FINAL REPORT

ON

FOUNDATION STABILIZATION RESEARCH STUDIES at

263 Madcap Lane

Fairbanks, Alaska

March 1999

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Revised: March 24, 1999

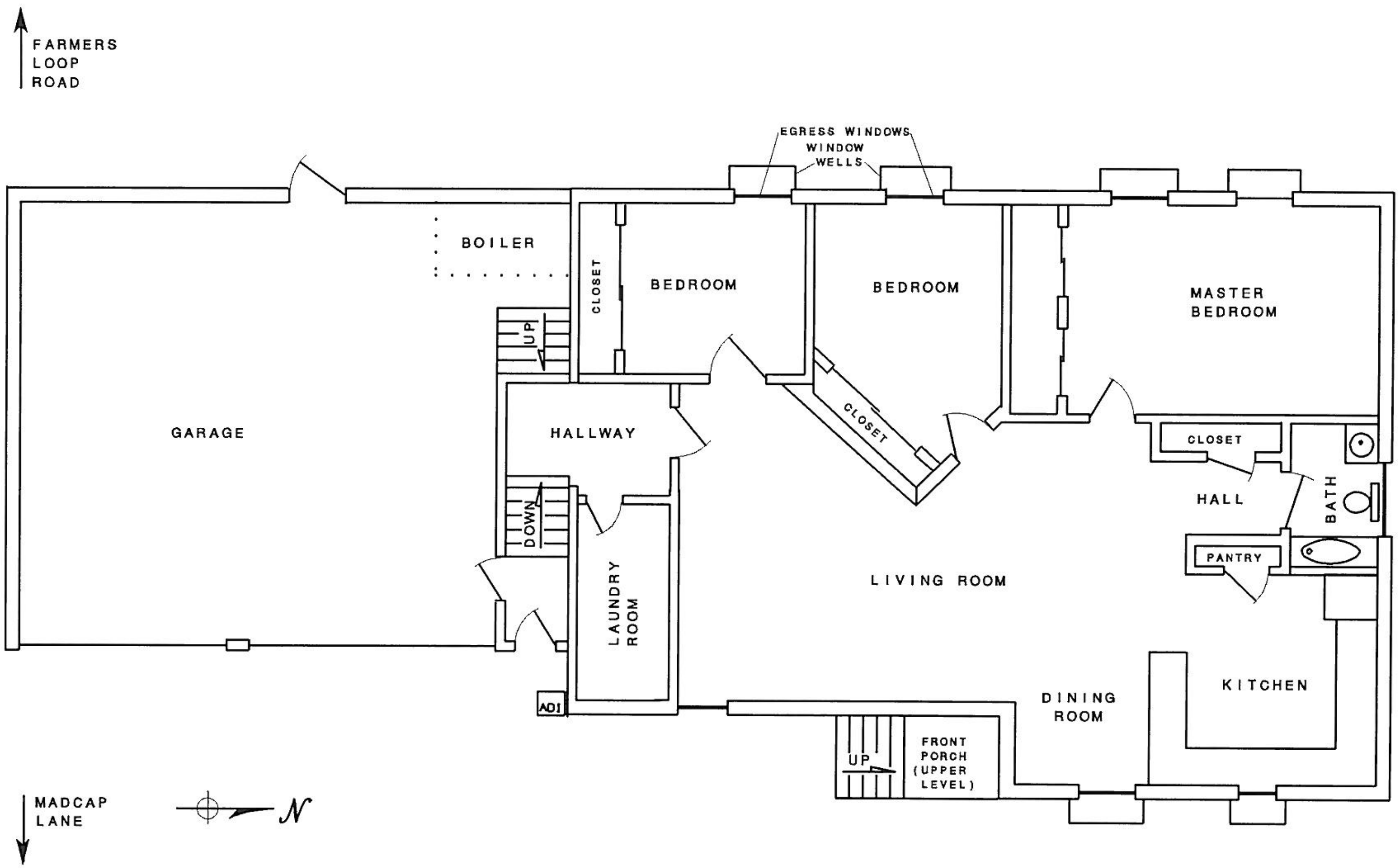
Introduction

This property is located at the foot of the hills that border Fairbanks on the northwest. The main transportation artery for this area is Farmer's Loop Road which runs along the lower portion of the hills at approximately the uphill boundary of permafrost. Much of the land south and east (the downhill side of the road) of Farmer's Loop Road in Fairbanks, Alaska is underlain by permafrost, most of which is thaw unstable. This property lies east of the road in a shallow valley containing a small lake (Ballaine Lake) located across Farmer's Loop from the property.

The structure at this location is underlain by permafrost. The property was transferred to the Permafrost Technology Foundation for the purpose of research to develop and test technology which would make it possible to economically stabilize the building foundation. This structure has a heated daylight basement, making it a particularly difficult challenge. Yet, it represents many homes in the area that have heated basements and are underlain by thaw-unstable permafrost. A solution to this problem will be most beneficial to a number of other home owners in the Alaska area and elsewhere in the North where similar conditions prevail.

Structure Description

The structure is a split level, daylight basement residence. The upper floor contains three bedrooms, two baths, a kitchen, dining room, living room and entry. The basement contains a three bedroom apartment with kitchen-dining room, living room and one bath (figure 1). A laundry room is also in the basement outside of the apartment and serves both upstairs and basement tenants. A two-car garage is at ground level, approximately half way between the upper level and the basement level and provides inside entrance to both the upper level and the basement apartment. Private outside entrances are available to both levels at the front of the house (figure 1). A door leads from the garage to the back yard. The back yard faces Farmers Loop Road, to the west, while the front yard faces Madcap Lane. Madcap Lane is a short street, approximately ¼ mile long, that



PERMAFROST TECHNOLOGY FOUNDATION

263 MADCAP LN. FAIRBANKS, AK

BASEMENT AND GARAGE FLOOR PLAN

FIG. 1

parallels Farmer's Loop Road near the University of Alaska Campus. Several other structures on Madcap Lane are in structural distress due to thaw settlement into the ice-rich permafrost in this area. The soil in the vicinity of Madcap Lane is silt, with high organic content. Permafrost generally underlies the vicinity. The soil beneath this structure is thawed to a depth of approximately 40 feet and has a high moisture content.

Level Measurements

Level measurement were taken to determine the relative elevation of the basement floor and foundation. The level measurements were made using a small precise telescopic level mounted on a tripod (sometime referred to as a "contractor's level") 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 in.).

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 precise same spot as the previous measurement or if an electrical cord or a magazine etc. happened to be under the rod (even the thickness of a few sheets of paper will show up at this precision). 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 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 up to as much as a few inches. These errors however are readily discernible when the data is plotted as a function of time (see the appendix).

Level data on the concrete slab floor in the basement was collected several times a year and accumulated for a period of seven years. The level data plotted on charts as a function of time are shown in the appendix of this report. Each measurement location is designated on the floor plan by a letter. Different groups of letters were plotted together on the charts to show relevant comparisons such as the south wall or the diagonal across the structure. 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. From this data, differential elevations between various parts of the floor can be seen easily and tracked with time.

This system, however does not give information as to the absolute elevation of the house with respect to the ground outside, and 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 of the structure. No such stable reference or benchmark was available at this location. Two reference benchmarks were attempted. One was the top of the thermistor casing and the second was a nail driven into a large tree in the front yard. Neither reference proved to be reliably stable unfortunately. Nevertheless, the relative elevations allow differential settlement to be tracked, and that is the most important information for the purpose of these studies.

For perspective, a differential floor elevation of one to two inches (25 mm to 50 mm) across the length of an average room is not noticeable to the unaided eye. Up to four inches (100 mm) over the distance across a normal room, although noticeable, is not an overly unpleasant condition with which to live.

High moisture content soils also raise the concern of settlement during a dynamic event such as an earthquake. During the period over which the level measurements were made on this house there were 15 earthquakes in the Fairbanks vicinity (approximately 30 mile radius) whose magnitudes were greater than Richter 4.0. Of those 15, one was ranked as 5.0 on Nov 1, 1992 and one was 6.2 on October 6, 1995. This last one was the most significant event, since it was not only 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 the data on level measurements shows that no significant measurable settlement can be identified in our data during any of these events. This suggests that either settlement into the loose soils beneath the structure was not triggered by a dynamic event of this magnitude or that settlement into the loose soils was already complete before the Permafrost Technology Foundation started monitoring the structure. These circumstances and observations do not preclude the possibility of settlement during a more severe earthquake or other type of dynamic event, but they are an indication of the relative stability of the structure.

Temperature Measurement

Two permafrost test borings were drilled outside of the house, and a thermistor string with 12 thermistors was placed in each hole. The thermistor strings were positioned to measure temperatures at the surface of the ground and at depths of 4, 12, 20, 28, 32, 34, 36, 37, 38, 39 and 39.5 feet in borehole number one and at depths of 2, 6, 10, 18, 26, 28, 30, 31, 32, 33 and 33 feet-8 inches in borehole number two. In addition to the boreholes outside of the house, two holes were drilled through the basement floor. Thermistor strings were also installed in these holes. Later, a fifth thermistor string was added to the two outside strings resulting in 5 strings measuring temperature to as deep as 46 feet below the surface. These temperatures were monitored periodically at the same time the level measurements were taken (and sometimes more often) resulting in a data base of seven years of soil temperatures for the site. The temperature data was plotted with respect to time on charts to give a graphic indication of the soil temperature trends over the duration of the study. Samples of these charts are included in the appendix of this report.

Thermistors are capable of measuring temperature to the nearest one thousandth of a °C. Thermistors were used because they are more precise 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 strings were calibrated before placing them in the hole, but since once installed they are buried, it is impractical to remove them without destroying them, therefore the secondary calibration cannot be made. The temperatures, therefore, are reliable to about a tenth of a degree Celsius. For the purposes required for these studies, an accuracy of one tenth of a degree Celsius is considered adequate.

Thermistors located at various depths makes it possible to track the temperatures at those depths to determine if the permafrost is getting deeper, remaining stable, or actually rising. The data also points out 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.

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Geotechnical Exploration

In order to determine the condition of the soils below the structure, boreholes were drilled and samples of the soil were taken at regular intervals of depth (see appendix for borehole logs). Samples were collected by driving a split-spoon sample core barrel through the hollow stem 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. Below this, the soils were sampled with a dry core barrel. This brings to the surface a five-foot-long, three-inch-diameter, intact soil sample. Representative soil samples were then sent to the laboratory for analysis of grain size and water content. With this data, a model of the soil conditions and types was constructed for the hole. This model does not necessarily apply to the soils under the structure since soil conditions can, and often do, change radically over short distances, but if boreholes on both sides of the structure are similar in nature, then the type of soils beneath the house can be at least inferred.

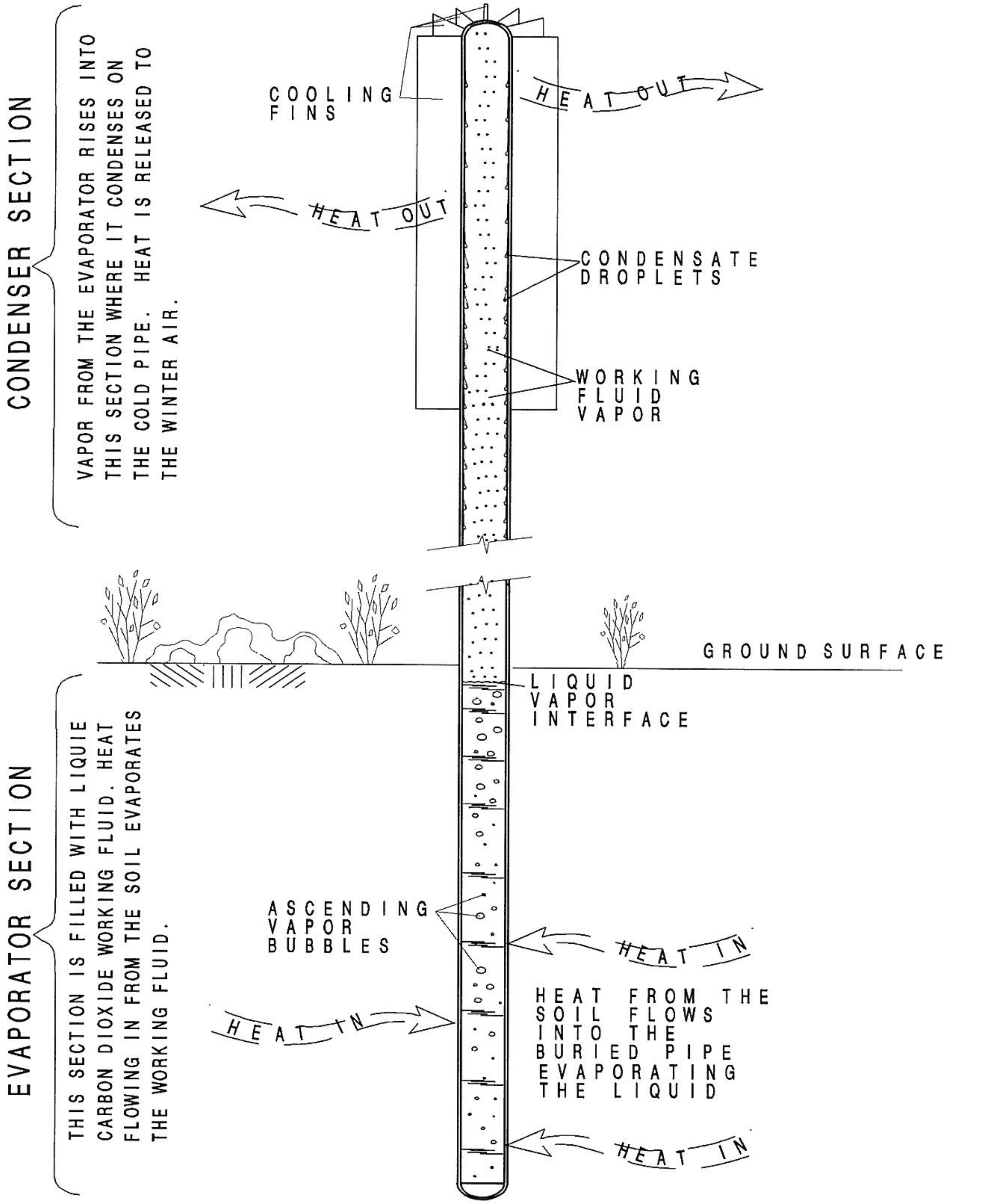
Two holes were also drilled inside the house through the basement floor slab. Due to the limited height available, these holes were drilled with a small portable drill rig. With this type of drill, only "grab samples" could be taken from the auger cuttings. Figure 2 shows the small mobile drill rig in operation in the basement of the house.

Stabilization Research

The finished full daylight basement constituted a substantial value to the structure at this site. The stabilization method used should be one that would, if at all possible, preserve and protect this valuable portion of the structure. Soils beneath the structure were supersaturated silt and were thawed to a depth of slightly over 40 ft. The thaw bulb beneath the structure was close to what is normally considered to be the mature or maximum depth of thaw for a structure of this size. However, due to the complete change in the thermal regime in this area caused by the construction on all sides of the site it can be reasonably argued that the permafrost in the area will continue to thaw until it disappears completely. Some sites in the general vicinity are permafrost free but have features such as old thermokarsts and voids within the ground that indicate previous permafrost. Another consideration was the very high moisture content of the soil found beneath the house during drilling of the borehole through the floor slab. Considering all aspect of the situation presented at this property, this site appeared to be an ideal location for the installation of thermosyphons to protect the remaining permafrost.

Thermosyphons: Thermosyphons are passive heat transfer devices that intercept the heat flowing into the ground through the basement floor and walls and carry it to the surface where it is carried away by the cold winter air. Thermosyphons contain no moving parts and require no energy to operate. They are, quite simply, pipes one end of which is placed into the ground while the other end remains above ground (see figure 3). The below-ground portion of the pipe contains a liquid working fluid such as carbon dioxide (CO_2), and the above-ground portion contains vapor (gas) of that working fluid. They move heat by the principle of natural convection. The pressure in the pipes is adjusted during installation so that the liquid working fluid in the below-ground portion of the pipe boils at the temperature of the thawed ground. The boiling action turns the liquid CO_2 to a vapor while absorbing enormous amounts of heat (called the latent heat of vaporization). The CO_2 vapor has a much lower density than the CO_2 liquid and, therefore, it rises in the pipe to the above-ground portion where it condenses on the colder above-ground pipe wall. The heat of vaporization in the vapor (which is extracted during the condensation process) is transferred to the pipe wall and then carried away by the cold winter air. The vapor condensate (now a liquid) trickles down the pipe wall to the below-ground portion where it boils again to start the process over. The above-ground section of pipe has fins attached to enhance the heat transfer process and enhance the dispersal of latent heat to the cold air as rapidly as possible since one of the limiting factors in thermosyphon operation is the ability of the above-ground portion of the pipe to dispose of the latent heat thus keeping the condensation process going.

Thermosyphons only work when the above-ground portion (called the condenser section) is colder than the below-ground portion (called the evaporator section) since the condensation of the vapor in the condenser section is necessary to lower the pressure in the pipe to the point where the liquid CO_2 will boil. Therefore, thermosyphons only transfer heat out of the ground during the winter. In the summer time (or for that matter,



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THERMOSYPHON DETAILS

CARBON DIOXIDE THERMOSYPHONS
INSTALLED AT 263 MADCAP LN.

FIG. 3

any time when the above-ground portion is warmer than the buried portion) the condensation process stops and the thermosyphons become dormant Thermosyphons must transfer enough heat during cold weather to cool the ground sufficiently below its initial temperature so that during warm weather, while they are dormant, the heat entering the soil from the house and from warm weather at the surface of the ground will be absorbed by the frozen soil around the thermosyphon and will not raise the temperature of the soil back to the point that the permafrost once again begins to thaw. In other words, to stabilize the permafrost the thermosyphons must transfer more heat out during cold weather than enters during warm weather.

The use of thermosyphons and other related heat tube devices to protect permafrost has been common practice in the North for many years since they were initially invented by Erv Long then of the Corps of Engineers (now president and CEO of Arctic foundations in Anchorage, AK.). However, very few systems installed on residential buildings have been equipped with sufficient instrumentation and documented to allow the evaluation of their performance and the refining of their design in this rather critical application.

The generic term "heat pipe" is used for a variety of heat transfer devices that are available and have been used for the purpose of drawing heat from the soil to sub-cool it for the purpose of protecting permafrost. The name "Thermosyphon" is commonly used to designate those devices that use a two phase (i.e. boiling and condensing) operation. Other heat pipes operate using single phase working fluid (all liquid or all gas). They also operate on the convection principle that warm fluid is more buoyant than cold fluid and rises to the top of the pipe where it is cooled by the colder conditions above ground and thus circulates back down to the bottom of the pipe.

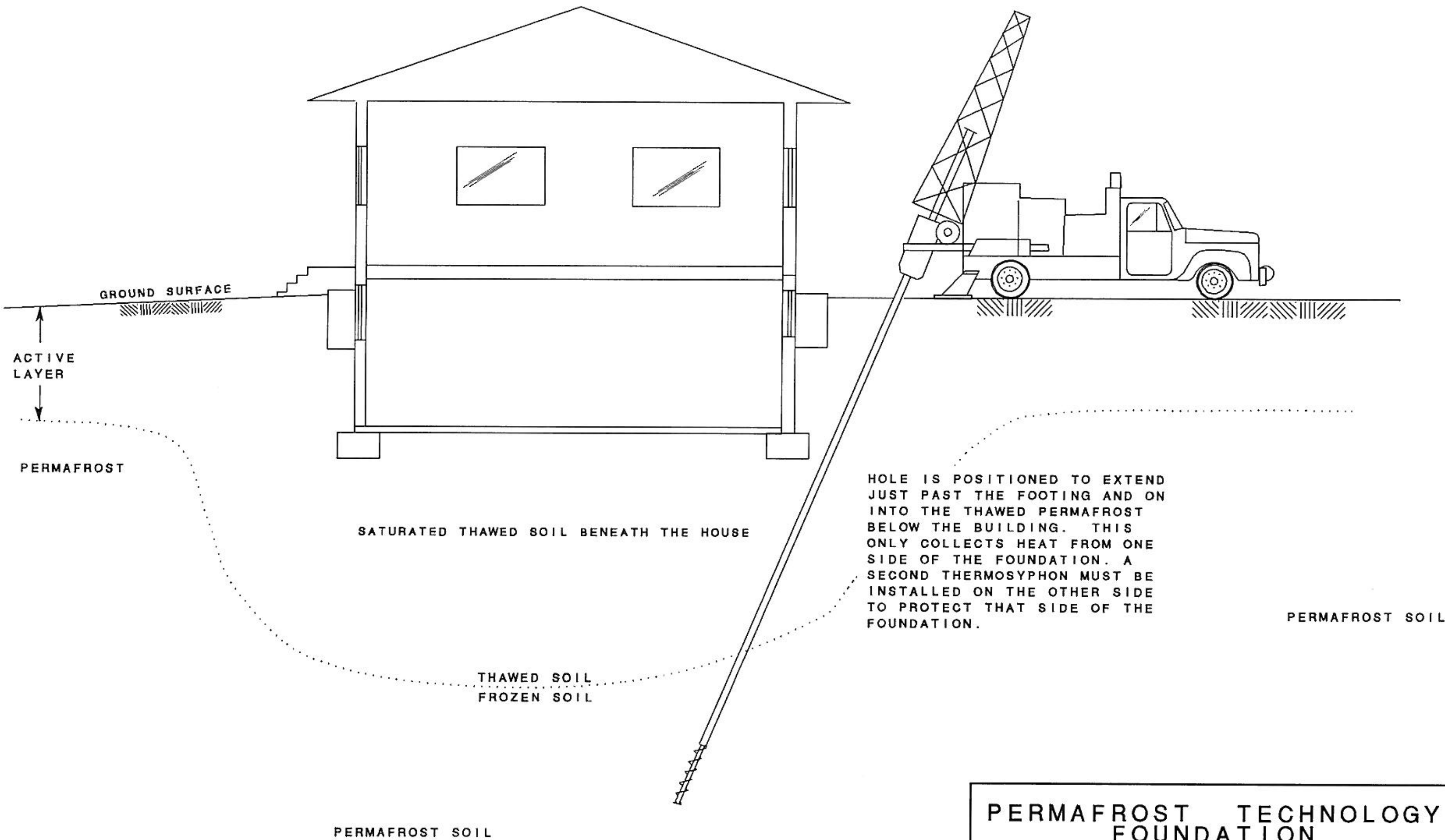
Single phase heat pipe devices operate at lower heat transfer rates initially because they do not have the advantage where the working fluid carries the latent heat of vaporization (which is enormous) to the surface as do the 2 phase units. However, all heat pipes devices eventually are limited by the amount of heat that can move through the bulb of frozen soil that grows around the buried portion of the pipe to get to the working fluid. Because this limitation is common to all heat pipes, they all operate at about the same rate after they have reached a mature operating cycle, usually several months to a few years. A more complete discussion of heat pipes, their operation, limitations and working fluids can be found in *Construction in Cold Regions* by McFadden and Bennett (1991), see the bibliography.

