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Dec 1993
ECI 450 St. Cloud State

MINNESOTA GROUND FROST STUDY

Frost Study Introduction

Information about the depth of frost penetration into the soil is very important in a number of fields. Meteorologists and Hydrologists use frost depth information in determining the potential for spring flooding and precipitation run-off. Engineers use frost depth information to determine the proper design of roads, buildings and other engineering works. Agriculturists can predict spring soil moisture and impact of soil microbiology by using the frost depth data. Overall, frost depth penetration is very important to know, but very little research has been done on factors that determine how meteorological and soil types affect ground frost depth penetration.

Over the past twenty year, the Army Corp of Engineers have been coordinating the collection of data pertaining to the depth of ground frost penetration at thirty seven sites across North Dakota, Minnesota, Wisconsin and Michigan. The data collected was a result of the effort put forward by many field observers who measured ground frost depth using frost tubes provided by the Army Corp. of Engineers. This data may have been used by the site to determine what impact the ground frost would have had on agriculture, flood prevention, or transportation across soils during the winter and spring months within the local area. Finally, once the frost season ended, the ground frost data was collected from each site and archived as a tool for future frost depth studies.

Given what we know about the science of ground frost, we can only speculate using the laws of physics and chemistry how deep frost has penetrated into the ground given certain physical and meteorological conditions. Scientists have developed models and equations to approximate the depth of ground frost, but it is difficult to really know how accurate these models are without actually comparing theoretical data to empirical data. The frost data collected by the field observers has provided an opportunity to study the statistics of seasonal ground frost in the upper Midwest and also an opportunity to compare theory with empirical data.

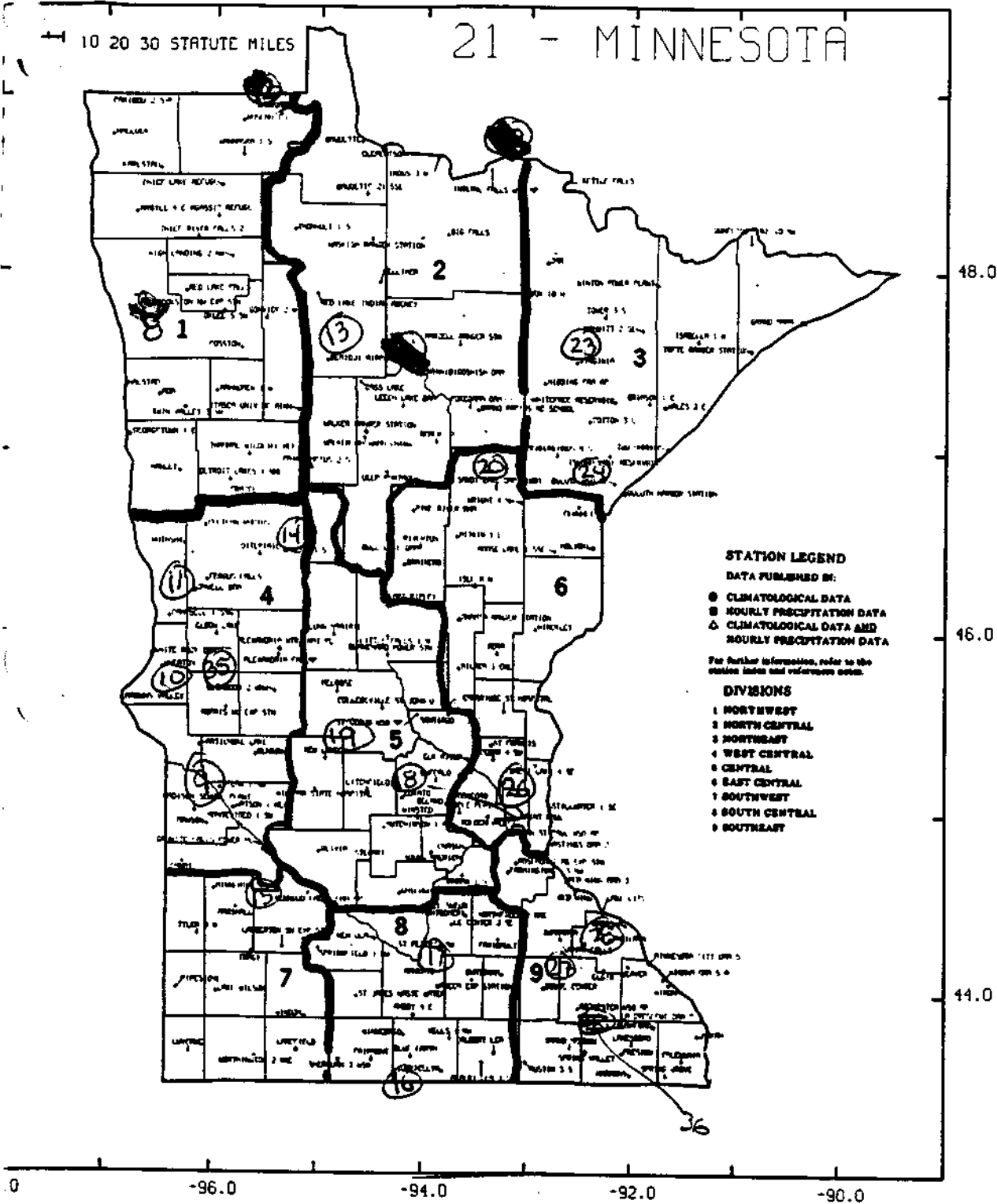
In coordination with the University of Minnesota Soil Sciences, the St. Paul Army Corp. of Engineers, and the efforts of many observers and researchers, research has been conducted using the data collected by the Army Corp. of Engineers to determine statistical ground frost information for the Minnesota region. In addition to the statistical information, empirical data has been compared to theoretical data to provide an opportunity to recognize similarities and differences.

The objectives of this study will cover the following areas of research:

- Ground Frost Data Collection
- Initial Freezing Point of Soil Subsurface
- Maximum Depth of Ground Frost
- Initial Melting of Ground Frost
- Final Melting Point of Ground Frost
- Other...

date

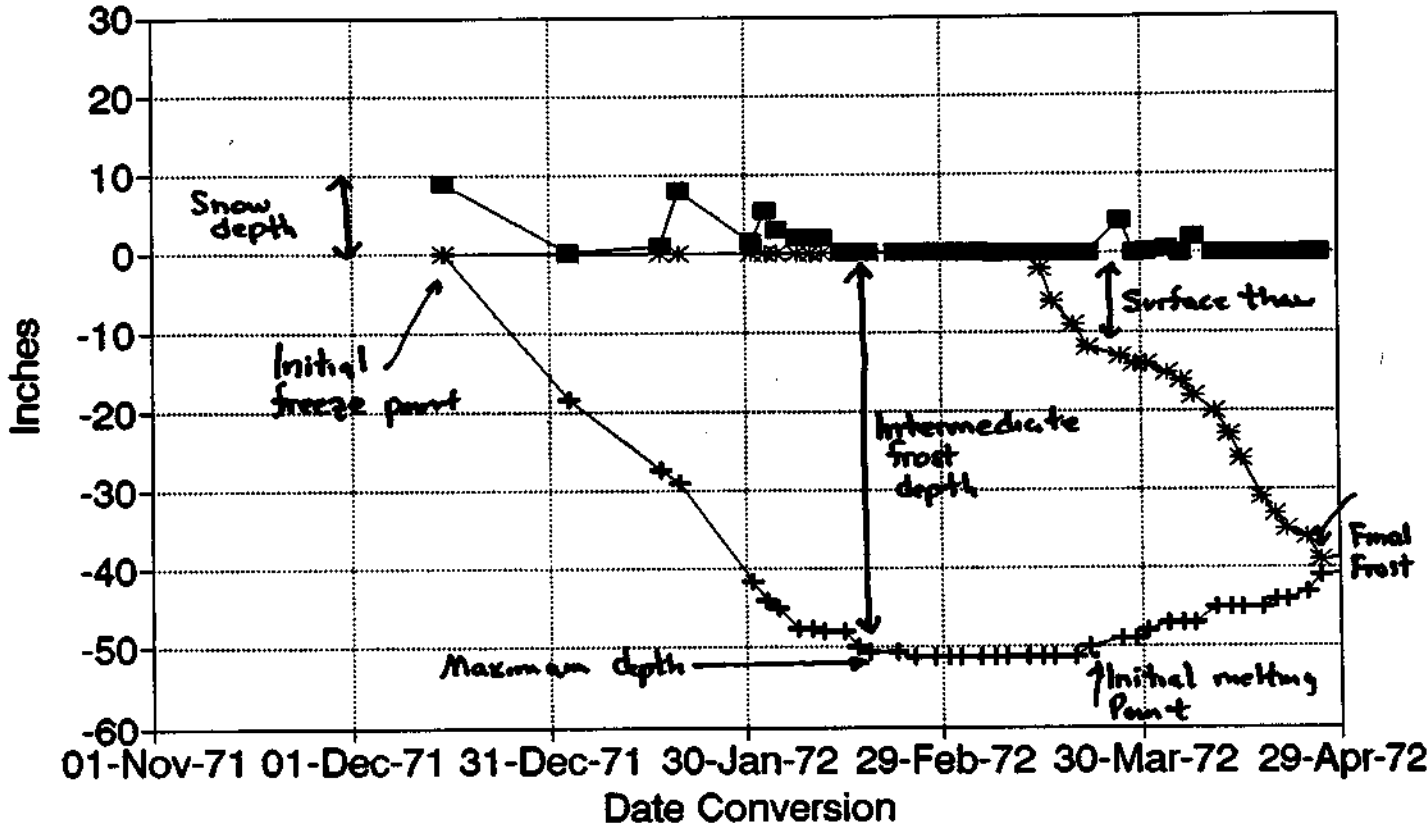
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Ground Frost Data

Example Only



Ground Frost Data Collection:

Data Collection Method:

For the past twenty two years, field observers at each data site have been instructed to make ground frost depth observations at least every other week using what is known as a frost tube to measure freezing depth. In addition to measuring the frost depth, snow depth and temperature readings were also recorded. The data was then calculated to determine the following:

- **Actual Depth of Ground Frost**
- **Depth of Thawed Surface**
- **Maximum Depth of Ground Frost**
- **Depth of Thawed Soil Subsurface**
- **Depth of Intermediate Ground Frost**

In interest of avoiding confusion of the terms above, the meaning of the terms are given below.

