTILIZER is a large cost factor in the growing of a crop. Whether applied through the irrigation water or by surface application, Jet Fill Tensiometers allow you to save expensive fertilizer by providing precise information to limit percolation of water and dissolved fertilizer only to the root zone—avoiding over irrigation that carries fertilizer beyond the root zone and wasting it.

LABOR is an expensive part of each irrigation cycle. By indicating moisture conditions accurately, Jet Fill Tensiometers frequently make it possible to reduce the number of irrigation cycles for the production of a crop, saving all the associated labor.

CROP YIELD: By making it possible to regulate moisture conditions to ideal levels during crop production, Jet Fill Tensiometers make it possible to realize substantially increased crop yields per acre.

CONSULTANTS PLAY AN INCREASINGLY IMPORTANT ROLE IN CROP PRODUCTION IN MANY COUNTRIES. THE USE OF JET FILL TENSIOMETERS INSURES THE CONSULTANT OF COST-EFFECTIVE MOISTURE CONTROL AND THE GROWER OF MAXIMUM CROP YIELDS.

ORDER YOUR JET FILLS BY MODEL NUMBER

MODEL 2725A SERIES

Ideal for general irrigation control purposes. Provided with Jet Fill Reservoir Cap and fixed pointer vacuum gauge.

Stock size available:

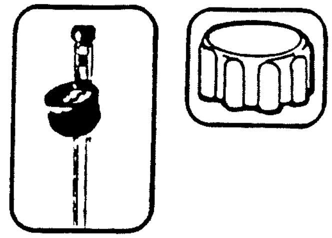
2725AL06	JET FILL TENSIOMETER	6" size
2725AL12	JET FILL TENSIOMETER	12" size
2725AL18	JET FILL TENSIOMETER	18" size
2725AL24	JET FILL TENSIOMETER	24" size
2725AL30	JET FILL TENSIOMETER	30" size
2725AL36	JET FILL TENSIOMETER	36" size
2725AL42	JET FILL TENSIOMETER	42" size
2725AL48	JET FILL TENSIOMETER	48" size
2725AL60	JET FILL TENSIOMETER	60" size

MODEL 2725AR SERIES

Ideal for research purposes. Provided with Jet Fill Reservoir Cap and recalibrator type vacuum gauge.

Stock size available:

2725ARL06	JET FILL TENSIOMETER	6" size
2725ARL12	JET FILL TENSIOMETER	12" size
2725ARL18	JET FILL TENSIOMETER	18" size
2725ARL24	JET FILL TENSIOMETER	24" size
2725ARL30	JET FILL TENSIOMETER	30" size
2725ARL36	JET FILL TENSIOMETER	36" size
2725ARL42	JET FILL TENSIOMETER	42" size
2725ARL48	JET FILL TENSIOMETER	48" size
2725ARL60	JET FILL TENSIOMETER	60" size



MODEL 2710 SERIES

An inexpensive, versatile tensiometer similar to the 2725 Series but supplied with solid sealing cap and fixed pointer vacuum gauge.

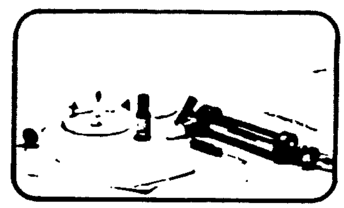
Stock size available:

2710L06	SOILMOISTURE TENSIOMETER	6" size
2710L12	SOILMOISTURE TENSIOMETER	12" size
2710L18	SOILMOISTURE TENSIOMETER	18" size
2710L24	SOILMOISTURE TENSIOMETER	24" size
2710L30	SOILMOISTURE TENSIOMETER	30" size
2710L36	SOILMOISTURE TENSIOMETER	36" size
2710L42	SOILMOISTURE TENSIOMETER	42" size
2710L48	SOILMOISTURE TENSIOMETER	48" size
2710L60	SOILMOISTURE TENSIOMETER	60" size

ACCESSORY ITEMS

2710K1 SERVICE KIT

Kit should be ordered with each initial order of tensiometers.



240L INSERTION TOOL

240L30	⅞" INSERTION TOOL	30" Length
240L54	⅞" INSERTION TOOL	54" Length
240L78	⅞" INSERTION TOOL	78" Length

Cuts ⅞" diameter hole in rock-free soils for rapid installation of 2725 and 2710 Series Tensiometers.

230D2 SOIL AUGER, 2" Diameter,
5' overall length for installation of tensiometers in rocky soils.