Installation of heat pipes: Heat pipes, such as thermosyphons, must be installed so that the heat absorbing section (evaporator section in thermosyphons) is buried between the heat source and the permafrost that they must protect. In new construction, this is simply a matter of planning; the heat tubes are placed in the appropriate location and the construction carried out around them. When they must be installed on an existing structure, especially one that is already suffering from some thaw instability, installation becomes much more difficult and more expensive. Sometimes it is possible to drill a hole into the ground at an angle such that the hole extends beneath the footing of the structure (figure 4). The heat pipe is then placed in the hole and the annulus around the pipe is filled with a slurry of soil to provide good heat transfer characteristics between the soil and the heat pipe.

In many instances, however, the soil beneath the structure is supersaturated with water from the thawing permafrost. This soil has the consistency of very thick soup or catsup and it promptly sloughs into and fills the hole when the drill rod is drawn out of the hole. This is somewhat like trying to drill a hole in a bucket of water, except that, unlike water, the supersaturated soil resists attempts to insert the heat pipe. The soil conditions at the Madcap Lane site fit this description perfectly. Therefore, a new method of installing the heat pipes (thermosyphons in this case) had to be developed.

During the drilling operation, the hole is filled with the drill bit (auger) and the drill stem (Kelly rod). It is only as this hardware is withdrawn that the hole closes up. Attempts to use the heat pipe as the drill stem and then leave it in the hole (abandoning the drill bit) when it had reached the desired location had been made in two previous installations, one to install thermosyphons under the runway at the Bethel, Alaska airport, and another to install thermosyphons under a road section at Farmer's Loop Road (approximately one mile from this site) in Fairbanks, Alaska. Once installed in this manner, the thermosyphon was finished by welding the above ground section (the condenser) to the pipe and then filling it with the working fluid. These attempts ran into numerous difficulties and proved to be impractical both economically and from a performance consideration. One of the most serious problems involved leaks in the thermosyphon pipe that were generated during the drilling process. Drilling also was very difficult since the drill stem had to be made up of welded on sections of thermosyphon pipe (requiring a certified pressure vessel welder on the site throughout the drilling) and, once the hole was started, the drill bit could not be withdrawn from the hole for replacement or service. A new installation method was clearly needed.

In order to get the pipe into its location without the problems associated with using it as a drill stem, a directional drill was used. This drill was capable of drilling the hole in an arc that extended under the building and exited at the surface on the opposite side of the building (figure 5.) The drill bit was then removed and the previously prepared thermosyphon pipe was attached to the drill stem (which was still in the hole and extended under the house). As the drill stem was withdrawn from the hole the attached thermosyphon pipe was pulled into the hole. In this manner, the hole was never left empty, and thus had no opportunity to collapse. The length of the hole arc and the thermosyphon pipe were adjusted so that when the pipe was drawn all the way back to the beginning of the hole, the buried end of the thermosyphon was at the deepest point of the arc. The hole was directionally controlled so that the deepest portion of the arc was under the foundation wall on the opposite side of the building (figure 6). The evaporator section of the thermosyphon was thus positioned so that it extended under the entire width of the building, and its end was at the lowest point of the arc. This provided a



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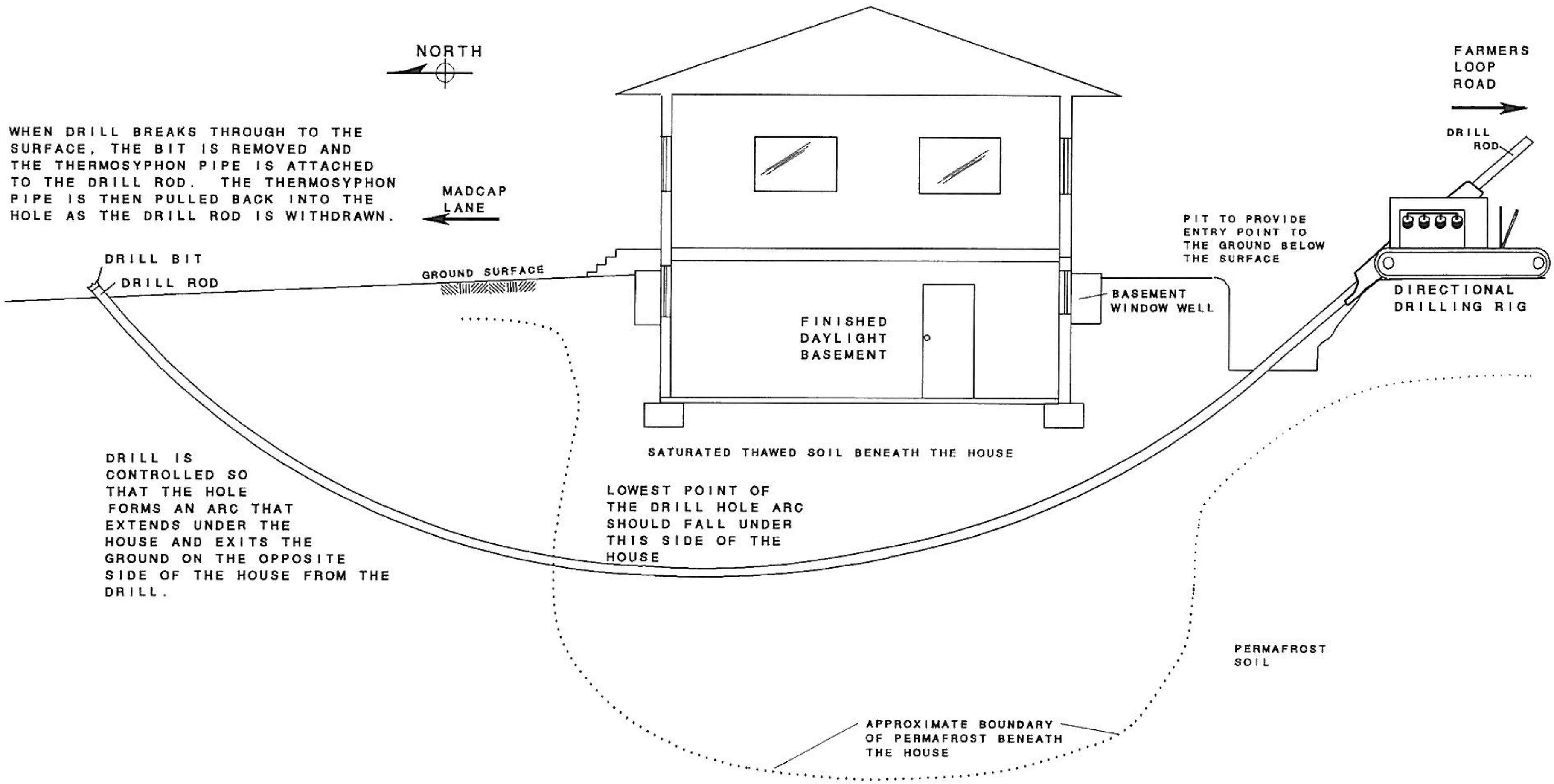
THERMOSYPHON INSTALLATIONS

TYPICAL ANGLE INSTALLATION OF THERMOSYHPHONS AROUND A BUILDING

FIG. 4



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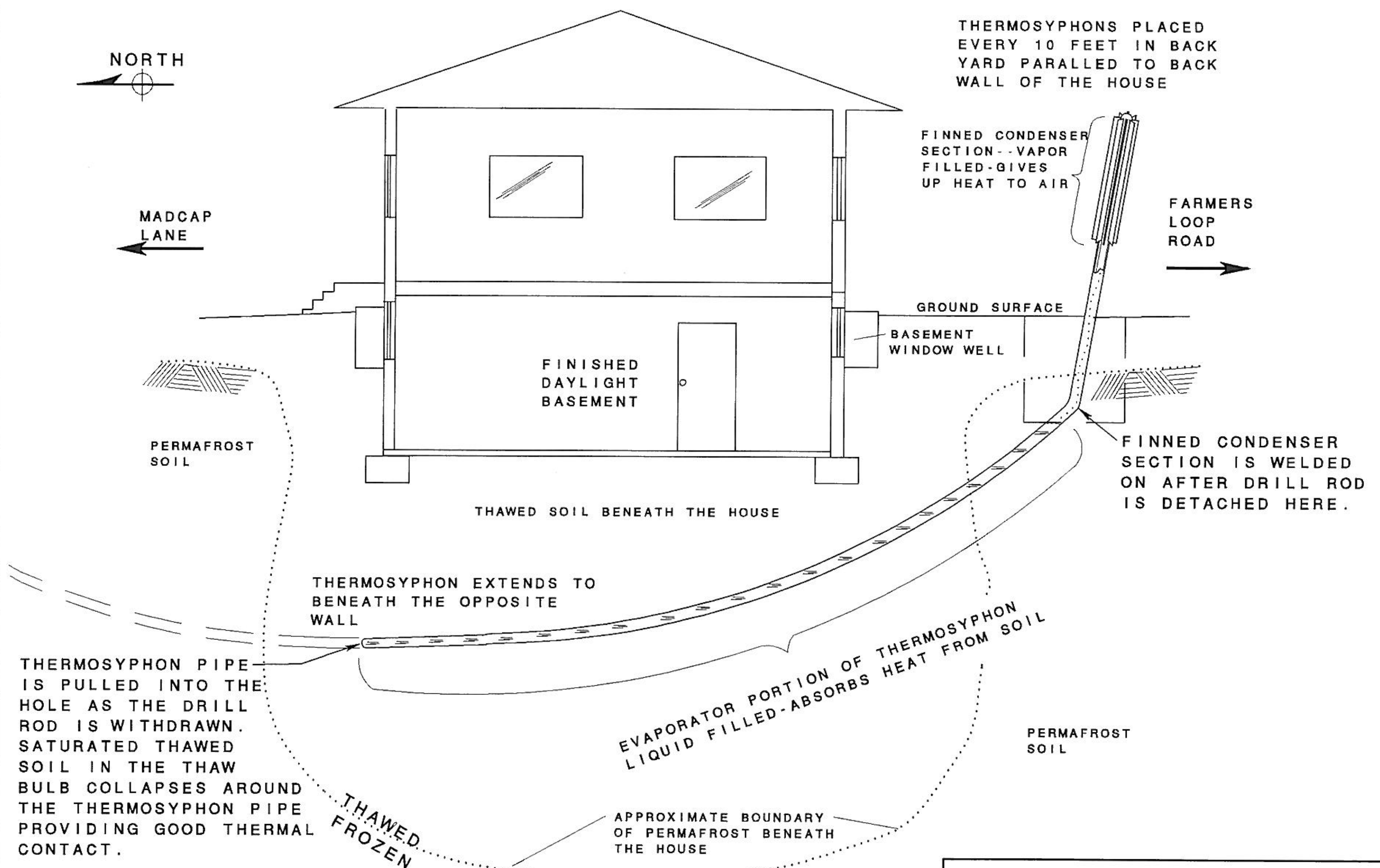
DIRECTIONAL DRILLING INSTALLATION OF THERMOSYHPHONS

FIG. 5



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DETAILS OF THERMOSYPHON INSTALLATION USING DIRECTIONAL DRILLING AT 263 MADCAP LANE

FIG. 6

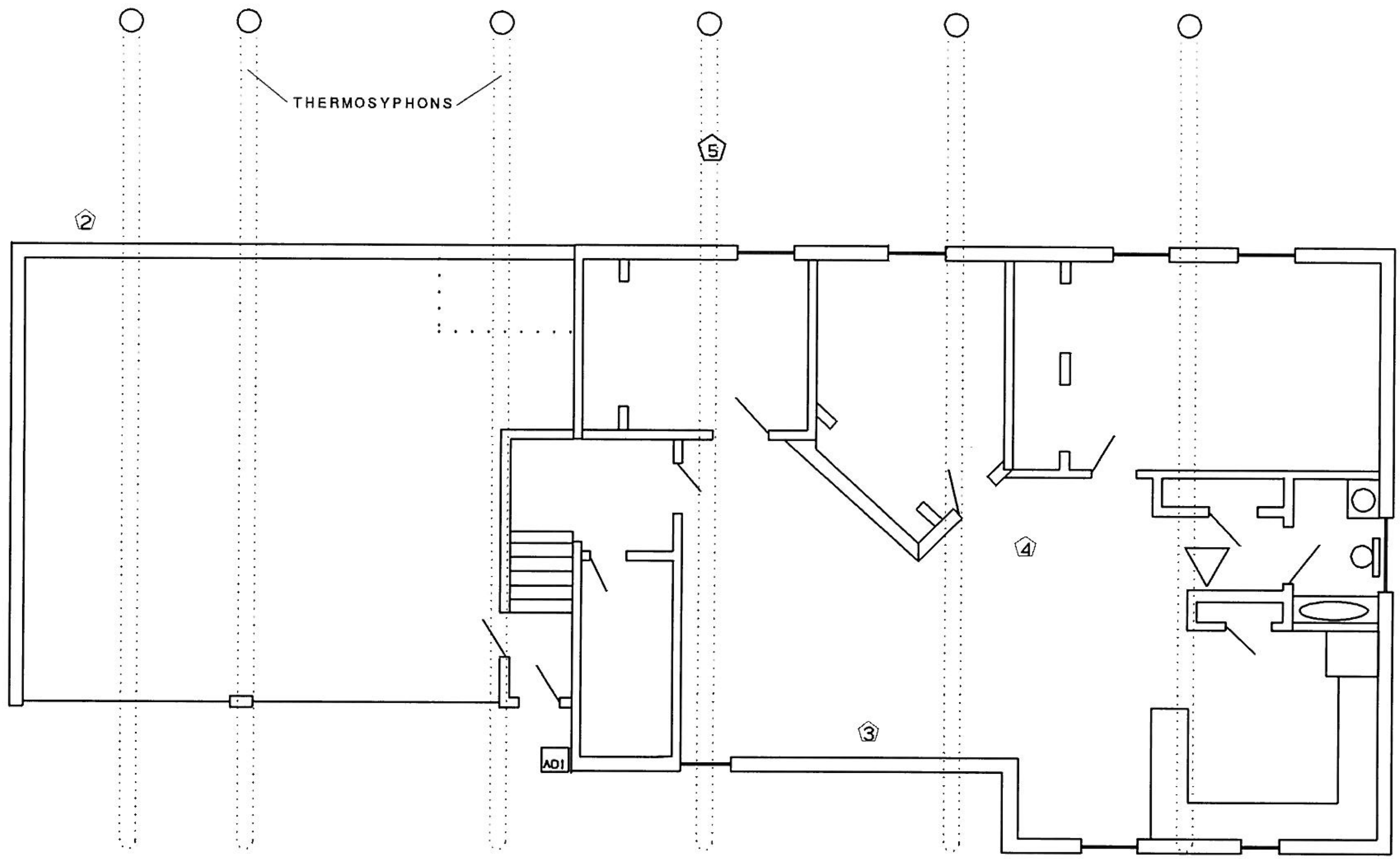
positive slope to the thermosyphon from the end of the evaporator section (its lowest end) to the above ground condenser section. When this was finished, the drill stem was removed from the thermosyphon pipe and the condenser section (complete with fins) was welded onto the pipe. The unit was then charged with CO_2. Since CO_2 requires an internal pressure of approximately 480 psi., all welding on the thermosyphon had to be done by a certified pressure vessel welder.

One of the main advantages of this technique is that the soupy soils collapse around the thermosyphon providing excellent heat transfer characteristics between the soil and the pipe, and the finished pipe is located where it is needed with the evaporator section extending under the entire width of the house. A second advantage is that instead of extending under just the footing as is the case with the traditional angle approach, the thermosyphon now extends under the house from one side to the other so that it can collect heat from the entire floor area instead of just under the footing. Still another advantage is that the thermosyphon pipe does not develop leaks associated with the drilling operation that plagued the evaporator section of previous installations discussed above. Disadvantages of this method include the need for a directional drill and skilled operators and the need to do pressure vessel welding at the site. Although this technique is a big improvement in both installation and performance, retrofit installation is still not inexpensive.

Six thermosyphons were installed using the above technique. Calculations showed that a spacing of 10 feet apart across the back of the house at Madcap Lane would produce a shield of frozen soil that would intercept heat from the floor and walls of the heated basement to protect the permafrost from further thawing. Installation attempted to match the ten foot spacing although the first two were not spaced correctly due to miscommunication with the drill operators. (figure 7) shows the thermosyphon locations as well as other instrumentation and measurement details. The condenser portions are all in the back yard where they are less intrusive. From the front of the house there is no indication of the thermosyphons' presence.

Results and Conclusions

A serious area of concern when using refrigeration devices of any kind to refreeze the soil under a structure is the possibility of frost heaving. Differential elevation caused by heaving may cause differential wracking of the structure much the same as does settlement due to thawing permafrost. This is particularly worrisome when the soils beneath the building are at or near saturation and when the thaw bulb is very deep. Both of these conditions were present and of concern at this site. The thaw depth was slightly over 40 ft under the center of the basement floor (figure 14), and the moisture content of the soil was at or in excess of saturation figure 2. Careful monitoring of the basement and garage floor level suggests some evidence of either heaving (particularly in the garage) or settlement (on the north end of the building) or a combination of both. On the basement



MADCAP THERMISTOR STRING LOCATIONS

LEGEND:

⬠ THERMISTOR STRING

□ AIR TEMPERATURE

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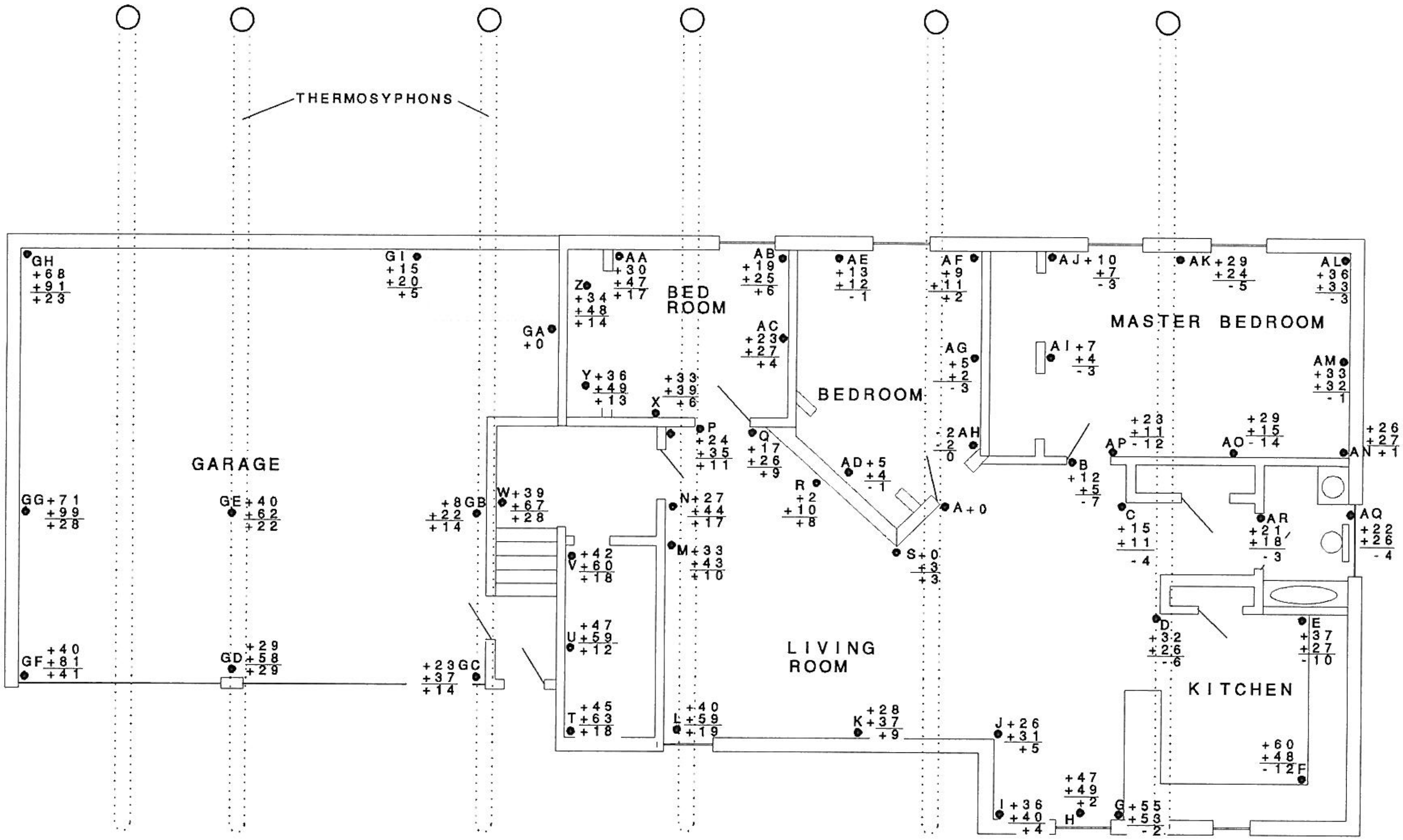
LOCATION OF THERMISTOR STRINGS AND THERMOSYPHONS

FIG. 7

level, a differential elevation change of 40 mm (1.6 inches) is found on the landing at the bottom of the stairs. The floor along the east wall of the basement (the living room area) shows a differential elevation change with respect to point A that varies from -19mm (0.75 inches) in the northeast corner of the kitchen (point F) to + 31 mm (1.2 inches) in the southeast corner of the living room (point L).

The garage floor slab may have heaved. Figures 8 and 9 show the differential elevation of numerous monitoring points at various times during the seven year experiment. By 1999 the northeast corner (pt. GF) had risen 66 mm (2.6 in.) with respect to point GA (Fig. 9). The garage and the basement use different reference points so the two levels cannot be compared except to note that there is a general upward slope from the north wall towards the south wall of each level (figures 10, 11 and 12). It must be kept in mind that this differential could also be a combination of subsidence of the north portion of the house combined with heaving of the south portion. Without a reliable outside reference benchmark (which is not available in the area), and an initial measurement between that benchmark and point A, it is difficult to resolve the question of heaving vs. settling. However, when elevations along the walls are considered together as a set, it is significant that as the distance from point A increases, the elevation of the point increases in all cases. This is not characteristic of frost heaving which would be expected to show up as irregular increases in elevation in the vicinity of the thermosyphons. The selective elevation increase directly correlated with distance from point A (which is near the center of the basement and therefore subject to the greatest thaw depth beneath it) and suggests subsidence in the central portion of the slab near where point A is located.

Figures 8 through 12 show a gradual trend of continual differential elevation change from the north to the south side of the house, and in the seven years of data record the elevation change has accumulated enough to cause some minor problems with the usability of the house. Doors in the basement apartment at points A and P are binding because the door jamb is no longer perfectly square. This is easily correctable, but it does confirm an unresolved problem with differential movement. It would normally be expected that if settlement due to thawing permafrost were occurring, that the south and especially the southwest corner of the house would settle first and to the greatest degree. However, this is not the case since the only point showing a negative elevation change is at point AH which is very near point A in the northern third of the structure. A possible explanation may be as follows: the deepest portion of the thaw bulb beneath the house should be near the center of the heated basement slab. Assuming that the cooling effect of the thermosyphon in this region was equal to the others, then it would require more time for this thermosyphon to build a large enough frost bulb to stop the subsidence into the thawed (and very soupy soil, see figure 2) soils. The thermosyphons under the rest of the house have a shallower thaw depth to deal with and may have stabilized or even heaved the soil in their vicinity. This would suggest that the garage slab would show more elevation increase than the basement slab since it is both closer to the surface and somewhat cooler than the heated apartment. Figures 8, 9 and 12 confirm that the greatest elevation increase has been in the garage points which are farthest from point A.