Actual Depth of Ground Frost: The boundary between frozen soil and unfrozen soil below the frozen layer.

Depth of Thawed Surface: Defined as the layer above the frozen layer that melts. Usually this is caused by melting of the soil layer that interfaces the atmosphere.

Maximum Depth of Ground Frost: The maximum depth that the ground frost has penetrated to during the season.

Before
Hawaii Frost
Data Collection

Depth of Thawed Soil Subsurface : Defined as the difference between the maximum depth of ground frost minus the depth of the bottom layer of frost.

Depth of Intermediate Ground Frost : Calculated as the difference between actual ground frost depth minus the depth of thawed subsurface.

Ground Frost Depth Observations

Observers used frost tubes as an instrument for determining the depth of frost by estimating a color change in the frost tube liquid in reference to a measurement system on the frost tube itself. The range of measurement possible with the frost tube is from 0 - 60 inches. Most measurements were made to the nearest inch but in some cases, the measurement was made to the nearest 1/4 inch. For the purpose of this study, data will be rounded to the nearest inch or it will be noted if different.

Errors in observation data have occurred in some cases when the frost tube was not working properly (ie., leaking). These data errors have been omitted from the study when it was possible to ignore them.

Frost Tube Characteristics:

Frost tubes are a convenient way of determining the depth of frost penetration into the soil, but there are some draw backs to the instrument itself. The first drawback of the frost tube is that the area around the frost tube can be altered by observers packing down snow around the base of the tube. This causes a change in the snow density and may alter the results of the data slightly. Secondly, there is a time lag of approximately 96 hours from the time that the frost actually occurs to the time that the tube actually acknowledges the changes. Finally, the frost tube is an instrument having different physical and chemical properties than the surrounding soil which reacts differently to temperature changes. Despite these downfalls, when compared to a thermocouple, the frost tube gives reliable readings.

Data Collection Problems:

Some of the problems that occurred with the collection of the ground frost data stemmed from the malfunction of the frost tube to incorrect data entry on the form provided by the Army Corp of Engineers. It has been noted that most problems were corrected quickly, therefore, most of the data submitted to the frost study was usable.

Another problem that had to be considered in producing results for the frost study is the frequency of data collection from the frost tubes. Collection of frost depth data ranged from every 1 -3 days to once every three weeks. In most cases, the average collection frequency was once every two weeks and more frequently as thawing occurred. Some of the data in the frost study had to be adjusted so that significant frost event dates could be calculated.

Finally, the results of the frost depth study does not take some factors in consideration. Some of the factors that could not be calculated was soil types and surface features. It is the goal of this study to consider these factors as the information becomes available.

Special Notes on Data Collection per Site

Initial Freezing Point:

Introduction:

The initial freezing point of the soil occurs when the soil heat loss exceeds the heat gained at the surface from the atmosphere and from the heat flow from warmer subsurface soils. Since there can be numerous initial freezing points caused by diurnal heat gain and heat loss, the most initial freezing point that this study will consider is the point where the net heat flow causes the temperature of the soil to be equal to or below the temperature of freezing for water. However, it should be noted that the ground may not be frozen solid when the initial freezing point occurs because the water in the soil may contain minerals which can lower the freezing point temperature of the moisture below the freezing point of pure water.

Factors that Impact the Initial Freezing Point:

The most obvious factor that will impact the development of the initial freezing layer or frost is temperature. When the temperature of the atmosphere drops below 0 C, the reduction of heat flow into the soil causes a greater heat flow outward toward the surface. Soil moisture also affects the initial freezing of the soil because of the increased heat capacity and thermal conductivity of the soil surface. The initial freezing point of soils tend to be delayed if the soil contains greater amounts of moisture than if the soil was dry. If water has replaced air pockets that exist in dry soil, then this increases the thermal conductivity of the soil since air is a poor conductor of heat than water. It would be expected that the soil with the greater moisture content would experience greater frost depths than dry soils as winter progresses. Experiments have shown that thermal conductivity difference does not exceed 30% in coarse material and is lower in fine textured soil pending on the amount of water in the soil.

Snow cover will impact the freezing point of soils by providing an insulation layer between the subsurface and the atmosphere thus causing little interaction between the heat transfer process of the atmosphere and the subsurface soil. Differences in vegetation on the surface also affects the initial freezing point of the soil as compared to a non- vegetated surface.

Upper Midwest Initial Freezing Dates: –

It is generally believed that the farther you travel northward toward Canada in the Midwest states, the more likely the initial frost date will be sooner than the southern part of the states. But can it be assumed that the initial frost date is relatively the same as you go from west to east? To compare how northern Minnesota initial freeze dates differ from southern Minnesota freeze dates and how Minnesota compares to other Midwest states, initial freeze dates from all 37 sites in the Midwest were averaged and compared to each other to show the trend of initial freezing by longitude and latitude.

Average Freezing Dates by Latitude:

To calculate the initial freezing point date by latitude, the average of initial freezing dates for each site was considered through the years of 1971 - 1988. By graphing each site by latitude, a distinctive slope occurs in the plotted graph of Average Frost Date versus Latitude. By taking the least square fit line of the data points, it was found that the change of the average freezing date in comparison to the change of the latitude was approximately 3.3 days greater per 1 degree latitude toward the south. Putting this in perspective, the average freezing date for northern Minnesota is 20 days earlier than it would be in southern Minnesota.

Graph of Average Frost Date by Latitude

Average Freezing Date by Longitude.

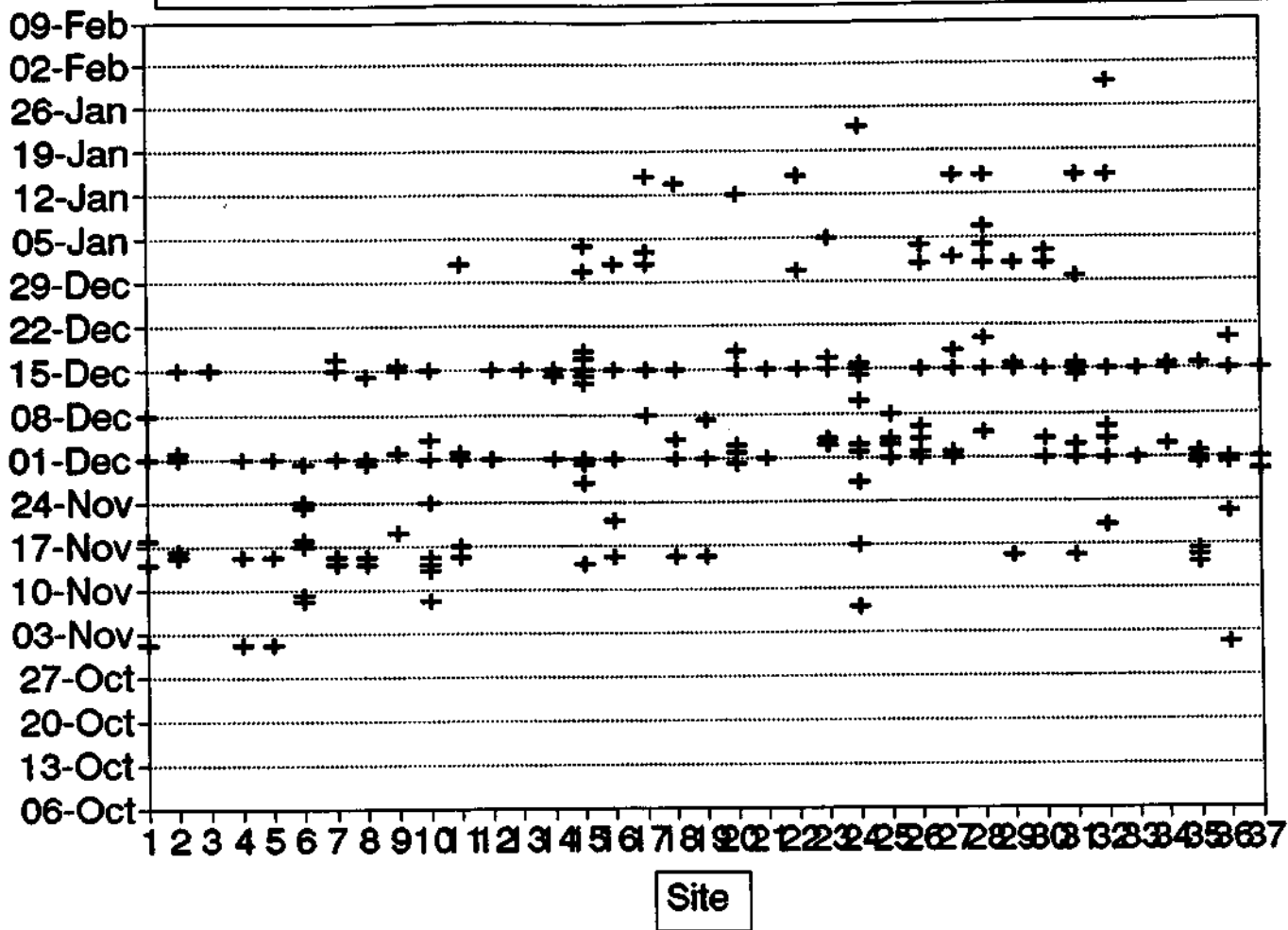
To show a correlation between the initial freezing point date as a function of longitude, not all sites could be used because of the differences of latitude in the North Dakota sites versus the Minnesota and Wisconsin sites. Therefore, only select sites north of the 46 N parallel were used in North Dakota and Minnesota along with one site in Michigan. The correlation of longitude and the first frost date is as strong as the correlation of longitude and the first frost, thus it shows that on average North Dakota will experience a frost date about 10 days earlier than Northern Minnesota. There is at least two different possible explanations for this phenomenon:

