

PERMAFROST
TECHNOLOGY
FOUNDATION

FINAL REPORT

FOUNDATION STABILITY
RESEARCH

AT

1732 RISE ROAD
FAIRBANKS, ALASKA

JUNE 1998



Final Report
on
Foundation Stabilization Research
Studies on

1732 Rise Rd.
Fairbanks, Alaska

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Introduction

This is a small wood frame house that was constructed on a perimeter footing with interior blocks with an all-weather wood perimeter wall and posts. The foundation was about 3 feet below the surrounding grade and the house was about 2 feet above grade leaving a large enclosed crawl space. By the late 1980's there had been significant settlement of the foundation and some cosmetic, if not structural, distress.

There was a permafrost investigation done on the property, but the house was vacated and deeded over to the Permafrost Technology Foundation (PTF) in 1991 to use in a study of house foundations on permafrost terrain. This study consisted of drilling two additional borings, releveled the house, putting it on a new foundation system, and monitoring settlement and temperature. This is the final report for the Permafrost Technology Foundation study.

Structure Description

The house is basically two stories with the living quarters and one bedroom downstairs and a loft with bedrooms upstairs. A floor plan of the lower floor is presented in Figure 1.

The house currently sits on a series of screw jacks to make it easy to relevel. The jacks were designed and constructed by Pearson Enterprises in Fairbanks. The jacks consist of a piece of allthread that is rigidly attached to a steel base plate. The top of the allthread runs through a sleeve which is rigidly attached to the beams supporting the house. The house is raised and lowered by adjusting the nut on the allthread with a large wrench. There is about 12 inches of adjustment available. If more is needed, the following procedure can be followed: place a support under the beam, compress the jack, place soil or other non-degradable material under the jack base plate, and support the house on the jack again.

It will be necessary to keep the jacks rust free or the releveled operation will become difficult, or impossible, with the existing screw jacks. The jacks have been used several times in the past several years with relative ease.

The house should be monitored, and releveled if necessary, each year in the late summer, say July or August. The time of year is important because there will be some differential

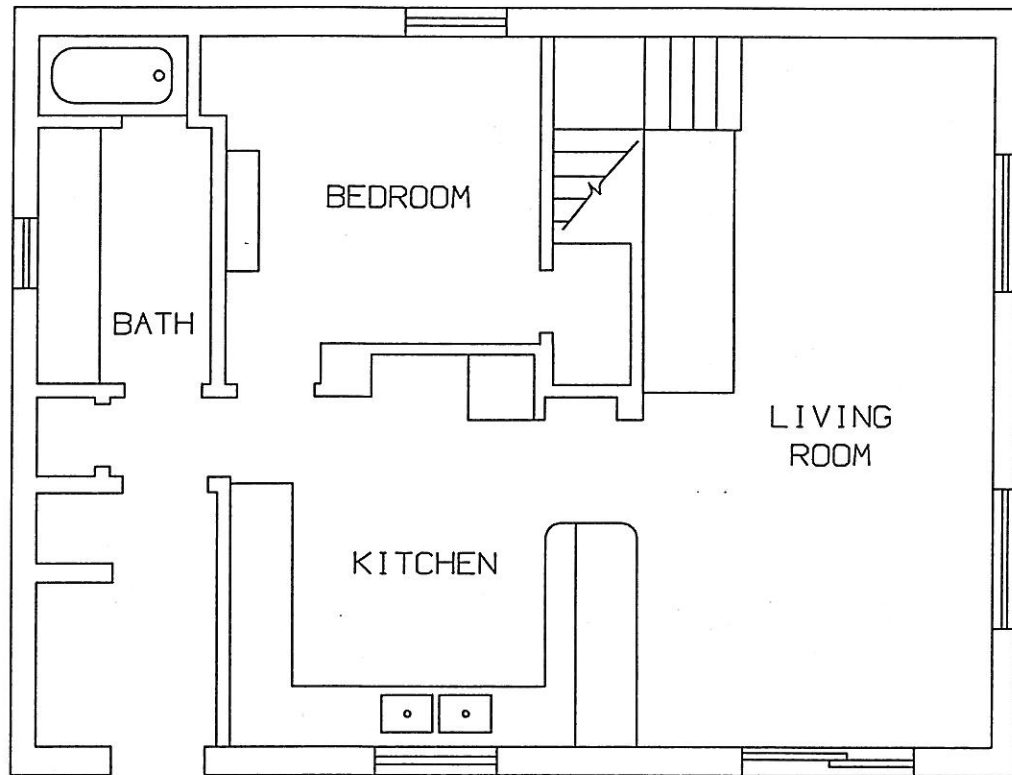


B-2

B-1



TH-1



Legend: B – Hollow stem auger boring, drilled for the Permafrost Technology Foundation
TH – Solid stem auger boring drilled by Clarke Engineering

FIGURE 1 – FLOOR PLAN OF MAIN LEVEL OF HOUSE ON RISE RD
SHOWING LOCATIONS OF SUBSURFACE EXPLORATIONS

movement caused by frost heaving and the late summer is the only time of year when these effects can be avoided.

To aid in monitoring and releveling, each jack point has a fluid level attached to it so that it is easy to see the relative elevation of each point from one central location near the front door of the house. In order for the fluid levels to be functional, the fluid level must be at the same elevation relative to the structure on the outside of the house. A constant distance which was measured from the bottom of the siding was used throughout this study. Once it has been verified that the fluid levels all have the proper amount of fluid in them, the relative elevations seen at the common point near the front door are the relative elevations of each jack point. Individual jacks can then be raised or lowered as desired to make the structure level. The fluid in the levels must be a 50-50 mix of antifreeze and water to keep it from freezing. Fluids that are more viscous should not be used.

The house had been badly deformed in the late 1980's and several of the beams have taken a set. This makes it impossible to make every point in the house at exactly the same elevation. The differential elevation within the house can be reduced to less than 1 inch, which is well within normal house tolerances. The point at which releveling will be necessary is a function of the tolerance of the structure and the tolerance of the owner. In general, the house can withstand several inches of differential elevation, which is more than most owners will be willing to endure.

The house has a large deck constructed on the south side to provide shade to the foundation and to slow thawing of the permafrost. The deck is supported by a post resting on concrete foundation blocks. The deck is light enough to be relevelled using a car jack and gravel fill under the concrete block footings.

The jacks were originally designed for earthquake resistance when 6 inches of jack are exposed and the jack pads are placed on level ground. The as-built is somewhat different than the design. However, if a jack is extended more than 6 inches, or if the soil under a particular jack pad is on a mound of soil, the stability will be reduced. A effort should be made to keep the average jack extension less than 6 inches and to keep the soil under the base plate fairly level for at least 2 feet in all directions. The base plates should not be buried. It is the intent that the building be allowed to move around over the ground surface during a major earthquake. This movement should be less damaging than trying to hold the jack points firm in one location.

Level Measurements

Background

Level measurements were taken to determine the relative elevation of the floor. The level measurements were made using a small precise telescopic level (sometime referred to as a "contractor's level") mounted on a tripod, and a surveyor's rod calibrated in millimeters. The millimeter rod was used instead of a standard surveyor's rod to give

more precision to the measurements. Since the distance from the level to the rod was rarely over 15 feet, the rod could easily be read to the nearest millimeter (0.04 inch).

It should be noted, however, that when level measurements are this precise, that perturbations can, and do, occur. These small changes are due to the placement of the rod from one measurement set to the next. Often the rod had to be placed behind furniture, and it was impossible to determine if it was sitting on the same spot as the previous measurement, or if an electrical cord or something else happened to be under the rod. Even the thickness of a few sheets of paper will show up at this precision. Many of the areas are carpeted, which makes it particularly difficult to get consistent readings.

There was also the possibility for a gross error in reading the rod, since the level had the standard three cross hairs (center, upper, and lower) used for measuring distances in surveying. If the operator was careless or inexperienced (student labor was used for these measurements), a reading could be made using either the upper or lower cross hair instead of the center one. This error would yield an elevation that was in error by several tens of millimeters. These errors are readily discernible when the data is plotted as a function of time.

Level data was collected several times a year and accumulated for a period of five and a half years. Each measurement location is designated on the floor plan by a letter, as shown on Figure B-1. The settlement data are presented in Table B-1. The data from different groups of letters were plotted together to show relevant comparisons such as along the south wall or along the diagonal across the structure. These charts are shown on Figures B-2 through B-8. In each chart, all levels are referenced to a single reference, Point A. This allows the elevation of each point to be compared as a relative elevation on the floor plan with respect to point A.

This approach does not give information as to the absolute elevation of the house with respect to the ground outside. Therefore, any elevation variation of point A is also reflected in all other points. Determining absolute elevations requires a stable surveyor's benchmark or other stable reference outside the structure. No such reference or benchmark was available at this location. Nevertheless, the relative elevations allow differential settlement to be tracked, and that is the most important information for this study.

About a year after the measurements were started an old well casing was discovered on the back side of the house which we could use as a benchmark. Measurements were continued the same throughout the whole study with Point A in the house as the reference but after October 6, 1992, the benchmark was also included in the measurements.

All the data, except the benchmark are plotted on Figure 2. Several things are obvious from this figure.

- The house was over 250mm (10 inches) out of level when PTF took possession in July 1991.

Elevations of all Points on Rise Rd. Relative to Point A

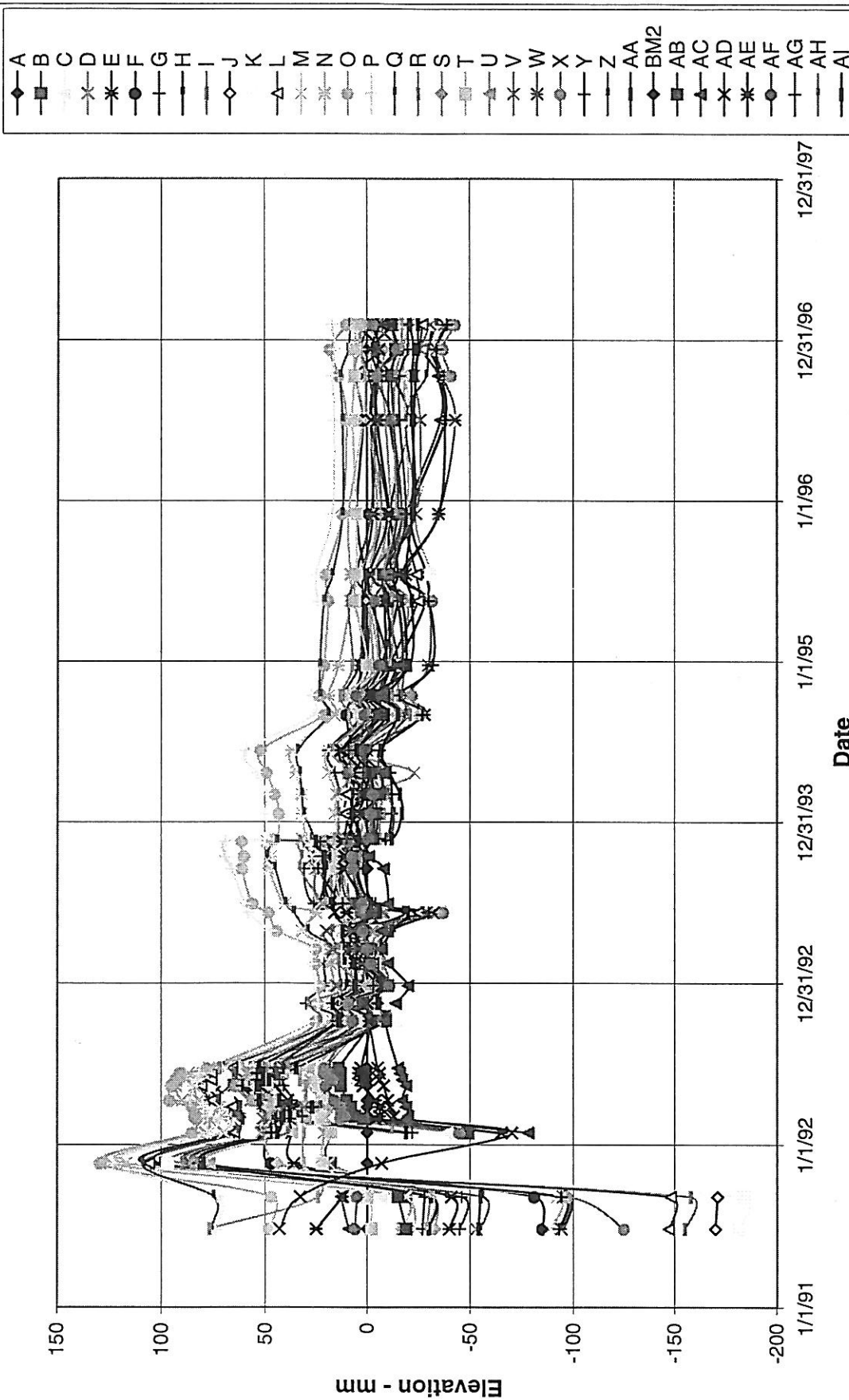


FIGURE 2

- The house was put on the jack foundation in the fall of 1991 and was releveled several times over the next year.
- The house was again releveled in the fall of 1993 and the fall of 1994
- The differential movement seemed to get larger, at the rate of about 20 mm per year for the first couple of years and then seems to have stopped in the last three years.

The elevation relative to the benchmark is shown in Figure 3. This data confirms the above observations and indicates that the structure was settling uniformly at a rate of about 25 mm per year in 1996 and that the rate of settlement seems to be decreasing with time.

Earthquakes and Other Dynamic Events

The presence of loose soils gives rise to the concern for settlement during a dynamic event such as an earthquake. During the period over which the level measurements were made, there were 15 earthquakes over a Richter Magnitude of 4.0. The two largest were a Magnitude 5.0 on November 1, 1992, and a Magnitude 6.2 on October 6, 1995. This last one was the most significant, not only because it was the largest but it was also the shallowest at only 9 km below the surface. It was felt very strongly by residents of Fairbanks, however, reviewing our settlement data we can not see any settlement that can be attributed to an earthquake. This suggests that significant settlement will not be caused by future earthquakes producing the same intensity. This does not preclude the possibility of settlement during a more severe earthquake or other type of dynamic event.

Temperature Measurements

Temperature measurements were made with thermistors, which were read with a datalogger and converted, automatically to temperature.

When the test borings were drilled, thermistor strings with twelve thermistors each were placed in the hole prior to backfilling. The locations of the thermistor strings are shown on Figure C-1. The depths of the thermistors are shown on the data sheets, Table C-1 and on the boring logs, Figures A-1 and A-2. These temperatures were monitored periodically resulting in a database of five and one half years of temperatures at the site. The raw data is shown in Table C-1. The temperature data was plotted with respect to time on charts to give a graphic indication of the trends over the duration of the study. These charts are shown on Figures C-2 through C-12.

Thermistors are capable of measuring temperature to the nearest one thousandth of a degree Centigrade. However, the nearest one tenth of a degree is probably satisfactory for our purposes for everything except the location of the actual freezing front. Thermistors were used because they are more accurate and easier to read than thermocouples; however, they have the disadvantage of being more fragile, and they can drift a few thousands of a degree over time. To obtain the maximum accuracy, the strings must be calibrated in a reference bath both before and after their use. These thermistor

Absolute Elevations of all Points on Rise Rd.

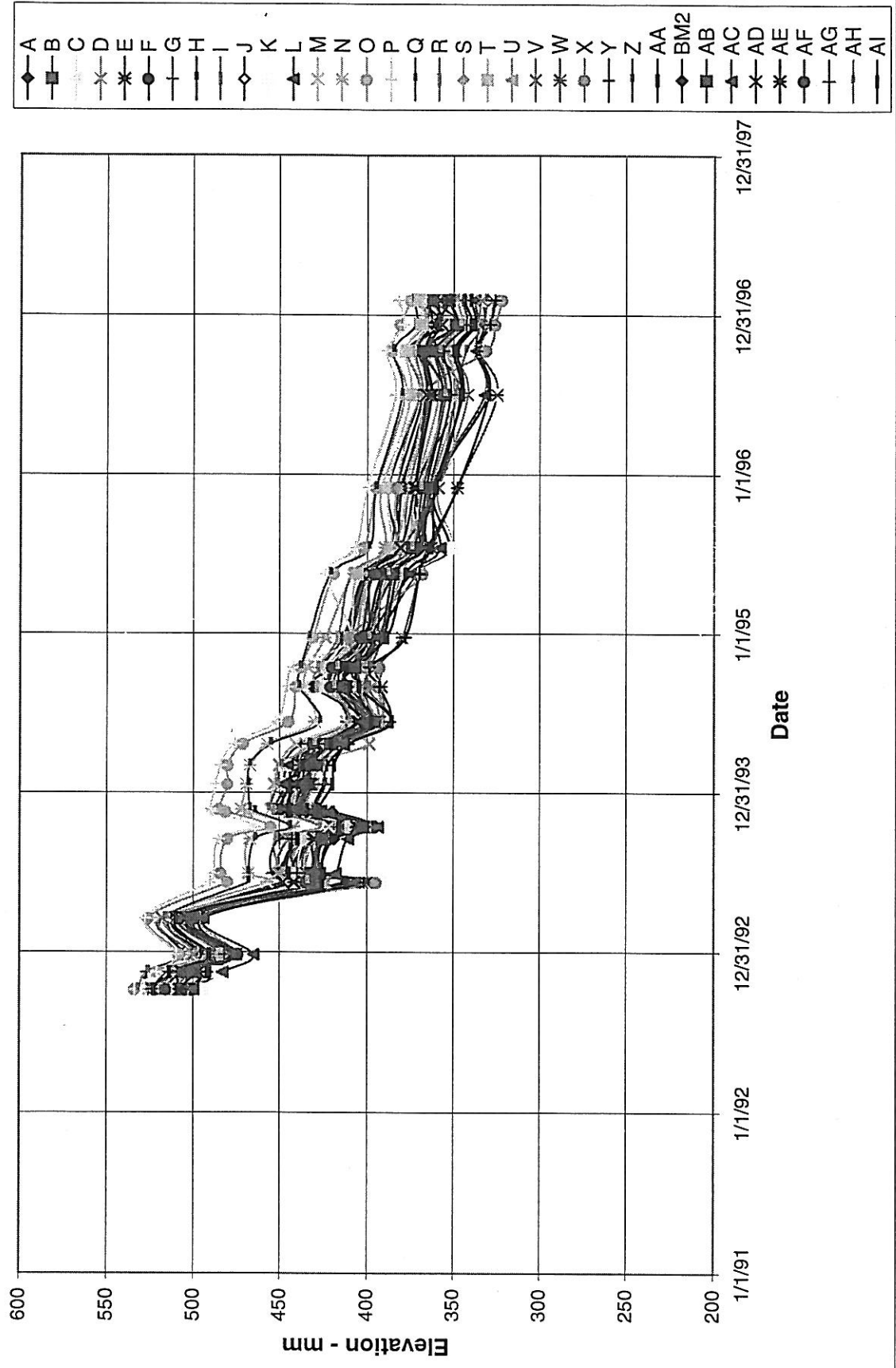


FIGURE 3

strings were calibrated before placing them in the hole, but since they are buried after installation, it is impractical to remove them without destroying them, therefore the secondary calibration cannot be made. The temperatures, therefore, cannot be relied upon to more than about a tenth of a degree.