KEY:

LOCATION DESIGNATOR > M +33 — LEVEL ON 12/3/91 (mm)
+43 — LEVEL ON 12/12/96 (mm)
+10 — DIFFERENTIAL SETTLEMENT (mm)

○ BENCHMARK (TOP OF THERMISTOR STRING CASING)

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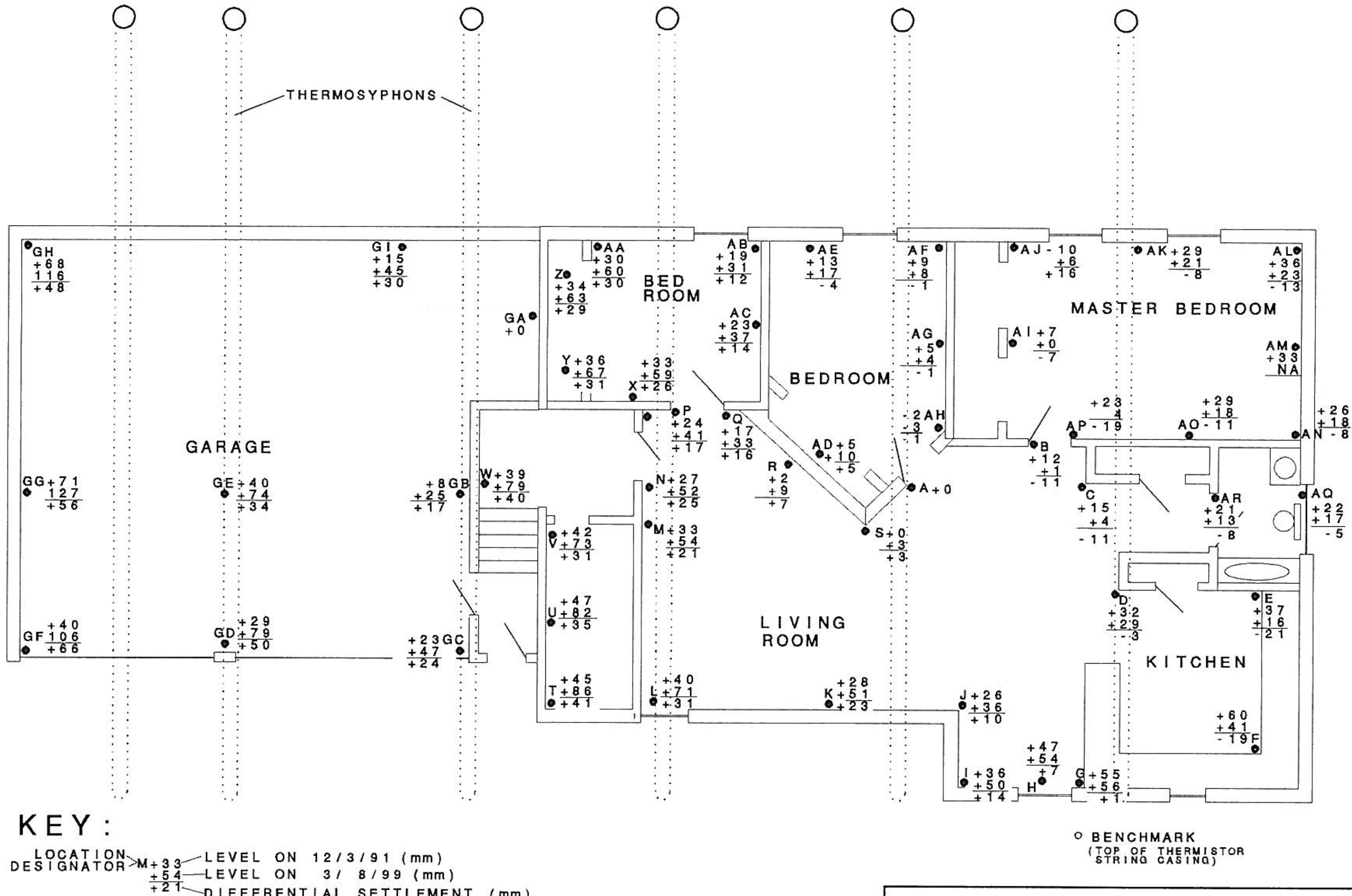
DIFFERENTIAL ELEVATIONS ON THE BASEMENT AND GARAGE FLOOR OVER 5 YEARS OF DATA ACCUMULATION

FIG. 8



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DIFFERENTIAL ELEVATIONS ON THE BASEMENT AND GARAGE FLOOR OVER 5 YEARS OF DATA ACCUMULATION

FIG. 9

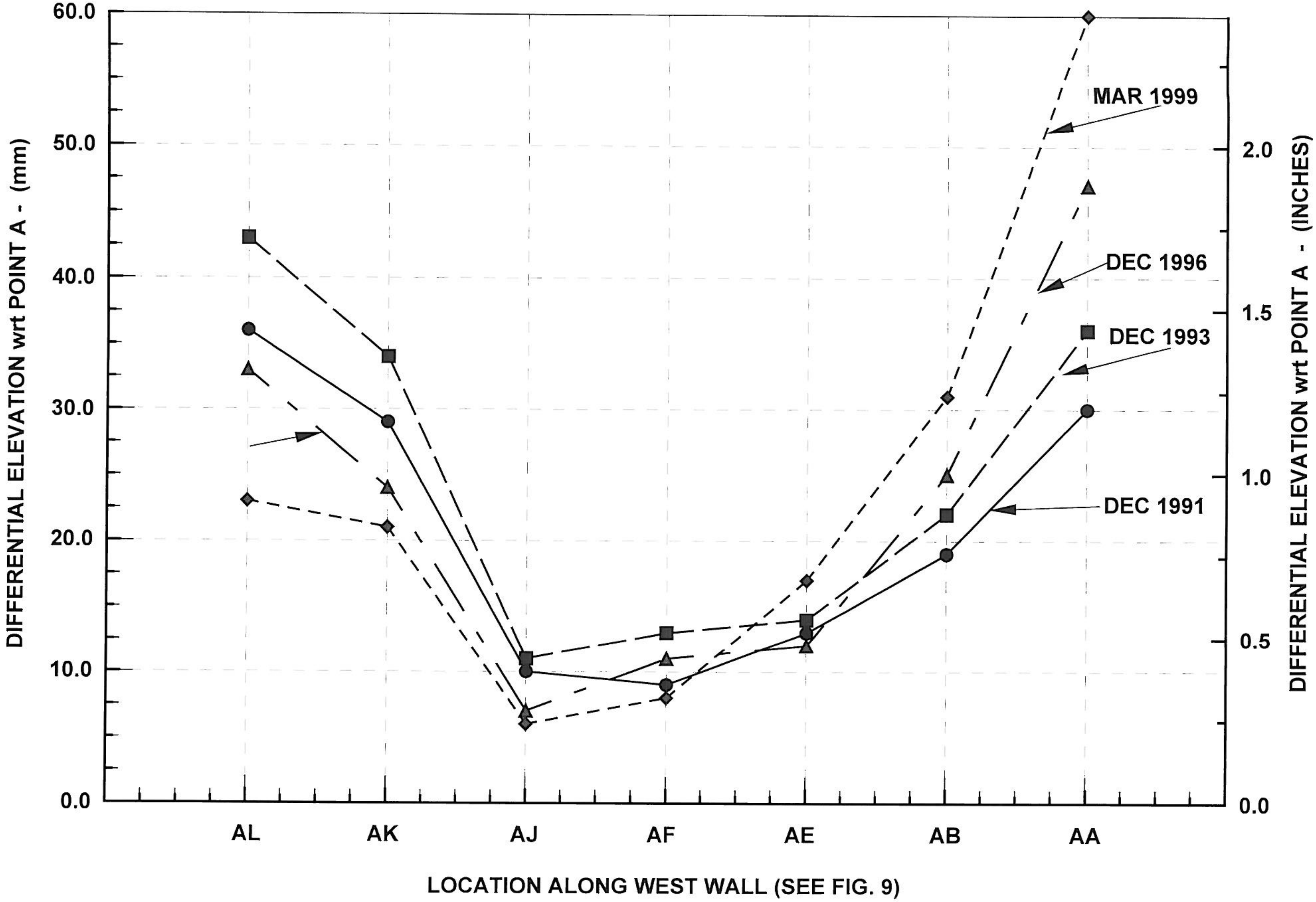

FIGURE 10 - ELEVATION VS TIME ALONG WEST WALL

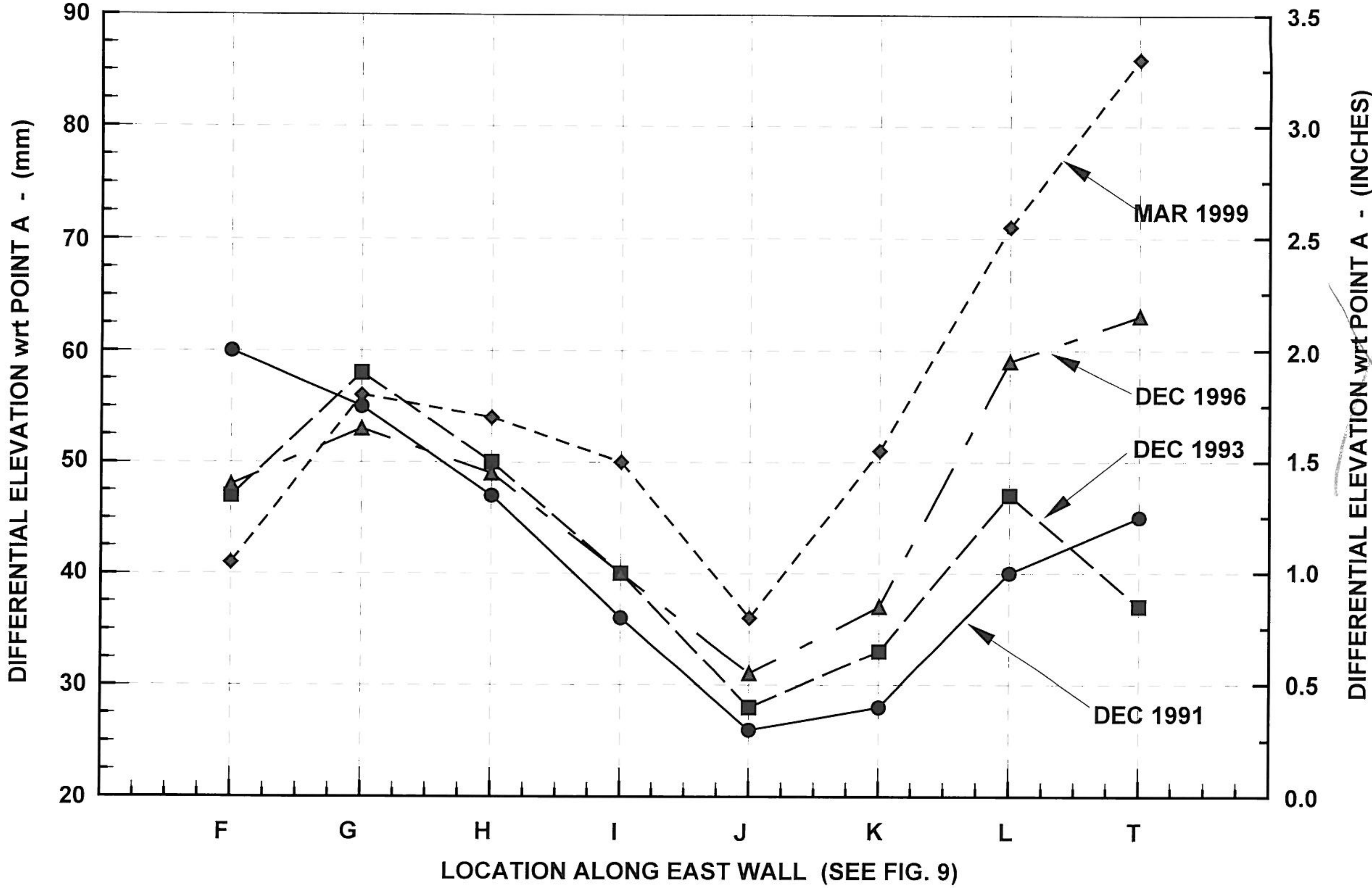

FIGURE 11 - ELEVATION VS TIME ALONG EAST WALL

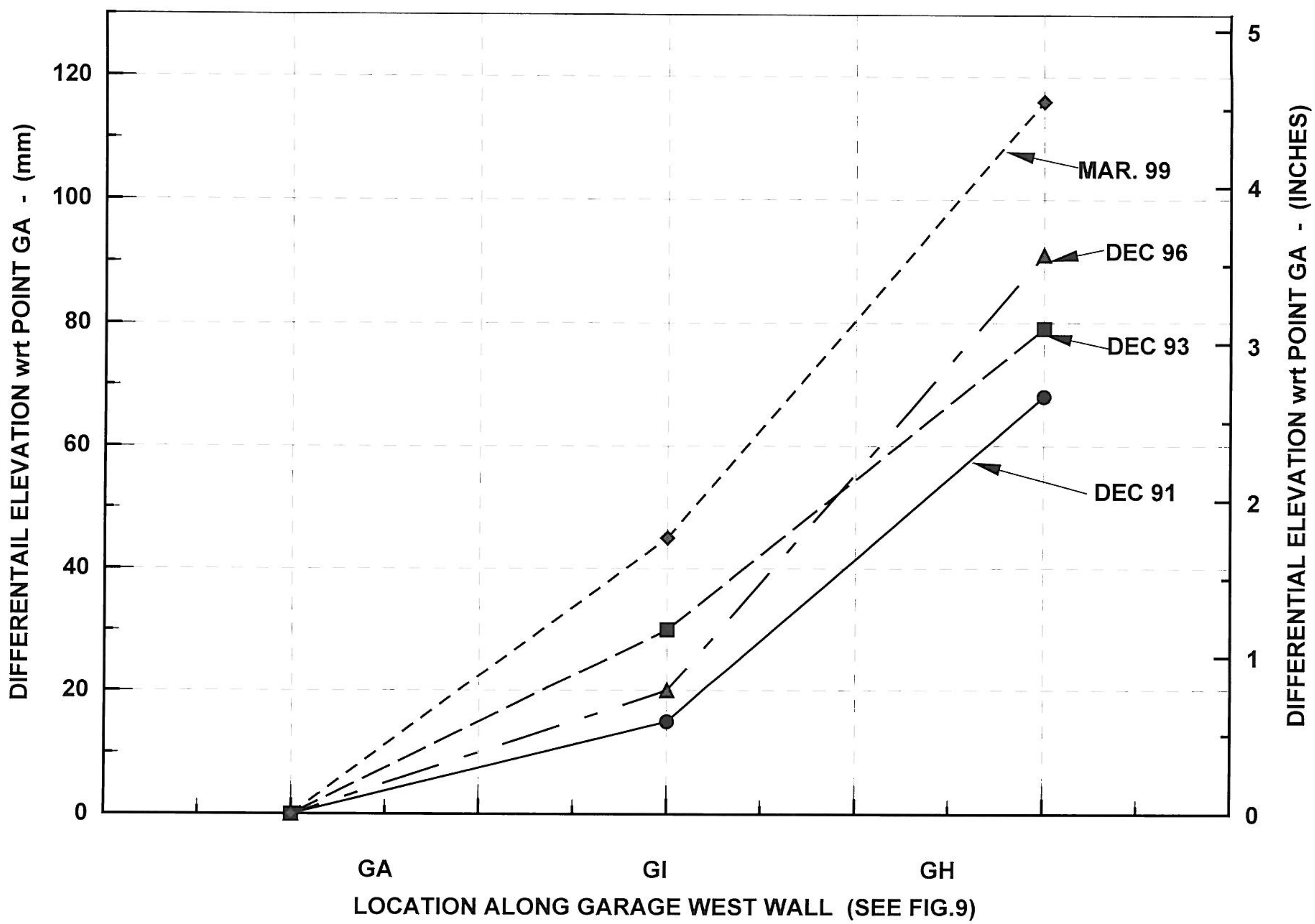

FIGURE 12 - ELEVATION OF GARAGE WEST WALL VS TIME

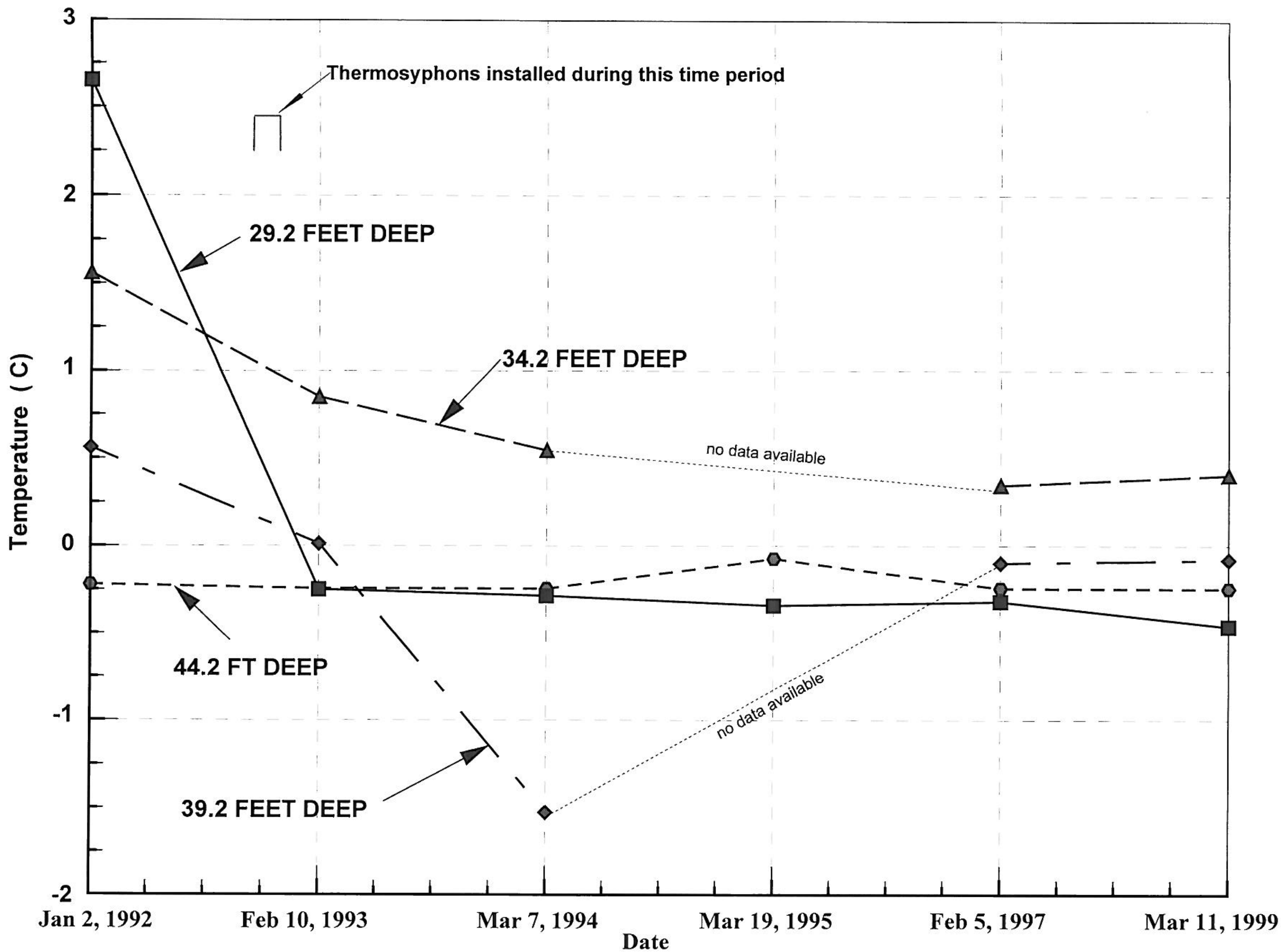

FIGURE 13 - TEMPERTURES AT TEPTH - tHERMISTOR sTRING 3 vs DATE

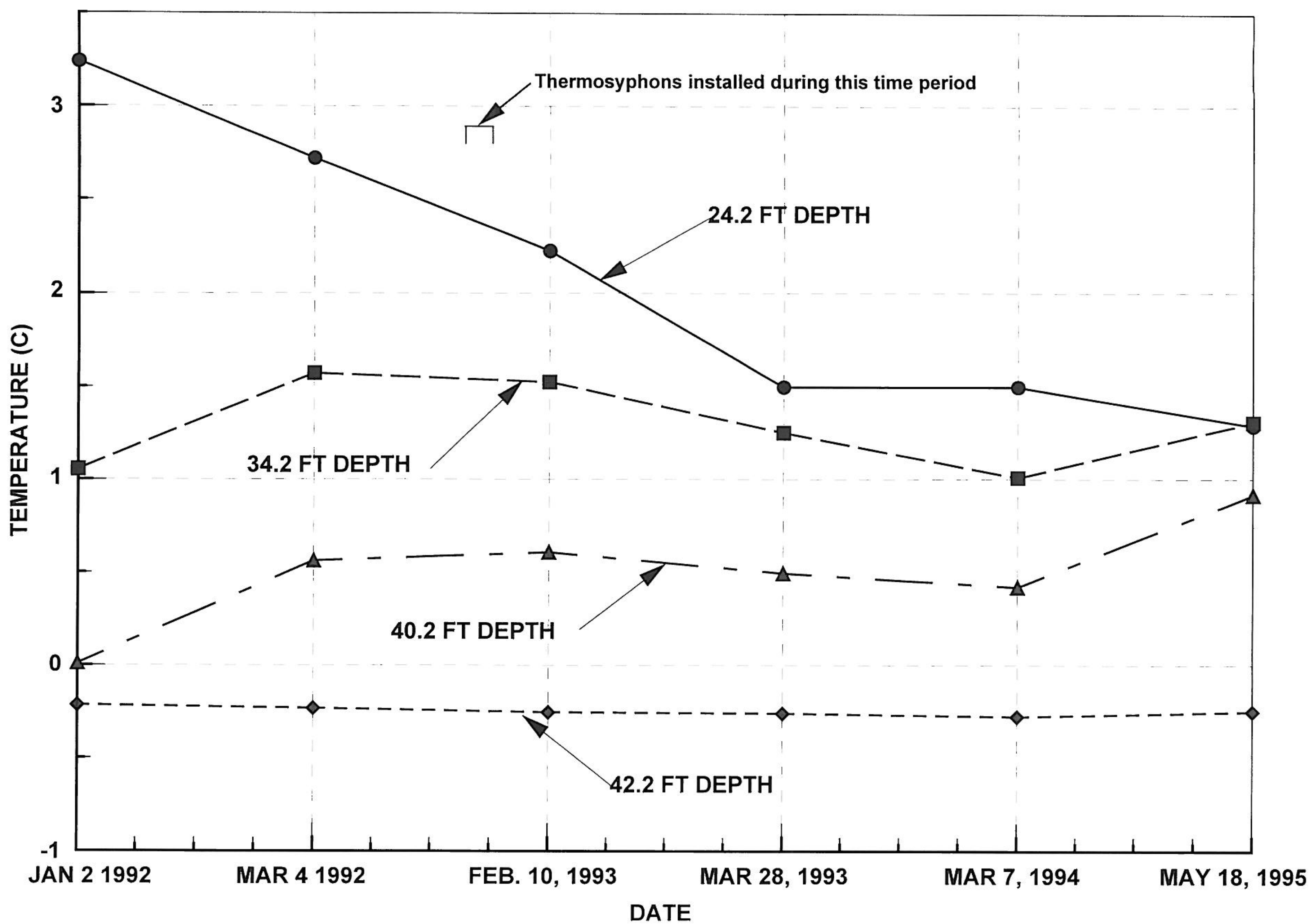

FIGURE 14 - TEMPERATURES AT DEPTH - THERMISTOR STRING 4 vs DATE

Temperature data from thermistor string 4 (figure 14) which is under the center of the basement floor slab of the house (see fig. 7) show a steady decline in temperatures beneath the floor (after the thermosyphon installation) until sometime between March 1994 and May 1995 at which time temperatures begin a slight rise. Unfortunately thermistor string 4 ceased operating after May 1995 so no further data is available. Thermistor string 3 (figure 13) which is centered along the east wall of the basement (see fig. 7) shows a very small temperature rise, above the permafrost, but not until after February 1997. Conversely temperatures from thermistor string 2 (figure 15) which is on the southwest end of the building (fig. 7) show a continual decline for the entire period after the thermosyphons were installed in the fall of 1992. This data gives support to the theory of a combination of settlement under the center of the house and heaving at each end.