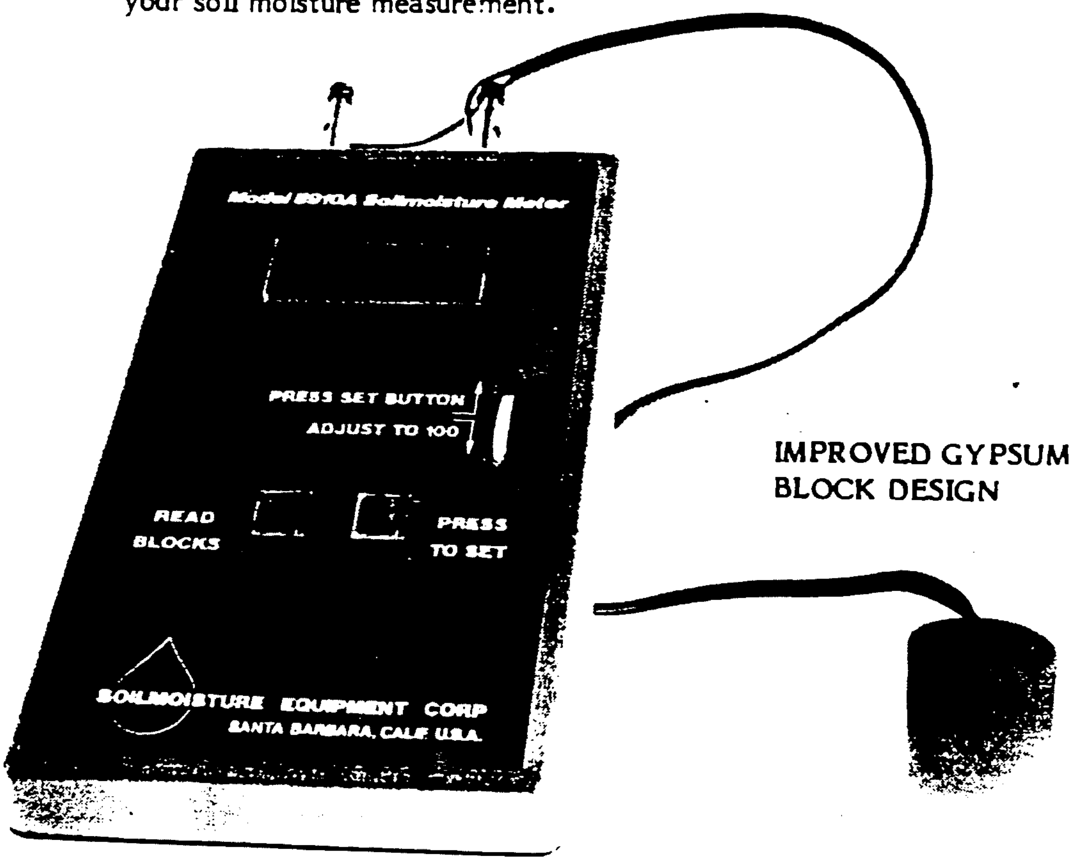
2010	**MONTHLY CHART FORMS, pad of 100**
2041	**TENSIOMETER CHART, 12 months**
2720L60	**EXTENSION TUBE, 60" size**

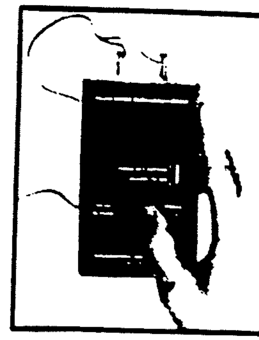
Used to extend the length of all 2725 and 2710 Series Tensiometers.

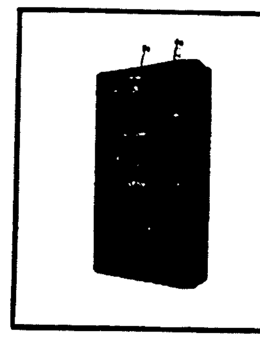
NEW PRODUCT RELEASES

NOW! A DIGITAL READOUT FOR OUR SOILMOISTURE METER

Large, easy reading display add convenience & accuracy to your soil moisture measurement.







IMPROVED GYPSUM BLOCK DESIGN

PAT. PEND.

MODEL 5910-A SOILMOISTURE METER

Rugged plastic case fits your hand, and has Stainless Steel belt clip for carrying. Solid state A.C. circuitry assure long trouble free service. Low battery power indicator. Standard 9V battery, easily replaceable. Knife action spring terminals make positive electrical connection to Soilmoisture Block leads. Completely compatible with older Model 5910 Meter & 5200 Blocks.

MODEL 5201 SOILMOISTURE BLOCKS

New "Slim" design gypsum blocks are completely compatible with older models. With life expectancy of 3-5 years under usual soil conditions, these inexpensive blocks make it possible to use a sufficient number to obtain full moisture information. Buffering action of the gypsum compensates for varying salinity conditions to give reliable moisture content information. Uniformity of block construction eliminates need for calibration when used for irrigation control purposes in commercial agriculture. Patent pending.