Thermistors located at various depths allow us to track the temperatures at those depths to determine if the permafrost is getting deeper, remaining stable, or actually rising. The data also alerts us to any anomalies in temperature that may occur due to outside influences such as new construction nearby, landscaping modifications, or damage or deterioration of protective insulation.

Figures 4 and 5 show the data from the permafrost in Borings B-1 and B-2 respectively. Several pieces of data were considered to be in error and were eliminated prior to making the plots shown. The data from both borings seem to show a steady decrease in the temperature of the permafrost outside the perimeter of the house. The rates of decrease are very small, on the order of 0.05 degrees Centigrade per year.

Figures 6 and 7 show the data from the active layer in Borings B-1 and B-2 respectively. The scale has been adjusted so that only the data near the freezing temperature are shown. Careful observation of these figures shows that each thermistor has a temperature below freezing at some time of year. If these readings were correct, it would mean the active layer is reaching the top of the permafrost at least at the boring locations and during the period monitored. For the reasons mentioned above, it is quite possible that the amount measured below freezing is less than the accuracy of the thermistors and that there is a thawed zone below the active layer and above the permafrost. One would expect the active layer to be far less than 20 feet at this location hence it is likely that the thermistor readings are misleading.

The elevated foundation should provide an average ground surface temperature which is below that of the surrounding terrain. Perhaps it will be reduced to below freezing and the area under the house will eventually refreeze.

Geotechnical Exploration

In order to determine the condition of the soils near the structure at the start of our study, two boreholes were drilled and samples of the soil were taken as shown on the Boring Logs, Figures B-1 and B-2. Samples of the unfrozen soil were collected by driving a split spoon sampler out the bottom of a hollow stem auger using a 300-pound hammer and a 30 inch drop. The number of hammer blows required to drive the core barrel gives information on the competency of the soil at each sample depth. These samples are considered "disturbed samples." However, since they are retrieved essentially intact in their natural state they provide useful information about the soil. This method of sampling was continued until frozen ground was encountered.

The frozen soils were sampled with a dry core barrel. The 3-inch diameter core barrel was drilled into the frozen ground about 5 feet below the auger. The sampler was then

Temperature Data From Permafrost in Boring B-1

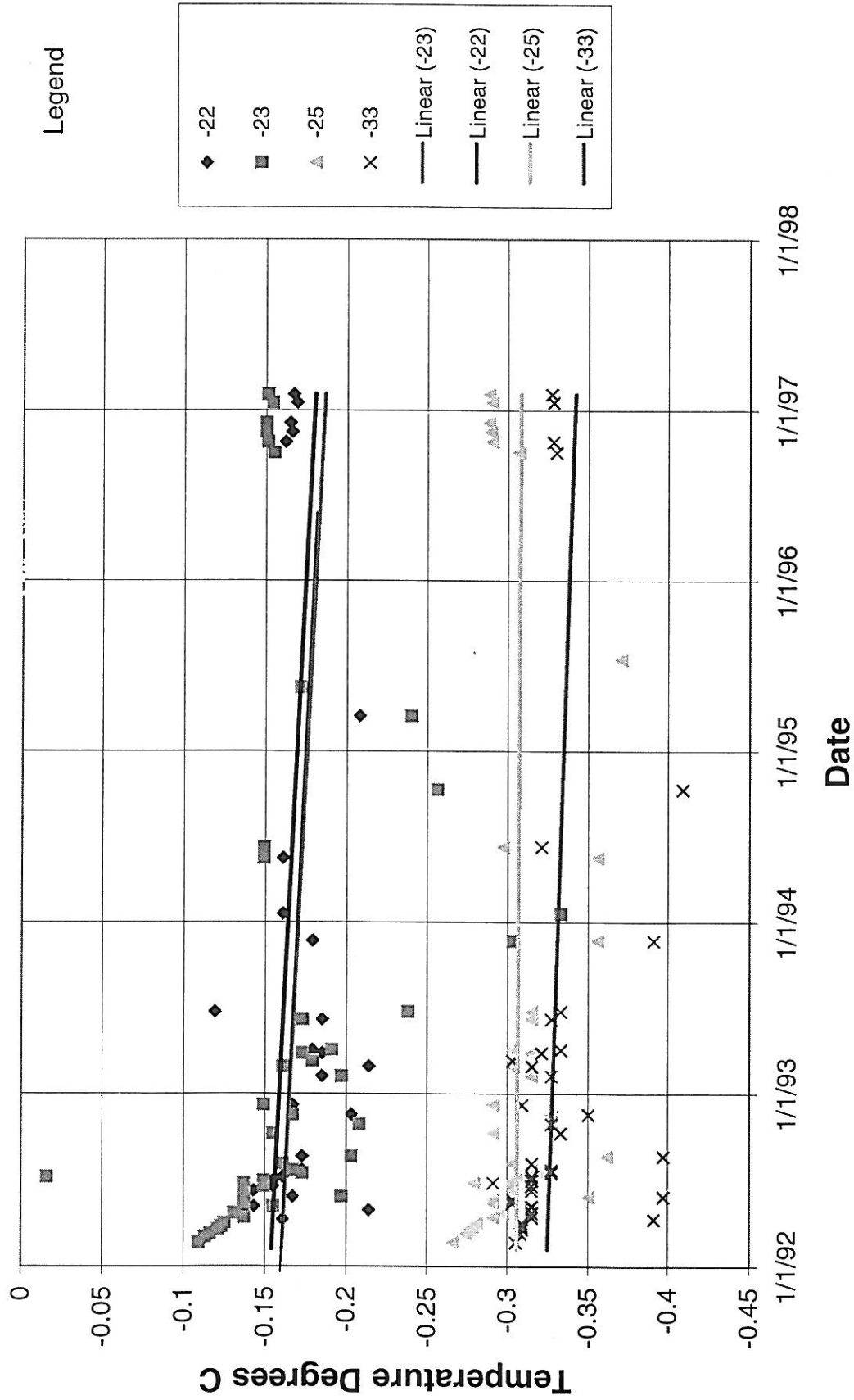


FIGURE 4

Temperature Data From Permafrost in Boring B-2

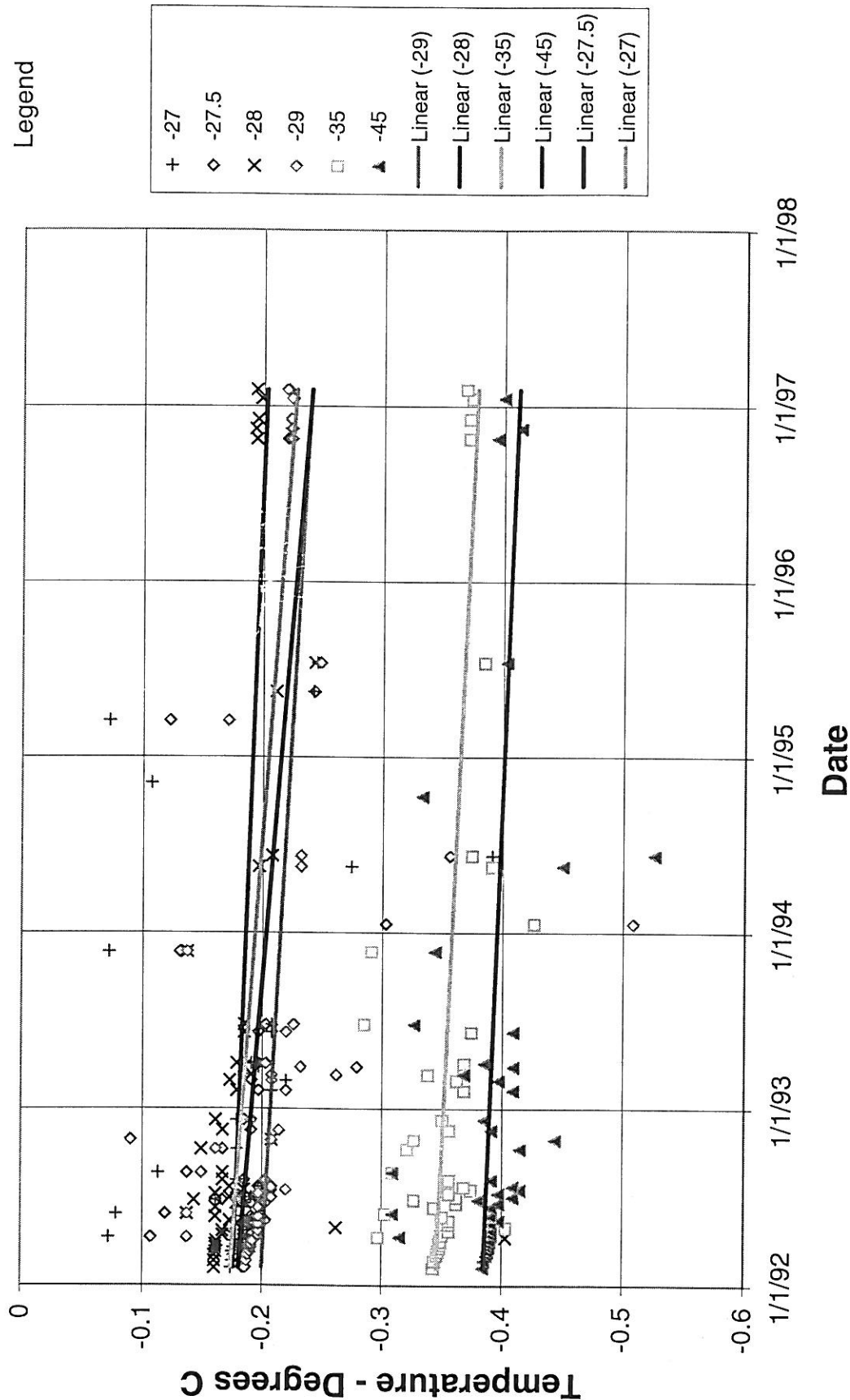


FIGURE 5

Temperature Data from Active Layer in Boring B-1

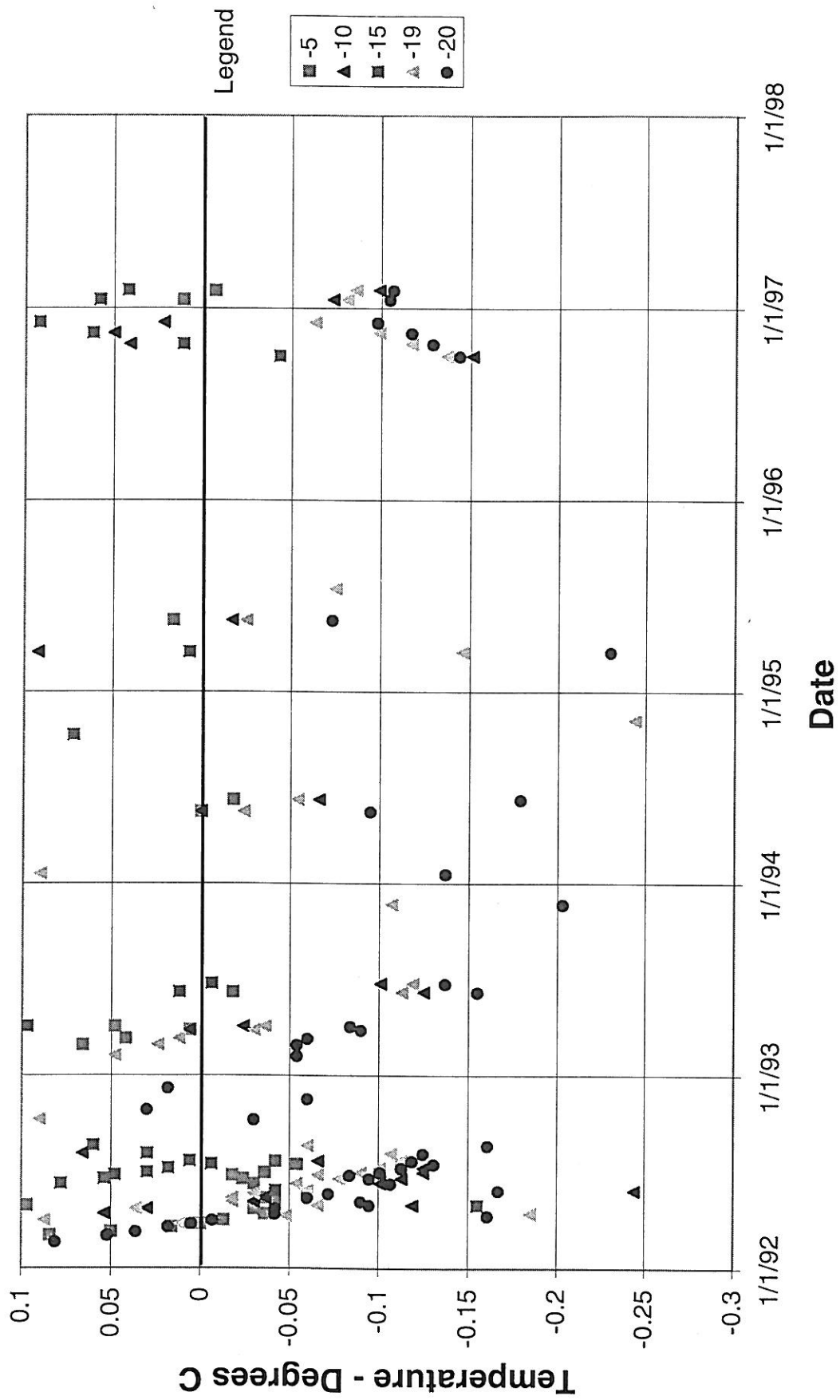


FIGURE 6

Temperature Data from Active Layer in Boring B-2

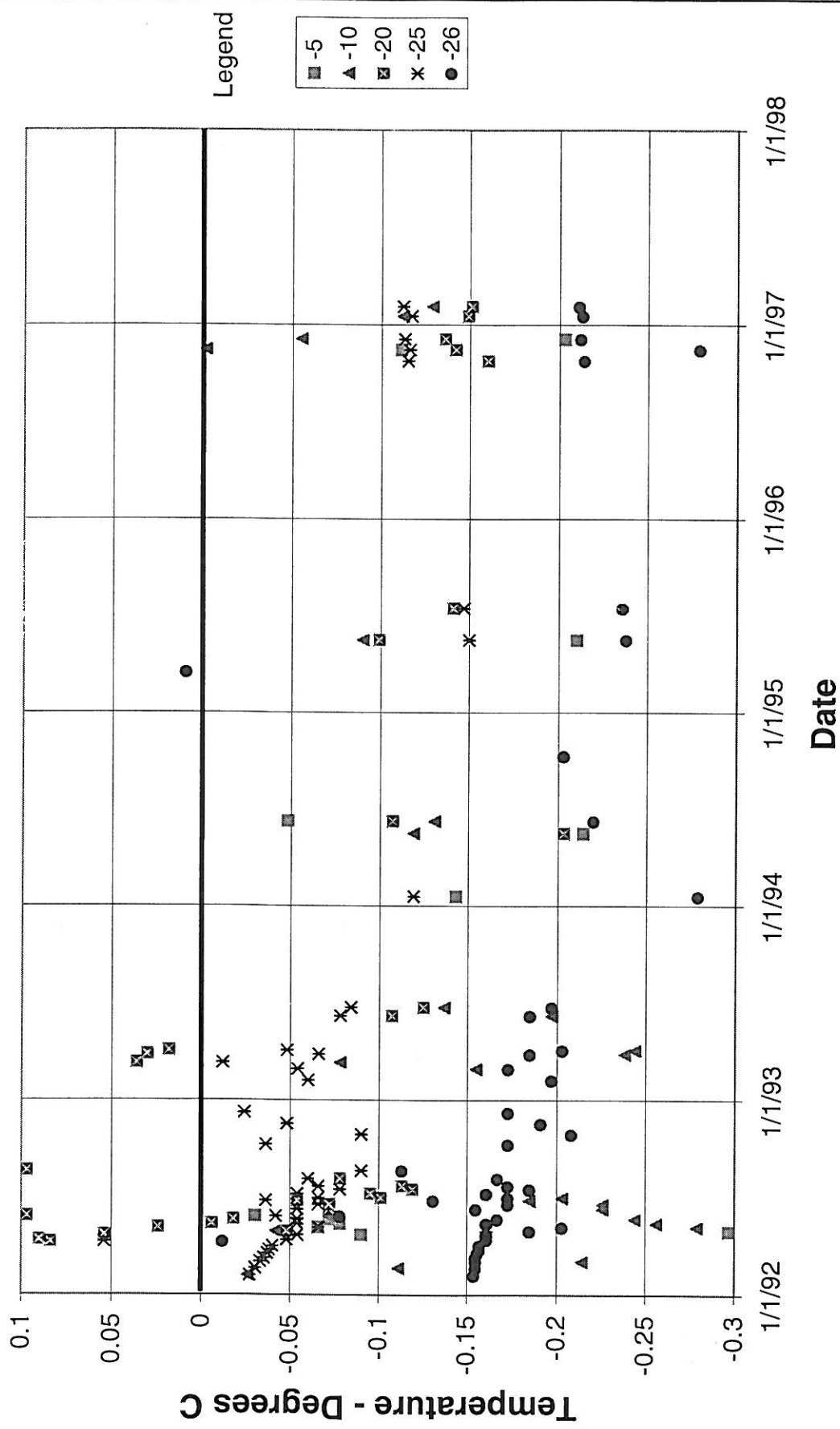


FIGURE 7

brought up to the surface and the soil pushed out of the tube. The soil was classified and representative samples were saved in their frozen state.