It is important to know if the thermosyphons have been working during the entire time period of the experiment. To assess their performance, in March 1999, the pressure in each thermosyphon was measured by Mr. Erv Long of Arctic Foundations and found to be above 475 psi in all six thermosyphons (see table 1). This confirms that they are all in perfect working order and have been throughout the entire experiment.

Table 1 Thermosyphon Pressure and Temperature checkup. March 17,1999

Thermosyphon	Pressure (psi)	Ambient pressure (psi)	Temperature (°F)
1. South end	475.5	18.5	23.0
2.	478.8	18.2	24.1
3.	484.2		25.3
4.	481.1		25.8
5.	483.8	17.5	25.5
6. North end	485.4	17.6	25.0

Outside air temperature = 19.8 °F

The thermal influence of the thermosyphons can be seen in the data from thermistor strings no. 3 and no. 4 which are buried under the floor slab in the basement (fig. 7). figures 16 and 17 show plots of temperature vs. depth at various times during the experiment. The general depth of the thermosyphon can be seen in each plot as the locally depressed temperature at approximately 29 feet at the east wall of the house (thermistor string 3, thermosyphon 5), and at approximately 14 feet deep in the center of the house (thermistor string 4, thermosyphon 5). This data along with the pressure measurements at the end of the experiment confirm that the thermosyphons are performing as they should and are not only intercepting heat entering the soil beneath the house, they have stopped further melting of the permafrost. However the continued mild subsidence (if that conclusion is correct) suggests that more cooling power is required under the center of the basement.

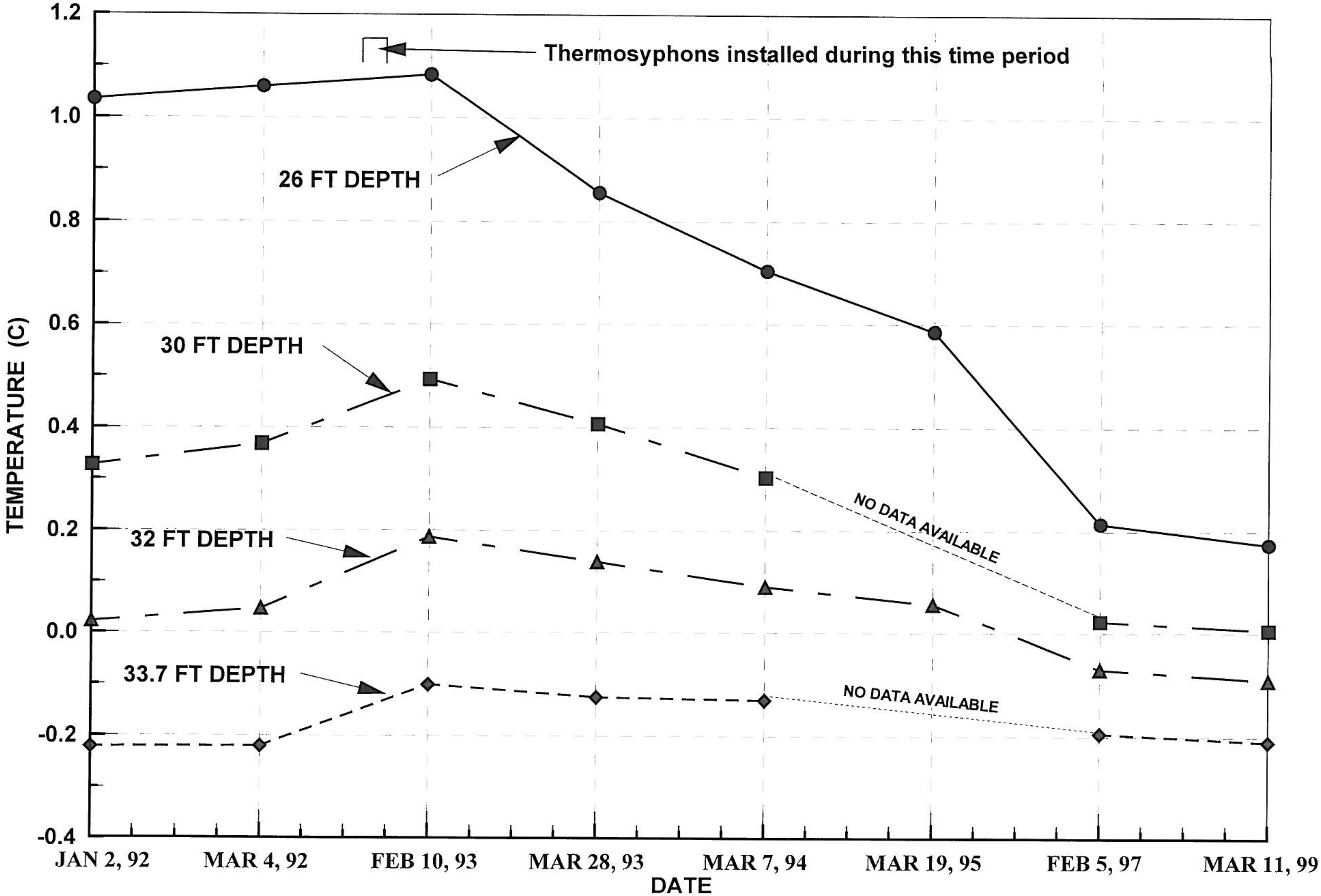

FIGURE 15 - TEMPERATURES AT DEPTH - THERMISTOR STRING 2 vs DATE

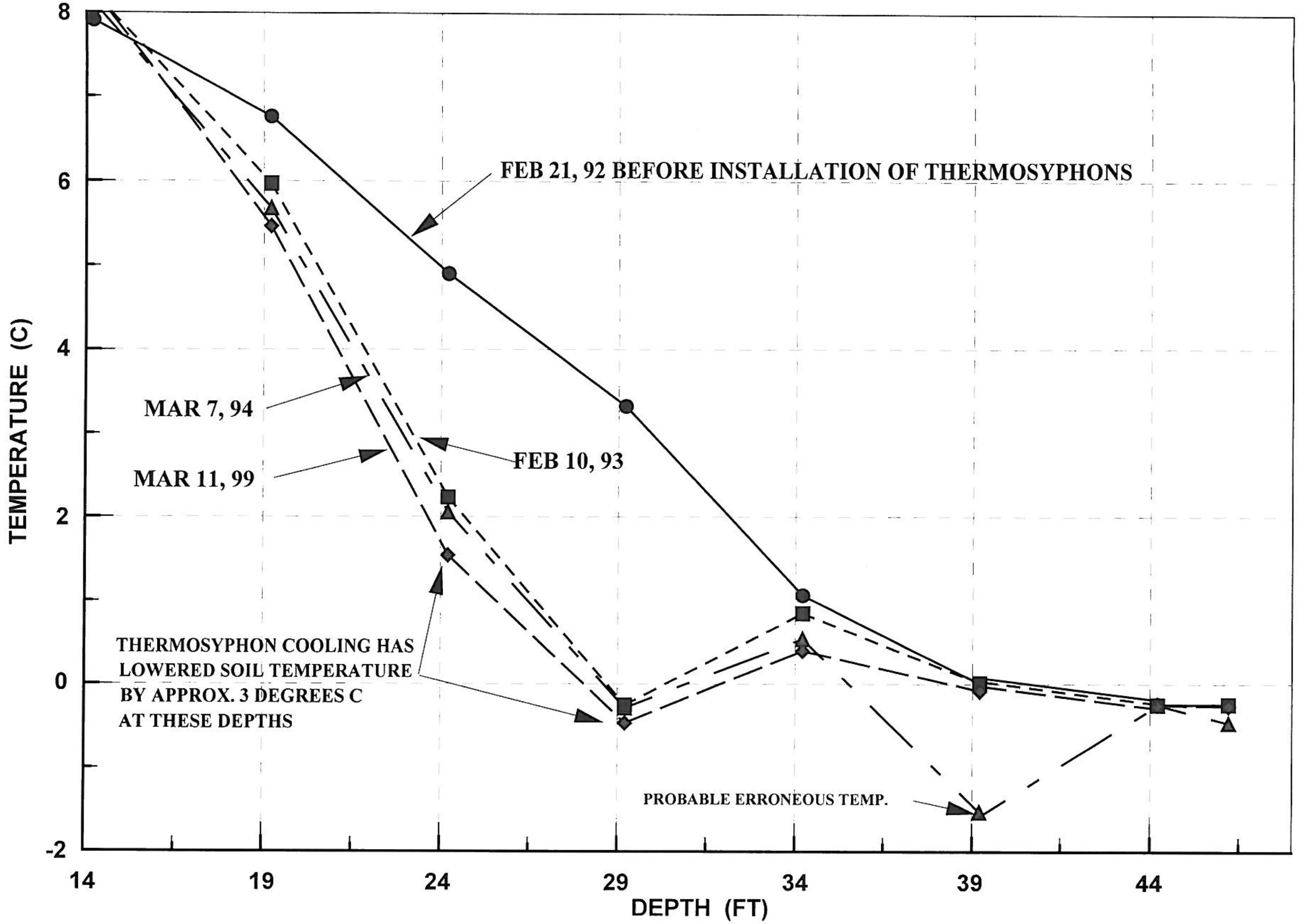

FIGURE 16 - TEMPERATURE OF THERMISTOR STRING 3 vs DEPTH

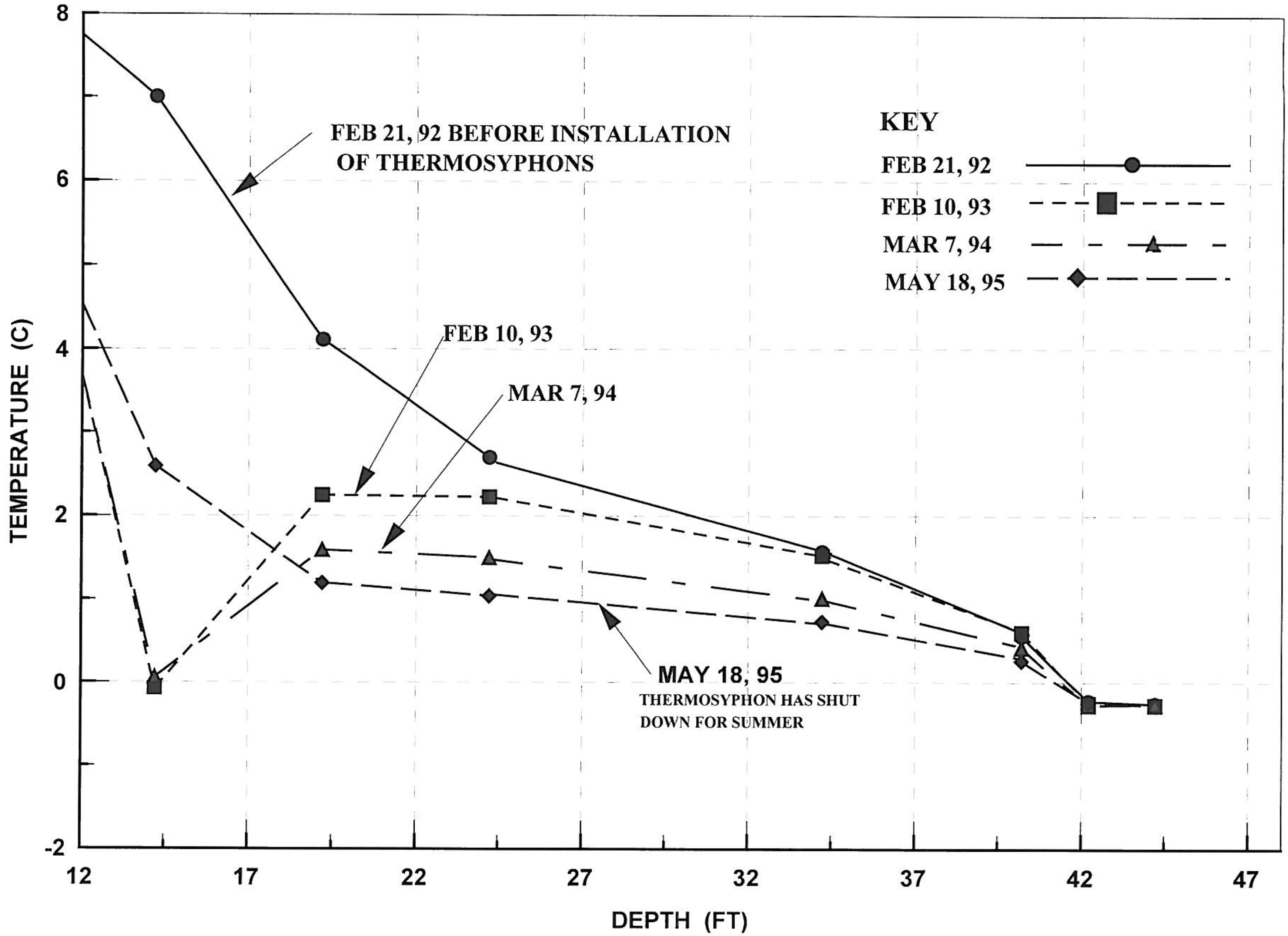

FIGURE 17 - TEMPERATURE OF THERMISTOR STRING 4 vs DEPTH

An additional thermosyphon placed between numbers 4 and 5 could bridge the wide spacing that resulted during installation and increase the cooling power. This requires that a directional drilling team be brought in to install the evaporator section of the new thermosyphon.

Another option is to increase the cooling power of the present units. The cooling power of a thermosyphon is dependent on the amount of heat that it can dissipate to the air. Increasing the amount of finned pipe in the condenser portion of the thermosyphon can increase its cooling power. Finned pipe can be increased in two ways. Lengthening the present pipes by adding additional finned sections so that they have more cooling surface exposed to the cold air and, as a result, extend higher above the roof of the house where they also can catch more wind is one option. Alternatively, a tee can be installed just below the present finned section and another section can be added so that the thermosyphon has a dual finned condenser section.

Keeping perspective, the present settlement rate is approximately two inches in seven years. At the present time there are no cracks or other evidence of any structural distress in the foundation walls. It is conceivable that another two inches could accumulate in the next seven years before it is necessary to relevel the house if minor adjustments are made to alleviate difficulties such as sticking doors etc.

The present stabilization system is operating and has reduced the settlement to a manageable rate. It could probably be upgraded to eliminate settlement altogether at a reasonable cost, but there is no immediate danger of structural damage.

One other effect of the permafrost beneath the house is that the soils have very poor drainage characteristics. The permafrost is an almost impermeable barrier below so that soil moisture must migrate away by percolating horizontally to find drainage. This results in a problem during spring breakup and during late summer if there is excessive rain. Water accumulates beneath the house and finds its way into the basement apartment during these times. This saturates the carpet in one area or another are requires the services of a professional carpet cleaner to vacuum up the water and dry the carpet. To eliminate this problem a de-watering system would have to be installed that provided drainage during these times of excess ground water from around the footings of the house to a wet sump from where is can be pumped to an acceptable drainage.

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Appendix

Bore Hole Logs

SOIL DESCRIPTION SURFACE ELEVATION:	GRAPHIC LOG	DEPTH	SAMPLE	GROUND WATER	DEPTH	PENETRATION RESISTANCE (300 LB WEIGHT, 30 IN. DROP) ▲ BLOWS PER FOOT 0 20 40
TAN TO GREY CLAYEY SILT		0–5–10	1, 2, 3, 4, 5		0, 5, 10	
DARK GREY CLAYEY SILT		15–20–25–30	6, 7, 8, 9, 10, 11, 12		15, 20, 25, 30	
GREY FINE SANDY SILT		35	13		35	

LEGEND

SILT
GRAVEL
SAND
CLAY
PEAT
ORGANIC CONTENT
FROZEN GROUND

IMPERVIOUS SEAL
WATER LEVEL
SCREENED INTERVAL
THERMISTOR
3 IN O.D. SPLIT SPOON SAMPLE
GRAB SAMPLE
3 IN. O.D. THIN-WALL SAMPLE
3 IN. O.D. DRY CORE RUN

● % WATER CONTENT

BORING LOG

NAME: 263 MADCAP LN.

LOCATION: 14'S, 4'W of N.E. CORNER

PAGE: ONE OF TWO

DATE: JUNE 1992

PERMAFROST TECHNOLOGY FOUNDATION

45X@PJL EOJ NAME = "MSJOB 7"

SOIL DESCRIPTION SURFACE ELEVATION:	GRAPHIC LOG	DEPTH	SAMPLE	GROUND WATER	DEPTH	PENETRATION RESISTANCE (300 LB WEIGHT, 30 IN. DROP) ▲ BLOWS PER FOOT 0 20 40
GREY FINE SANDY SILT		35		14	35	
				15		
		40		16	40	
ICE WITH SILT						
		45			45	
SILT						
ICE						
SILT		50			50	
BLUE GREY SILT						
DARK BROWN PEAT						
GREY SILT, Nbn, WITH SOME ICE LENSES		55			55	
ICE						
SILT, Nbn						
THAWED FINE SANDY SILT		60			60	
		65			65	
		70			70	

LEGEND

- SILT
- GRAVEL
- SAND
- CLAY
- PEAT
- ORGANIC CONTENT
- FROZEN GROUND
- IMPERVIOUS SEAL
- WATER LEVEL
- SCREENED INTERVAL
- THERMISTOR
- 3 IN O.D. SPLIT SPOON SAMPLE
- GRAB SAMPLE
- 3 IN. O.D. THIN-WALL SAMPLE
- 3 IN. O.D. DRY CORE RUN
- ● % WATER CONTENT

BORING LOG

NAME: 263 MADCAP LN.

LOCATION: 14'S., 4'W of N.E. CORNER

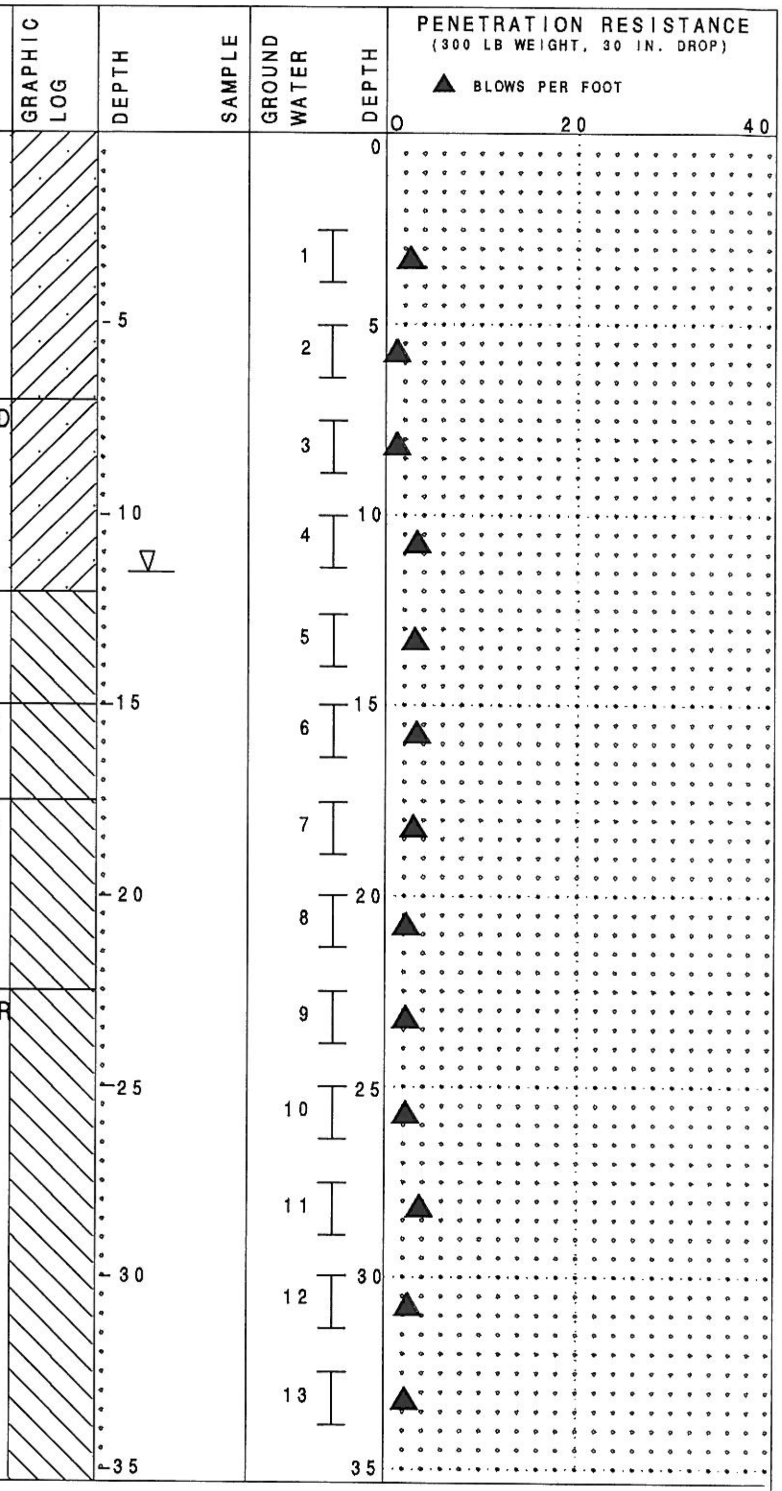
PAGE: TWO OF TWO

DATE: JUNE 1992

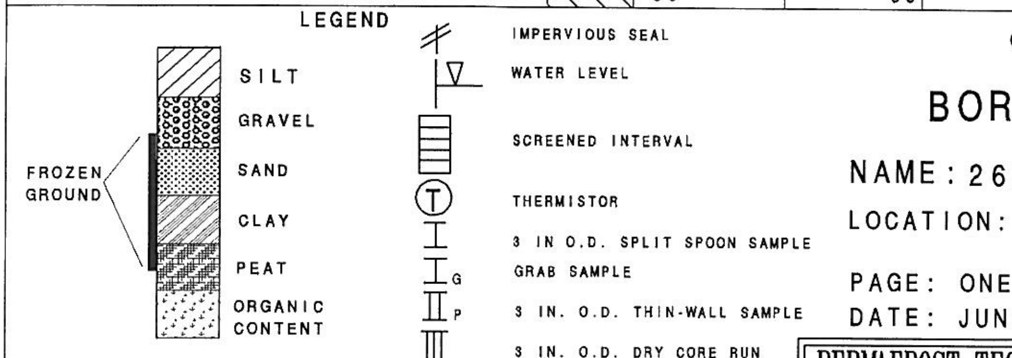
PERMAFROST TECHNOLOGY FOUNDATION

45X@PJL EOJ NAME = "MSJOB 9"

SOIL DESCRIPTION SURFACE ELEVATION:
BROWN SLTLY SANDY SILT WITH TRACE ORGANICS AND GRAVEL MOIST
BROWN SILT WITH TRACE OF SAND AND ORGANICS, VERY MOIST
GREY TO DK. GREY SILT MOTTLED, VERY MOIST
GREY SILT, SLGT ORGANIC ODOR VERY MOIST TO WET
GREY SILT, SLGT ORGANIC ODOR VERY MOIST TO WET, MEDIUM STIFF TO SOFT
GREY SILT, TRACE ORGANIC ODOR WET TO MOIST, BLACK STREAKS NEAR END. TOP V.WET, MEDIUM STIFF TO SOFT



LEGEND



BORING LOG

NAME: 263 MADCAP LN.