1. The differences in overall climatology between the 102W and 90W.
2. The topography and soil type differences.

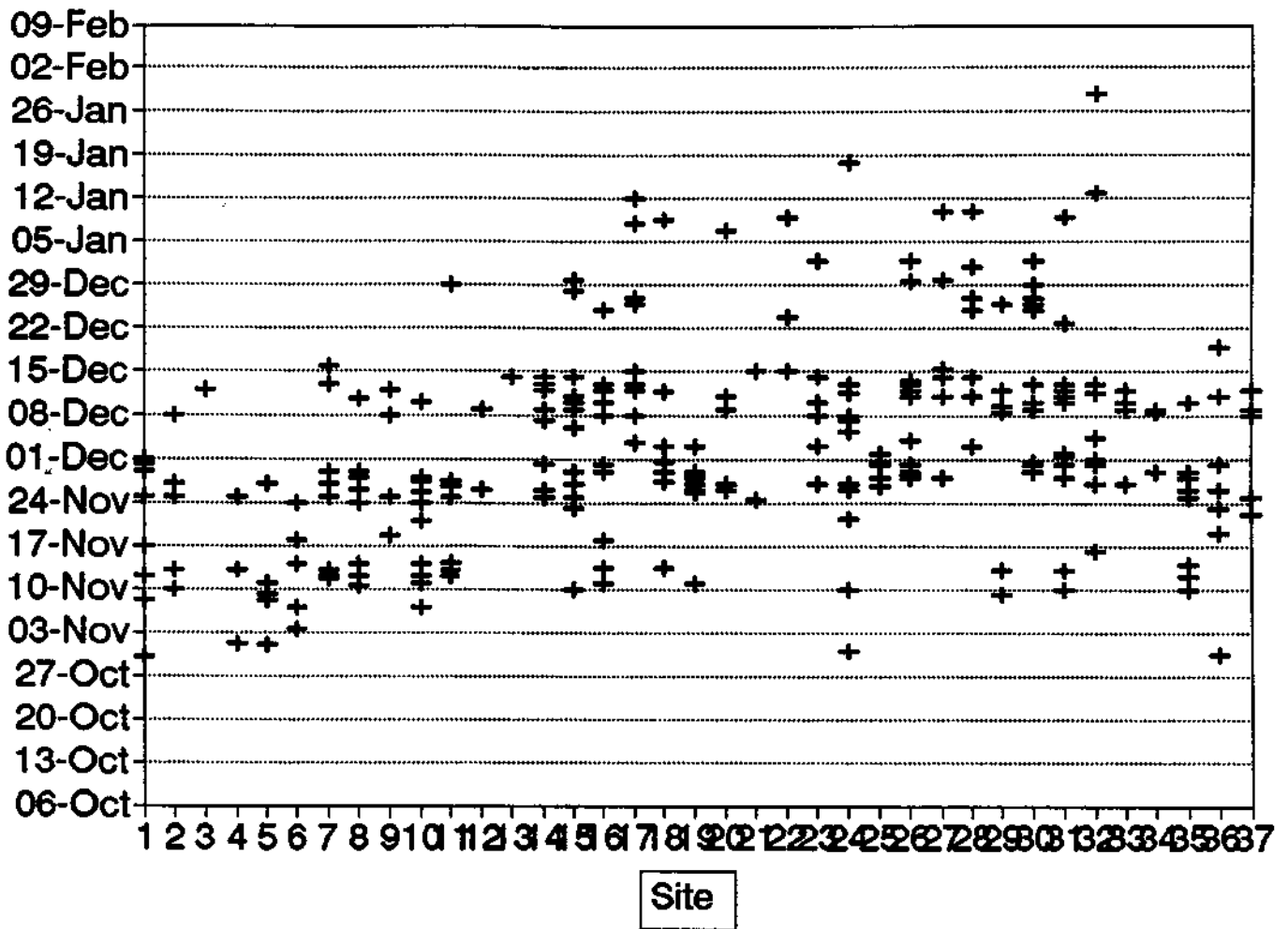
It cannot be shown with the data presented which explanation is more significant, but overall, the initial freezing point of soil depends primarily on the meteorological weather patterns over the defined area and the amount of moisture in the soil. In other words, if northern Minnesota is cooler and drier than North Dakota, Minnesota will have earlier initial freezing point dates than North Dakota.

Graph of Avg. Initial Frost Date Versus Latitude

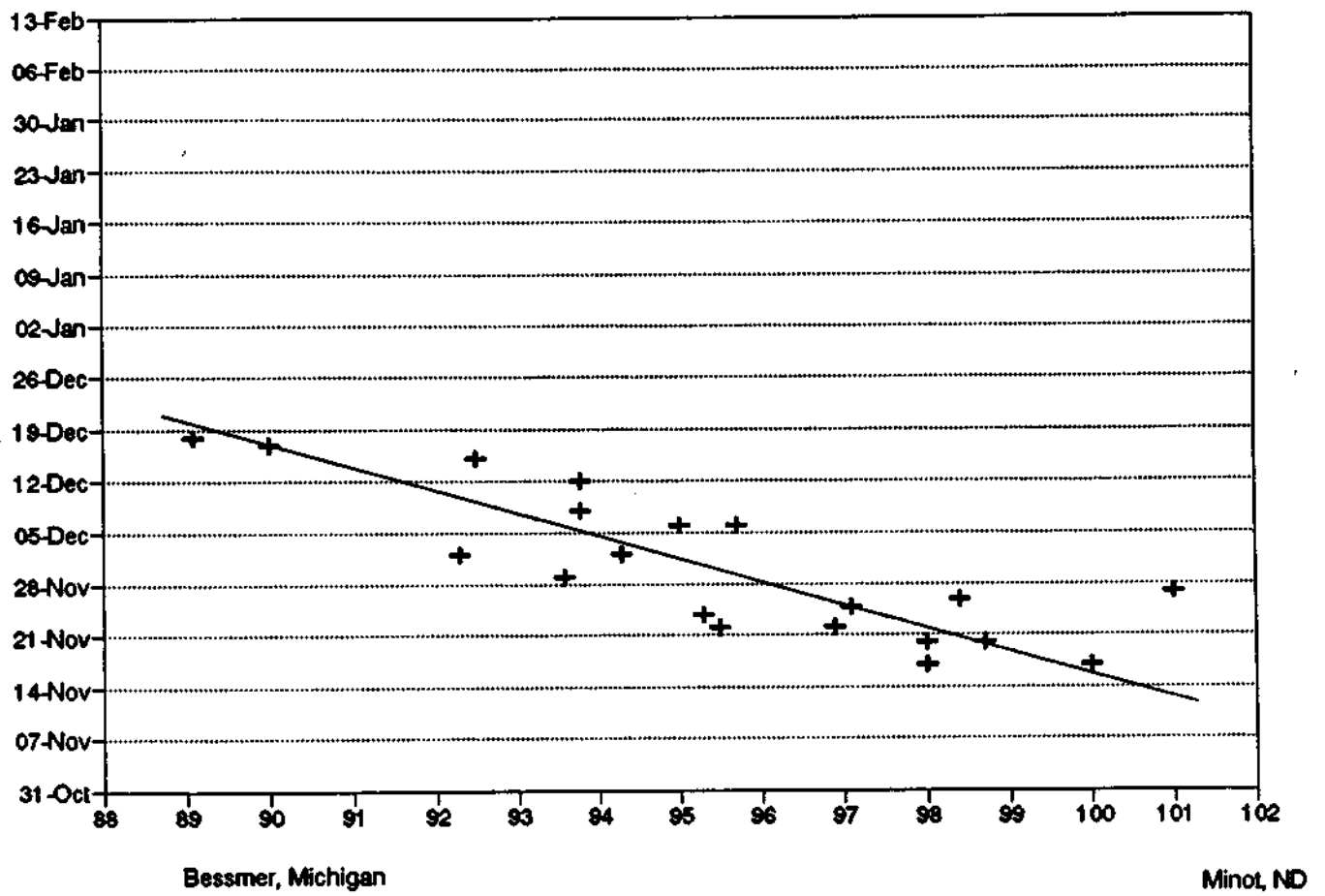
Initial Frost Date: Non-adjusted and within 5 days of actual date



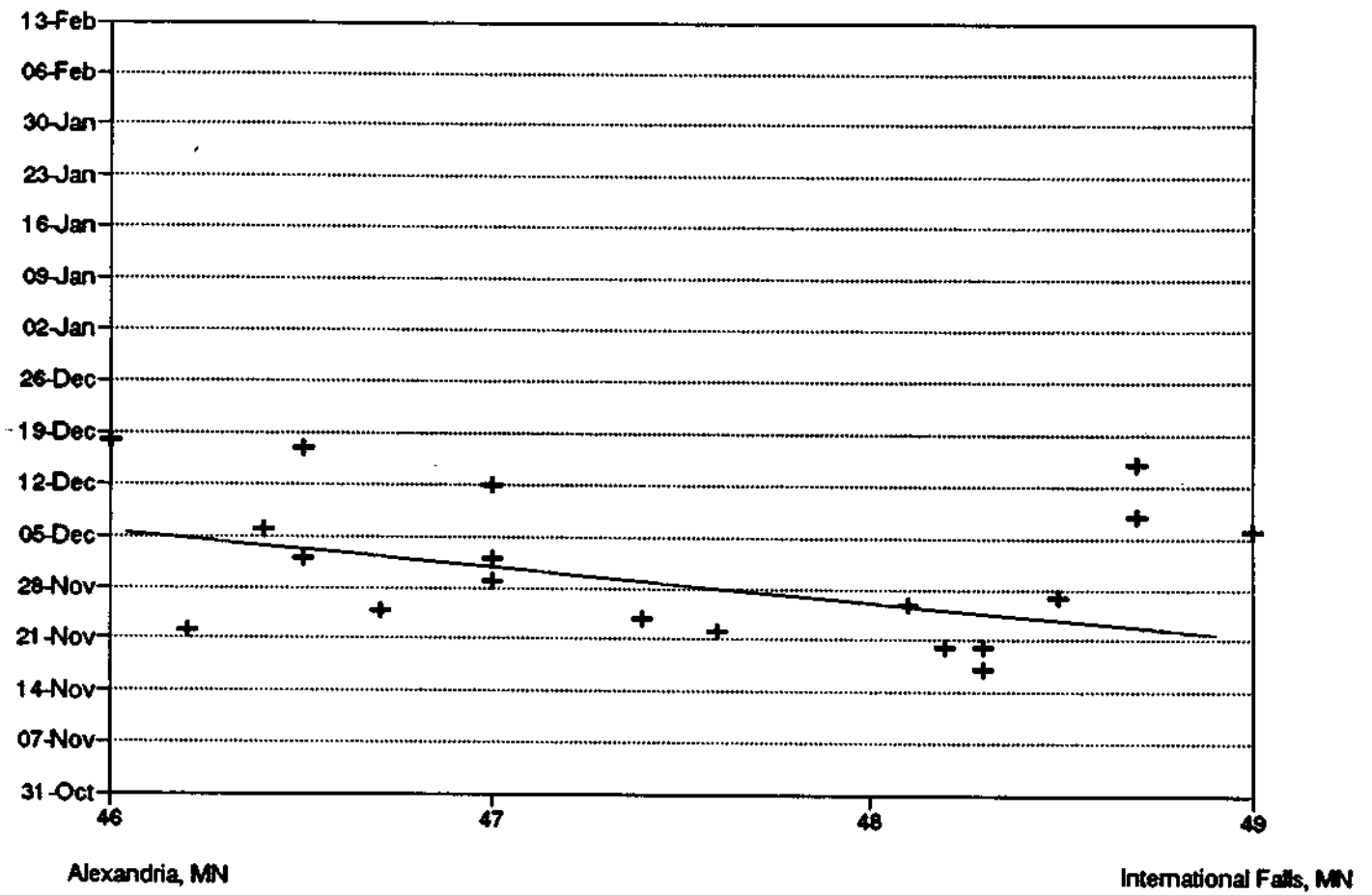
Initial Frost Date: Adjusted-Actual Initial Freezing Date.