Both borings, Figures B-1 and B-2, show the surficial layer of sand and gravel fill placed over the site prior to construction. This is underlain by brown silt that has a layer of black silt at about 20 feet. Permafrost was found at a depth of 21.8 feet in Boring B-1 near the center of the north wall and at 27.5 feet in Boring B-2 near the southwest corner of the building. All of the silt above the frozen ground was wet and soft. The permafrost was classified as Nbn with some ice crystals and thin ice lenses. Nbn means that the silt was bonded but did not have any visible ice or any excess ice. The classification was made visually at the time of drilling and the fact that excess ice was not detected does not mean that the permafrost is thaw stable.

Results and Conclusions

The structure is underlain by a thin layer of sand and gravel fill overlying soft silt. Permafrost was found in the borings at a depth of about 20 feet on the north side of the structure and about 30 feet on the southwest corner. It could have been much deeper under the house and significantly higher farther away from the house.

The combination of the temperature measurements and the settlement measurements indicate that the thawing of the permafrost is stopping and that the house is becoming more stable with time. This is a very delicate balance and changes such as global warming, removing the deck, blocking airflow under the house, changing drainage, etc., may upset this balance and start the permafrost thawing again.

The jacking system seems to be working well and there is no reason to believe that it will not continue to work well in the future if the allthread is kept rust free. It would be desirable to keep the jacks compressed as much as possible and to keep the area around each jack pad level for a distance of at least 2 feet in all directions.

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Appendices

Appendix A

Bore Hole Logs

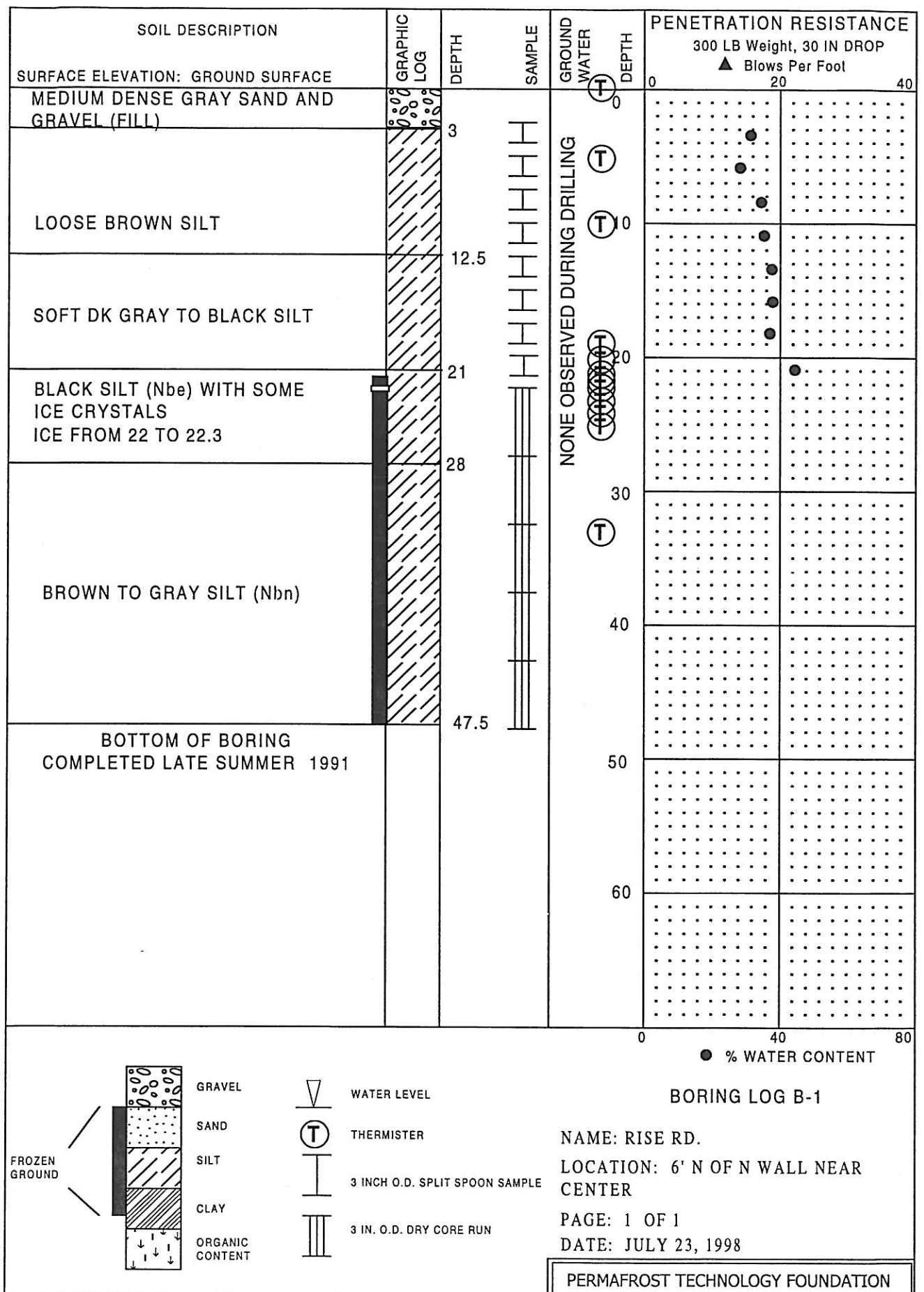


FIGURE A-1

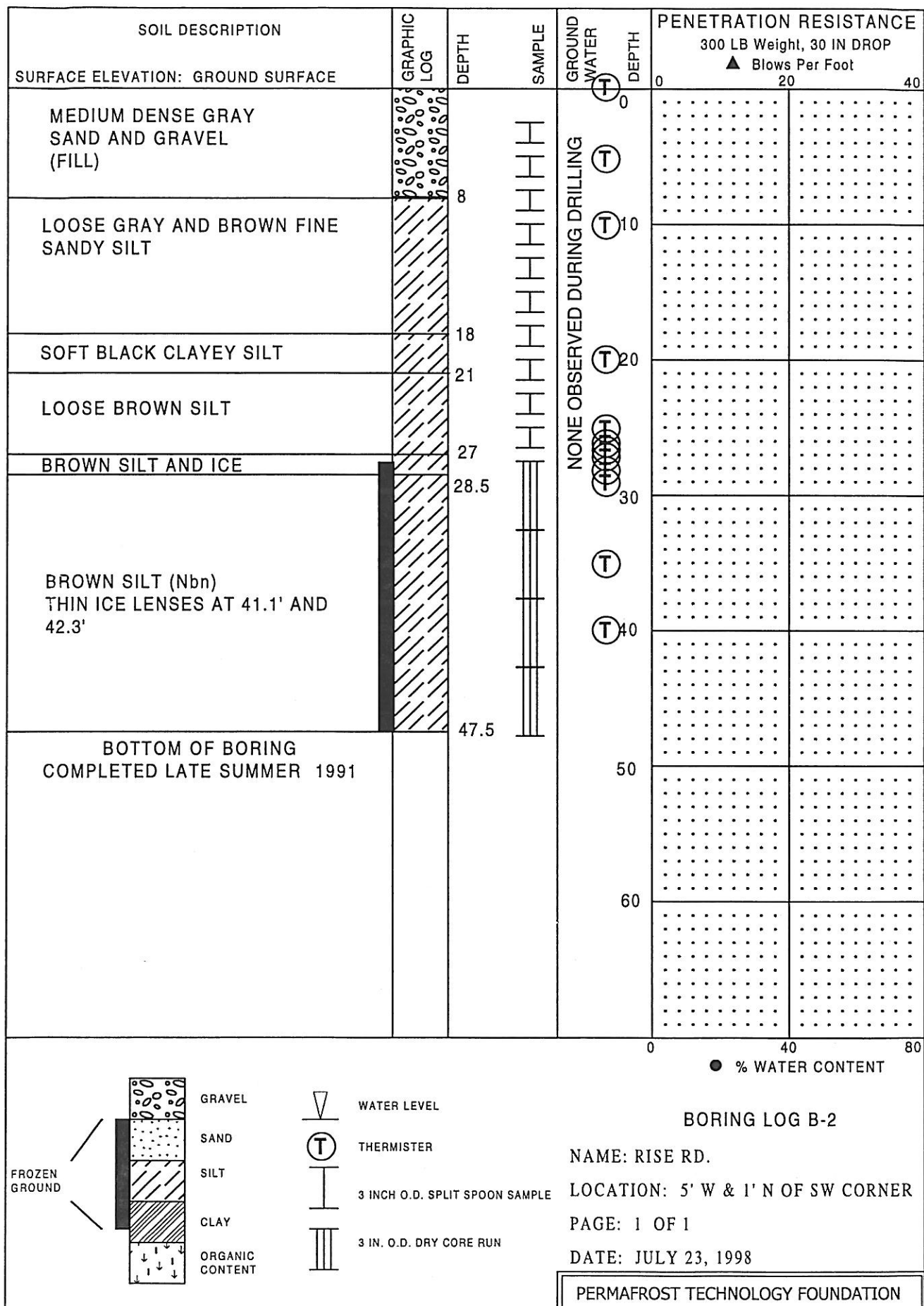


FIGURE A-2

Appendix B

Level Measurements

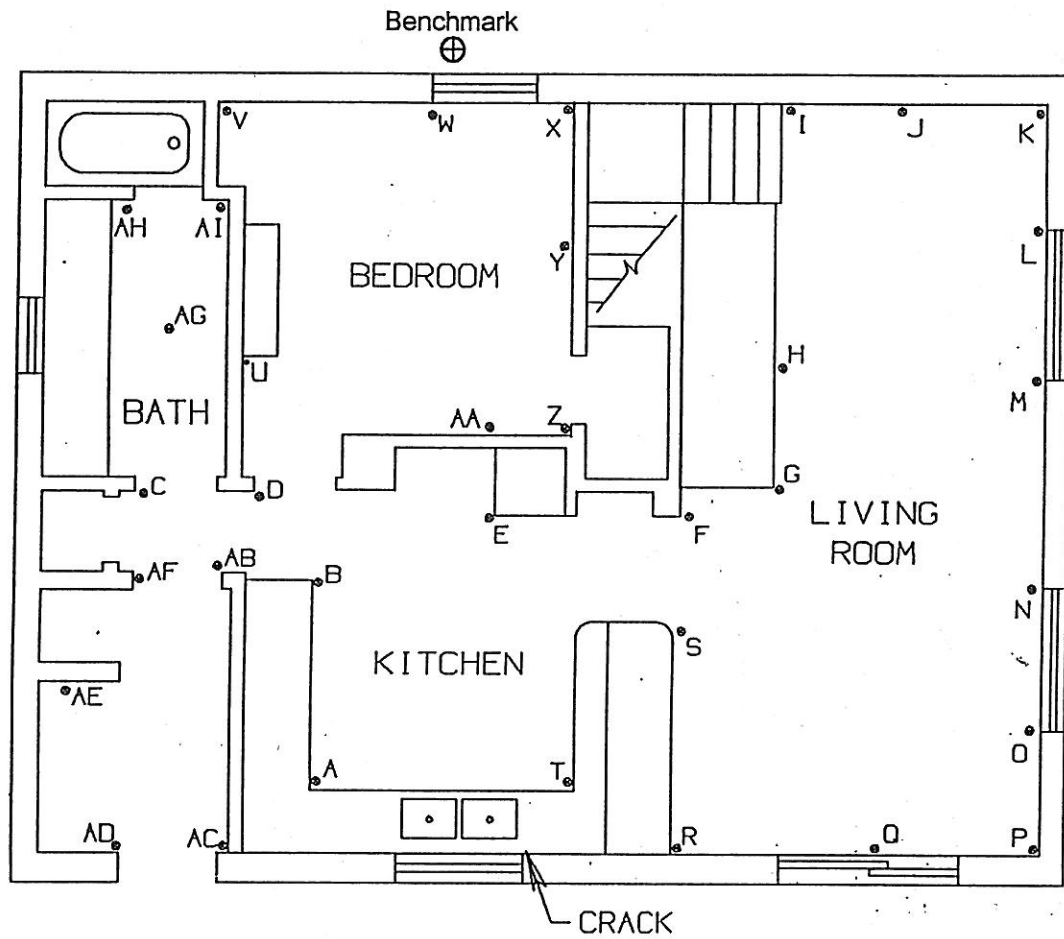


FIGURE B-1 – FLOOR PLAN OF HOUSE ON RISE RD.
SHOWING LOCATIONS OF LEVEL MEASUREMENTS

Settlement Readings From Rise Rd.

	6/26/91	9/6/91	11/20/91	1/28/92	2/28/92	3/5/92	3/26/92	4/10/92	5/13/92	5/26/92	6/10/92	6/22/92
A	0	0	0	0	0	0	0	0	0	0	0	0
B	-18	-19	18	18	19	13	19	19	23	22	20	21
C	26	-7		-39	22	19	21	23	27	26	26	26
D	-24	-19	19	21	21	21	24	22	29	28	26	27
E	-40	-41	36	37	38	33	37	39	45	43	42	41
F	-85	-81	47	48	47	46	50	48	58	59	56	58
G	-45	-46	105	65	64	64	67	77	80	75	82	70
H	-95	-96	100	64	62	58	63	72	77	71	72	62
I	-155	-158	90	46	45	43	46	57	62	59	61	49
J	-170	-171		54	52	52	55	66	74	68	67	59
K	-181	-184	97	57	52	56	58	68	77	70	69	61
L	-147	-148	106	65	63	64	66	76	81	76	76	66
M	-89	-92	117	70	65	71	72	82	84	82	80	69
N	-17	-19	124	79	77	80	81	90	93	88	87	77
O	48	47	129	85	83	84	85	96	95	93	91	78
P	74	73	123	78	72	78	80	86	85	83	82	71
Q	76	75	109	63	63	65	62	73	67	64	65	57
R	77	24	31	31	28	30	32	30	30	33	33	72
S	-33	-31	44	50	49	45	49	49	55	54	53	56
T	-2	0	22	18	23	23	23	22	24	23	24	22
U	-29	-30	77	37	34	38	20	47	49	45	41	29
V	-53		88	52	51	49	31	57	63	60	59	50
W	-94	-95	86	49	48	48	31	55	65	60	56	48
X	-125	-97	84	46	40	41	26	56	64	58	55	45
Y	-93	-94	82	47	45	44	27	52	61	58	54	41
Z	-55	-56	83	39	42	43	23	51	50	49	45	39
AA	-30	-31	80	44	42	41	27	53	54	48	45	35
BM2												
AB	-19	-15		-49	2	6	8	10	13	14	13	14
AC	9	13		-78	-19	-20	-19	-17	-19	-17	-16	-15
AD	43	33	-7	-70	-12	-13	-11	-10	-8	-6	-6	-5
AE	25	12		-65	-4	-6	-6	-4	2	3	4	3
AF	6	5		-45	13	11	13	16	20	17	21	21
AG	-27	-28		-22	38	32	42	37	41	43	44	45
AH	-29	-31		-12	48	38	48	48	59	58	59	61
AI	-54	-55		-19	42	38	38	43	53	51	51	53

TABLE B-1

Settlement Readings From Rise Rd.

	10/6/92	11/15/92	12/25/92	2/13/93	3/18/93	4/28/93	6/9/93	6/29/93	9/16/93	10/14/93	11/17/93	11/23/93
A	0	0	0	0	0	0	0	0	0	0	0	0
B	1	5	2	2	4	3	0	8	10	10	10	-2
C	9	11	2	11	13	15	13	16	21	21	24	11
D	4	6	7	8	9	10	6	15	18	17	18	4
E	3	5	6	6	9	0	-4	12	13	14	14	-2
F	13	14	3	5	8	-2	-3	22	16	18	17	-1
G	17	30	21	21	16	7	1	26	31	26	31	13
H	7	16	10	11	11	3	-18	18	20	18	20	5
I	-11	-7	-1	1	1	-1	-39	0	4	5	5	3
J	-10	-4	-1	1	0	1	-35	13	11	9	10	4
K	-14	-10	-6	-4	-6	-4	-39	5	10	12	10	4
L	-7	-4	-4	-3	-4	2	-25	10	15	12	19	7
M	2	6	3	4	5	12	-5	23	26	27	28	15
N	17	17	16	18	18	32	25	40	48	47	49	32
O	25	24	23	25	25	44	48	56	61	60	61	45
P	25	24	25	27	27	47	58	60	66	69	69	50
Q	15	13	13	14	15	29	36	40	45	49	44	27
R	6	3	-10	-8	-6	10	11	17	18	17	21	4
S	10	11	-4	-2	-1	-5	-3	9	13	12	14	-3
T	1	-1	-2	-1	0	5	9	12	16	14	14	4
U	-2	1	1	4	4	4	-7	7	12	12	17	-4
V	8	12	15	17	17	20	-8	22	25	21	24	11
W	-2	2	6	8	8	6	-29	7	12	9	12	-3
X	-8	-3	-4	2	2	0	-37	1	5	3	6	0
Y	-9	-5	-7	-4	-4	-11	-30	-4	2	2	4	-9
Z	-6	-5	-5	-3	-3	-10	-20	0	5	2	6	-10
AA	-8	-5	-7	-7	-7	-12	-20	-2	5	1	4	-12
BM2	-509	-497	-485		-501		-432	-428	-419	-395	-420	-440
AB	-2	2	-10	-1	0	2	0	4	7	8	8	-3
AC	-9	-14	-20	-10	-7	-7	-3	-10	-8	-1	2	-1
AD	-1	0	-7	2	4	8	16	1	7	7	8	9
AE	-1	10	-8	2	3	6	10	2	11	11	12	6
AF	7	9	-11	-2	0	2	3	2	7	7	9	-1
AG	15	17	-3	4	6	8	-2	12	24	22	23	10
AH	23	29	6	14	14	17	2	20	33	32	33	16
AI	14	17	6	6	9	12	-6	17	21	21	25	4

TABLE B-1

Settlement Readings From Rise Rd.