LOCATION: S.W. CORNER

PAGE: ONE OF TWO

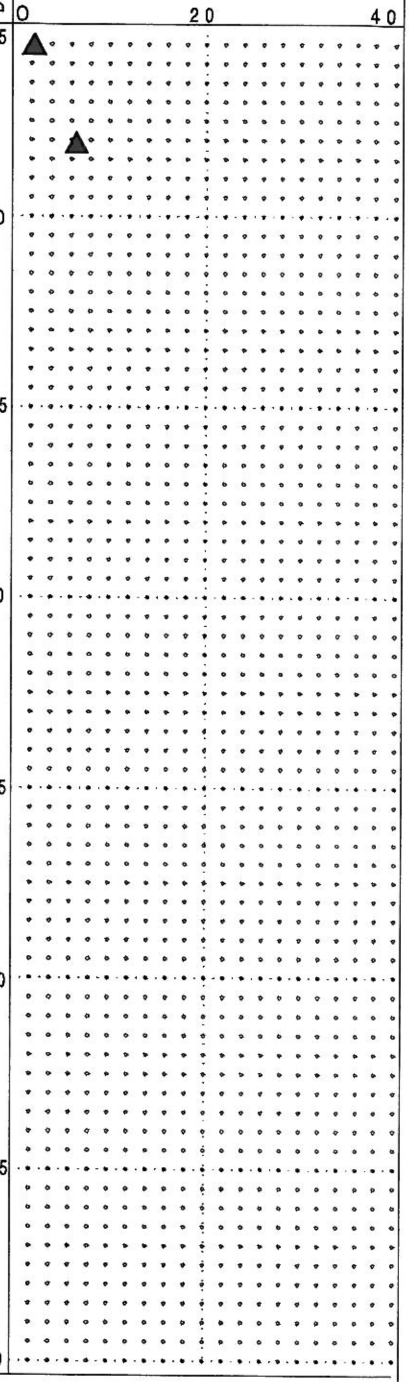
DATE: JUNE 29, 1992

PERMAFROST TECHNOLOGY FOUNDATION

SOIL DESCRIPTION SURFACE ELEVATION:	GRAPHIC LOG	DEPTH	SAMPLE	GROUND WATER	DEPTH
GREY SILT, TR. ORGANIC ODOR V.MOIST TO WET, MEDIUM STIFF TO SOFT		35		14	35
GREY SILT, STRONG ORGANIC ODOR, Nbn, VERY WET				15	
BROWN TO BLK SILT, Nbn, STRONG ORGANIC ODOR		40			40
LT BROWN ICE WITH SILT INCLUSIONS.					
		45 BOH			45
		50			50
		55			55
		60			60
		65			65
		70			70

PENETRATION RESISTANCE
(300 LB WEIGHT, 30 IN. DROP)

▲ BLOWS PER FOOT



● % WATER CONTENT

LEGEND

SILT
GRAVEL
SAND
CLAY
PEAT
ORGANIC CONTENT
FROZEN GROUND

IMPERVIOUS SEAL
WATER LEVEL
SCREENED INTERVAL
THERMISTOR
3 IN O.D. SPLIT SPOON SAMPLE
GRAB SAMPLE
3 IN. O.D. THIN-WALL SAMPLE
3 IN. O.D. DRY CORE RUN

BORING LOG

NAME: 263 MADCAP LN.
LOCATION: S.W. CORNER
PAGE: TWO OF TWO
DATE: JUNE 29, 1992

PERMAFROST TECHNOLOGY FOUNDATION

Temperature Measurements

Madcap Thermistor Temperture Log

Operator T and R McFadden
Date: 3/11/99

		String #1			String #2			String # 3	
Therm #	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)	Depth (ft)		Temp (C)
1	0		#VALUE!	0	27083	-9.619	4.2	8004	14.602
2	4		#VALUE!	2	25138	-8.239	6.2	9249	11.533
3	12		#VALUE!	6	16771	-0.527	9.2	10094	9.705
4	20		#VALUE!	10	16353	-0.033	14.2	10826	8.255
5	28		#VALUE!	18	16068	0.311	19.2	12407	5.469
6	32		#VALUE!	26	16181	0.174	24.2	15093	1.545
7	34		#NUM!	28	16286	0.047	29.2	16716	-0.463
8	36		#NUM!	30	16321	0.005	34.2	15995	0.401
9	37		#NUM!	31	16347	-0.026	39.2	16393	-0.081
10	38		#NUM!	32	16401	-0.091	44.2	16532	-0.246
11	39		#NUM!	33	16411	-0.103	45.2	16566	-0.287
12	39.5		#NUM!	33.7	16501	-0.210	46.2	16543	-0.259

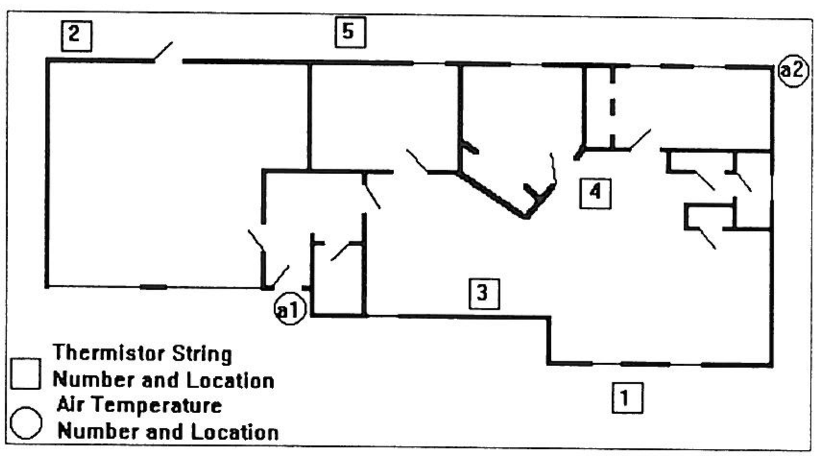
		String #4			AIR			String # 5	
Therm #	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)
1	4.2		#NUM!	A2		#NUM!	0	21238	-5.072
2	6.2		#NUM!			#NUM!	5	16343	-0.021
3	8.2		#NUM!			#NUM!	10	15547	0.960
4	10.2		#NUM!			#NUM!	20	15064	1.583
5	14.2		#NUM!			#NUM!	25	15333	1.233
6	19.2		#NUM!			#NUM!	30	15757	0.696
7	24.2		#NUM!			#NUM!	35	16195	0.157
8	34.2		#NUM!			#NUM!	38	16428	-0.123
9	40.2		#NUM!			#NUM!	39	16513	-0.224
10	42.2		#NUM!			#NUM!	40	16497	-0.205
11	43.2		#NUM!			#NUM!	41	16627	-0.358
12	44.2		#NUM!		#N/A	#N/A	41.5	16540	-0.256

MC Thermistor Temperature Log

Operator : Sara/B-O
Date : 2/5/97

	String #1			String #2			String #3		
Therm #	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)
1	0	21232	-5.067	0	22581	-6.232	4.2	7988	14.645
2	4	16484	-0.19	2	21691	-5.472	6.2	9336	11.336
3	12	12879	4.714	6	16514	-0.225	9.2	10241	9.404
4	20	13736	3.419	10	16284	0.05	14.2	10955	8.011
5	28	15223	1.375	18	15992	0.405	19.2	12467	5.371
6	32	15597	0.896	26	16148	0.214	24.2	15020	1.641
7	34	15816	0.622	28	16267	0.07	29.2	16594	-0.32
8	36	15943	0.465	30	16306	0.023	34.2	16041	0.344
9	37	16041	0.344	31	16333	-0.009	39.2	16407	-0.098
10	38	16139	0.225	32	16384	-0.07	44.2	16529	-0.243
11	39	16243	0.099	33	16400	-0.09	45.2	16556	-0.275
12	39.5	#N/A	#N/A	33.7	16488	-0.194	46.2	16555	-0.274

	String #4			AIR			String #5		
Therm #	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)
1	4.2	#N/A	#N/A	A2	#N/A	#N/A	0	21560	-5.358
2	6.2	#N/A	#N/A				5	16387	-0.074
3	8.2	#N/A	#N/A				10	15438	1.098
4	10.2	#N/A	#N/A				20	15010	1.654
5	14.2	#N/A	#N/A				25	15315	1.256
6	19.2	#N/A	#N/A				30	15770	0.679
7	24.2	#N/A	#N/A				35	16199	0.152
8	34.2	#N/A	#N/A				38	16445	-0.143
9	40.2	#N/A	#N/A				39	16527	-0.24
10	42.2	#N/A	#N/A				40	16488	-0.194
11	43.2	#N/A	#N/A				41	16604	-0.331
12	44.2	#N/A	#N/A				41.5	16535	-0.25

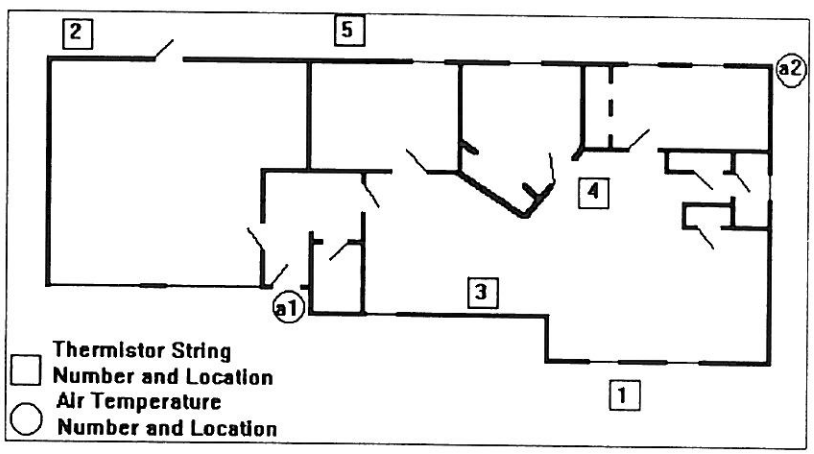


MC Thermistor Temperature Log

Operator : u
Date : 3/19/95

Therm #	String #1 Depth (ft)	String #1 R (avg)	String #1 Temp (C)	String #2 Depth (ft)	String #2 R (avg)	String #2 Temp (C)	String #3 Depth (ft)	String #3 R (avg)	String #3 Temp (C)
1	0	#N/A	#N/A	0	#N/A	#N/A	4.2	#N/A	#N/A
2	4	14774	1.968	2	23440	-6.933	6.2	9841	10.234
3	12	12691	5.011	6	16392	-0.08	9.2	10578	8.733
4	20	13568	3.666	10	16070	0.309	14.2	11221	7.518
5	28	15075	1.569	18	15603	0.889	19.2	12618	5.127
6	32	15496	1.025	26	15845	0.586	24.2	14937	1.751
7	34	15741	0.716	28	16017	0.374	29.2	16612	-0.341
8	36	15894	0.525	30	#N/A	#N/A	34.2	#N/A	#N/A
9	37	16002	0.392	31	16168	0.19	39.2	5997	20.906
10	38	16108	0.263	32	16279	0.056	44.2	16387	-0.074
11	39	#N/A	#N/A	33	#N/A	#N/A	45.2	#N/A	#N/A
12	39.5	#N/A	#N/A	33.7	#N/A	#N/A	46.2	#N/A	#N/A

Therm #	String #4 Depth (ft)	String #4 R (avg)	String #4 Temp (C)	AIR Depth (ft)	AIR R (avg)	AIR Temp (C)	String #5 Depth (ft)	String #5 R (avg)	String #5 Temp (C)
1	4.2	16529	-0.243	A2	16535	-0.25	0	16553	-0.271
2	6.2	#N/A	#N/A				5	16534	-0.249
3	8.2	8033	14.525				10	#N/A	#N/A
4	10.2	9310	11.395				20	16136	0.229
5	14.2	11999	6.148				25	15370	1.186
6	19.2	16360	-0.042				30	15226	1.371
7	24.2	15293	1.285				35	15708	0.757
8	34.2	15277	1.305				38	16191	0.162
9	40.2	15584	0.913				39	16482	-0.187
10	42.2	16040	0.346				40	16554	-0.272
11	43.2	#N/A	#N/A				41	#N/A	#N/A
12	44.2	#N/A	#N/A				41.5	#N/A	#N/A

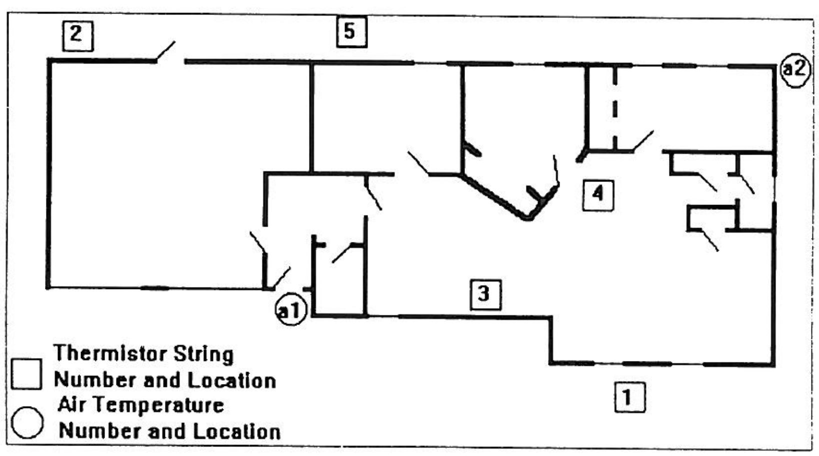


MC Thermistor Temperature Log

Operator : ma
Date : 3/7/94

	String #1			String #2			String #3		
Therm #	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)
1	0	22165	-5.881	0	24965	-8.111	4.2	8245	13.968
2	4	15270	1.314	2	23990	-7.368	6.2	9565	10.828
3	12	12510	5.301	6	16355	-0.036	9.2	10290	9.305
4	20	13405	3.908	10	15905	0.512	14.2	10900	8.115
5	28	15160	1.457	18	15420	1.121	19.2	12280	5.677
6	32	15400	1.147	26	15750	0.704	24.2	14710	2.054
7	34	15660	0.817	28	15940	0.468	29.2	16565	-0.285
8	36	15845	0.586	30	16075	0.303	34.2	15880	0.543
9	37	15960	0.444	31	16140	0.224	39.2	17655	-1.527
10	38	16075	0.303	32	16250	0.09	44.2	16530	-0.244
11	39	16220	0.127	33	16310	0.018	45.2	16590	-0.315
12	39.5	16190	0.163	33.7	16435	-0.131	46.2	16715	-0.462

	String #4			AIR			String #5		
Therm #	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)
1	4.2	6770	18.229	A2	21425	-5.239	0	19315	-3.261
2	6.2	7570	15.801				5	16050	0.333
3	8.2	8970	12.179				10	15370	1.186
4	10.2	11710	6.645				20	16580	-0.303
5	14.2	16275	0.06				25	15310	1.263
6	19.2	15060	1.588				30	15850	0.58
7	24.2	15130	1.496				35	16220	0.127
8	34.2	15510	1.007				38	16495	-0.203
9	40.2	15980	0.419				39	16570	-0.291
10	42.2	16560	-0.279				40	16515	-0.226
11	43.2	16570	-0.291				41	16585	-0.309
12	44.2	16550	-0.268				41.5	16585	-0.309

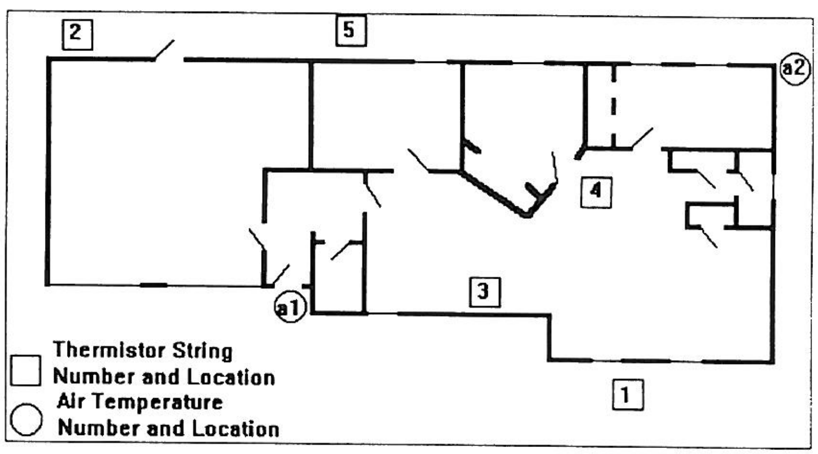


MC Thermistor Temperature Log

Operator : Eric
Date : 2/10/93

	String #1			String #2			String #3		
Therm #	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)
1	0	17915	-1.81	0	27525	-9.918	4.2	8585	13.108
2	4	14495	2.347	2	25230	-8.307	6.2	9580	10.795
3	12	12550	5.237	6	16300	0.03	9.2	10250	9.386
4	20	13260	4.127	10	15665	0.811	14.2	10840	8.228
5	28	14800	1.933	18	14970	1.707	19.2	12105	5.969
6	32	15290	1.289	26	15450	1.083	24.2	14580	2.23
7	34	15555	0.95	28	15710	0.754	29.2	16535	-0.25
8	36	15765	0.686	30	15920	0.493	34.2	15635	0.849
9	37	15890	0.53	31	16020	0.37	39.2	16315	0.012
10	38	16035	0.352	32	16170	0.187	44.2	16530	-0.244
11	39	16185	0.169	33	16260	0.078	45.2	16560	-0.279
12	39.5	16160	0.199	33.7	16410	-0.101	46.2	16525	-0.238

	String #4			AIR			String #5		
Therm #	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)
1	4.2	7000	17.499	A2	32335	-12.853	0	22070	-5.8
2	6.2	7730	15.35				5	17185	-1.002
3	8.2	9090	11.898				10	15280	1.302
4	10.2	11650	6.75				20	14380	2.505
5	14.2	16390	-0.078				25	14790	1.947
6	19.2	14570	2.244				30	15450	1.083
7	24.2	14585	2.224				35	16120	0.248
8	34.2	15110	1.523				38	16515	-0.226
9	40.2	15830	0.605				39	16560	-0.279
10	42.2	16540	-0.256				40	16515	-0.226
11	43.2	16570	-0.291				41	16590	-0.315
12	44.2	16560	-0.279				41.5	16530	-0.244



MC Thermistor Temperature Log

Operator : Yuan
Date : 1/2/92

	String #1			String #2			String #3		
Therm #	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)	Depth (ft)	R (avg)	Temp (C)
1	0	21759.45	-5.532	0	29536	-11.21	4.2	6848	17.979
2	4	15280.95	1.3	2	20693.4	-4.579	6.2	7500.95	15.999
3	12	12563.35	5.215	6	15034.1	1.622	9.2	8862.2	12.434
4	20	13383.45	3.94	10	14066	2.945	14.2	11006.9	7.914
5	28	14732	2.024	18	14296.2	2.621	19.2	11599.25	6.839
6	32	15241.2	1.352	26	15488.1	1.035	24.2	13377.05	3.95
7	34	15533.1	0.977	28	15820.1	0.617	29.2	14274.95	2.651
8	36	15763.85	0.687	30	16055.2	0.327	34.2	15081.7	1.56
9	37	15910.25	0.505	31	16168.9	0.189	39.2	15865.05	0.561
10	38	16050.05	0.333	32	16307.1	0.022	44.2	16511.15	-0.222
11	39	16219.35	0.128	33	16395.5	-0.084	45.2	16548.3	-0.266
12	39.5	16203.65	0.146	33.7	16511	-0.221	46.2	16533.55	-0.248

	String #4		
Therm #	Depth (ft)	R (avg)	Temp (C)
1	4.2	8149.75	14.216
2	6.2	9142.75	11.776
3	8.2	9948.25	10.007
4	10.2	10635.05	8.622
5	14.2	11508.55	6.999
6	19.2	12832.9	4.786
7	24.2	13861.2	3.238
8	34.2	15471.7	1.055
9	40.2	16317	0.01
10	42.2	16506.25	-0.216
11	43.2	16521.4	-0.234
12	44.2	16508.55	-0.219

Level Measurements

Madcap Level Data
Operator:

	Previous Elevation	New reading	New Elevation	Elevation Difference
Date	12/12/96	3/8/99	3/8/99	3/8/99
A (1)	0	594	0	0
B (1)	5	595	1	-4
C (1)	11	598	4	-7
D(1)	26	623	29	3
E (1)	27	610	16	-11
F (1)	48	635	41	-7
G (1)	53	650	56	3
H (1)	49	648	54	5
I (1)	40	644	50	10
J (1)	31	630	36	5
K (1)	37	645	51	14
L (1)	59	665	71	12
M (1)	43	648	54	11
N (1)	44	646	52	8
O (1)	49	653	59	10
P (1)	35	635	41	6
Q (1)	26	627	33	7
R (1)	10	603	9	-1
S (1)	3	597	3	0
Q(2)**	\	585	\	\
T (2)	63	638	86	23
U (2)	59	634	82	23
V (2)	60	625	73	13
W (2)	67	631	79	12
TP (2)	619	1186	634	15
Q (3)**	\	626	\	\
X (3)	39	652	59	20
Y(3)	49	660	67	18
Z (3)	48	656	63	15
AA (3)	47	653	60	13
AB (3)	25	624	31	6
AC (3)	27	630	37	10
A (4)**	\	624	\	\
AD (4)	4	634	10	6
AE (4)	12	641	17	5
AF (4)	11	632	8	-3
AG (4)	2	628	4	2
AH (4)	-2	621	-3	-1
B (5)**	\	621	\	\
AI (5)	4	620	0	-4

	Previous Elevation	New reading	New Elevation	Elevation Difference
Date	12/12/96	3/8/99	3/8/99	3/8/99
AJ (5)	7	626	6	-1
AK (5)	24	641	21	-3
AL (5)	33	643	23	-10
AM (5)	32	NA	#VALUE!	#VALUE!
AN (5)	27	638	18	-9
AO (5)	15	638	18	3
AP (5)	11	624	4	-7
A (6)	\	617	\	\
AQ (6)	25	634	17	-8
AR (6)	20	630	13	-7

GA (7)	0	538	0	0
GB (7)	22	563	25	3
GC (7)	37	585	47	10
GD (7)	58	617	79	21
GE (7)	62	612	74	12
GF (7)	81	644	106	25
GG (7)	99	665	127	28
GH (7)	91	654	116	25
GI (7)	20	583	45	25
GJ (7)	41	584	46	5

TP (8)	\		\	
GJ (8)	\		\	
BM (8)***	1627		#VALUE!	#VALUE!
BMG (8)***	410	\	#VALUE!	#VALUE!