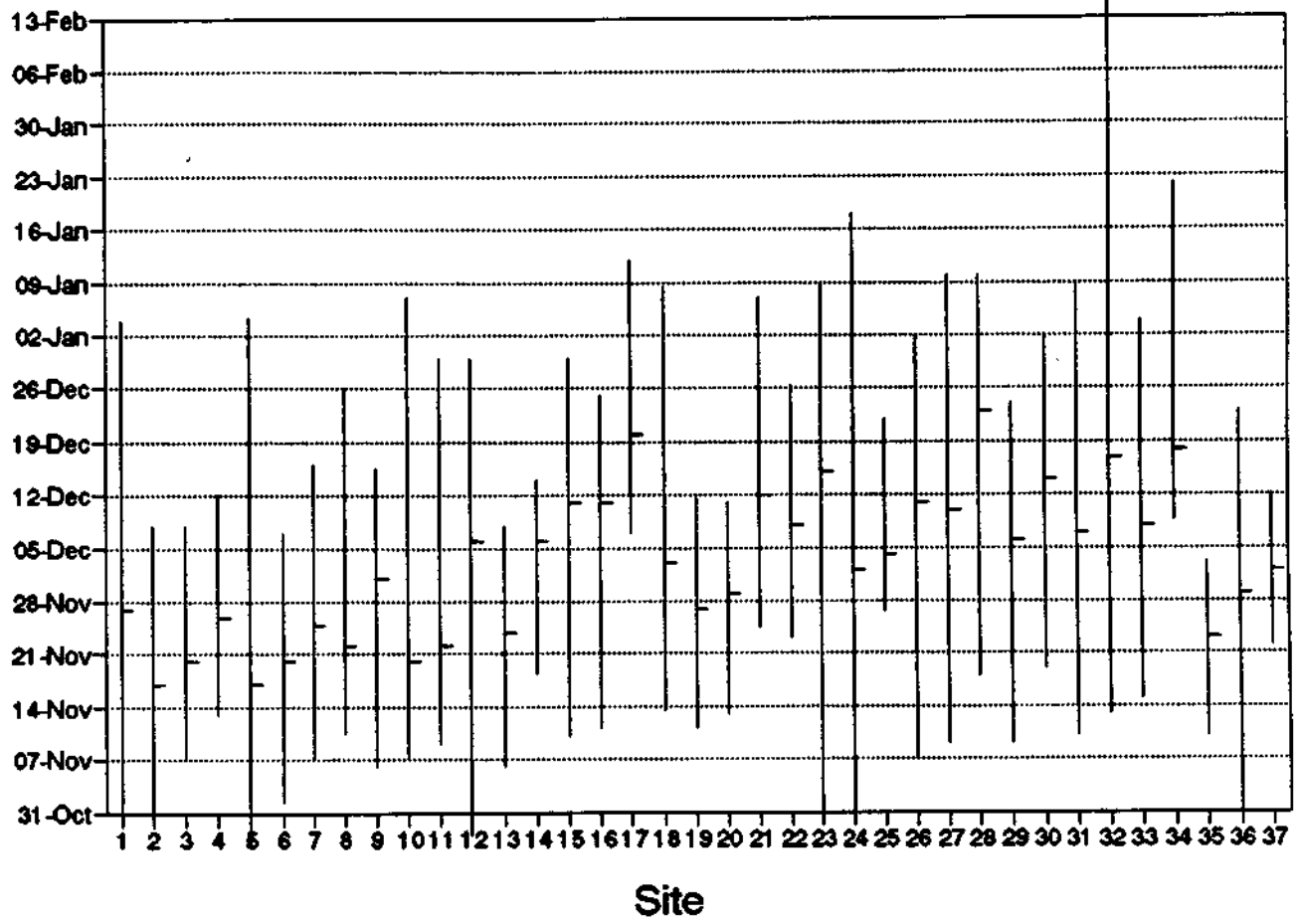
Change in Longitude versus Change in Avg Initial Frost Date



Change in Latitude Versus Change in Avg Initial Frost Date



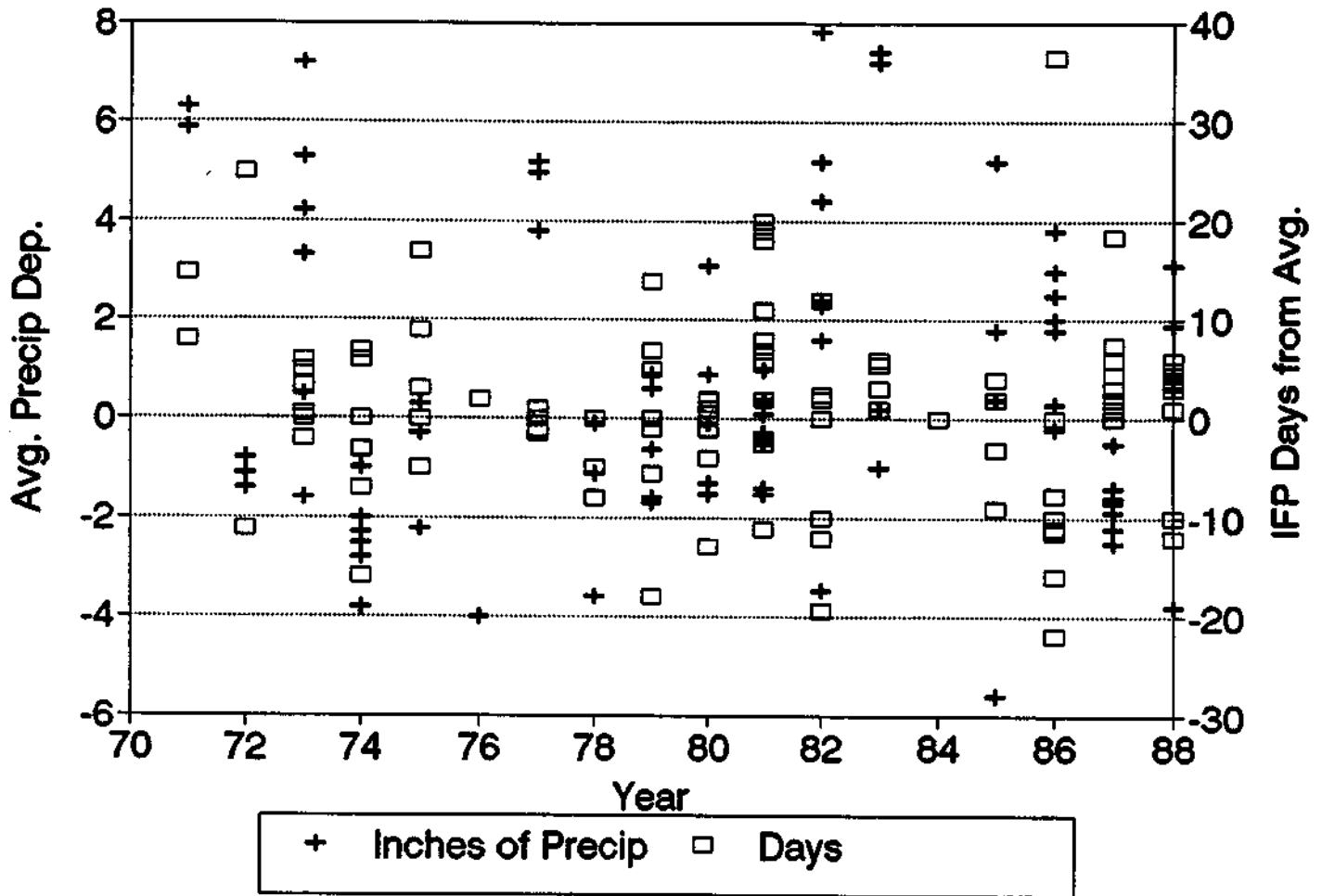
History of Initial Frost Date Ranges by Site



Initial Freezing
Point

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Correlation between Avg. Precip Departure and Avg. IFP Departure