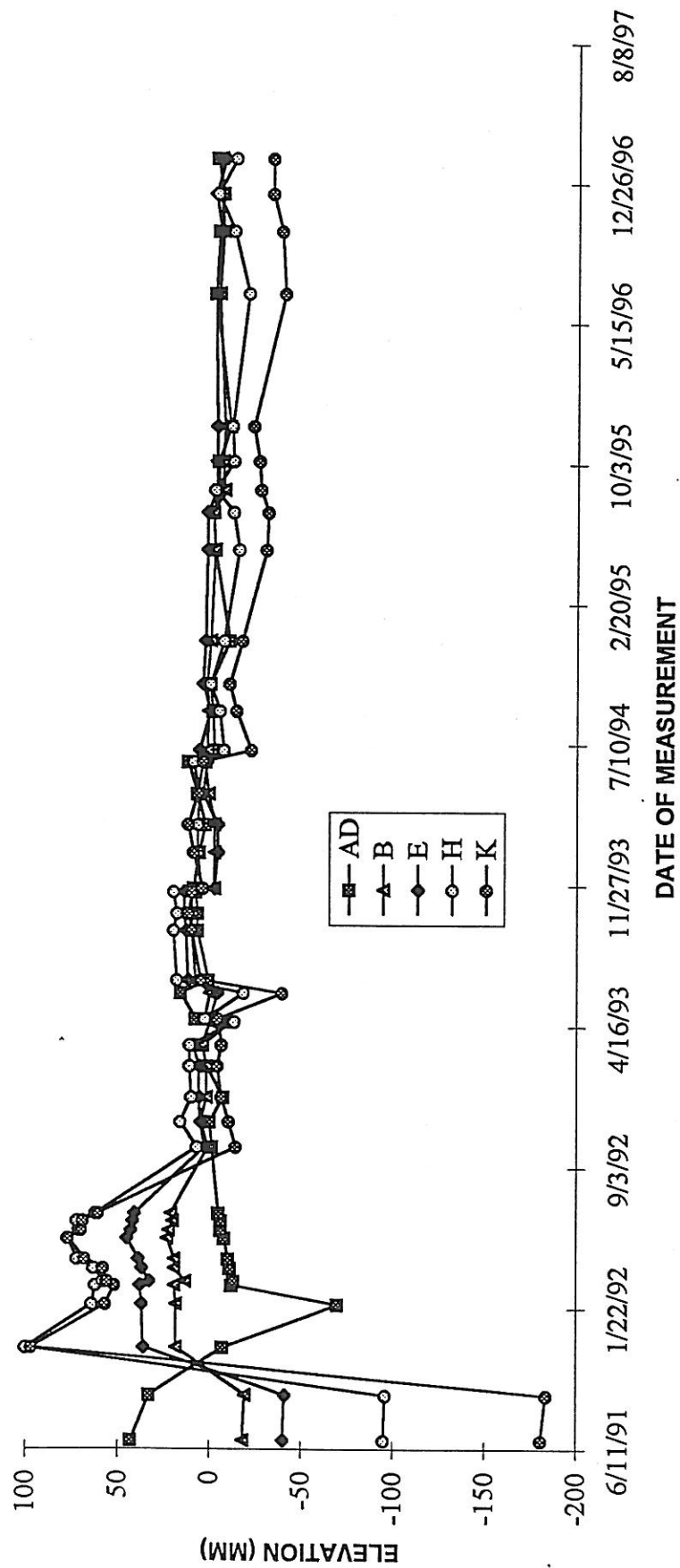
	1/19/94	3/4/94	4/22/94	6/12/94	9/1/94	10/15/94	12/23/94	5/18/95	7/17/95	12/2/95	7/2/96	10/11/96
A	0	0	0	0	0	0	0	0	0	0	0	0
B	-2	-2	1	3	1	2	2	-2	-1	-7	-4	-6
C	10	10	12	17	2	5	-2	-1	1	-5	-1	-1
D	2	1	-23	10	-3	10	-5	-1	-1	-5	-2	-2
E	-4	-4	4	2	0	4	3	2	2	-3	-2	-5
F	-1	-2	4	7	10	7	2	1	1	5	2	5
G	10	13	16	19	2	11	4	0	5	-2	-4	-1
H	7	7	6	9	-5	0	-7	-15	-12	-11	-20	-12
I	5	3	6	2	-21	-15	-18	-29	-31	-24	-38	-36
J	7	8	7	6	-16	-10	-15	-29	-29	-22	-38	-36
K	9	12	7	4	-14	-10	-17	-30	-31	-23	-40	-38
L	11	10	10	10	-14	-6	-11	-25	-24	-20	-36	-35
M	16	15	19	19	-3	4	-4	-14	-10	-9	-21	-18
N	32	32	35	37	16	19	14	8	8	9	2	6
O	43	45	49	52	21	23	21	19	20	12	10	14
P	50	49	54	59	26	27	24	24	25	17	16	17
Q	31	32	33	34	19	23	23	21	17	12	12	13
R	4	5	11	6	9	13	7	9	4	-7	0	1
S	-4	-5	0	2	-1	2	-3	-1	-4	-11	-9	-7
T	4	3	7	7	4	8	0	6	5	5	7	6
U	-6	-7	-2	3	-14	-10	-19	-17	-3	-19	-19	-18
V	6	3	3	10	-16	-10	-16	-20	-8	-24	-26	-23
W	-5	-3	-1	0	-28	-20	-30	-30	-19	-35	-43	-37
X	-2	-1	1	-6	-26	-22	-32	-32	-17	-35	-38	-41
Y	-12	-12	-11	-7	-27	-16	-32	-30	-3	-23	-19	-35
Z	-13	-10	-6	-7	-19	-17	-18	-15	-3	-23	-22	-29
AA	-17	-16	-11	-7	-15	-10	-19	-17	-8	-23	-22	-22
BM2	-437	-435	-422	-393	-420	-315	-410	-400	-382	-383	-368	-372
AB	-3	-3	-2	3	-6	-6	-11	-10	-8	-15	-13	-12
AC	1	-6	-7	3	-6	-7	-15	-9	-8	-17	-11	-11
AD	6	3	7	12	-1	0	-10	-2	-1	-10	-2	-4
AE	4	2	8	13	-8	-2	-9	-9	-15	-11	-5	-5
AF	-2	-3	9	6	1	5	-6	-4	-11	-17	-12	-5
AG	7	4	2	9	-6	-5	-17	-15	-13	-19	-16	-16
AH	14	14	8	17	-1	2	-11	-12	-8	-14	-13	-14
AI	7	2	-1	5	-10	-3	-21	-22	-19	-22	-23	-24

TABLE B-1

Settlement Readings From Rise Rd.

	12/10/96	2/4/97
A	0	0
B	-5	-5
C	-4	-3
D	-3	-4
E	-2	-7
F	-5	5
G	3	-1
H	-3	-13
I	-31	-33
J	-31	-32
K	-33	-33
L	-27	-27
M	-16	-18
N	4	4
O	18	10
P	16	17
Q	9	8
R	3	3
S	-8	0
T	6	5
U	-18	-21
V	-26	-31
W	-34	-38
X	-37	-43
Y	-34	-39
Z	-30	-34
AA	-23	-21
BM2	-363	-365
AB	-14	-12
AC	-15	-12
AD	-6	-3
AE	-14	-12
AF	-15	-3
AG	-20	-20
AH	-17	-17
AI	-25	-25

RISE CHART 1



RISE CHART 2

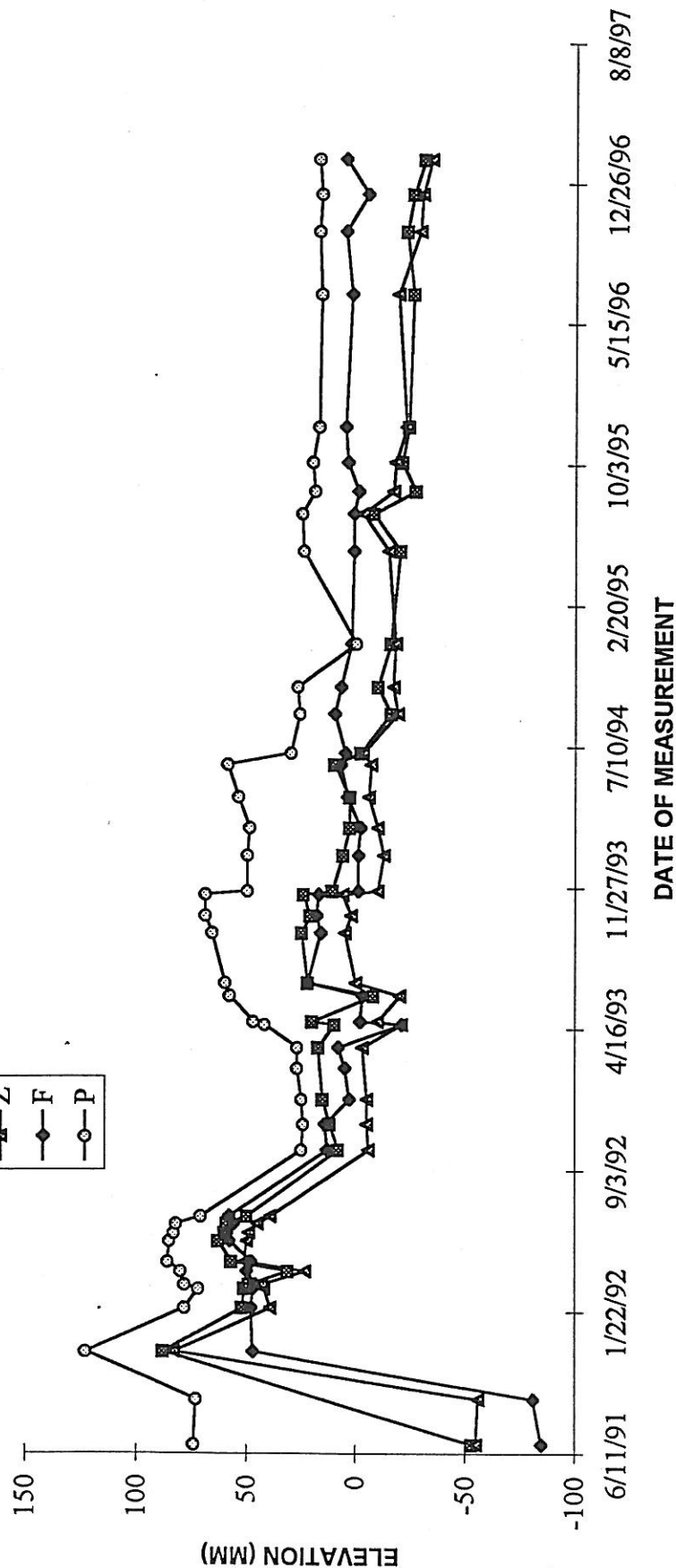
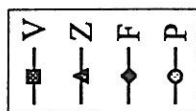


FIGURE B-3

RISE CHART 3

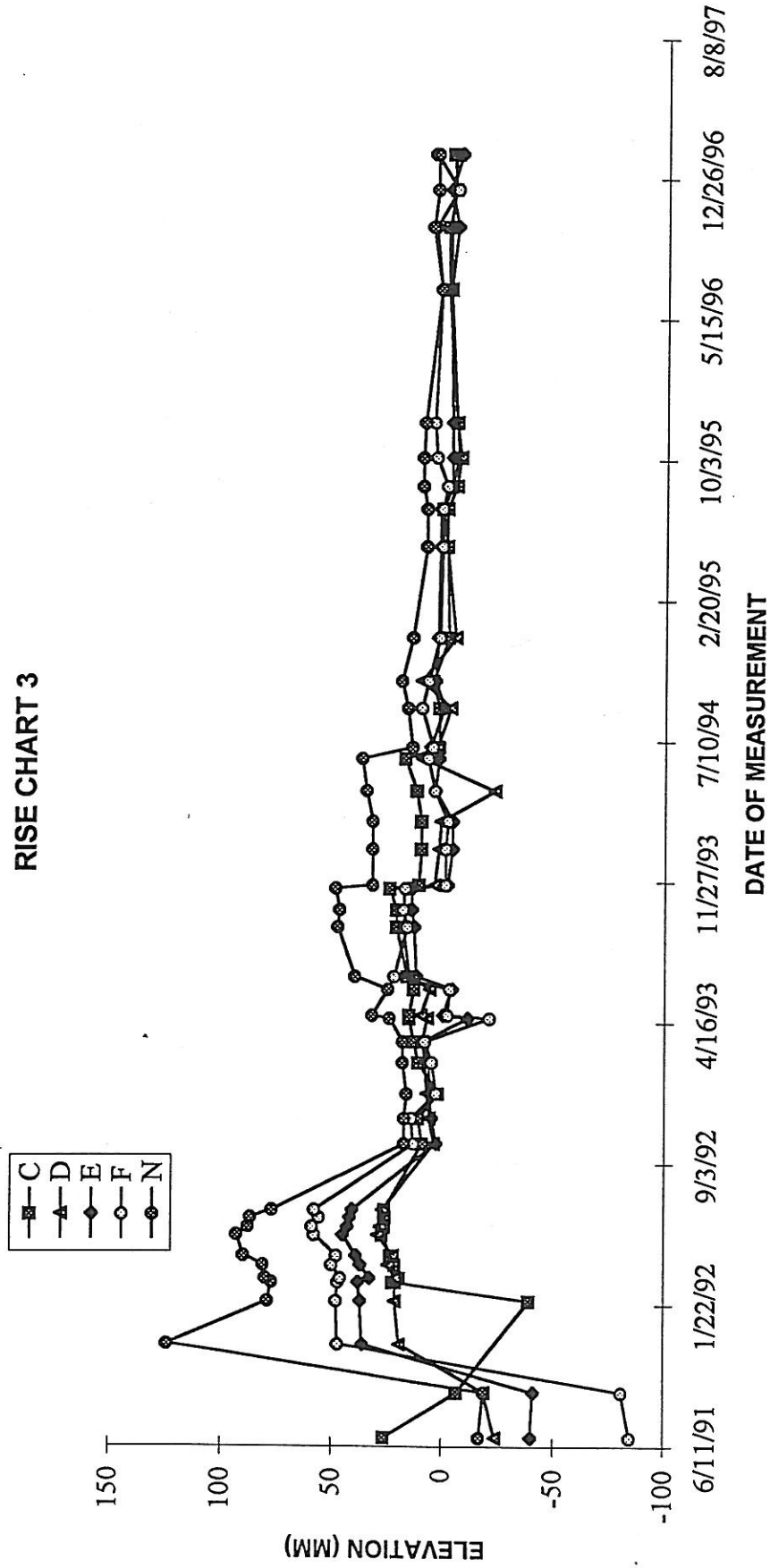


FIGURE B-4

RISE CHART 4

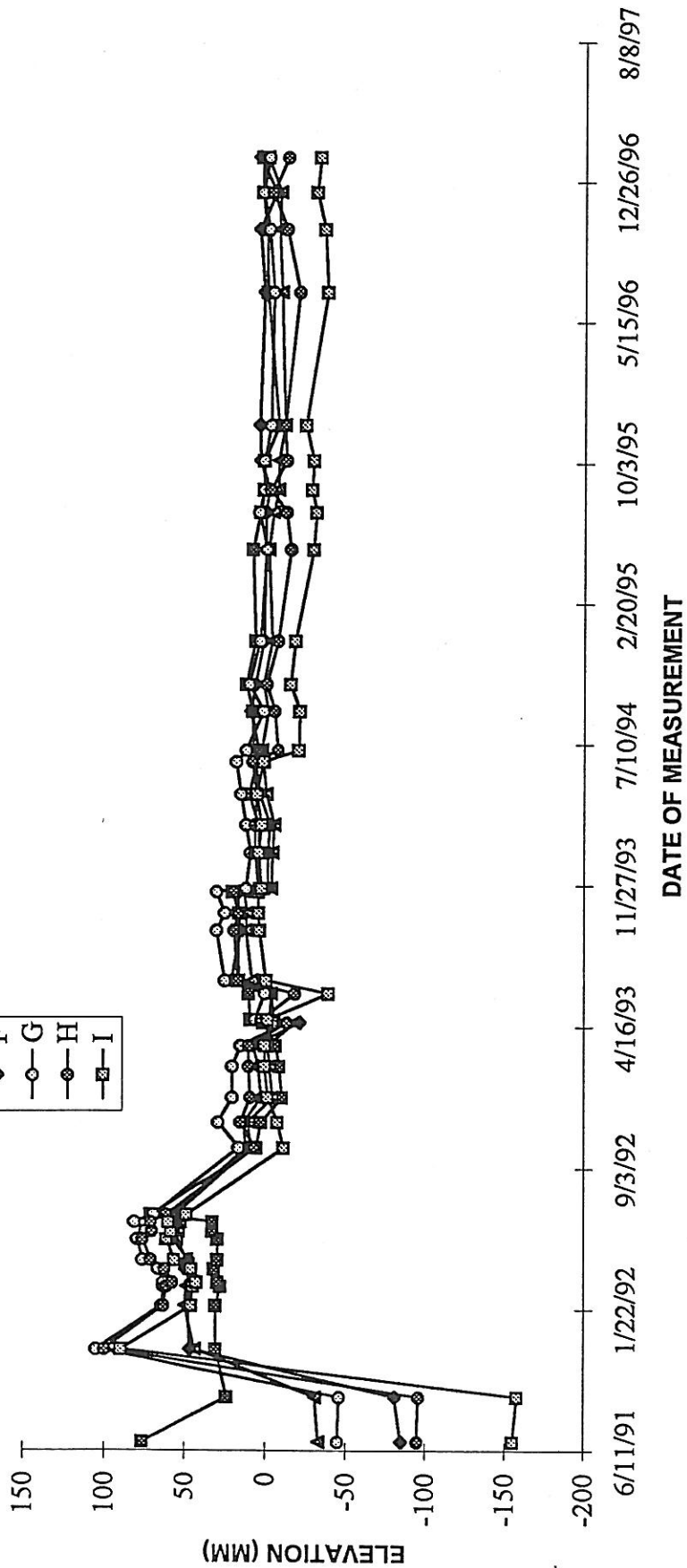
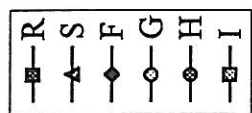