A(1)-A(4)	-30
A(1)-A(6)	-23
B(1)-B(5)	-26
Q(1)-Q(2)	42
Q(1)-Q(3)	1
TP(2)-TP(8)	#VALUE!
M8)-TP(8)	#VALUE!
GJ(7)-GJ(8)	#VALUE!

Madcap Level Data
Operator : sara/b-o

	Previous Elevation	New Reading	New Elevation	Elevation Difference
Date	10/17/96	12/12/96	12/12/96	(mm)
A (1)*	0	357	0	0
B (1)	5	362	5	0
C (1)	10	368	11	1
D (1)	25	383	26	1
E (1)	26	384	27	1
F (1)	48	405	48	0
G (1)	51	410	53	2
H (1)	47	406	49	2
I (1)	40	397	40	0
J (1)	28	388	31	3
K (1)	34	394	37	3
L (1)	54	416	59	5
M (1)	43	400	43	0
N (1)	41	401	44	3
O (1)	47	406	49	2
P (1)	34	392	35	1
Q (1)	24	383	26	2
R (1)	7	367	10	3
S (1)	2	360	3	1
Q (2)**	\	329	\	\
T (2)	65	366	63	-2
U (2)	64	362	59	-5
V (2)	57	363	60	3
W (2)	64	370	67	3
TP (2)	615	922	619	4
Q (3)**	\	339	\	\
X (3)	49	352	39	-10
Y (3)	50	362	49	-1
Z (3)	48	361	48	0
AA (3)	45	360	47	2
AB (3)	25	338	25	0
AC (3)	29	340	27	-2
A (4)**	\	337	\	\
AD (4)	2	341	4	2
AE (4)	10	349	12	2
AF (4)	9	348	11	2
AG (4)	1	339	2	1
AH (4)	-3	335	-2	1
B (5)**	\	333	\	\
AI (5)	5	332	4	-1

	Previous Elevation	New Reading	New Elevation	Elevation Difference
AJ (5)	8	335	7	-1
AK (5)	25	352	24	-1
AL (5)	32	361	33	1
AM (5)	34	360	32	-2
AN (5)	28	355	27	-1
AO (5)	18	343	15	-3
AP (5)	11	339	11	0
A (6)**	\	335	\	\
AQ (6)	26	360	25	-1
AR (6)	19	355	20	1

GA (7)*	0	298	0	0
GB (7)	23	320	22	-1
GC (7)	38	335	37	-1
GD (7)	52	356	58	6
GE (7)	60	360	62	2
GF (7)	76	379	81	5
GG (7)	103	397	99	-4
GH (7)	91	389	91	0
GI (7)	23	318	20	-3
GJ (7)	40	339	41	1

TP (8)	\	97	\	\
GJ (8)	\	833	\	\
BM (8)***	1591	1202	1627	36
BMG (8)***	420	\	410	-10

A(1) - A(4)=	20
A(1) - A(6)=	22
B(1) - B(5)=	29
Q(1) - Q(2)=	54
Q(1) - Q(3)=	44
TP(2) - TP(8)=	825
M(8) - TP(8)=	1105
GJ(7) - GJ(8)=	-494

* Points "A (1)" &"GA (7)" should be the first points measured in the house & the garage, respectively. These points then become tha datums from which all other points are referenced.

** Points "A", "B" and "Q" are the common points used to correlate data from all points to point "A (1)".

*** BM (8) and BMG (8) are the elevations of the benchmark with respect to points A (1) and GA (7), respectively.

Note : The garage level measurements are independent of those within the house.

Madcap Level Data
Operator : sandy,ma

	Previous Elevation	New Reading	New Elevation	Elevation Difference
Date	11/12/93	12/23/93	12/23/93	(mm)
A (1)*	0	450	0	0
B (1)	11	462	12	1
C (1)	18	467	17	-1
D (1)	20	469	19	-1
E (1)	25	475	25	0
F (1)	47	497	47	0
G (1)	52	508	58	6
H (1)	47	500	50	3
I (1)	37	490	40	3
J (1)	29	478	28	-1
K (1)	36	483	33	-3
L (1)	44	497	47	3
M (1)	30	483	33	3
N (1)	32	483	33	1
O (1)	37	487	37	0
P (1)	25	476	26	1
Q (1)	20	470	20	0
R (1)	4	455	5	1
S (1)	0	452	2	2
Q (2)**	\	435	\	\
T (2)	42	452	37	-5
U (2)	41	453	38	-3
V (2)	35	448	33	-2
W (2)	33	453	38	5
TP (2)	591	1003	588	-3
Q (3)**	\	446	\	\
X (3)	37	462	36	-1
Y (3)	39	467	41	2
Z (3)	37	462	36	-1
AA (3)	35	462	36	1
AB (3)	20	448	22	2
AC (3)	24	452	26	2
A (4)**	\	457	\	\
AD (4)	3	462	5	2
AE (4)	23	471	14	-9
AF (4)	10	470	13	3
AG (4)	8	465	8	0
AH (4)	1	458	1	0
B (5)**	\	460	\	\
AI (5)	8	455	7	-1

	Previous Elevation	New Reading	New Elevation	Elevation Difference
AJ (5)	13	459	11	-2
AK (5)	33	482	34	1
AL (5)	44	491	43	-1
AM (5)	43	492	44	1
AN (5)	42	497	49	7
AO (5)	35	479	31	-4
AP (5)	19	468	20	1
A (6)**	\	465	\	\
AQ (6)	27	491	26	-1
AR (6)	17	483	18	1

GA (7)*	0	408	0	0
GB (7)	17	430	22	5
GC (7)	30	440	32	2
GD (7)	42	449	41	-1
GE (7)	50	456	48	-2
GF (7)	56	475	67	11
GG (7)	81	495	87	6
GH (7)	80	487	79	-1
GI (7)	32	438	30	-2
GJ (7)	33	442	34	1

TP (8)	\	217	\	\
GJ (8)	\	951	\	\
BM (8)***	1304	1314	1468	164
BMG (8)***	391	\	397	6

A(1) - A(4)=	-7
A(1) - A(6)=	-15
B(1) - B(5)=	2
Q(1) - Q(2)=	35
Q(1) - Q(3)=	24
TP(2) - TP(8)=	786
BM(8) - TP(8)=	1097
GJ(7) - GJ(8)=	-509

* Points "A (1)" &"GA (7)" should be the first points measured in the house & the garage, respectively. These points then become tha datums from which all other points are referenced.

** Points "A", "B" and "Q" are the common points used to correlate data from all points to point "A (1)".

*** BM (8) and BMG (8) are the elevations of the benchmark with respect to points A (1) and GA (7), respectively.

Note : The garage level measurements are independent of those within the house.

Madcap Level Data

Operator : DLB, Mark

	Previous Elevation^1	New Reading	New Elevation	Elevation Difference
Date	6/24/91		12/3/91	
A (1)*	0		0	0
B (1)	N/A		12	N/A
C (1)	61		15	-46
D (1)	32		32	0
E (1)	36		37	1
F (1)	56		60	4
G (1)	102		55	-47
H (1)	94		47	-47
I (1)	81		36	-45
J (1)	22		26	4
K (1)	33		28	-5
L (1)	N/A		40	N/A
M (1)	N/A		33	N/A
N (1)	N/A		27	N/A
O (1)	N/A		34	N/A
P (1)	N/A		24	N/A
Q (1)	N/A		17	N/A
R (1)	N/A		2	N/A
S (1)	N/A		0	N/A
Q (2)**	\		\	\
T (2)	46		45	-1
U (2)	45		47	2
V (2)	39		42	3
W (2)	N/A		39	N/A
Q (3)**	\		\	\
X (3)	N/A		33	N/A
Y (3)	37		36	-1
Z (3)	36		34	-2
AA (3)	N/A		30	N/A
AB (3)	18		19	1
AC (3)	N/A		23	N/A
A (4)**	\		\	\
AD (4)	12		5	-7
AE (4)	16		13	-3
AF (4)	11		9	-2
AG (4)	N/A		5	N/A
AH (4)	-3		-2	1
B (5)**	\		\	\
AI (5)	N/A		7	N/A

	Previous Elevation	New Reading	New Elevation	Elevation Difference
AJ (5)	56		10	-46
AK (5)	73		29	-44
AL (5)	86		36	-50
AM (5)	87		33	-54
AN (5)	80		26	-54
AO (5)	N/A		N/A	N/A
AP (5)	72		N/A	N/A
A (6)**	\		\	\
AQ (6)	N/A		N/A	N/A
AR (6)	N/A		N/A	N/A

GA*	0		0	0
GB	9		8	-1
GC	21		23	2
GD	27		29	2
GE	29		40	11
GF	41		40	-1
GG	68		71	3
GH	65		68	3
GI	26		15	-11

A(1) - A(4)= 0
A(1) - A(6)= 0
B(1) - B(5)= 0
Q(1) - Q(2)= 0
Q(1) - Q(3)= 0

* Points "A (1)" &"GA" should be the first points measured in the house & the garage, respectively. These points then become tha datums from which all other points are referenced.

** Points "A", "B" and "Q" are the common points used to correlate data from all points to point "A (1)".

Note : The garage level measurements are independent of those within the house.

Engineering Reports

ARCTIC FOUNDATIONS, INC.

March 25, 1999

Permafrost Technology Foundation
Attn: Terry McFadden
3875 Geist Road # E-275
Fairbanks, AK 99709

Re: Thermoprobe Installations on Madcap Lane, Fairbanks, AK

Temperatures and pressure were checked on Wednesday, 17 March 1999 between 13:45 –15:00. Contact temperatures were taken with a WAHL Model 392M platinum contact thermometer. Pressure was taken with a PSI TRONIX digital 600 psi absolute pressure gage. Measurements were taken on the shady side of all probes below the bottom of the fins. Air temperature was increasing during the period of test.

Measurement Location	Contact Temp (°F)	CO2 Pressure (psi)	CO2 Temp (°F)
Beginning Air temp	17.2	-	-
Probe 1	23.0	475.5	27.9
Probe 2	24.1	478.8	28.3
Probe 3	25.3	484.2	29.1
Probe 4	25.8	481.1	28.7
Probe 5	25.5	483.8	29.6
Probe 6	25.0	485.4	29.3
Ending Air temp	19.8		

The capacity of existing units can be increased by tilting radiators to increase airflow through the fins in this area of very dead air. Total heat extraction can also be increased by adding a condenser to the opposite end of the evaporators, by enlarging the existing radiator or by installing additional units.

Sincerely,

Erwin L. Long P.E.
President

5621 Arctic Boulevard • Anchorage, Alaska 99518-1667
Phone: (907) 562-2741 • Fax: (907) 562-0153 • Internet: arcfnd@alaska.net

STUTZMANN ENGINEERING ASSOC., INC.
P.O. BOX 1429
FAIRBANKS, ALASKA 99707
(907) 452-4094

April 16, 1991

Alaskan Home Properties
1246 Log Cabin Court
Fairbanks, Alaska 99701

Attn: Ron Price

Re: AHFC #32310(Dennis)
MBS - No Pool; WA #93070
263 Madcap Lane
Fairbanks, Alaska 99701

Gentlemen:

As per your request an onsite inspection of the above referenced structure was performed on April 15, 1991. This report addresses the findings of that inspection and includes some recommendations for the repair of those discrepancies found.

EXISTING CONDITIONS

The existing structure is a single story, wood framed dwelling constructed upon a daylight basement foundation. A two car garage is attached to the south side of the dwelling and an apartment unit is contained within a portion of the basement area.

The upper level contains approximately 1290 square feet (sq. ft.) of living area and is comprised of three bedrooms, two full baths, kitchen-dining room, a large livingroom and an entry area. The basement level contains approximately 1215 sq. ft. of total area. The apartment unit comprises approximately 600 sq. ft. of the basement area and contains one bedroom, kitchen-dining-living room area and a full bath. The remainder of the basement is unfinished open area with the exception of a storage room.

The foundation of the dwelling portion of the structure consists of a 6 course high block foundation wall. The above grade portion of the basement walls are of standard wood frame construction. The foundation of the garage portion of the structure is not known. Concrete sidewalks are present on all sides of this portion of the building prohibiting excavation to determine footing burial depth.

The roof of the entire structure is of gable design and of on site construction with 2" x 6" top chord members. It is surfaced on the exterior with 3-tab composition shingles. The ceiling is insulated with a combination of fiberglass batt and rigid fiberboard insulation. The combined thickness varies depending on location of measurement.

The exterior walls of the dwelling are of 2" x 4" construction and are insulated with fiberglass insulation. An interior polyethylene vapor barrier was found in all areas investigated.

DISCREPANCIES FOUND AND RECOMMENDED SOLUTIONS

Item #1: This property is located within an area of known permafrost. As of this date, soil borings have not been drilled to more accurately determine the underlying soils. As per the "Soil Survey of the Fairbanks Area Alaska", U.S.D.A., Soil Conservation Service, Series 1959, No. 25, September 1963, this property is underlain by soils of the Minto series. This soil series consists of nearly level to moderately sloping, moderately well drained soils that have developed in micaceous silty material. This material is many feet thick over bedrock. Many areas of Minto soils are underlain at depths of 6 feet, or more, by irregular and discontinuous masses of ice. After clearing, soil subsidence may result due to the thawing of this underlying ice. Numerous houses within this subdivision do indicate past settlement.

Elevation readings were taken within the structure to determine if differential settlement of the dwelling has occurred. These readings were taken within the basement, upper floor and garage areas. The following elevation differentials were recorded: basement floor, 2.4"; upper floor, 2"; garage floor, 2.5". It is not uncommon to find an elevation differential of 3/4" - 1" within a dwelling of this size. Differentials in excess of 2" though are somewhat excessive and possible causes should be investigated. Within the dwelling there are also other indications of differential movement. These include, some sheetrock cracking (not excessive) and doors which do not close, stick or have unequal clearances around their perimeter.

The elevation differences are not readily noticeable without the use of an instrument and the structure is quite serviceable as existing. I do recommend however that soils borings be performed to more accurately determine the existing underlying soils and a possible cause of the existing elevation differences.

Item #2: Inspection of the basement area revealed that approximately the center 1/2 of the basement floor surface is covered with water. The maximum water depth is approximately 1/2" in the center of the basement. Much of the carpet located in the apartment living room, hallway and bedroom area is saturated.

The actual entry point of the water was not found but the water appears to be coming into the basement from along the base of the west foundation wall and the southwest corner of the basement open area. This portion of the foundation is on the Farmers Loop Road side of the structure and a general inspection of the exterior surface drainage indicates that poor drainage away from the building maybe the cause of the water problem.

The ground on this side of the structure does not appear to slope away from the building. Drainage would be virtually impossible in accurately determine at this time due to the existing 4' of snow cover.

Presently there is an existing concrete sidewalk along and adjacent to the entire west side of the structure. It appears that the top of this sidewalk is slightly higher than the existing block foundation wall of the basement area. This leads me to believe that the sidewalk was added to raise the grade next to the foundation and to improve the drainage away from the building. Water may now be piping under the concrete walk and down along the exterior of the foundation wall until reaching an entry point into the basement area.

A more accurate analysis of the exterior surface drainage on the west and north sides of the structure should be made after the snow cover is gone. It is recommended that the ground slope away from the foundation at a rate of 5% for 10 feet minimum. Swales should then be constructed to rid the site of water. It is also recommended that the exterior ground surface be no closer than 6" below the bottom of non preservative treated wood members. As previously mentioned the existing sidewalk in this area appears to be slightly higher than the existing block foundation wall.

The installation of waterproofing material on the exterior of the block foundation wall may also be necessary if drainage alone does not solve the problem.

Item #3: Investigation within the basement area also revealed that the existing block foundation wall is leaning inwards at a slope of approximately 3/8" in 24" in areas. This is most noticeable in the open portion of the basement. The foundation wall appears to be quite solid and no noticeable cracks or failures were found. Approximately 1/2 of the foundation wall is finished due to the apartment area. This portion of the block foundation wall was not investigated.

These walls may have been pushed inward due to the freezing and expansion of the wet perimeter soils surrounding the foundation. In our opinion, improvement of the exterior surface drainage to allow these soils to somewhat dry should reduce the possibility of any further deflection occurring.

The existing foundation wall deflection does not appear to be a serious threat to the structural integrity of the structure and if halted at this time, no additional repairs would be expected.

Item #4: Investigation of the roof areas revealed that the existing roofs are of gable design and onsite construction. An indepth inspection and analysis of these areas was not performed. Past experience has indicated that adequate onsite inspection and structural analysis is virtually impossible on roofs of this nature. The nailing techniques, type and number of nails used at all connections, quality and condition of wood used are some of the unknowns. Past analysis of onsite constructed roofs has indicated that virtually all are inadequate to support design loading conditions. Analysis of this roof would be expected to be similar.

This structure was constructed in 1969, as per the Fairbanks North Star Borough records. The roof has functioned adequately for the past 22 years. It is not known if snow was periodically removed from the roof during that time to prevent overloading.

In our opinion, since this roof has functioned adequately for this period of time we would expect it to continue to do so. We therefore recommend that excessive snow be removed from the roof as necessary to prevent overloading of the existing roof members.

Item #5: Inspection within the basement area revealed that the center support beam for the upper level floor is comprised of three 2" x 10" members. This beam is currently spanning over 12 1/2 feet in the unfinished portion of the basement and is the sole support of the center 1/2 of the floor in this area. The remaining beam span in the unfinished area has a portion of its floor loading supported by the storage room perimeter wall.

The existing 12 1/2 foot beam span is excessive for the existing beam construction and design loading conditions. We therefore recommend that an additional support post be installed at the midpoint of the existing long span in the unfinished open portion of the basement. A 6" x 6", DF #2, or better, or steel support column capable of supporting a 5000 pound load should be installed. The column should be fastened to the existing beam and pinned to the floor surface to prevent lateral movement. The sag should be removed from the beam during this installation.

Item #6: Inspection within the basement apartment area revealed water staining and sheetrock damage on the ceiling of the hallway and bathroom areas. Within the bathroom some minor rotting of the floor joists and center floor support beam was also found. This rotting did not appear to be excessively bad and additional support of the floor joist members is provided for by the basement interior partition walls. The center support beam is therefore not as critical in this area.

This staining and rotting does indicate a possible long term leak and should be investigated to prevent additional damage to the structure. If the rotting is more serious than anticipated some repair of structural members may be necessary.

Item #7: Inspection within all bedroom areas reveal that all existing bedroom windows do not meet the currently accepted egress standards. Replacement of these windows may be necessary.

Item #8: There are existing galvanized metal gutters installed at most eave locations. These gutters appear to be functioning adequately in most areas but repair is necessary at some locations. Many downspouts are also missing and new ones should be installed to help route the roof runoff farther away from the foundation.

We recommend that the existing gutters be repaired as necessary and that new downspouts, elbows and splashblocks be installed as necessary.

Photos are included with this report.

All of the above construction shall conform to standard practice and the Uniform Building Code.

Our recommendations are based on problems which were readily apparent during the inspection. This report is meant to address only those concerns specifically mentioned herein and does not address the adequacy of the structure as a whole. Construction methods identified in one particular area have been assumed to be representative of like portions of the building. Hidden structural defects or deficiencies which may exist, but have not manifested themselves through some movement or failure, were likely to not have been identified with the inspection.

If the contractor encounters more structural problems during construction, he should contact us for our recommendations. It is assumed the contractor will be knowledgeable enough to perform his duties in a proper manner and be capable of identifying other possible deficiencies if they are revealed during construction.

Prior to commencing work, the contractor should contact us to set up an inspection schedule. It is the responsibility of the contractor to contact us as work progresses, so that we can inspect items being repaired. Repairs should not be covered before inspection.

If you have any questions regarding this report, please contact our office.

Sincerely,

STUTZMANN ENGINEERING ASSOC., INC.

James H. Altherr, C.E.
75-RP

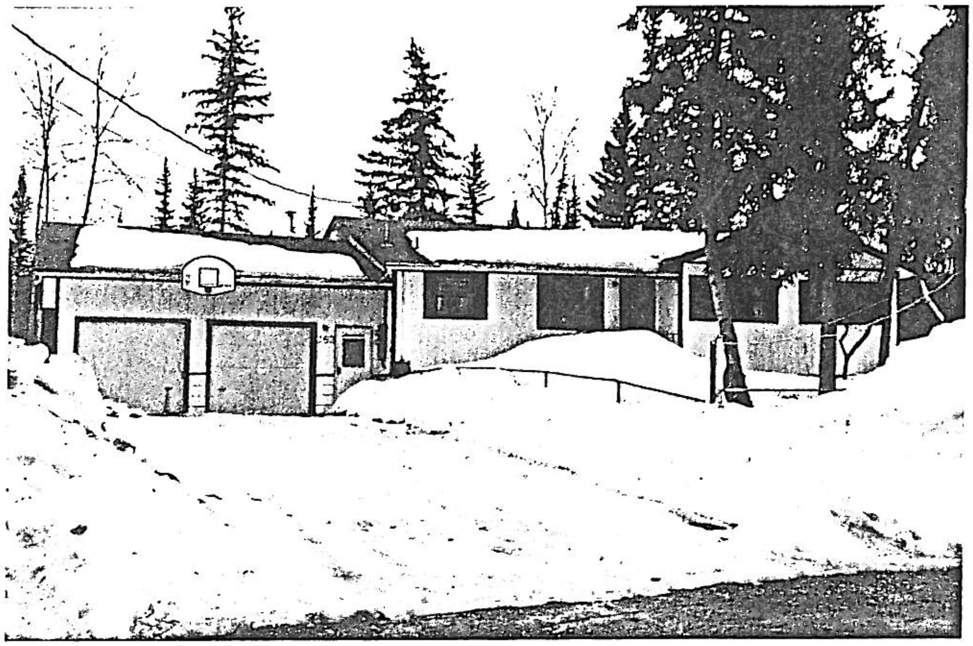


PHOTO #1: THE FRONT OF THE HOUSE LOCATED AT 263 MADCAP LANE.

PHOTO #2: THE FRONT OF THE HOUSE.