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Site	Average Frost	Earliest Frost	Latest Frost	Average Error	Latitude	Longitude	UpdateAVG
Site	Average Frost	Earliest Frost	Latest Frost	Average Error	Latitude	Longitude	UpdateAVG
1	27-Nov	30-Oct	04-Jan	7.28	101	48.5	28-Nov
2	17-Nov	29-Oct	08-Dec	12.43	100	48.3	17-Nov
3	20-Nov	07-Nov	08-Dec	14.00	98.7	48.2	21-Nov
4	26-Nov	13-Nov	12-Dec	10.17	98.4	48.1	27-Nov
5	17-Nov	27-Oct	04-Jan	10.74	98	48.3	18-Nov
6	20-Nov	01-Nov	07-Dec	9.45	98	48.3	20-Nov
7	25-Nov	07-Nov	16-Dec	8.54	97.1	48.7	25-Nov
8	29-Nov	10-Nov	26-Dec	8.36	96.9	47.6	22-Nov
9	01-Dec	06-Nov	15-Dec	13.68	96.3	45.2	01-Dec
10	24-Nov	07-Nov	07-Jan	6.89	96.1	45.8	20-Nov
11	26-Nov	09-Nov	30-Dec	11.75	95.5	46.2	22-Nov
12	06-Dec	28-Oct	30-Dec	19.25	95.7	49	06-Dec
13	24-Nov	06-Nov	08-Dec	15.40	95.3	47.4	25-Nov
14	01-Dec	18-Nov	14-Dec	8.29	95	46.4	06-Dec
15	04-Dec	10-Nov	30-Dec	5.79	95.3	44.3	11-Dec
16	02-Dec	11-Nov	25-Dec	5.26	93.9	43.5	11-Dec
17	21-Dec	07-Dec	12-Jan	5.37	93.9	44.3	20-Dec
18	08-Dec	13-Nov	06-Jan	7.31	93.9	45	03-Dec
19	27-Nov	11-Nov	11-Dec	8.94	94.1	45.4	27-Nov
20	29-Nov	13-Nov	11-Dec	11.37	93.6	47	29-Nov
21	12-Dec	24-Nov	07-Jan	11.90	93.8	47	13-Dec
22	08-Dec	23-Nov	26-Dec	9.45	93.8	48.7	09-Dec
23	17-Nov	29-Jan	09-Jan	8.79	92.5	48.7	15-Dec
24	02-Dec	31-Oct	18-Jan	7.31	92.3	47	02-Dec
25	04-Dec	26-Nov	22-Dec	8.98	91.9	45.8	04-Dec
26	06-Dec	07-Nov	02-Jan	4.67	92.9	45	11-Dec
27	06-Dec	09-Nov	10-Jan	8.33	92.7	44	10-Dec
28	20-Dec	18-Nov	10-Jan	6.15	92	44	23-Dec
29	06-Dec	09-Nov	24-Dec	9.95	91.2	43.2	07-Dec
30	14-Dec	19-Nov	02-Jan	5.72	91	44.5	14-Dec
31	07-Dec	10-Nov	09-Jan	4.22	91.2	45.5	08-Dec
32	17-Dec	13-Nov	07-Mar	3.77	90	46.5	18-Dec
33	08-Dec	15-Nov	04-Jan	7.86	89.8	43.8	08-Dec
34	17-Dec	08-Dec	22-Jan	7.90	89.1	46	18-Dec
35	24-Nov	10-Nov	03-Dec	8.44	88.8	45.7	23-Nov
36	30-Nov	30-Oct	23-Dec	4.50	92	44.5	29-Nov
37	02-Dec	22-Nov	12-Dec	10.96	94.3	46.5	02-Dec

FRATA

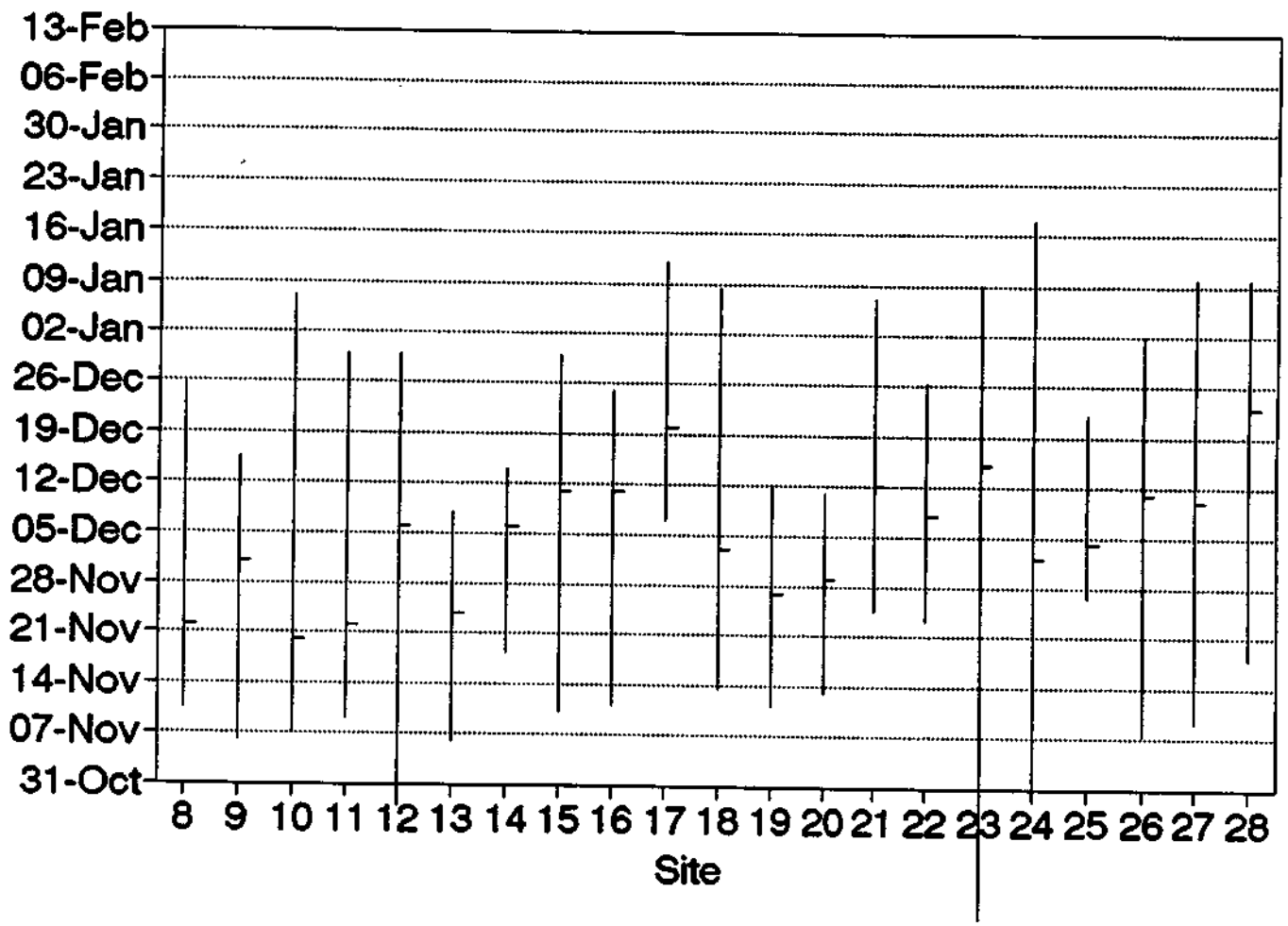
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			Latest Frost	Average Error	Latitude	Longitude
			Latest Frost	Average Error	Latitude	Longitude
			370	7.28	101	48.5
			343	12.43	100	48.3
			343	14.00	98.7	48.2
4	331.833333	318	347	10.17	98.4	48.1
5	322.670588	301	370.5	10.74	98	48.3
6	325.296875	306.5	342	9.45	98	48.3
7	330.892857	312	351	8.54	97.1	48.7
8	333.472222	315.5	361	8.36	96.9	47.6
9	336.205882	311	350.5	13.68	96.3	45.2
10	329.777778	312	373	8.89	96.1	45.8
11	331.955882	314	365	11.75	95.5	46.2
12	341.125	302	365	19.25	95.7	49
13	329.8	311	343	15.40	95.3	47.4
14	336.857143	323.5	349	8.29	95	46.4
15	339.666667	315	365	5.78	95.3	44.3
16	337.5	316	360	5.26	93.9	43.5
17	356.354545	342	378	5.37	93.9	44.3
18	343	318.5	374.5	7.31	93.9	45
19	332.111111	316	346.8	8.94	94.1	45.4
20	334.3	318	346	11.37	93.6	47
21	347.9	329.5	373	11.90	93.8	47
22	343.85	328	381.5	9.45	93.8	46.7
23	322.142857	30.5	375	8.79	92.5	48.7
24	337.083333	305	384	7.31	92.3	47
25	339.4	331.5	357	8.98	91.9	45.8
26	341	312.5	368	4.67	92.9	45
27	341.6	314	376	8.33	92.7	44
28	355.538462	323	376	6.15	92	44
29	341.75	314	359	9.95	91.2	43.2
30	349	324	368	5.72	91	44.5
31	342.65625	315	375	4.22	91.2	45.5
32	352.625	318	432.5	3.77	90	46.5
33	343.142857	320	370	7.86	89.8	43.8
34	352.9	343.5	398	7.90	89.1	46
35	329.0625	315	338	8.44	96.8	45.7
36	335.833333	304.5	358	4.50	92	44.5
37	337.038462	327	347	10.96	94.3	46.5

1

Site	Average Frost	Earliest Frost	Latest Frost	Average Error	Latitude	Longitude
Site	Average Frost	Earliest Frost	Latest Frost	Average Error	Latitude	Longitude
1	332.897059	304.25	370	7.28	101	48.5
2	322.433333	303	343	12.43	100	48.3
3	325.7	312	343	14.00	98.7	48.2
4	331.833333	318	347	10.17	98.4	48.1
5	322.670588	301	370.5	10.74	98	48.3
6	325.296875	308.5	342	9.45	98	48.3
7	330.892857	312	351	6.54	97.1	46.7
8	333.472222	315.5	361	8.36	96.9	47.6
9	336.205882	311	350.5	13.68	96.3	45.2
10	329.777778	312	373	6.89	96.1	45.8
11	331.955882	314	365	11.75	95.5	46.2
12	341.125	302	365	18.25	95.7	49
13	329.6	311	343	15.40	95.3	47.4
14	336.857143	323.5	349	8.29	95	46.4
15	339.666667	315	365	5.78	95.3	44.3
16	337.5	316	360	5.26	93.9	43.5
17	356.354545	342	378	5.37	93.9	44.3
18	343	318.5	374.5	7.31	93.9	45
19	332.111111	316	346.8	8.94	94.1	45.4
20	334.3	318	346	11.37	93.6	47
21	347.9	329.5	373	11.90	93.8	47
22	343.85	329	361.5	9.45	93.8	48.7
23	322.142857	30.5	375	8.79	92.5	48.7
24	337.083333	305	384	7.31	92.3	47
25	338.4	331.5	357	8.96	91.9	45.8
26	341	312.5	368	4.67	92.9	45
27	341.6	314	376	8.33	92.7	44
28	355.538462	323	376	6.15	92	44
29	341.75	314	359	9.95	91.2	43.2
30	349	324	368	5.72	91	44.5
31	342.65625	315	375	4.22	91.2	45.5
32	352.625	318	432.5	3.77	90	46.5
33	343.142857	320	370	7.86	89.8	43.8
34	352.9	343.5	388	7.90	89.1	46
35	329.0625	315	339	8.44	86.8	45.7
36	335.833333	304.5	358	4.50	92	44.5
37	337.038462	327	347	10.96	94.3	46.5

History of Minnesota Initial Frost Date Ranges



Notes Concerning Initial Freezing Dates for All Sites

Most sites did not report the initial freezing date of the soil. Instead, it was common for the site to start collecting data after the initial freezing date had actually occurred. In order to calculate an estimated initial frost date, an empirical calculation shown that the increase in frost depth in the - Y coordinate direction could be estimated to be one inch per day if the frost depth did not exceed 7 inches and snow fall was minimal. (1 - 5 inches). The IFP (Initial Freezing Point) date calculation will be researched further in order to show the fluctuations of ground frost development given different factors of soil types, moisture, snow cover, and temperature.