FIGURE B-5

RISE CHART 5

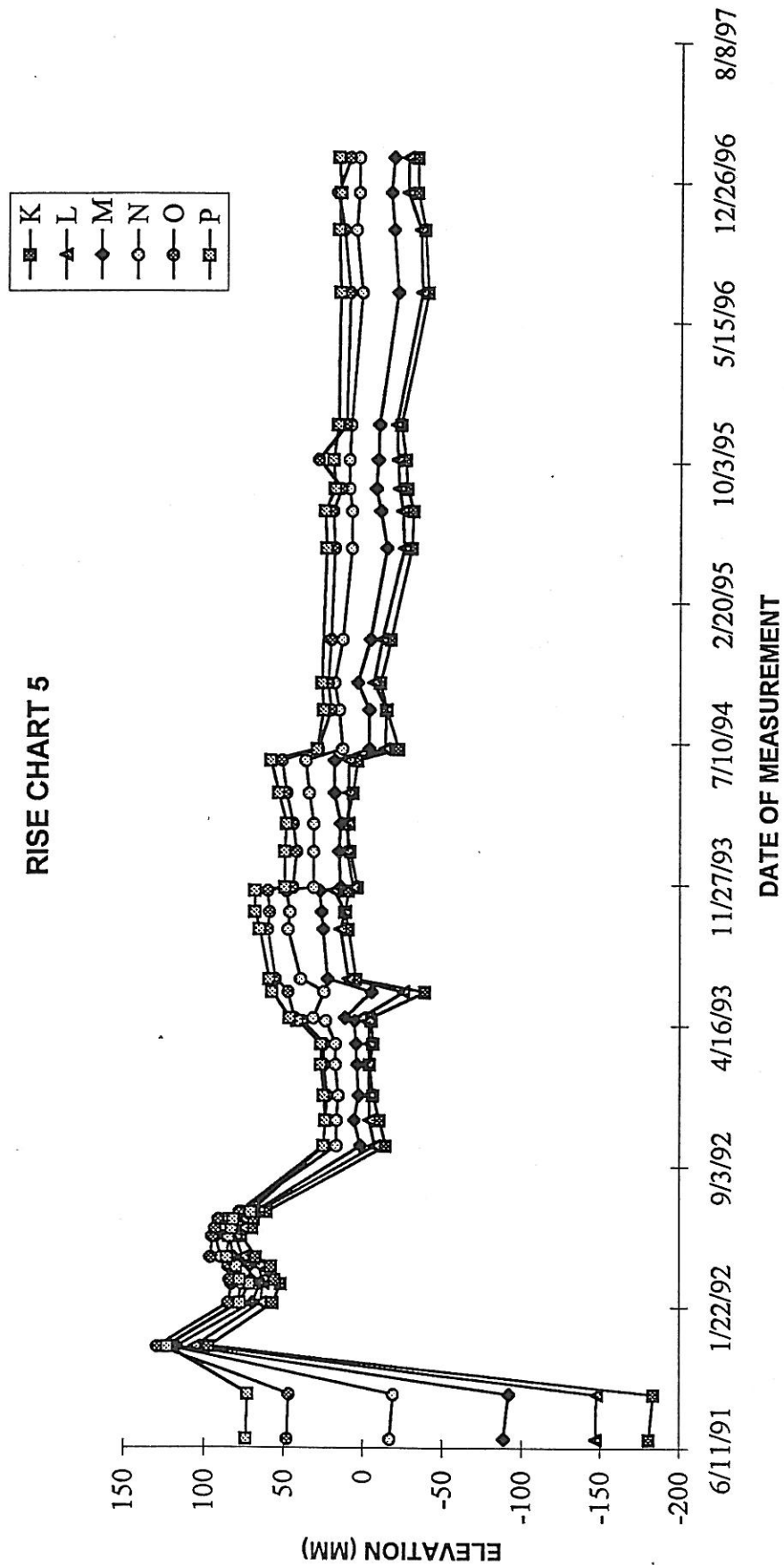


FIGURE B-6

RISE CHART 6

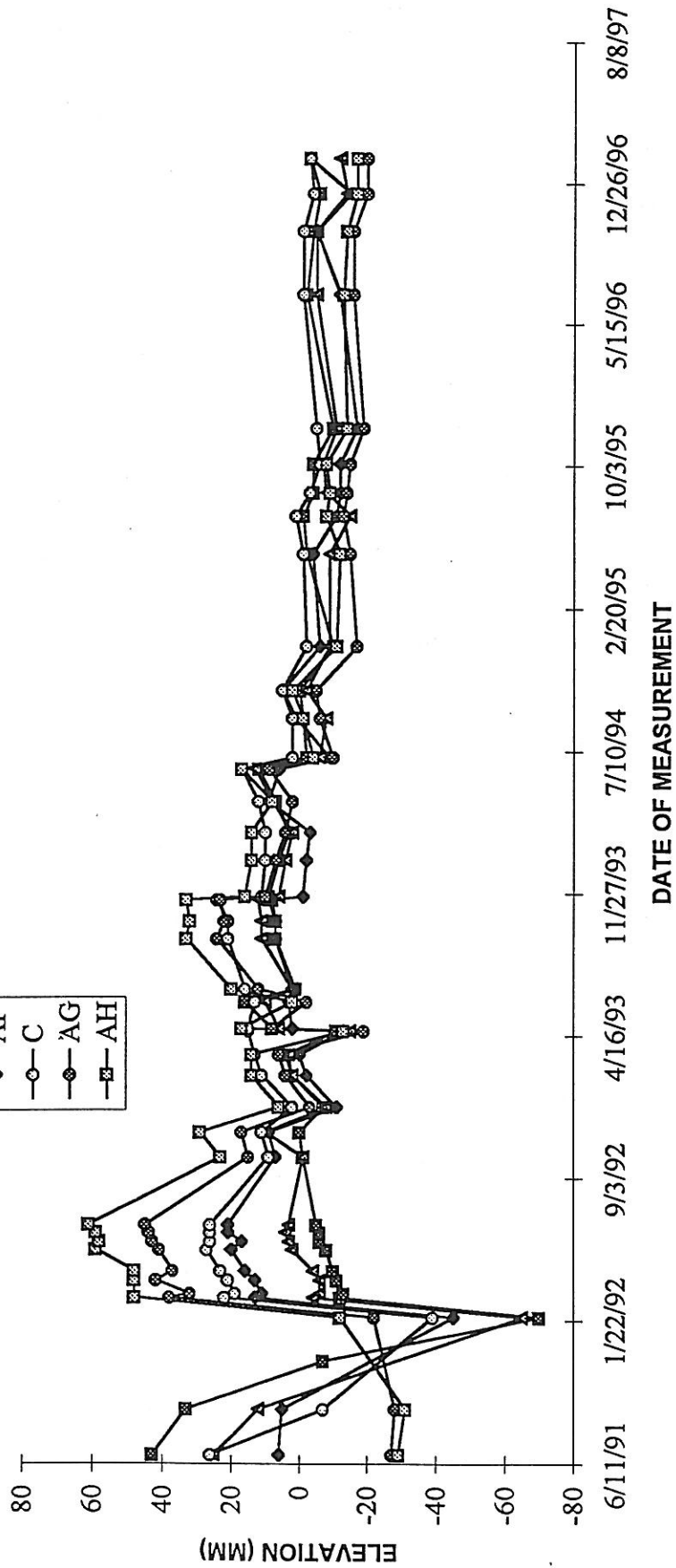
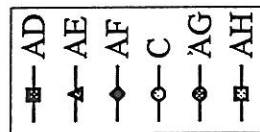


FIGURE B-7

RISE BENCHMARK

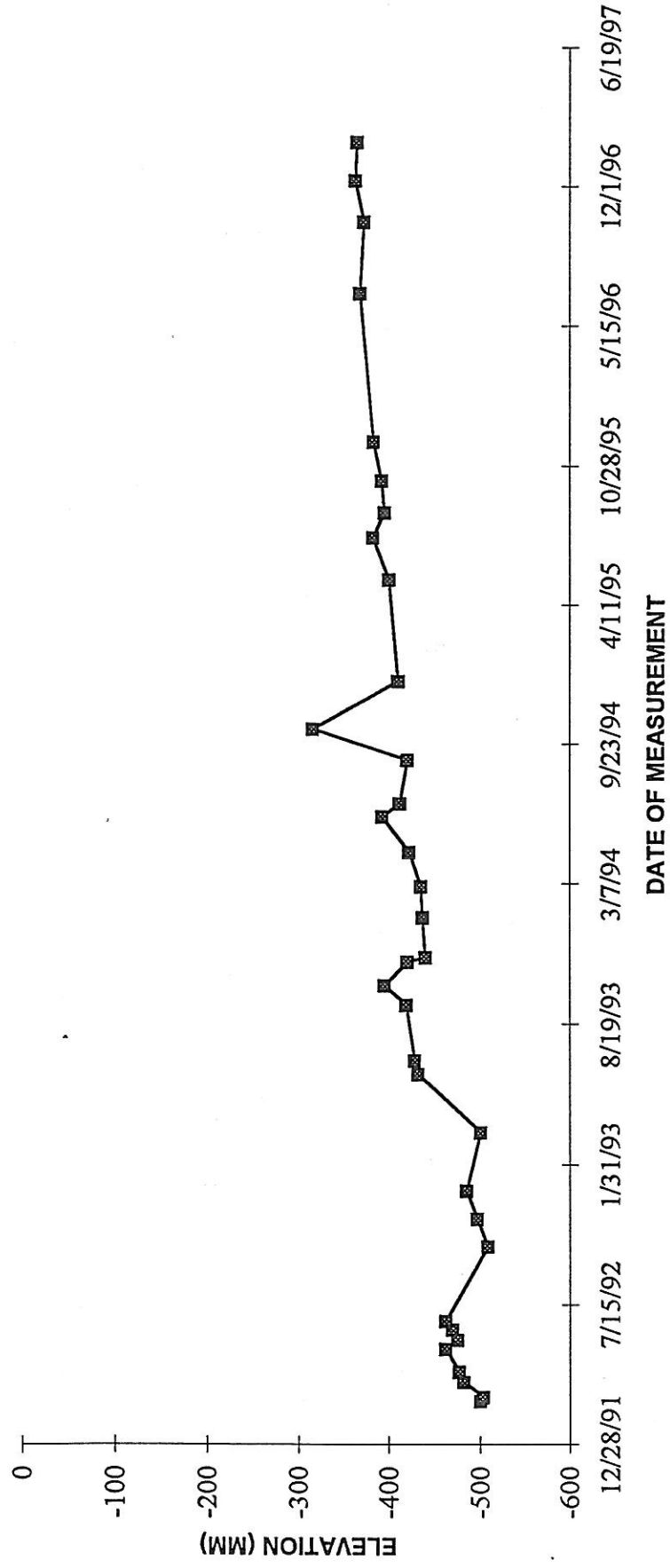


FIGURE B-8

Appendix C

Temperature Measurements

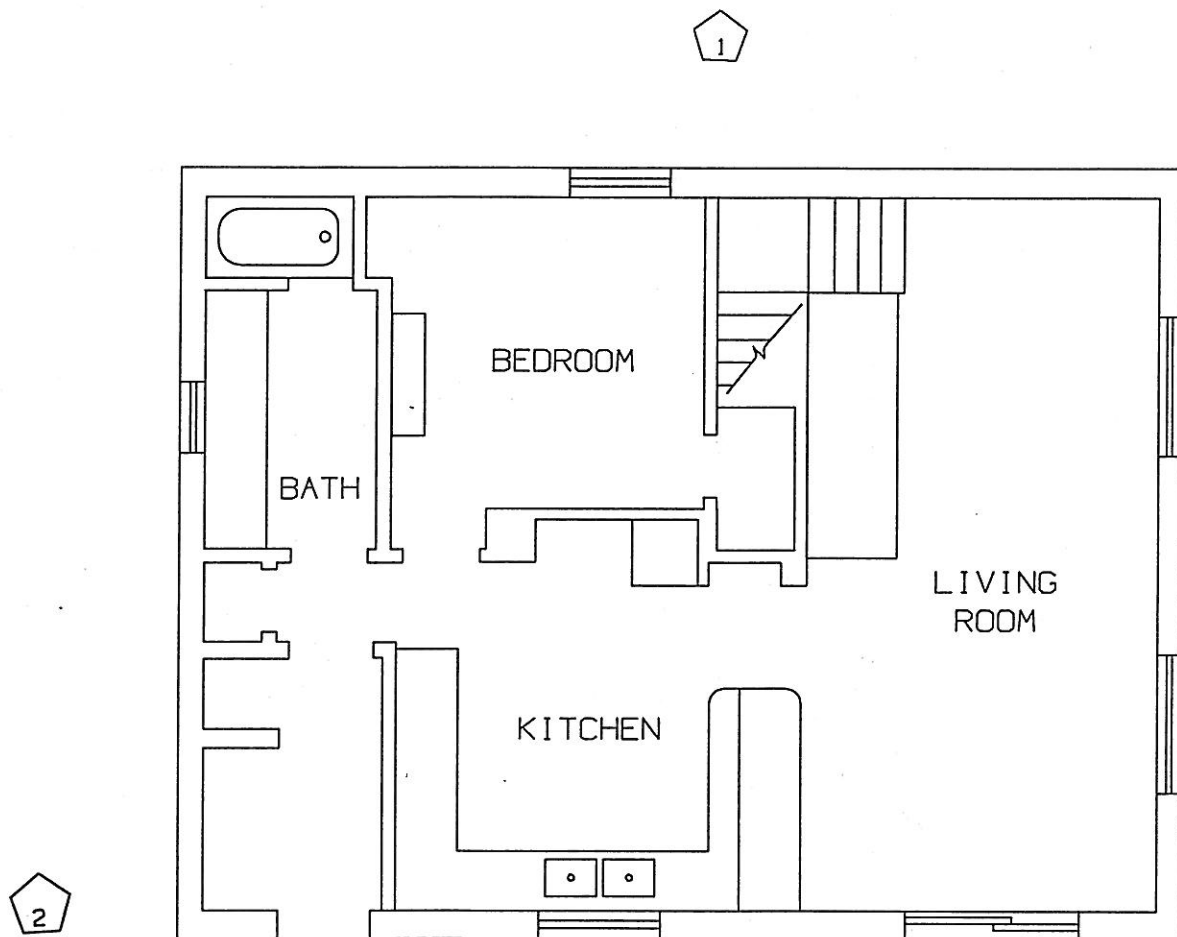


FIGURE C-1 – FLOOR PLAN OF HOUSE ON RISE RD.
SHOWING LOCATIONS OF THERMISTOR STRINGS

Thermistor Readings From Rise Rd.