SOILMOISTURE EQUIPMENT CORP.
P.O. Box 30025
Santa Barbara, CA 93105
U.S.A.

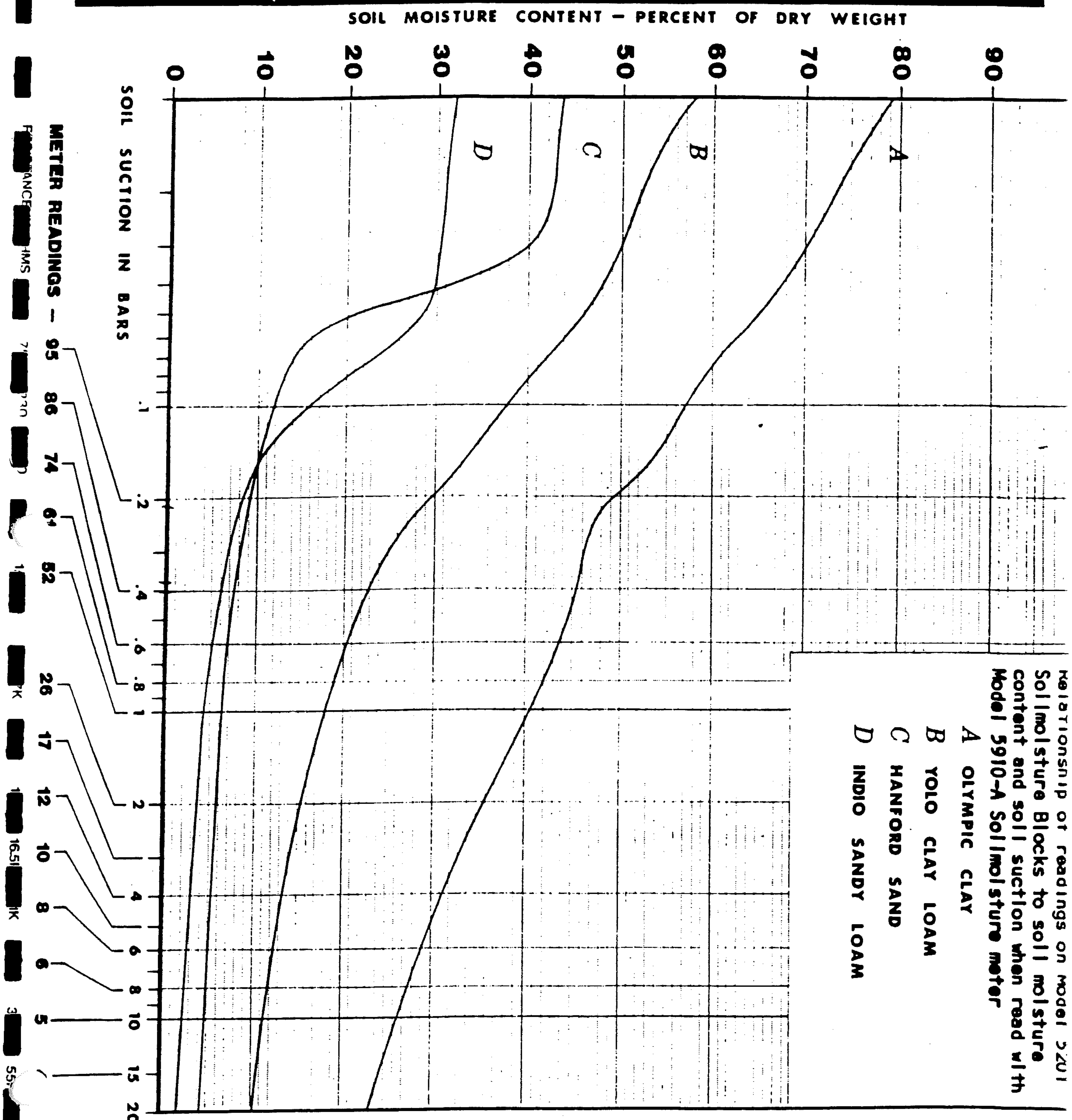
Telphone No. 805-964-3525
Telex No. 65-8424 Fax No. 805-683-2189
Cable Address: SOILCORP

SOILMOISTURE ®

MARCH 1983

ENGINEERING DETAILS

MODEL 5201 AND MODEL 5910-A SOIL MOISTURE RELATIONSHIPS



SOILMOISTURE EQUIPMENT CORP.
P. O. Box 30025
Santa Barbara, CA 93105
U.S.A.

Telephone No. (805) 964-3525
Telex No. 65-8424
Cable Address: SOILCORP

SOILMOISTURE