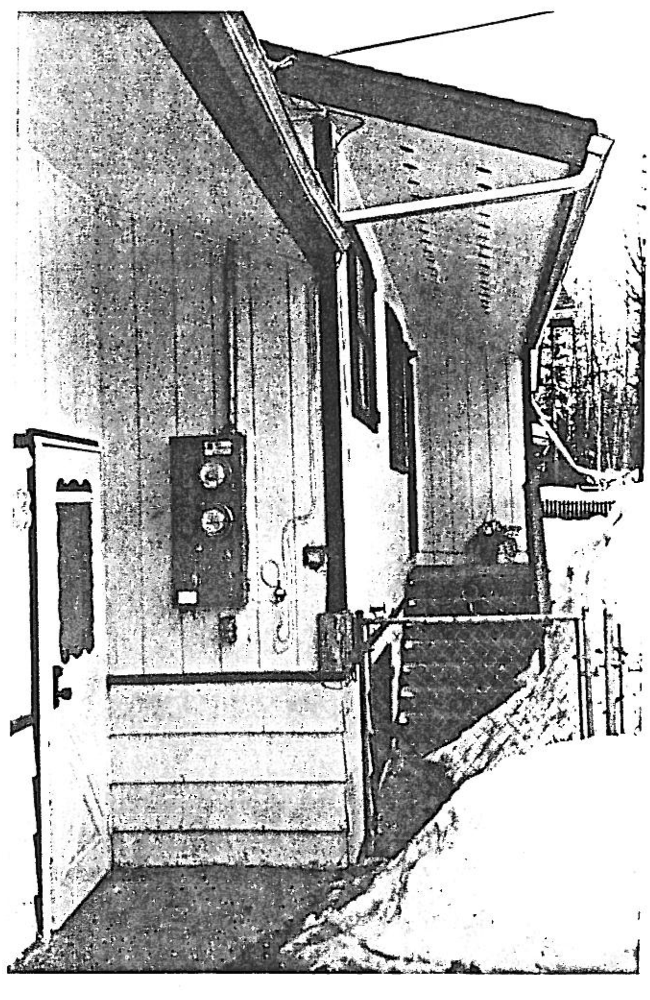
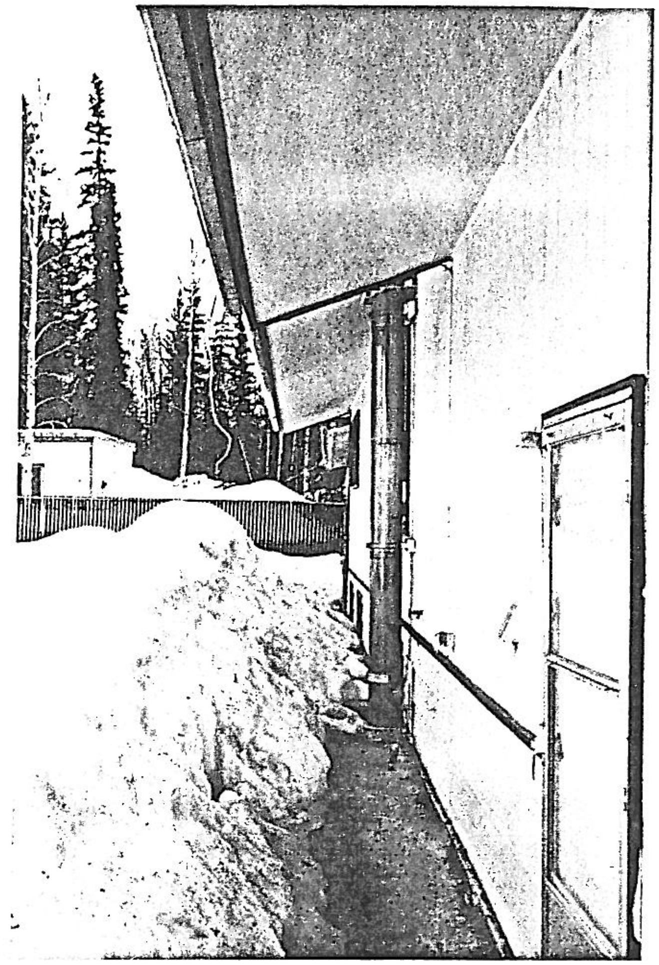


PHOTO #3: THE BACK
OF THE HOUSE, DOOR
AT RIGHT IS TO GARAGE.



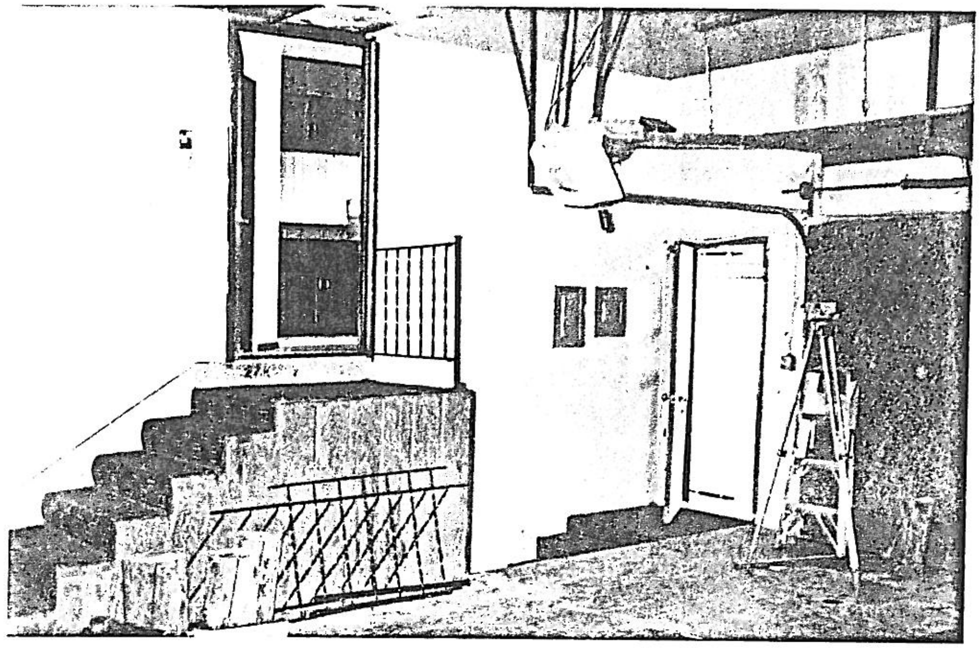


PHOTO #4: GARAGE AREA; ENTRY DOOR IS AT RIGHT WITH STAIRWAY TO BASEMENT, DOORWAY TO FIRST FLOOR IS AT UPPER LEFT.

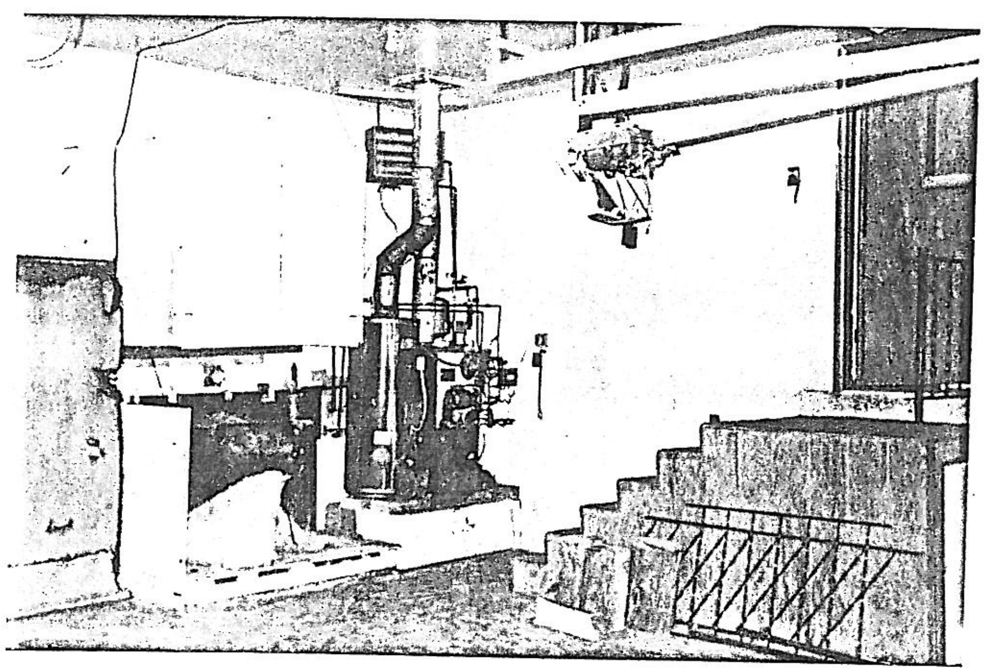


PHOTO #5: GARAGE AREA; FURNACE AND HOT WATER HEATER, BACK EXIT DOOR IS BEHIND CARPET AT LEFT.

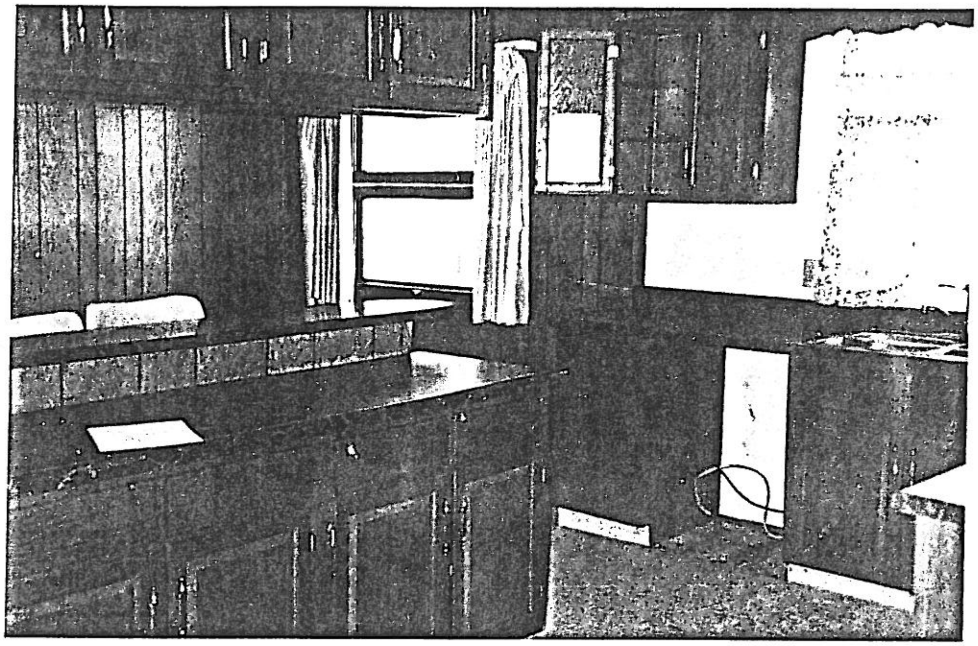


PHOTO #6: THE FIRST FLOOR KITCHEN AND DINING ROOM.

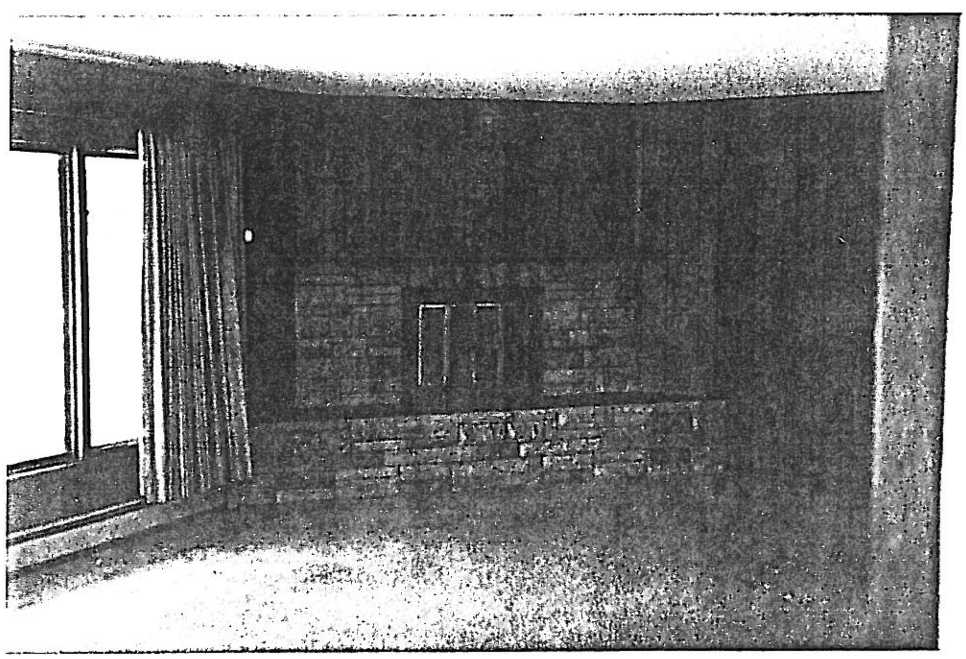


PHOTO #7: THE FIRST FLOOR LIVING ROOM.

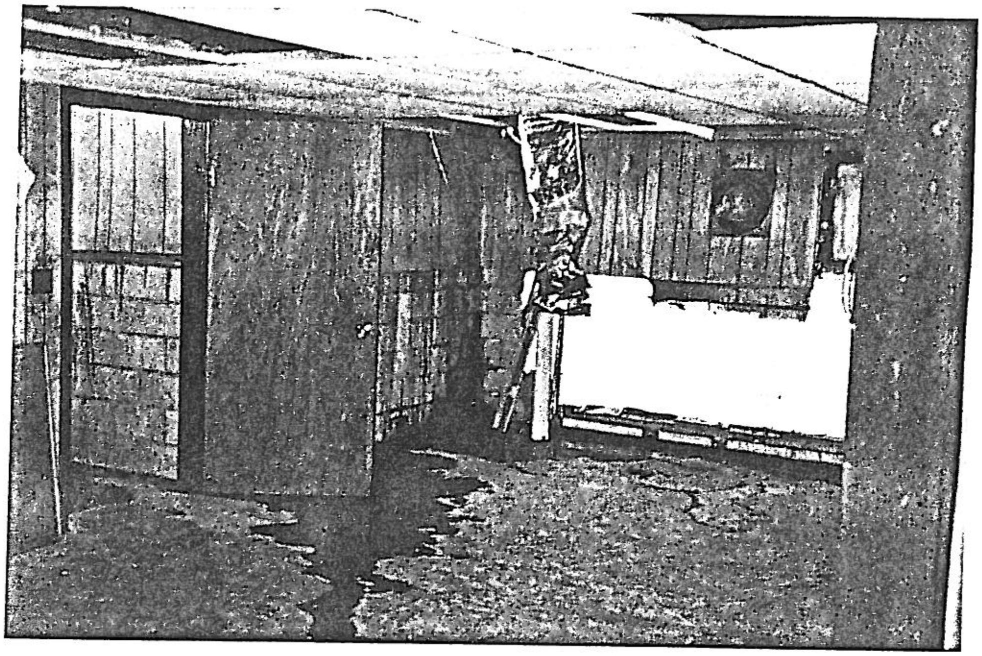


PHOTO #8: BASEMENT AREA; THE UNFINISHED PORTION ACCESS DOOR IS AT LEFT, POSSIBLE POINT OF WATER ENTRY IS AT THE FAR CORNER OF THE BLOCK FOUNDATION WALL.

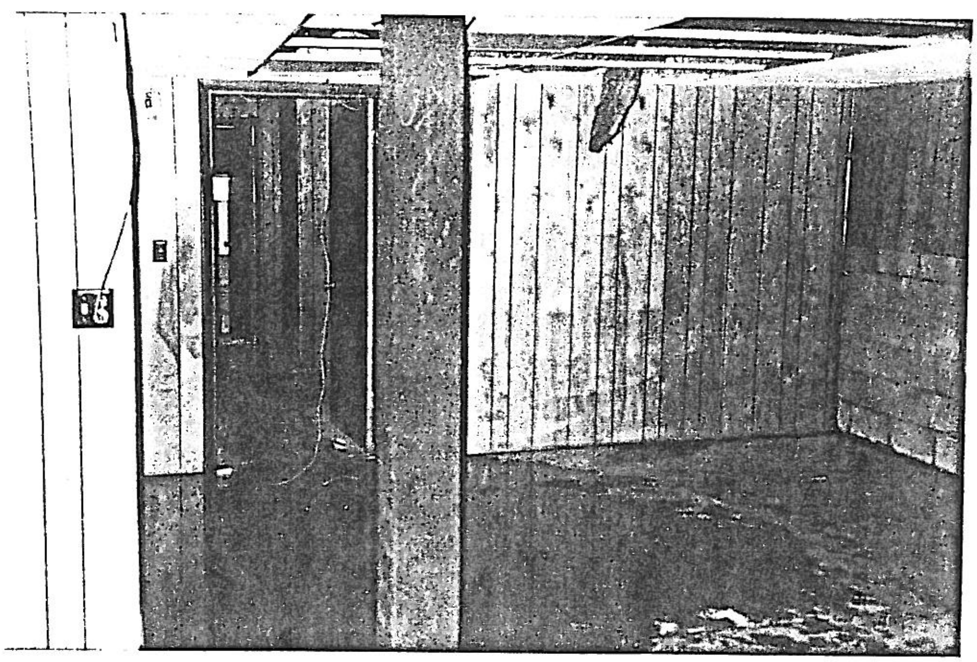


PHOTO #9: BASEMENT AREA; DOORWAY IN BACKGROUND IS TO THE APARTMENT UNIT, STANDING WATER ON FLOOR SURFACE, PHOTO TAKEN FROM ENTRY DOOR TO BASEMENT.

PHOTO #10: BASEMENT APARTMENT; KITCHEN AREA, PHOTO TAKEN FROM THE LIVING ROOM AREA.

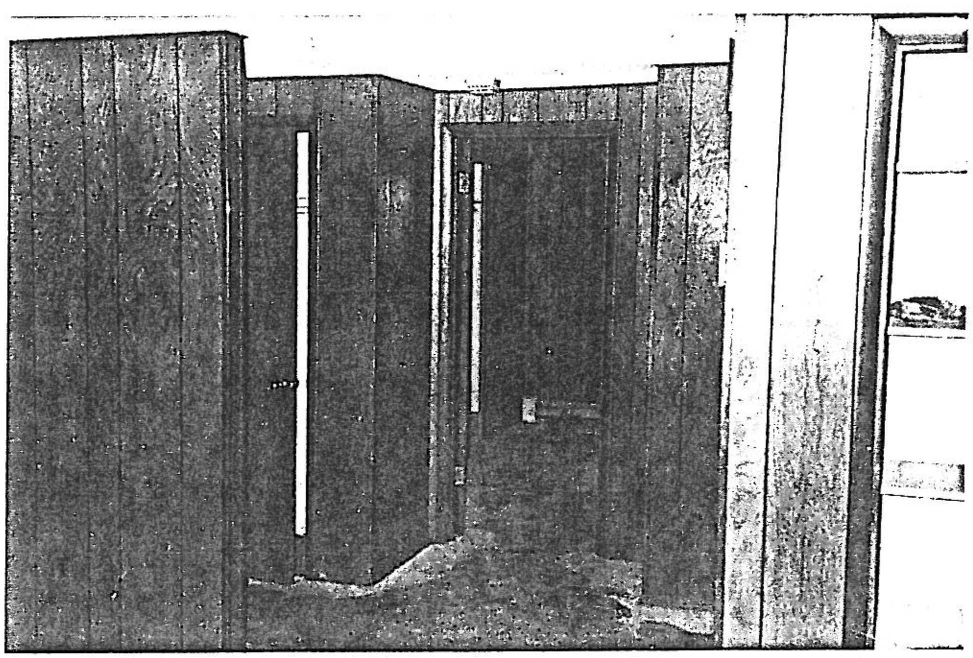


PHOTO #11: BASEMENT APARTMENT; HALLWAY AND BEDROOM AREA, CARPET IS WATER SOAKED IN THESE AREAS. PHOTO TAKEN FROM LIVING ROOM AREA.

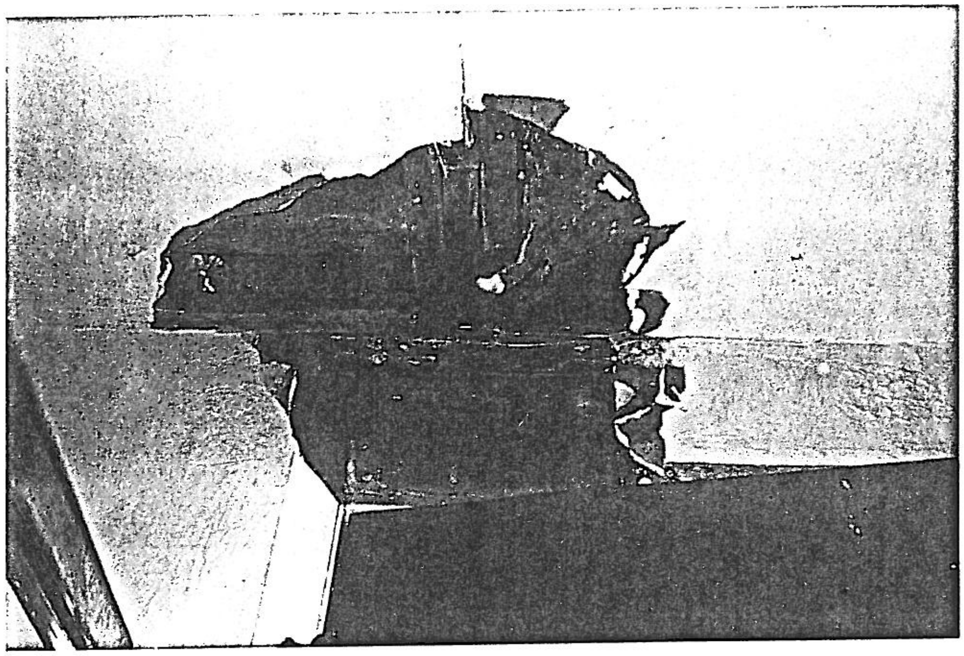


PHOTO #12: BASEMENT BATHROOM; THE EXISTING WATER DAMAGE AND ROTTING ON THE BATHROOM CEILING.

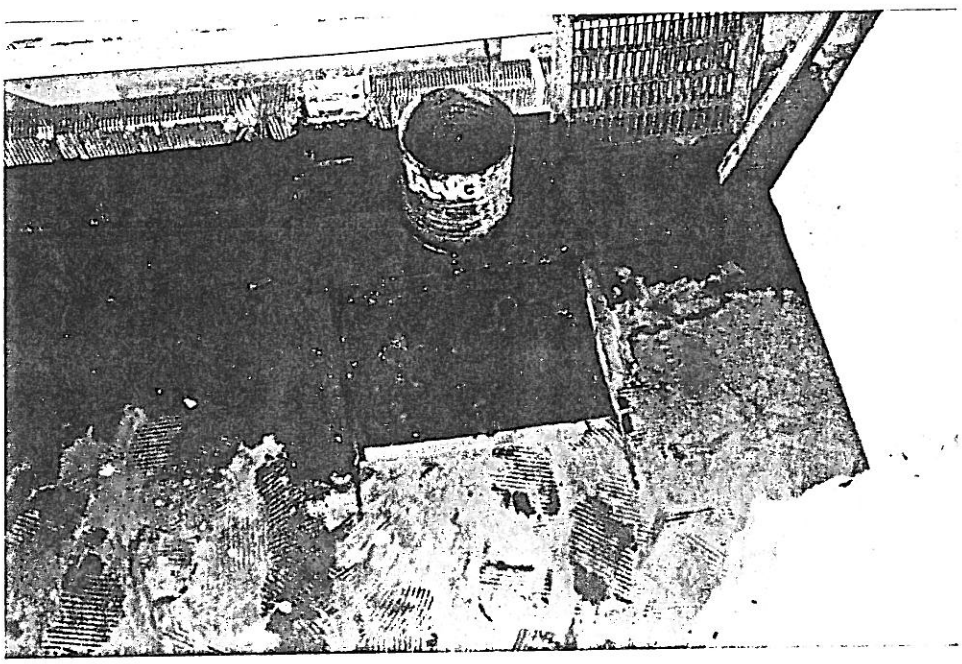


PHOTO #13: BASEMENT AREA; AN EXISTING HOLE CUT INTO THE BASEMENT FLOOR SLAB, SUMP AREA?, ONLY SEVERAL INCHES DEEP.