String 1
Depth

2/7/92	2/21/92	3/4/92	3/11/92	3/20/92	3/26/92	4/2/92	4/10/92	4/14/92	4/23/92	4/30/92	5/7/92
0	-5.734	-5.463	-4.148	-2.473	-1.813	-1.81	-3.101	-1.767	-0.143	-0.03	-0.25
-5	0.152	0.084	0.05	0.016	0	-0.013	-1.62	-0.036	-0.03	0.097	-0.042
-10	0.487	0.358	0.293	0.221	0.176	0.132	-0.333	0.054	0.03	-0.119	-0.03
-15	0.707	0.585	0.522	0.448	0.402	0.353	0.109	0.266	0.23	-0.155	0.151
-19	0.255	0.198	0.168	0.133	0.011	0.087	-0.048	-0.185	0.036	-0.066	-0.018
-20	0.081	0.052	0.036	0.018	0.005	-0.007	-0.161	-0.042	-0.042	-0.095	-0.09
-21	-0.04	-0.048	-0.051	-0.056	-0.06	-0.062	-0.173	-0.078	-0.072	-0.125	-0.09
-21.5	-0.084	-0.089	-0.09	-0.092	-0.095	-0.098	-0.191	-0.113	-0.101	-0.143	-0.113
-22	-0.11	-0.115	-0.117	-0.119	-0.122	-0.125	-0.161	-0.137	-0.137	-0.214	-0.143
-23	-0.109	-0.113	-0.116	-0.121	-0.123	-0.125		-0.137	-0.131	-0.315	-0.155
-25	-0.266		-0.274	-0.276	-0.278	-0.281	-0.45	-0.291	-0.297	-0.315	-0.315
-33	-0.305		-0.308	-0.309	-0.309	-0.309	-0.391	-0.315	-0.315		-0.315

String 2
Depth

2/7/92	2/21/92	3/4/92	3/11/92	3/20/92	3/26/92	4/2/92	4/10/92	4/14/92	4/23/92	4/30/92	5/7/92
-10.308	-3.627	-3.596	-1.258	-1.948	-0.126	-4.039	-0.072	-0.232	14.374	-0.09	9.195
-5	-0.026	-0.214	-3.79	-2.243	-0.337	-1.357	-1.843	-1.356	-0.09	-0.297	-0.066
-10	0.57	0.435	-0.314	-0.348	0.191	-0.316	0.297	-0.327	-0.321	-0.042	-0.279
-20	-0.027	-0.03	0.285	0.226	-0.038	0.153	0.084	0.09	0.054	-0.048	0.024
-25	-0.154	-0.155	-0.035	-0.037	-0.157	-0.04	0.054	-0.048	-0.054	-0.161	-0.066
-26	-0.174	-0.175	-0.155	-0.156	-0.178	-0.157	-0.012	-0.161	-0.161	-0.185	-0.203
-27	-0.184	-0.183	-0.175	-0.176	-0.185	-0.178	-0.072	-0.185	-0.185	-0.197	-0.185
-27.5	-0.16	-0.16	-0.184	-0.184	-0.185	-0.184	-0.107	-0.191	-0.185	-0.173	-0.191
-28	-0.186	-0.187	-0.161	-0.161	-0.161	-0.162	-0.403	-0.167	-0.167	-0.262	-0.179
-29	-0.343	-0.344	-0.19	-0.191	-0.191	-0.192	-0.137	-0.197	-0.197	-0.356	-0.197
-35	-0.384	-0.385	-0.347	-0.348	-0.348	-0.349	-0.297	-0.35	-0.356	-0.403	-0.356
-45			-0.388	-0.389	-0.389	-0.39	-0.315	-0.391	-0.391		-0.391

Thermistor Readings From Rise Rd.

String 1 Continued

Depth	5/14/92	5/22/92	5/28/92	6/10/92	6/19/92	6/26/92	7/1/92	7/9/92	7/17/92	7/23/92	8/6/92	8/21/92
0	-0.179	-185	20.95	4.704	7.31	8.2	10.806	11.634	11.691	11.794	12.899	17.593
-5	-0.036	-0.042	0.145	-0.03	-0.024	-0.018	-0.036	-0.327	-0.054	-0.042	2.749	9.457
-10	-0.036	-0.06	-0.244	-0.101	-0.113	-0.101	-0.125	-0.125	-0.113	-0.066	0.066	6.045
-15	0.151	0.127	-0.042	0.078	0.054	0.048	0.03	0.018	-0.006	0.006	0.03	0.06
-19	-0.018	-0.03	-0.06	-0.054	-0.078	-0.066	-0.09	-0.101	-0.113	-0.113	-0.107	-0.06
-20	-0.06	-0.072	-0.167	-0.107	-0.095	-0.084	-0.101	-0.113	-0.131	-0.119	-0.125	-0.161
-21	-0.078	-0.084	-0.197	-0.095	-0.09	-0.078	-0.095	-0.101	-0.125	-0.116	-0.113	-0.185
-21.5	-0.113	-0.107	-0.191	-0.113	-0.125	-0.107	-0.125	-0.131	-0.149	-0.143	-0.137	-0.185
-22	-0.137	-0.137	-0.167	-0.143	-0.155	-0.137	-0.155	-0.161	-0.173	-0.173	-0.161	-0.173
-23	-0.137	-0.137	-0.197	-0.137	-0.149	-0.137	-0.149	-0.0161	-0.173	-0.167	-0.161	-0.203
-25	-0.291	-0.291	-0.35	-0.303	-0.303	-0.279	-0.303	-0.309	-0.321	-0.315	-0.303	-0.362
-33	-0.303	-0.303	-0.397	-0.315	-0.315	-0.291	-0.315	-0.315	-0.327	-0.327	-0.315	-0.397

String 2 Continued

Depth	5/14/92	5/22/92	5/28/92	6/10/92	6/19/92	6/26/92	7/1/92	7/9/92	7/17/92	7/23/92	8/6/92	8/21/92
0	10.993	9.376	0	22.739	16.365	27.678	22.965	30.341	31.218	20.728	31.249	10.427
-5	-0.078	-0.072	-0.03	3.046	5.012	5.777	7.301	8.171	8.966	9.467	10.481	4.634
-10	-0.256	-0.244	-0.072	-0.226	-0.226	-0.185	-0.203	0.23	1.353	2.798	5.028	0.679
-20	-0.006	-0.018	0.097	-0.072	-0.072	-0.054	-0.101	-0.095	-0.119	-0.113	-0.078	0.097
-25	-0.054	-0.054	-0.042	-0.054	-0.066	-0.036	-0.066	-0.054	-0.078	-0.066	-0.06	-0.09
-26	-0.161	-0.167	-0.078	-0.155	-0.173	-0.131	-0.173	-0.161	-0.185	-0.173	-0.167	-0.113
-27	-0.185	-0.185	-0.078	-0.185	-0.185	-0.161	-0.191	-0.185	-0.203	-0.197	-0.179	-0.113
-27.5	-0.191	-0.191	-0.119	-0.197	-0.191	-0.167	-0.197	-0.179	-0.208	-0.197	-0.185	-0.137
-28	-0.173	-0.161	-0.137	-0.161	-0.179	-0.143	-0.173	-0.161	-0.185	-0.173	-0.167	-0.167
-29	-0.203	-0.197	-0.137	-0.197	-0.203	-0.179	-0.208	-0.197	-0.22	-0.208	-0.203	-0.149
-35	-0.356	-0.35	-0.303	-0.344	-0.362	-0.327	-0.362	-0.356	-0.374	-0.368	-0.356	-0.309
-45	-0.397	-0.391	-0.309	-0.391	-0.397	-0.38	-0.409	-0.397	-0.415	-0.409	-0.391	-0.309

Thermistor Readings From Rise Rd.

String 1 Continued

Depth	10/9/92	10/28/92	11/17/92	12/8/92	2/7/93	2/28/93	3/12/93	3/28/93	4/4/93	6/8/93	6/24/93	11/22/93
0	0.266	0.03	-0.125	-155	-1.466	-1.239	-1.127	-1.036	-0.923	6.368	9.386	-1.993
-5	2.547	1.667	0.88	0.704	0.121	0.066	0.042	0.006	0.048	-0.018	0.254	1.34
-10	1.92	1.536	1.224	0.905	0.242	0.139	0.109	0.006	-0.024	-0.125	-0.101	2.347
-15	0.779	0.893	0.798	0.761	0.364	0.285	0.248	0.181	0.097	0.012	-0.006	0.536
-19	0.09	0.151	0.109	0.181	0.048	0.024	0.012	-0.03	-0.036	-0.113	-0.119	-0.107
-20	-0.03	0.03	-0.06	0.018	-0.054	-0.054	-0.06	-0.09	-0.084	-0.155	-0.137	-0.203
-21	-0.095	-0.09	-0.131	-0.095	-0.113	-0.107	-0.131	-0.125	-0.125	-0.131	-0.137	-0.226
-21.5	-0.131	-0.208	-0.149	-0.143	-0.131	-0.149	-0.113	-0.149	-0.143	-0.149	-0.161	-0.214
-22	-0.155	-0.208	-0.203	-0.167	-0.185	-0.214	-0.179	-0.185	-0.179	-0.185	-0.119	-0.179
-23	-0.155	-0.208	-0.167	-0.149	-0.197	-0.161	-0.179	-0.173	-0.191	-0.173	-0.238	-0.303
-25	-0.291	-0.327	-0.327	-0.291	-0.315	-0.303	-0.303	-0.315	-0.303	-0.315	-0.315	-0.356
-33	-0.333	-0.327	-0.35	-0.309	-0.327	-0.315	-0.303	-0.321	-0.333	-0.327	-0.333	-0.391

String 2 Continued

Depth	10/9/92	10/28/92	11/17/92	12/8/92	2/7/93	2/28/93	3/12/93	3/28/93	4/4/93	6/8/93	6/24/93	11/22/93
0	1.019	-2.741	-9.412	-6.43	-8.359	-4.548	-4.363	-3.683	-0.161	16.146	17.829	-0.185
-5	1.49	0.395	-0.549	-0.923	-2.421	-1.988	-1.745	-1.472	-0.946	5.636	6.592	1.987
-10	3.089	1.8	0.842	0.419	-2.426	-0.155	-0.078	-0.238	-0.244	-0.197	-0.137	2.203
-20	0.867	0.893	0.867	0.729	0.242	0.139	0.036	0.03	0.018	-0.107	-0.125	1.529
-25	-0.036	-0.09	-0.048	-0.024	-0.06	-0.054	-0.012	-0.066	-0.048	-0.078	-0.084	0.487
-26	-0.173	-0.208	-0.191	-0.173	-0.197	-0.173	-0.849	-0.185	-0.203	-0.185	-0.197	0.181
-27	-0.179	-0.208	-0.214	-0.179	-0.208	-0.22	-0.185	-0.197	-0.191	-0.208	-0.208	-0.072
-27.5	-0.167	-0.09	-0.191	-0.185	-0.197	-0.191	-0.262	-0.279	-0.197	-0.197	-0.203	-0.131
-28	-0.149	-0.208	-0.167	-0.161	-0.179	-0.173	-0.191	-0.185	-0.179	-0.185	-0.185	-0.137
-29	-0.161	-0.208	-0.214	-0.191	-0.22	-0.208	-0.208	-0.232	-0.203	-0.22	-0.226	-0.137
-35	-0.321	-0.327	-0.356	-0.35	-0.368	-0.362	-0.338	-0.368	-0.368	-0.374	-0.285	-0.291
-45	-0.415	-0.444	-0.391	-0.385	-0.409	-0.397	-0.368	-0.409	-0.385	-0.409	-0.327	-0.344

Thermistor Readings From Rise Rd.

String 1 Continued
Depth

	1/19/94	5/18/94	6/10/94	10/11/94	11/8/94	3/18/95	5/18/95	7/17/95	10/2/96	10/25/96	11/15/96	12/5/96
0	-86	3.998	11.015	0.199	1.464	-0.977	0.016	3.685	0.623	-0.033	-0.141	-0.363
-5	0.592	0	-0.018	3.334	1.833	0.092	-0.017	0.559	-0.151	0.293	0.24	0.148
-10	0.792	0	-0.066	3.268	-11.384	0.007	0.151	0.135	-0.043	0.041	0.05	0.022
-15	0.88	0.175	0.103	0.072	-0.244	-0.146	-0.025	-0.075	-0.137	0.011	0.062	0.092
-19	0.09	-0.024	-0.054	-3.473	-0.385	-0.23	-0.073	-0.119	-0.144	-0.117	-0.099	-0.063
-20	-0.137	-0.095	-0.179	-7.738	-0.274	-0.236	-0.942	-0.36	-0.119	-0.129	-0.117	-0.098
-21	-0.078		-0.125	-0.514	-0.473	-0.235	-0.15	-0.142	-0.136	-0.111	-0.111	-0.105
-21.5	-0.149	-0.137	-0.25	-0.297	-0.462	-0.208	-0.174		-0.162	-0.136	-0.137	-0.135
-22	-0.161	-0.161	-0.279	-0.462	-6.631	-0.24	-0.172		-0.155	-0.151	-0.15	-0.165
-23	-0.333	-0.149	-0.149	-0.256	-3.261			-0.371	-0.307	-0.29	-0.289	-0.15
-25	-0.502	-0.356	-0.297	-3.449	-0.711				-0.33	-0.328		-0.288
-33	-0.45	-0.584	-0.321	-0.409	-1.35							

String 2 Continued
Depth

	1/19/94	5/18/94	6/10/94	10/11/94	11/8/94	3/18/95	5/18/95	7/17/95	10/2/96	10/25/96	11/15/96	12/5/96
0	-6.622	6.308	9.713	1.289	2.122	0.113	-0.21	5.603	-5.756	0.145	-4.121	-5.444
-5	-0.143	-0.214	-0.048	3.715	1.906	0.263	-0.09	1.133	0.246	0.145	-0.111	-0.203
-10	0.711	-0.119	-0.131	2.756	1.224	0.42	-0.099	-0.141	-0.16	0.246	-0.002	-0.055
-20	0.315	-0.203	-0.107	1.032	-5.941	0.122	-0.15	-0.147	-0.115	-0.115	-0.142	-0.136
-25	-0.119	-0.502	-0.321	0.199	-4.274	0.009	-0.238	-0.236	-0.214	-0.214	-0.116	-0.113
-26	-0.279	-0.421	-0.22	-0.203	-0.107	-0.072	-0.242	-0.245	-0.222	-0.222	-0.279	-0.212
-27	-1.461	-0.274	-0.391	-5.598		-0.122	-0.243	-0.248	-0.22	-0.22	-0.223	-0.222
-27.5	-0.303	-0.232	-0.356	-8.509		-0.626	-0.211	-0.243	-0.194	-0.194	-0.193	-0.195
-28	-0.929	-0.197	-0.208	-0.555	-9.729	-0.171		-0.248	-0.223	-0.223	-0.223	-0.222
-29	-0.508	-0.232	-0.232	-4.506	-4.872			-0.384	-0.371	-0.371	-0.371	-0.371
-35	-0.426	-0.391	-0.374		-1.093			-0.403	-0.394	-0.394	-0.414	
-45	-0.711	-0.45	-0.526	-0.333								

TABLE C-1

Thermistor Readings From Rise Rd.

String 1 Continued	
Depth	
	1/17/97
0	-2.053
-5	0.011
-10	-0.073
-15	0.058
-19	-0.081
-20	-0.105
-21	-0.109
-21.5	-0.14
-22	-0.169
-23	-0.154
-25	-0.29
-33	-0.328
	2/4/97
	-2.62
	-0.007
	-0.099
	0.042
	-0.086
	-0.107
	-0.107
	-0.14
	-0.167
	-0.151
	-0.288
	-0.327

String 2 Continued	
Depth	
	1/17/97
0	-7.99
-5	-2.585
-10	-0.112
-20	-0.149
-25	-0.117
-26	-0.213
-27	-0.224
-27.5	-0.224
-28	-0.198
-29	-0.223
-35	-0.373
-45	-0.4
	2/4/97
	-7.308
	-2.648
	-0.129
	-0.151
	-0.112
	-0.211
	-0.22
	-0.22
	-0.194
	-0.219
	-0.368

RISE STRING #1 SURFACE TEMPERATURE

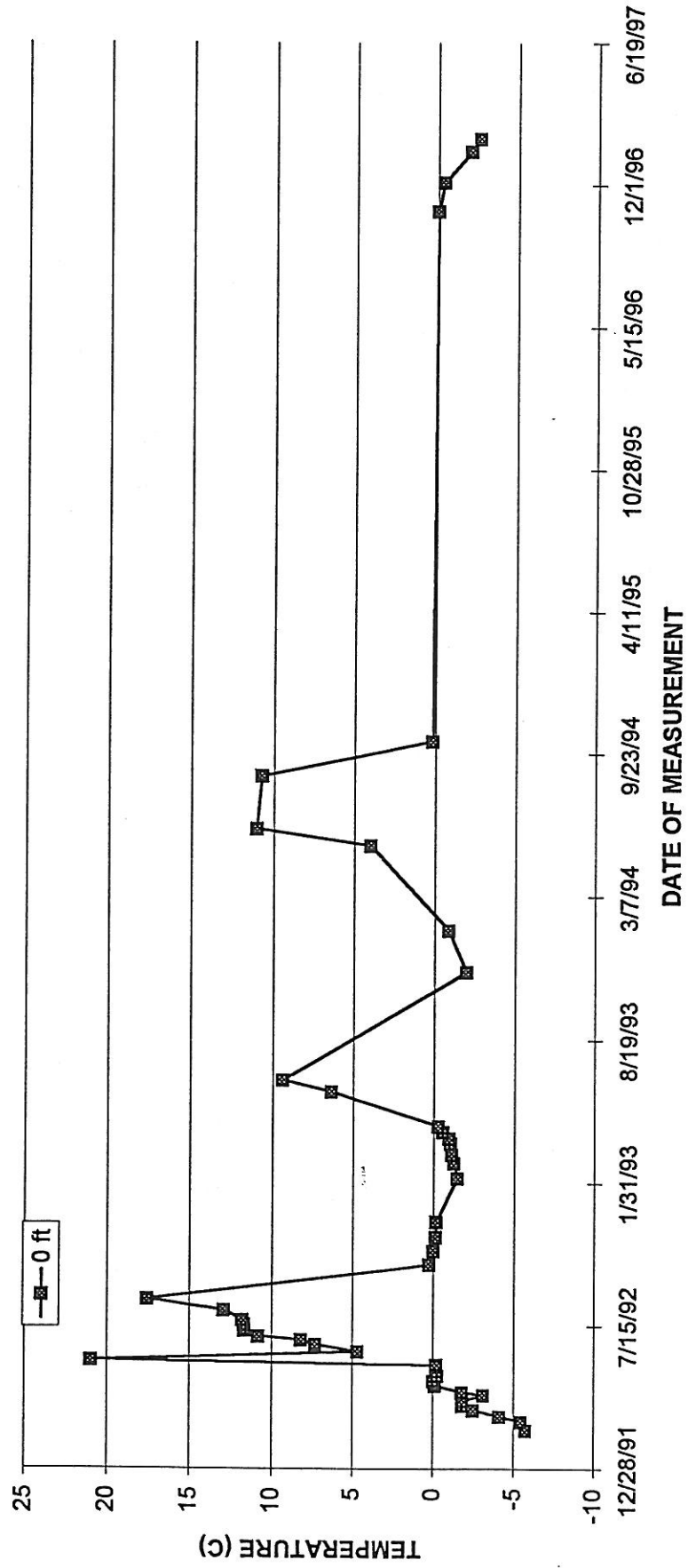


FIGURE C-2

RISE STRING #1 AT 5, 10 & 15 ft.