Minnesota Initial Freezing Point Date Averages:

The following data represents average initial freezing point dates for the Minnesota Region:

See data table

Frost Depth Maximum

Definition of Frost Depth Maximum

The frost depth maximum occurs when the upward heat flux from the subsurface starts to balance the downward heat flux deficit. Observations have shown that the balance between the two can typically exist for 7-10 days before having a decrease in the intermediate frost depth.

Factors that Determine the Maximum Frost Depth Date:

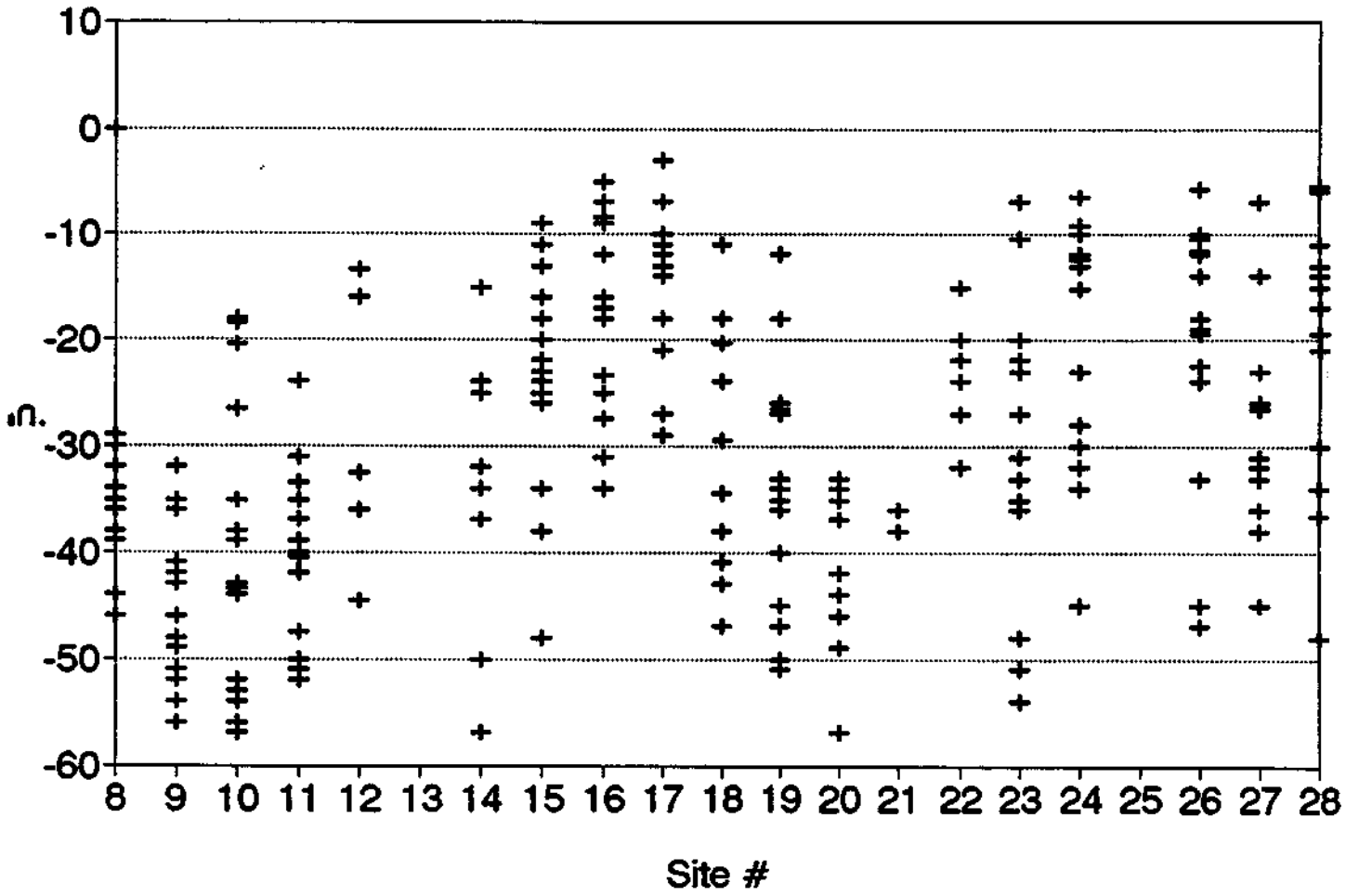
There are at least three factors that determine when a site will experience their maximum frost. The first factor involves the longitude and latitude differences between stations. Stations toward the north will see a maximum at a later date than the south. But overall, the most common time of the year for maximum frost depths was the second and third week in February. Secondly, sudden increase of snow depth will cause a frost depth maximum to occur earlier in the season if the snow remains until the initial melting point of the frost. Sites in northern Minnesota and southern Minnesota show a wide distribution of Max. frost depth dates when snow cover is increased. Finally, overall average temperatures for the season will determine when the maximum occurs across most sites consistently.

Factors that Determine the Depth of the Maximum Frost Depth:

1. Soil Types
2. Location (Long/Lat) - Freezing Index
3. Soil Moisture

Final Frost Data

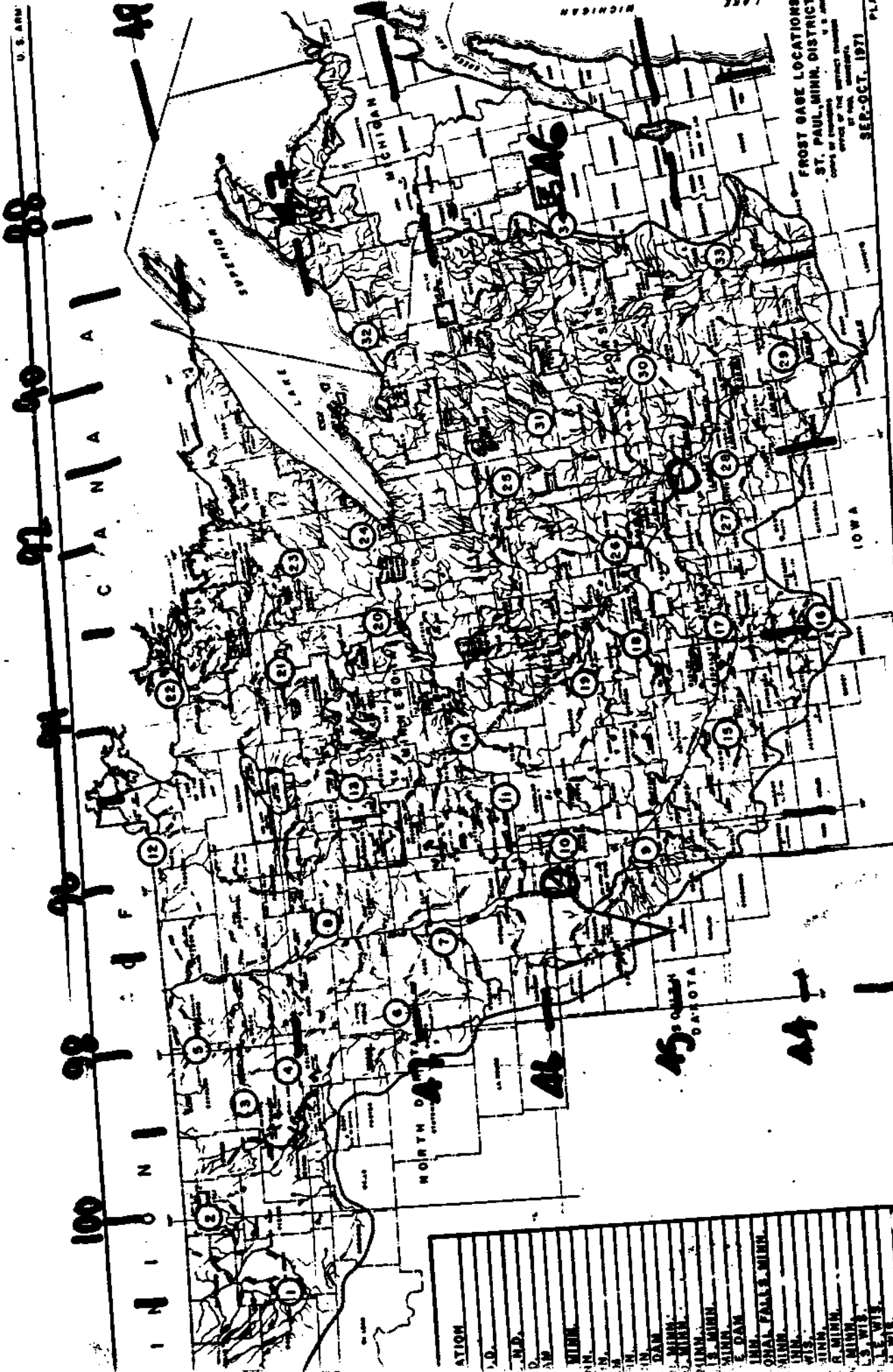
Plot of All recorded Maximum Frost Depths for Each Site



Sites:

1. ND Minot
2. ND Bottineau
3. ND Park River
4. ND Devils Lake
5. ND Langdon
6. ND Valley City
7. ND Fargo
8. MN Crookston
9. MN Watson
10. MN Morris
11. MN Fergus Falls
12. MN Roseau
13. MN Bemidji
14. MN Brainerd
15. MN Lambertton
16. MN North Winnebago
17. MN North Mankato
18. MN Minneapolis
19. MN St. Cloud
20. MN McGregor
21. MN Northome
22. MN International Falls
23. MN Virginia
24. MN Duluth
25. WI Spooner
26. MN St. Paul
27. MN Rochester
28. MN Winona
29. WI Gay Mills
30. WI Neillsville
31. WI Glen Flora
32. MI Bessmer
33. WI Mauston
34. MN Wausau
35. MN Wheaton
36. MN

- Longitude -

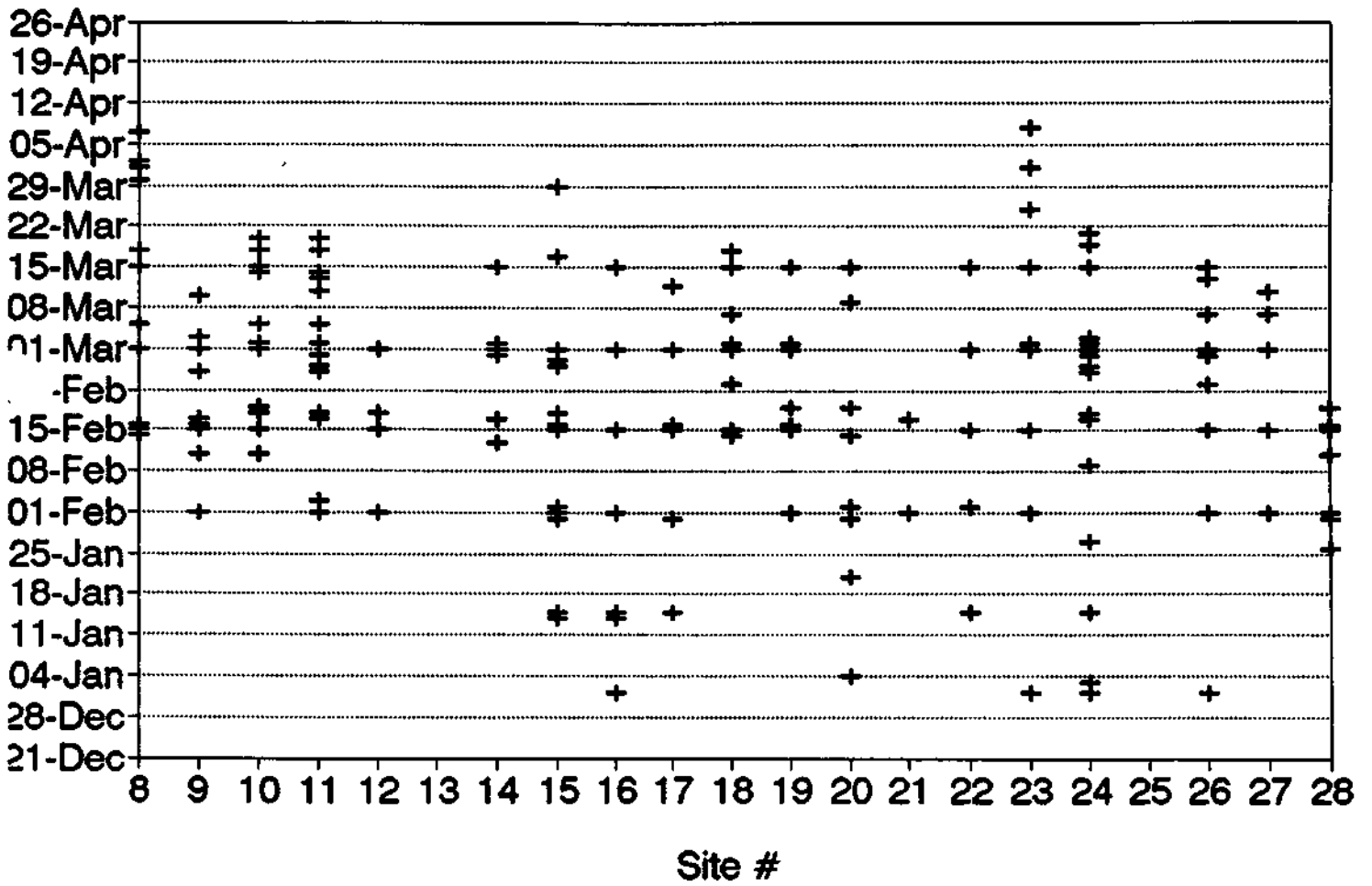


FROST BASE LOCATIONS
 ST. PAUL, MINN. DISTRICT
copy of complete project printed
 at the office of the project manager
 SEP-OCT. 1971

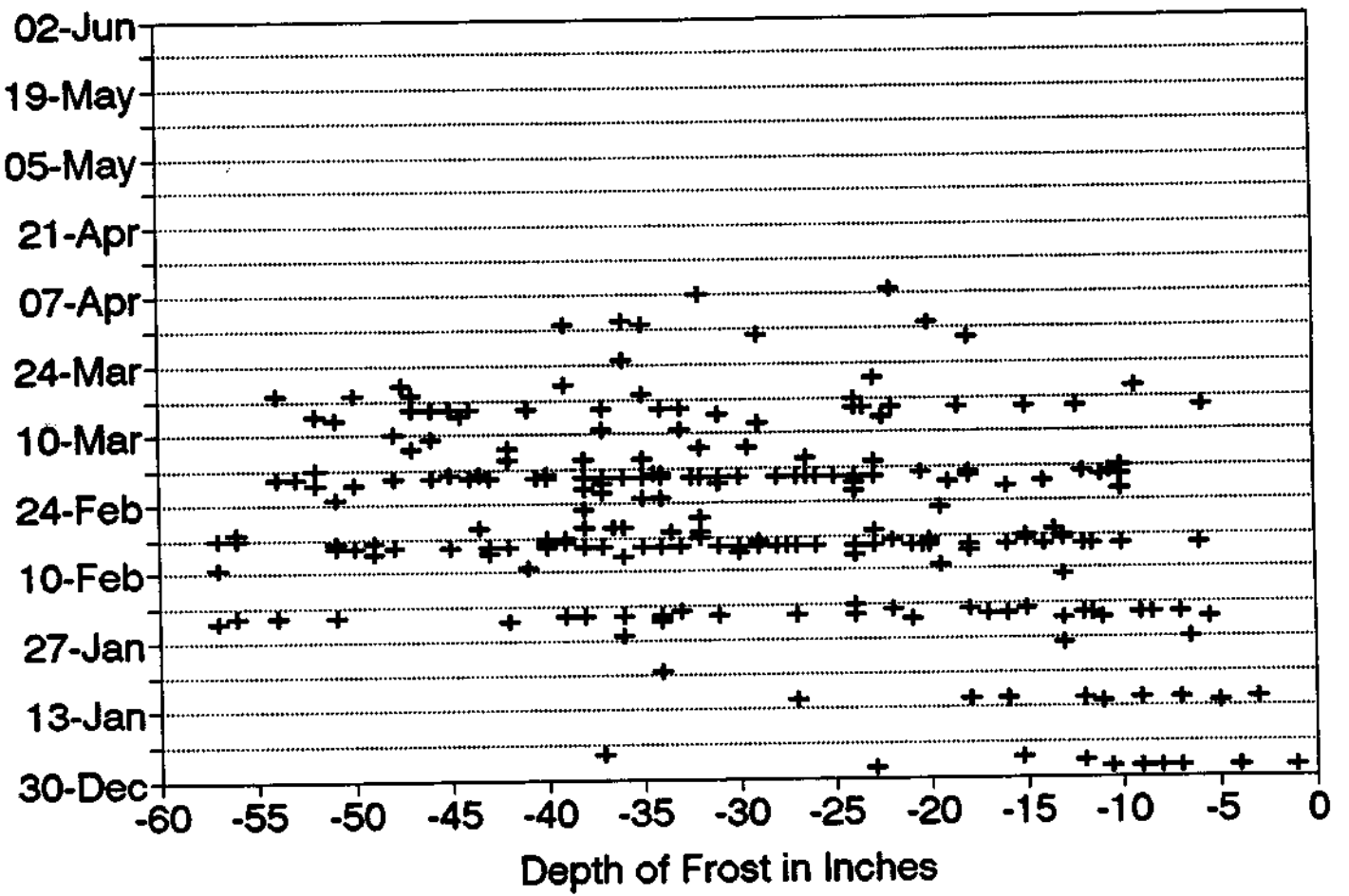
STATION	STATE
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2	MINN.
3	MINN.
4	MINN.
5	MINN.
6	MINN.
7	MINN.
8	MINN.
9	MINN.
10	MINN.
11	MINN.
12	MINN.
13	MINN.
14	MINN.
15	MINN.
16	MINN.
17	MINN.
18	MINN.
19	MINN.
20	MINN.
21	MINN.
22	MINN.
23	MINN.
24	MINN.
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29	MINN.
30	MINN.
31	MINN.
32	MINN.