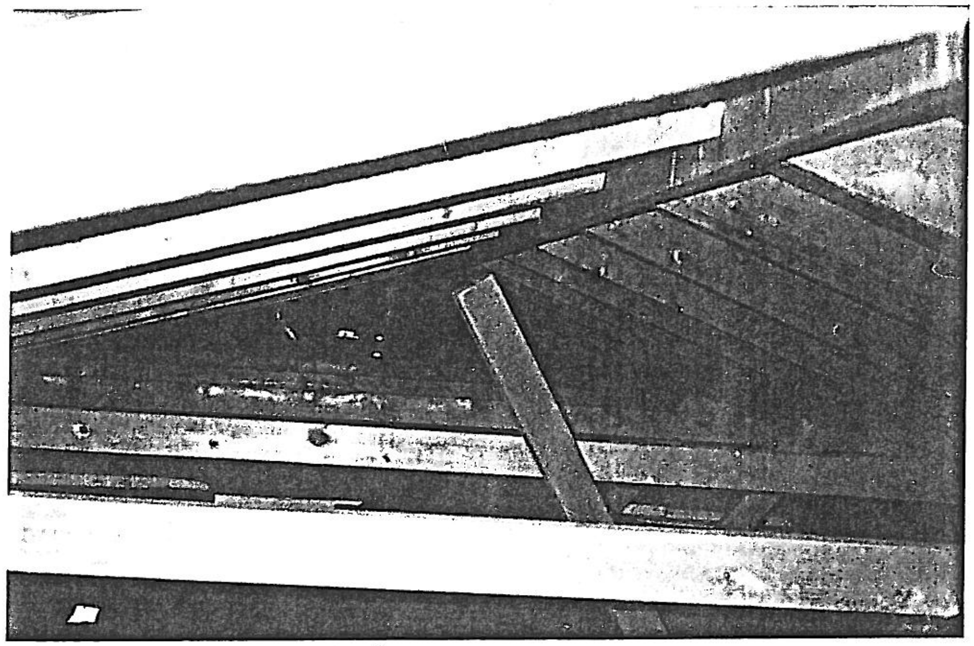


PHOTO #14: THE EXISTING ROOF SYSTEM LOCATED OVER THE HOUSE PORTION OF THE STRUCTURE.

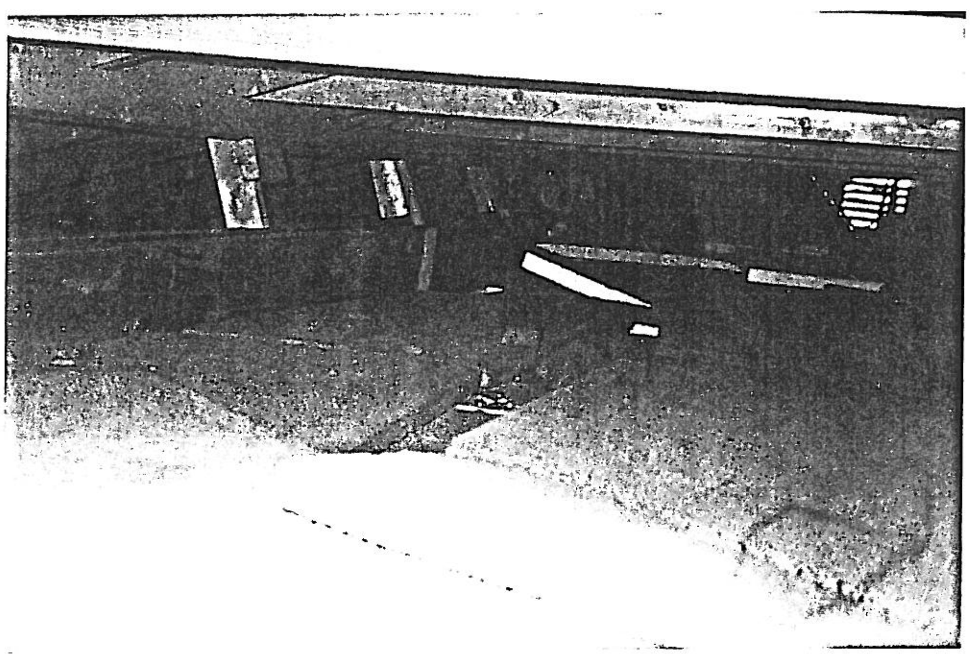
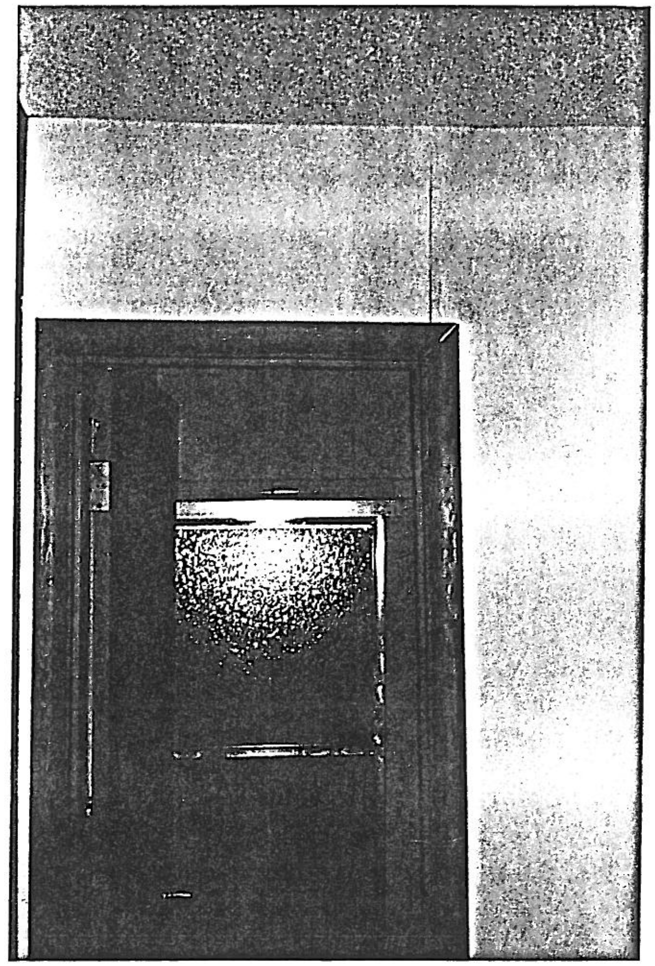


PHOTO #15: THE EXISTING HOUSE ROOF SYSTEM AND INSULATION, RIGID FIBERBOARD AND BEADBOARD INSULATION OVERLAYING THE FIBERGLASS INSULATION.

PHOTO #16: FIRST FLOOR MASTER BED-ROOM; EXISTING SHEETROCK CRACK ON THE WALL AT THE DOORWAY TO BATHROOM.



SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

SEATTLE
RICHLAND
FAIRBANKS
ANCHORAGE
SAINT LOUIS
BOSTON

April 14, 2000

Permafrost Technology Foundation
3875 Geist Road, Suite E
Fairbanks, Alaska 99709

Attn: Dr. Terry McFadden, P.E.

RE: OBSERVATION OF BASEMENT FOUNDATION DISTRESS, 263 MADCAP LANE, FAIRBANKS, ALASKA

In accordance with your request, we visited the residence at 263 Madcap Lane, on March 30, 2000, to observe the condition of the concrete foundation stem wall along the west side of the structure. We understand it was recently discovered that the wall paneling and vertical furring strips near the center of the west wall of the master bedroom "popped" loose from the wall. You requested an independent opinion from us regarding the cause of this distress and recommendations for mitigating the potential future propagation of the observed condition. This letter summarizes observations from our visit to the site and provides recommendations for mitigation of the concern.

We understand the structure has been studied since 1991, when it was transferred to the Permafrost Technology Foundation for the purpose of research. The result of this research led to modifications to the structure and property, which included significant drainage revisions to the west side and the installation of six thermosyphons beneath the structure. Analysis of the results of this previous study is beyond the scope of this project; however, the results indicate that some movement continues to occur in the floor slabs and foundations.

Observations

At the time of our visit the perimeter of the building had been cleared of snow, and the ground surface was generally visible near the perimeter of the structure on the west, north, and east sides. Some heave was noted in the window wells adjacent to the structure. The ground surface directly adjacent to the structure was generally flat or undulating with no clear slope away from the structure.

The concrete masonry unit (CMU) stem wall was exposed and visible inside the structure on the west wall of the master bedroom. No cracks were visible during our visit, although only a small portion of the wall was exposed. Using a 3-foot-long carpenter's level we estimated how far off from plumb the CMU stem wall was at this location. Our estimates revealed that the top of the 4-foot-tall CMU stem wall appears to be tilted inward about 1 to 1½ inches. Further observation

indicated the basement walls in the remaining two bedrooms, as well as the living and dining rooms, showed similar evidence of tilting inward.

Discussion

Although tilting in the basement stem wall is evident, it is not clear when the majority of the tilting occurred or what mechanisms caused the distress. It was also noted that the tilting of the stem wall would likely have gone unnoticed if the furring strips and paneling had not "popped" loose from its connection with the top plate of the wall.

We reviewed the report summarizing the research on this residence titled *Final Draft Report on Foundation Stabilization Research Studies at 263 Madcap Lane*. This document contains a separate report by Stutzmann Engineering Associates, Inc., dated April 16, 1991, summarizing an inspection made of the residence. Item #3 of this report stated that the existing CMU stem wall "is leaning inwards at a slope of approximately 3/8" in 24" in areas." This is approximately ¾ of an inch in 4 feet. The report also noted that "The foundation wall appears to be quite solid and no noticeable cracks or failures were found." The report further states that only a portion of the CMU stem wall was exposed at the time for observation. The conclusion for Item #3 of the Stutzmann report was "The existing foundation wall deflection does not appear to be a serious threat to the structural integrity of the structure and if halted at this time, no additional repairs would be expected."

During our brief site visit we observed the deflection and contemplated potential mechanisms that may have led to the tilting or deflection observed in the wall. We also discussed our observations with Dr. Tom Kinney, P.E., who had directed or performed the drainage improvements around this structure. Several mechanisms that could have led to the observed deflection were considered and are discussed below.

Although the window wells have jacked somewhat and drainage directly adjacent to the structure could be improved, we do not believe the tilting of the CMU stem wall is the result of seasonal frost jacking. With a continuously heated structure, seasonal freezing would develop vertical jacking forces on the soils adjacent to the structure. Lateral forces would be minimal and unlikely sufficient to cause lateral deflection of the wall.

As designed the installation of the thermosyphons and subsequent operation of these devices has led to cooling of the subgrade soils. A potential scenario for tilting of the wall is that jacking of the footings and CMU stem wall is the result of deep soils refreezing and subsequently heaving.

Differential vertical movement of the wall could potentially result in bending, resulting in a lateral deflection component at the top of the wall. The final draft research report for this residence concludes that some movement is expected to continue in this structure. In a discussion regarding settlement of the residence, the report states that " It is conceivable that another two inches could accumulate in the next seven years…"

A third and more likely cause of the tilting could be forces imposed on the wall during construction of the drainage improvements. We understand that during the regrading of the property a Bobcat loader was operated with the wheels directly adjacent to the structure. These forces would be more than sufficient to cause some deflection in the wall.

Conclusions

Noticeable tilting in the CMU stem walls was observed during our visit. Past reports state that a significant amount of tilting was observed almost ten years ago. It appears that additional tilting has occurred since that time, although the amount is difficult to quantify. The cause of this additional movement could be the result of construction activities or of differential movement of the structure and bending of the wall.

Based on the information reviewed and our discussions and observations, we believe a large portion of the tilting observed in the CMU stem wall has likely existed for some time. We also believe some additional tilting has occurred in the last ten years. Since movement (settlement or heave) of the residence is likely to occur in the we anticipate some additional tilting could also occur. We do not believe that the CMU stem walls are in danger of suddenly collapsing, although we recommend they be monitored.

Although seasonal frost heave was not anticipated to be a significant factor in the observed CMU stem wall deflection, we recommend grading the soil directly adjacent to the residence to maintain positive surface water flow away from the structure. Water should not be allowed to pond or flow near the structure at any time of year.

If you have any questions or comments or wish us to perform further investigations or studies, please contact Rohn Abbott or me.

Sincerely,

SHANNON & WILSON, INC.

Stephen Adamczak, Jr., P.E.
Senior Associate

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

SEATTLE
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BOSTON

April 14, 2000

McFadden Engineering
3875 Geist Road, Suite E
Fairbanks, Alaska 99709

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Sincerely,

SHANNON & WILSON, INC.

Stephen Adamczak, Jr., P.E.
Senior Associate

BOMA CONSTRUCTION
921 OLD STEESE NORTH
FAIRBANKS, ALASKA 99712
Ph 907 457 4592 Fax 907 457 1971
CELL 907-378-9454
E-MAIL boma@mosquitonet.com

5/14/00

REPAIRS FOR FOUNDATION ON MADCAP.

INCLUDES:

1. CRIBING (BRACING) OF FOUNDATION WALLS BEFORE EXCAVATION.
2. EXCAVATION OF FOUNDATI ON NORTH AND EAST SIDES.
3. REMOVAL OF FENCE.
4. PUSH EXISTING FOUNDATION WALLS BACK TO PLUMB.
5. INSTALL TIES IN FOOTING AND IN BLOCK WALLS.
6. EXTEND FOOTING 18", AND PLACE 8" POURED WALL ALONG BLOCK WALL WITH REINFORCING. SEE DRAWING.
7. REGRADE FOR POSITIVE DRAINAGE INSTALL 4" BLUE BOARD 90 DEGREES TO FOUNDATION WALL AND SEED.
8. REPLACE FENCE.
9. REPAIR INTERIOR TO LIKE CONDITION PRIOR TO DAMAGE.

EXCLUDES:

1. DAILY WATERING ON LAWN.

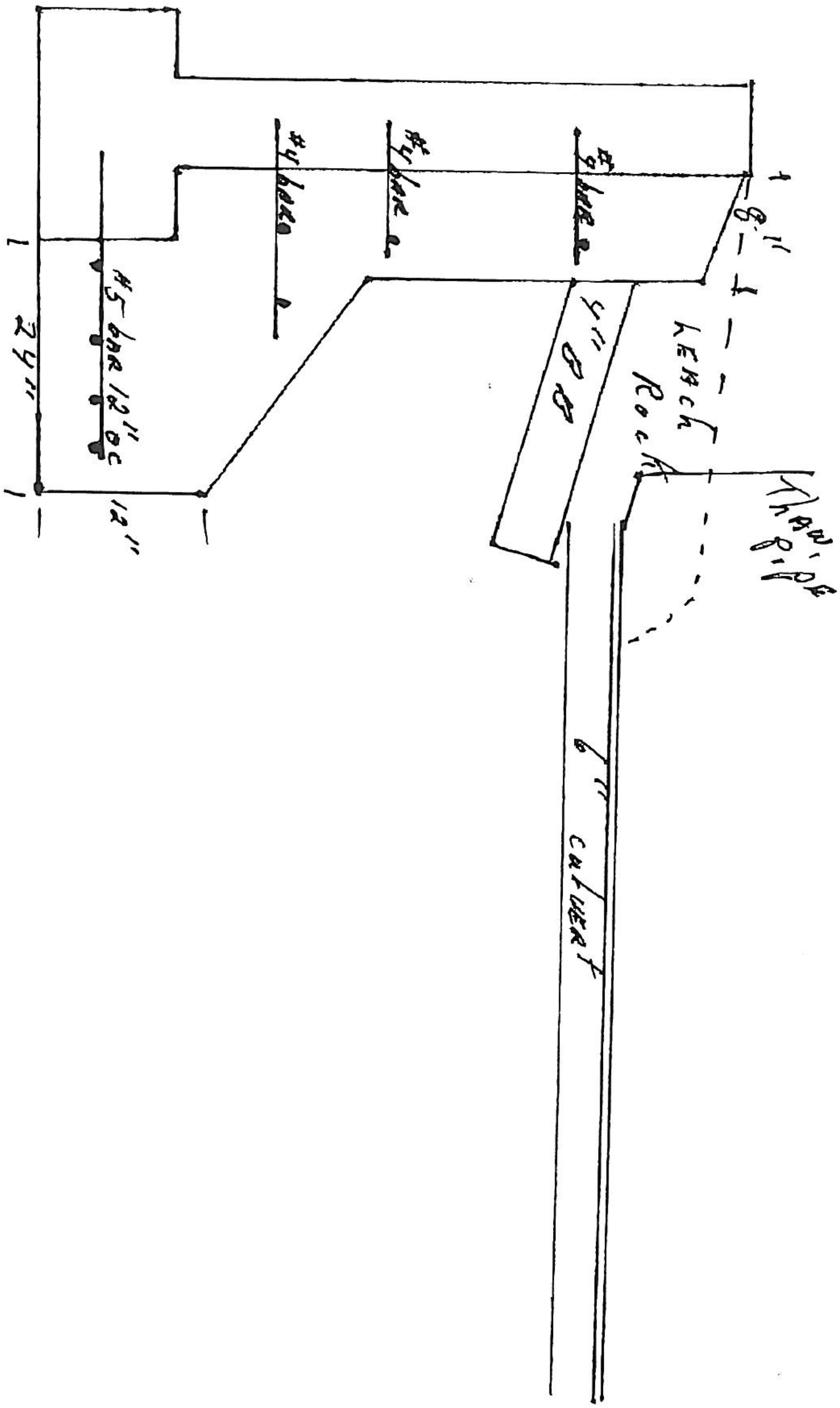
TOTAL MATERIAL AND LABOR $18,678.00

1. INSTALL FRENCH DRAIN ALONG EAST AND NORTH SIDE WITH 4 -6" CULVERTS DRAINING TO FARMERS LOOP EXISTING CULVERT. INSTALL THAW PIPES IN CULVERTS. SEE DRAWING

ADDIATIONAL LABOR AND MATERIAL $5,129.00

THANKS

MICHAEL F BOMA


#4 bar
#4 bar
#4 bars
#5 bar 12" OC
24"
12"
8"
Leach Rock
Thaw Pipe
6" culvert

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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RE: OBSERVATION OF BASEMENT FOUNDATION DISTRESS, 263 MADCAP LANE, FAIRBANKS, ALASKA

In accordance with your request, we visited the residence at 263 Madcap Lane, on March 30, 2000, to observe the condition of the concrete foundation stem wall along the west side of the structure. We understand it was recently discovered that the wall paneling and vertical furring strips near the center of the west wall of the master bedroom "popped" loose from the wall. You requested an independent opinion from us regarding the cause of this distress and recommendations for mitigating the potential future propagation of the observed condition. This letter summarizes observations from our visit to the site and provides recommendations for mitigation of the concern.

We understand the structure has been studied since 1991, when it was transferred to the Permafrost Technology Foundation for the purpose of research. The result of this research led to modifications to the structure and property, which included significant drainage revisions to the west side and the installation of six thermosyphons beneath the structure. Analysis of the results of this previous study is beyond the scope of this project; however, the results indicate that some movement continues to occur in the floor slabs and foundations.

Observations

At the time of our visit the perimeter of the building had been cleared of snow, and the ground surface was generally visible near the perimeter of the structure on the west, north, and east sides. Some heave was noted in the window wells adjacent to the structure. The ground surface directly adjacent to the structure was generally flat or undulating with no clear slope away from the structure.

The concrete masonry unit (CMU) stem wall was exposed and visible inside the structure on the west wall of the master bedroom. No cracks were visible during our visit, although only a small portion of the wall was exposed. Using a 3-foot-long carpenter's level we estimated how far off from plumb the CMU stem wall was at this location. Our estimates revealed that the top of the 4-foot-tall CMU stem wall appears to be tilted inward about 1 to 1½ inches. Further observation

indicated the basement walls in the remaining two bedrooms, as well as the living and dining rooms, showed similar evidence of tilting inward.

Discussion

Although tilting in the basement stem wall is evident, it is not clear when the majority of the tilting occurred or what mechanisms caused the distress. It was also noted that the tilting of the stem wall would likely have gone unnoticed if the furring strips and paneling had not "popped" loose from its connection with the top plate of the wall.

We reviewed the report summarizing the research on this residence titled *Final Draft Report on Foundation Stabilization Research Studies at 263 Madcap Lane*. This document contains a separate report by Stutzmann Engineering Associates, Inc., dated April 16, 1991, summarizing an inspection made of the residence. Item #3 of this report stated that the existing CMU stem wall "is leaning inwards at a slope of approximately 3/8" in 24" in areas." This is approximately ¾ of an inch in 4 feet. The report also noted that "The foundation wall appears to be quite solid and no noticeable cracks or failures were found." The report further states that only a portion of the CMU stem wall was exposed at the time for observation. The conclusion for Item #3 of the Stutzmann report was "The existing foundation wall deflection does not appear to be a serious threat to the structural integrity of the structure and if halted at this time, no additional repairs would be expected."

During our brief site visit we observed the deflection and contemplated potential mechanisms that may have led to the tilting or deflection observed in the wall. We also discussed our observations with Dr. Tom Kinney, P.E., who had directed or performed the drainage improvements around this structure. Several mechanisms that could have led to the observed deflection were considered and are discussed below.

Although the window wells have jacked somewhat and drainage directly adjacent to the structure could be improved, we do not believe the tilting of the CMU stem wall is the result of seasonal frost jacking. With a continuously heated structure, seasonal freezing would develop vertical jacking forces on the soils adjacent to the structure. Lateral forces would be minimal and unlikely sufficient to cause lateral deflection of the wall.

As designed the installation of the thermosyphons and subsequent operation of these devices has led to cooling of the subgrade soils. A potential scenario for tilting of the wall is that jacking of the footings and CMU stem wall is the result of deep soils refreezing and subsequently heaving.

Differential vertical movement of the wall could potentially result in bending, resulting in a lateral deflection component at the top of the wall. The final draft research report for this residence concludes that some movement is expected to continue in this structure. In a discussion regarding settlement of the residence, the report states that " It is conceivable that another two inches could accumulate in the next seven years…"

A third and more likely cause of the tilting could be forces imposed on the wall during construction of the drainage improvements. We understand that during the regrading of the property a Bobcat loader was operated with the wheels directly adjacent to the structure. These forces would be more than sufficient to cause some deflection in the wall.

Conclusions

Noticeable tilting in the CMU stem walls was observed during our visit. Past reports state that a significant amount of tilting was observed almost ten years ago. It appears that additional tilting has occurred since that time, although the amount is difficult to quantify. The cause of this additional movement could be the result of construction activities or of differential movement of the structure and bending of the wall.

Based on the information reviewed and our discussions and observations, we believe a large portion of the tilting observed in the CMU stem wall has likely existed for some time. We also believe some additional tilting has occurred in the last ten years. Since movement (settlement or heave) of the residence is likely to occur in the we anticipate some additional tilting could also occur. We do not believe that the CMU stem walls are in danger of suddenly collapsing, although we recommend they be monitored.

Although seasonal frost heave was not anticipated to be a significant factor in the observed CMU stem wall deflection, we recommend grading the soil directly adjacent to the residence to maintain positive surface water flow away from the structure. Water should not be allowed to pond or flow near the structure at any time of year.

If you have any questions or comments or wish us to perform further investigations or studies, please contact Rohn Abbott or me.

Sincerely,

SHANNON & WILSON, INC.

Stephen Adamczak, Jr., P.E.
Senior Associate

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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FAIRBANKS
ANCHORAGE
SAINT LOUIS
BOSTON

April 14, 2000

Permafrost Technology Foundation
3875 Geist Road, Suite E
Fairbanks, Alaska 99709

Attn: Dr. Terry McFadden, P.E.

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