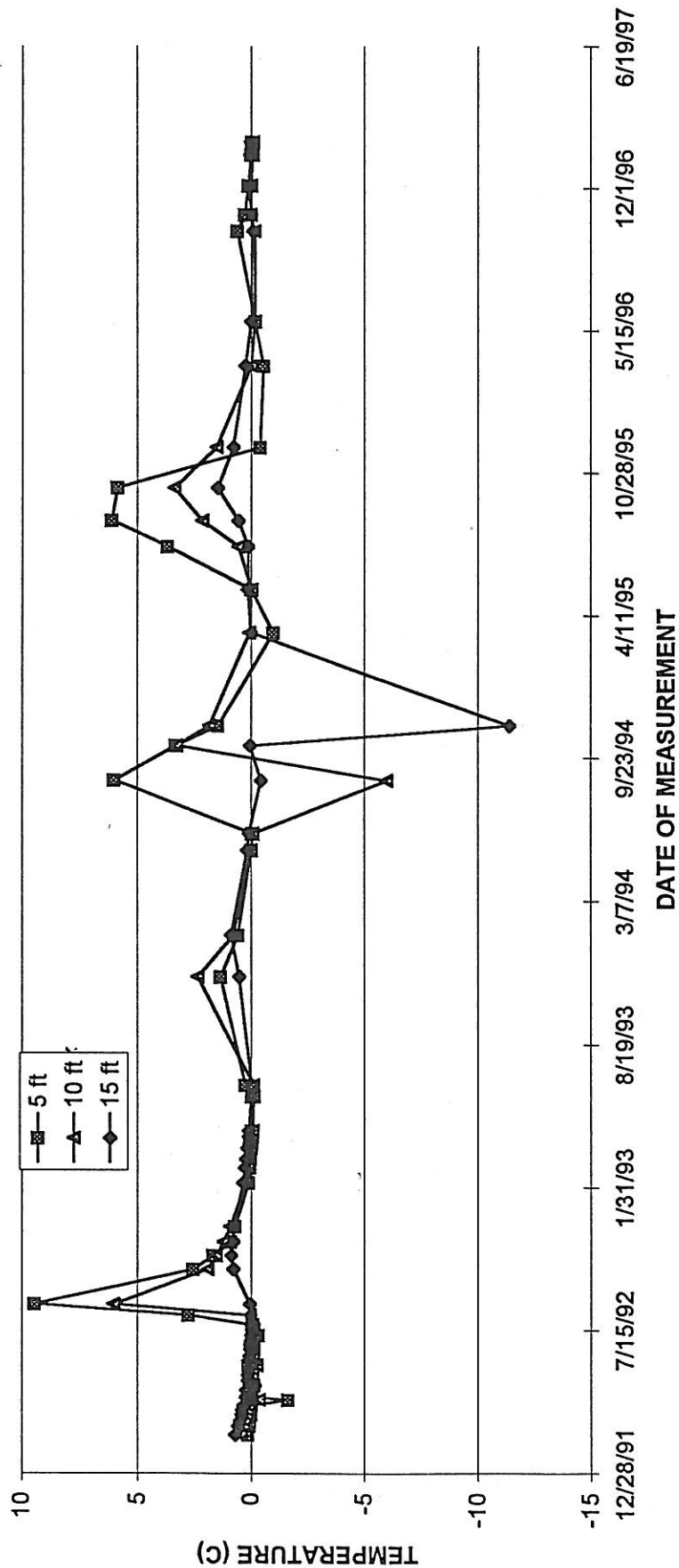


FIGURE C-3

RISE STRING #1 AT 19 & 20 ft.

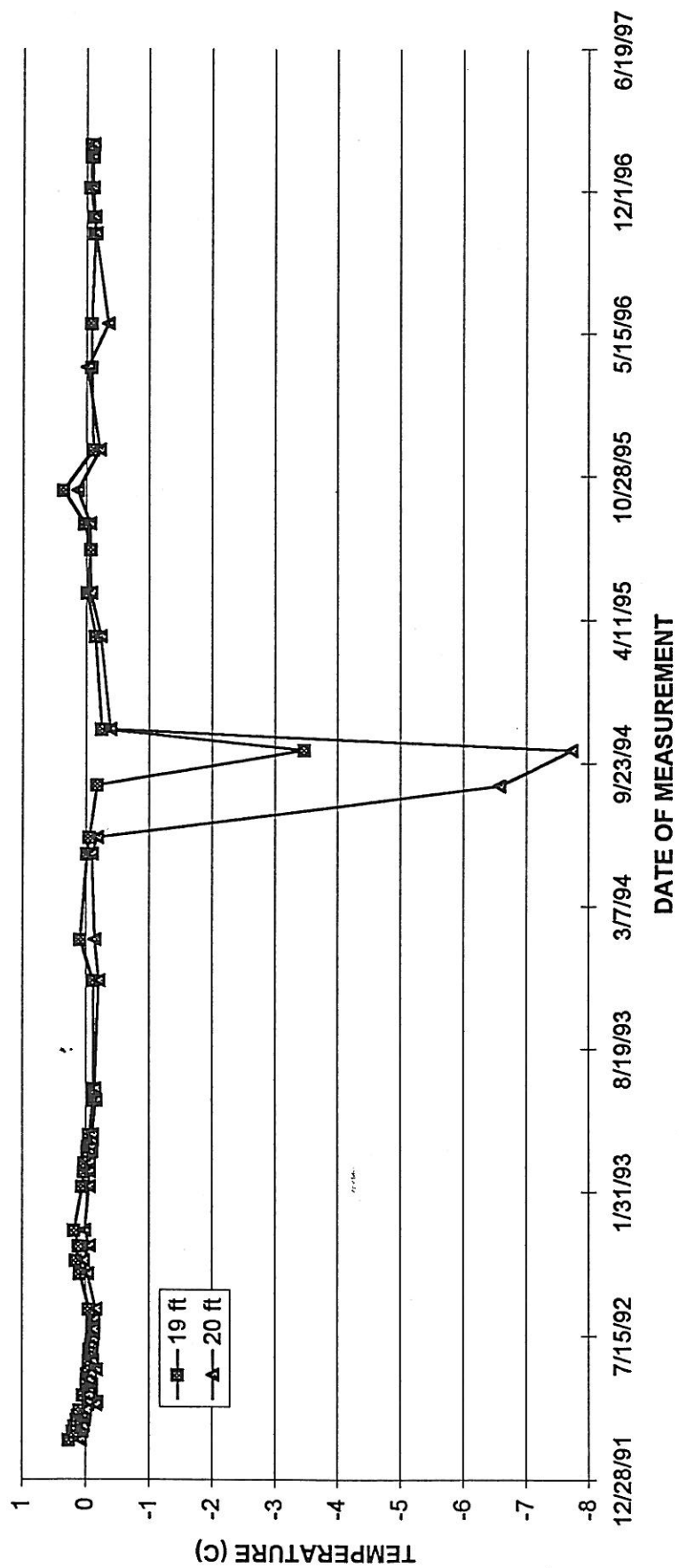


FIGURE C-4

RISE STRING #1 AT 21, 21.5, 22 & 23 ft.

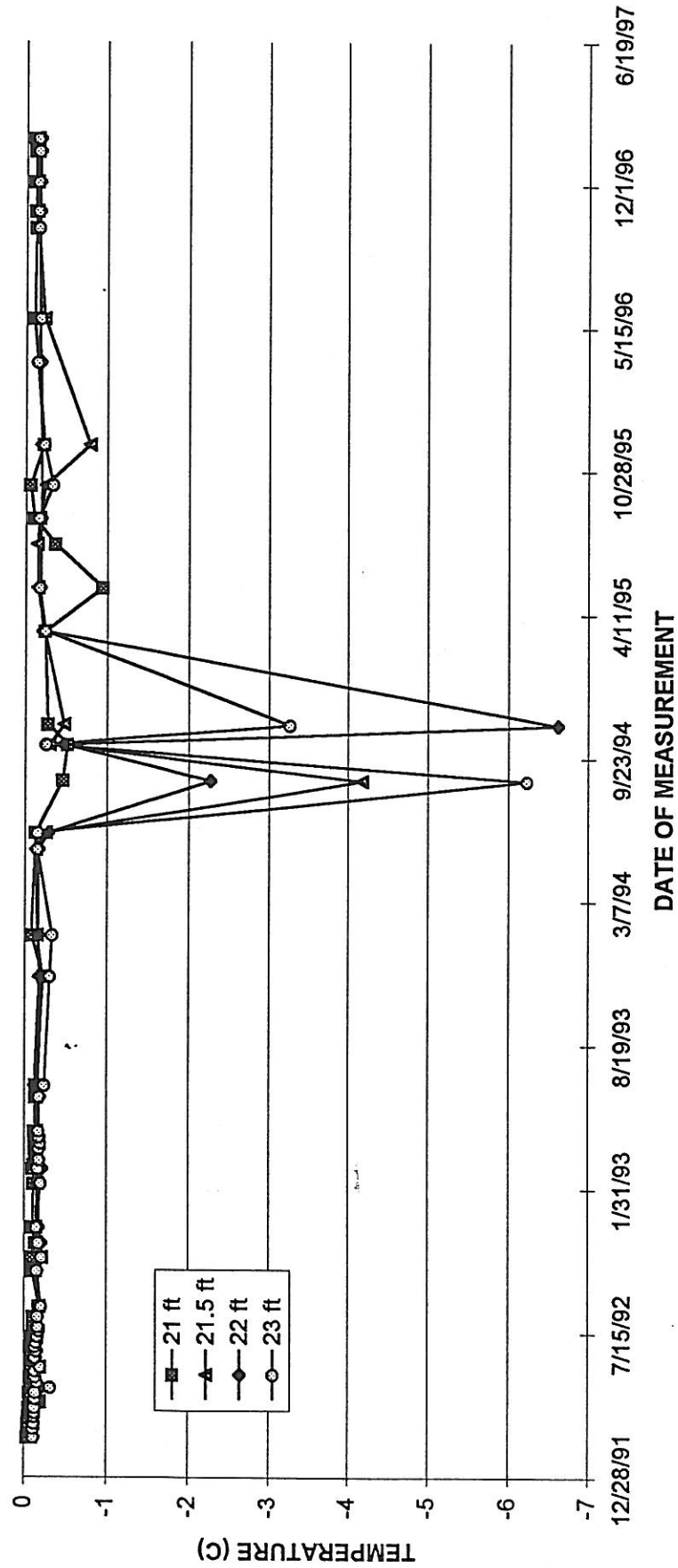


FIGURE C-5

RISE STRING #1 AT 25 & 33 ft.

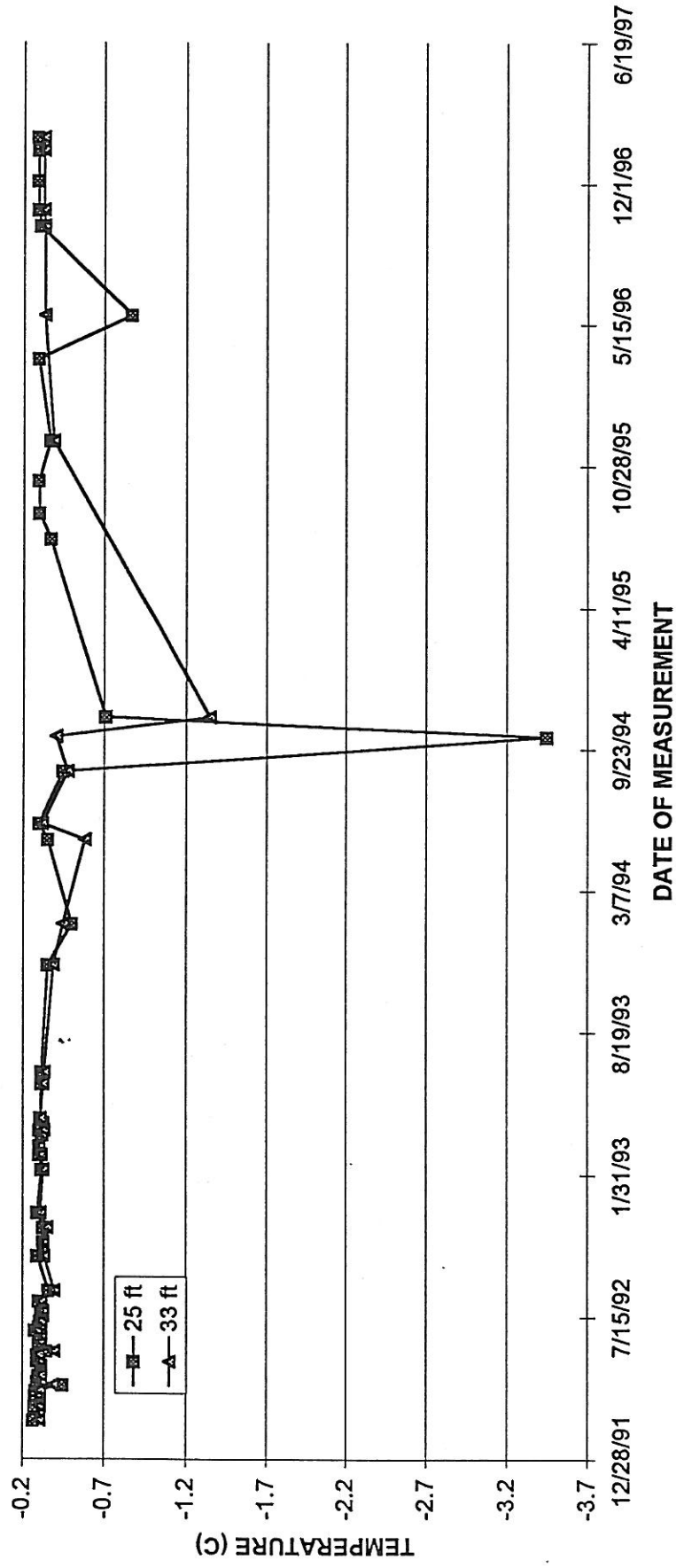


FIGURE C-6

RISE STRING #2 SURFACE TEMPERATURE

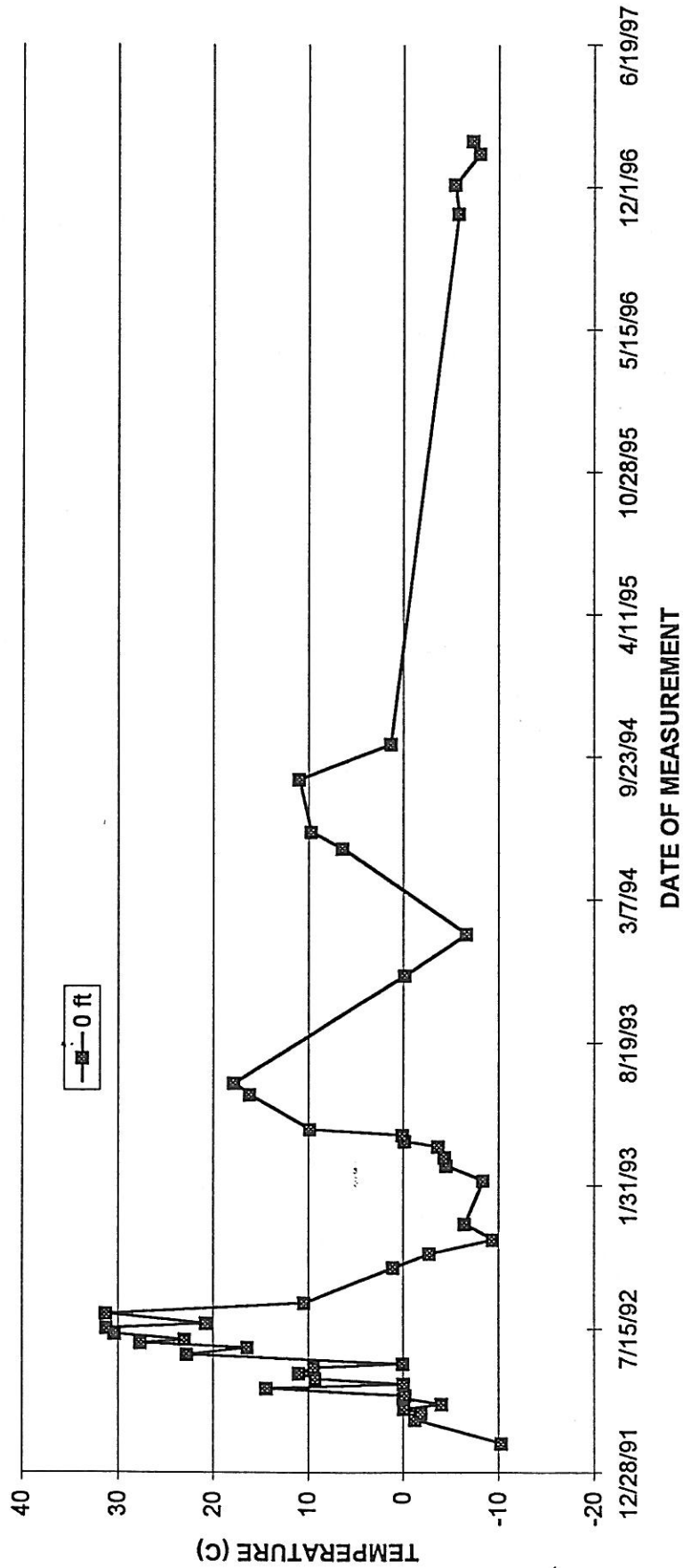


FIGURE C-7

RISE STRING #2 AT 5 ft.

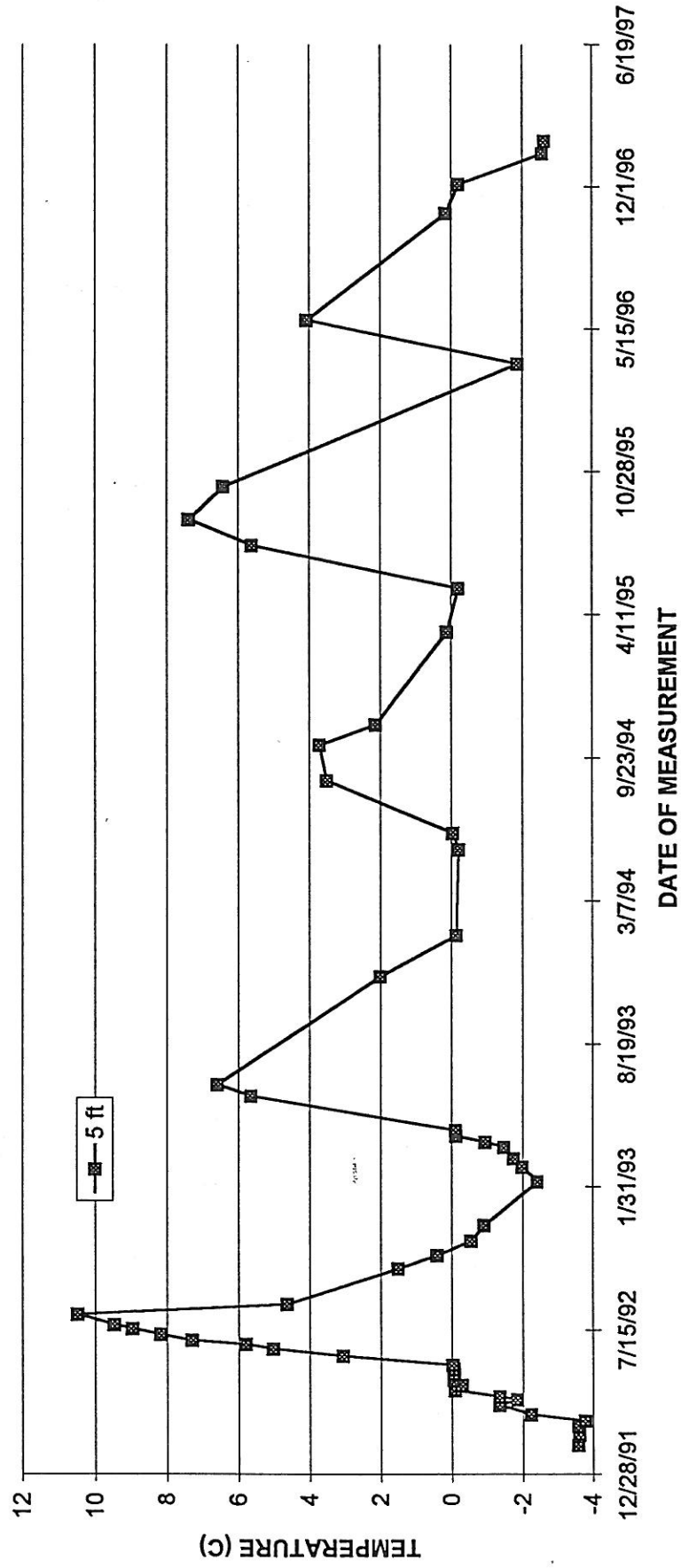


FIGURE C-8

RISE STRING #2 AT 10 ft.

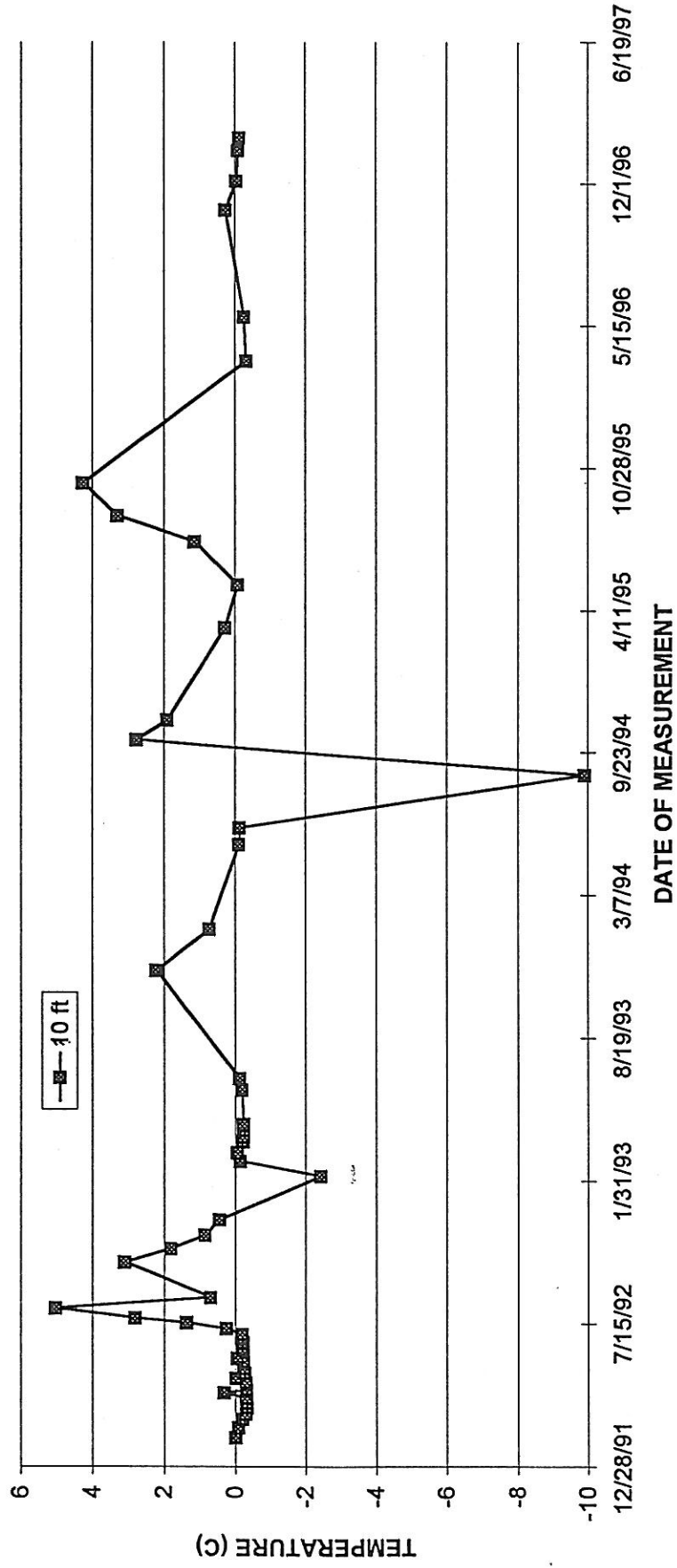


FIGURE C-9

RISE STRING #2 AT 20, 25 & 26 ft.

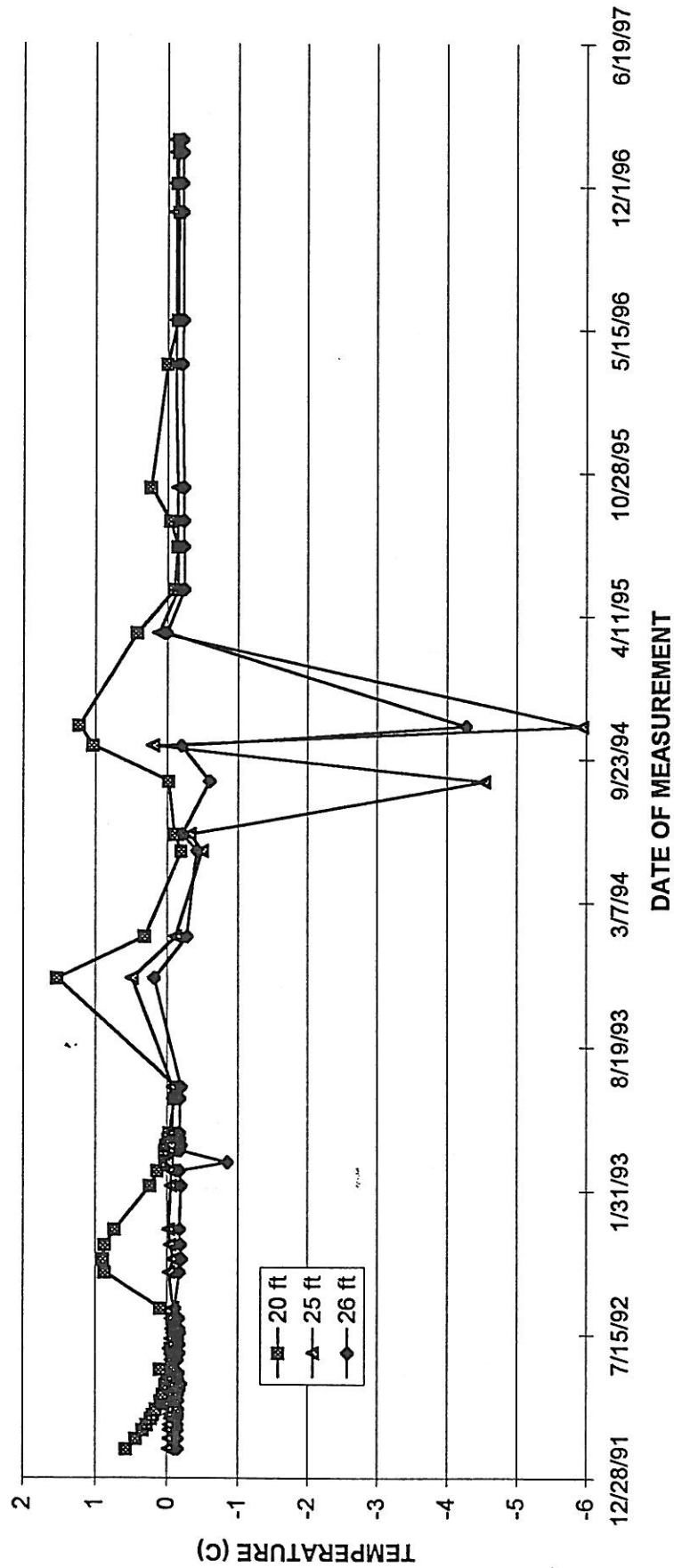


FIGURE C-10

RISE STRING #2 AT 27, 27.5, 28 & 29 ft.

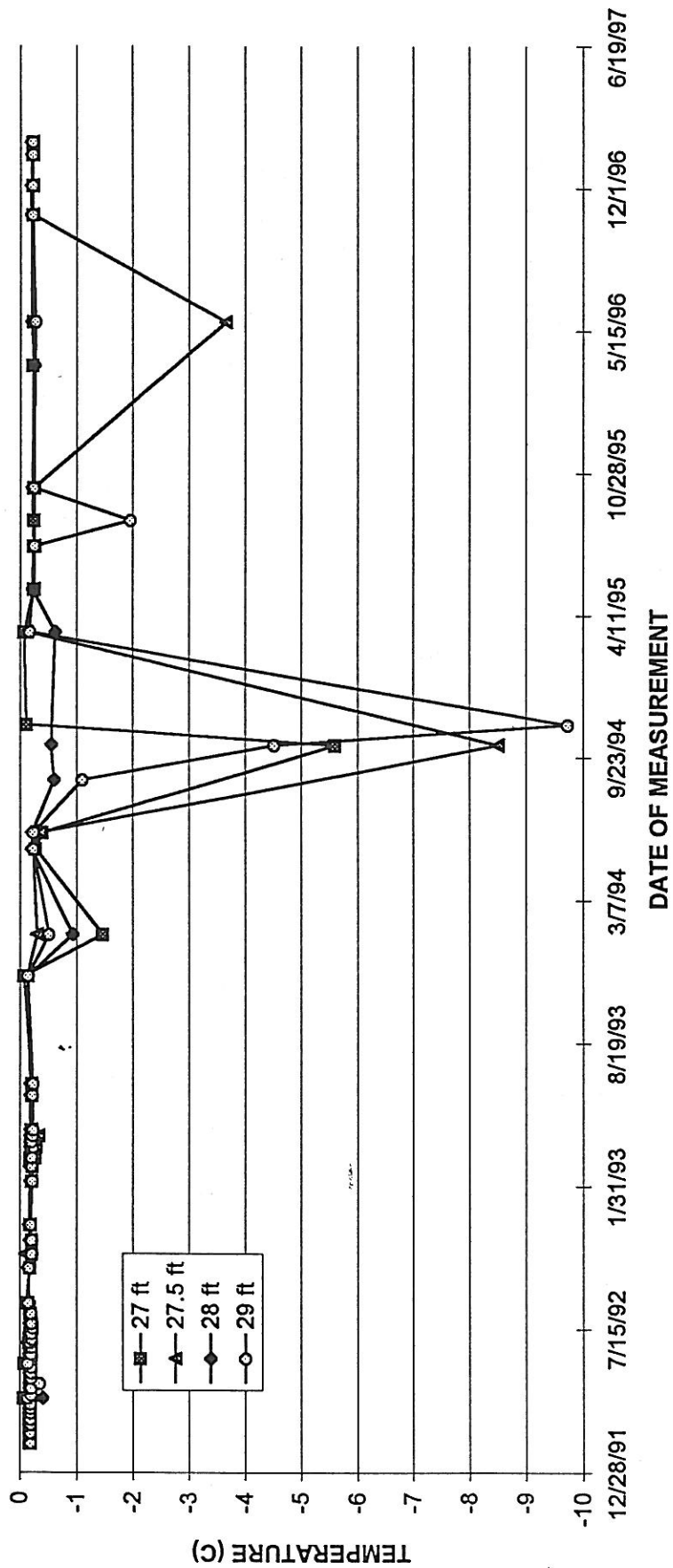


FIGURE C-11

RISE STRING #2 AT 35 & 45 ft.

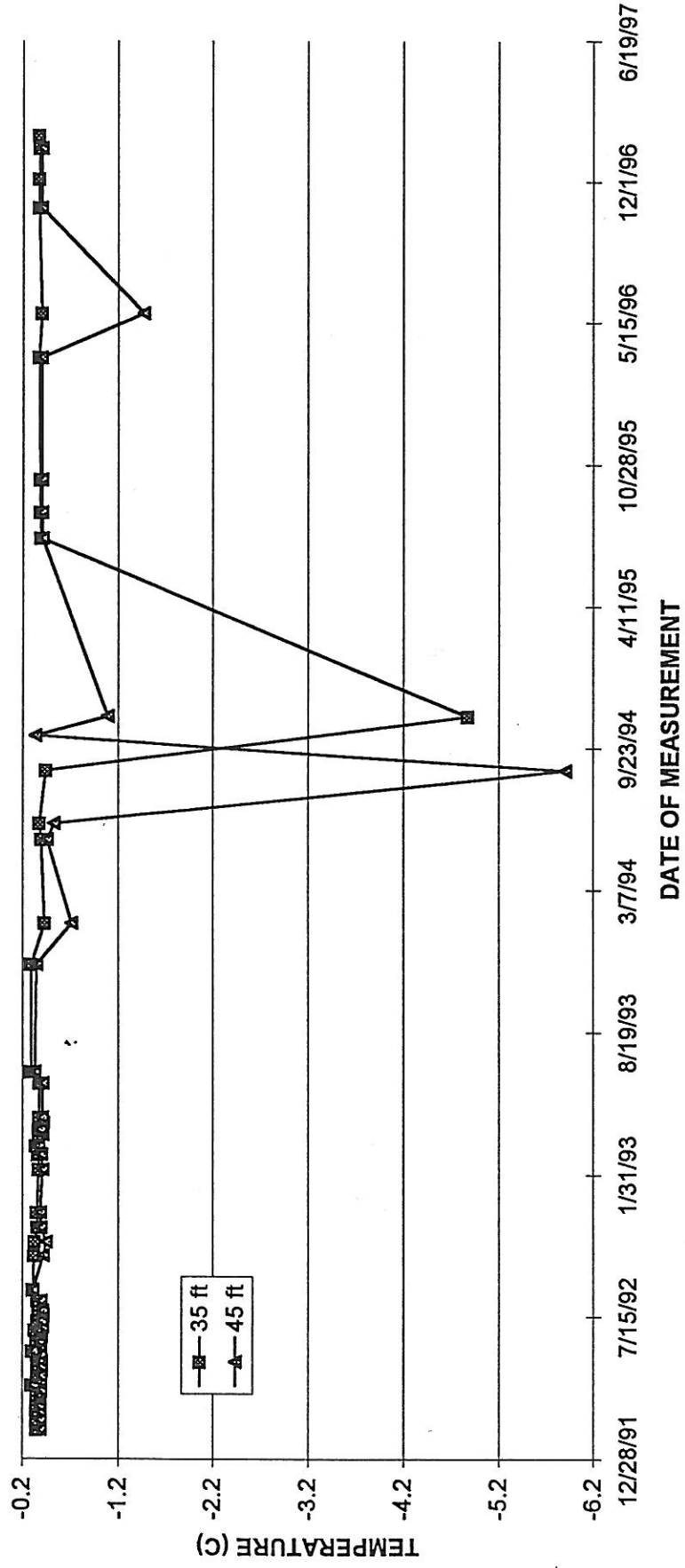


FIGURE C-12