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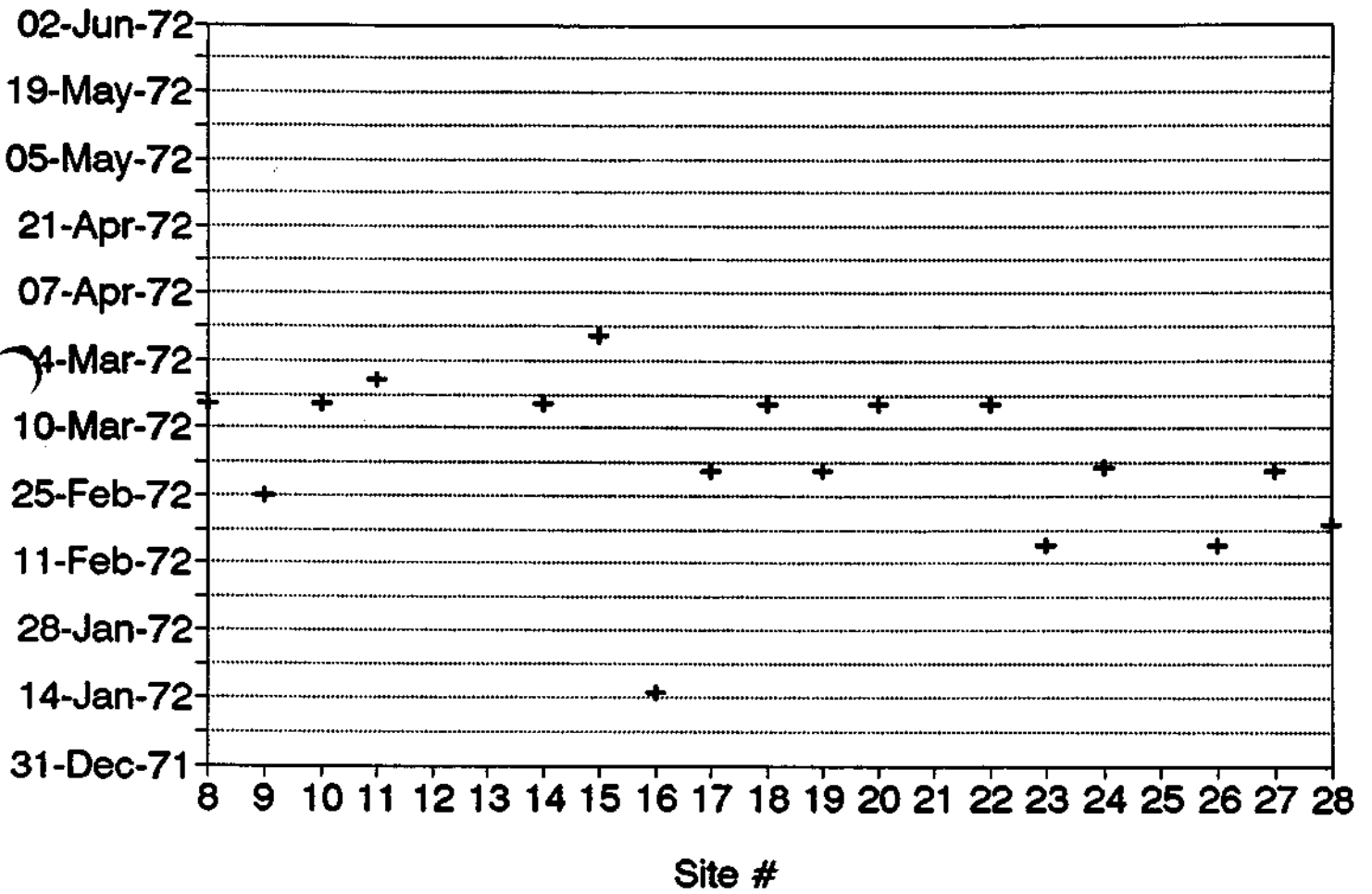
Maximum Frost Depth by Date



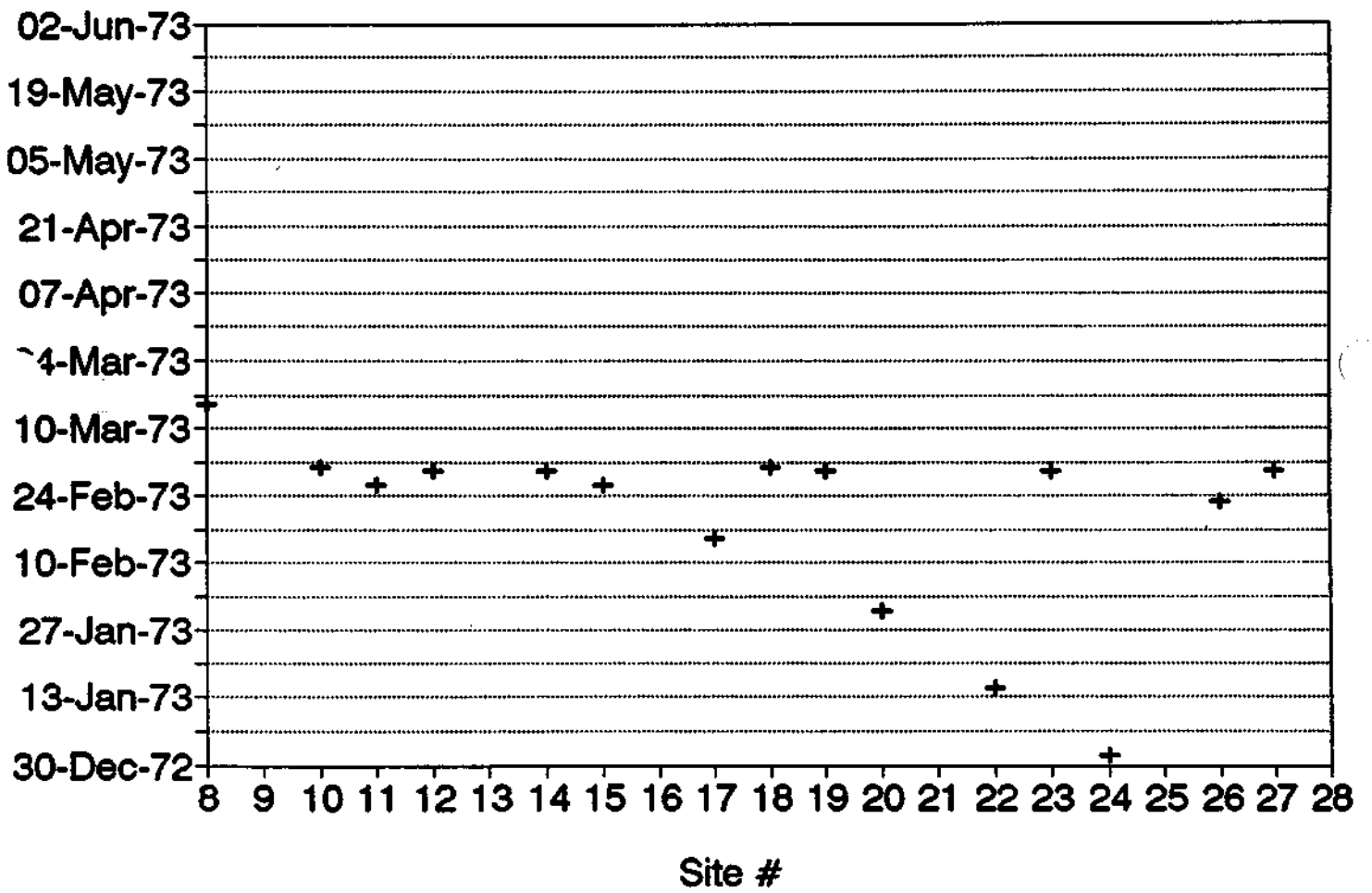
Date Versus Maximum Frost Depth



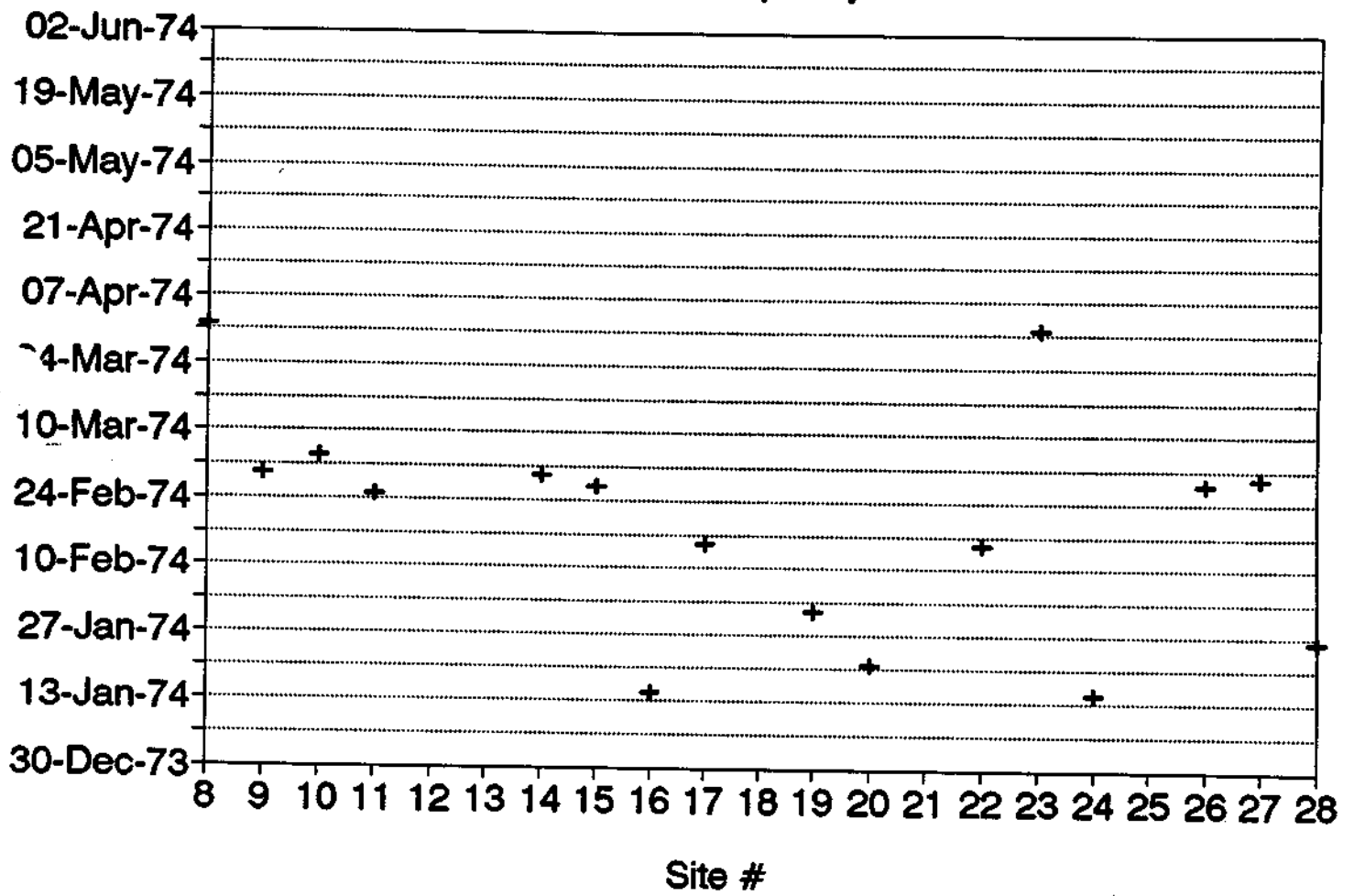
Maximum Frost Depth by Date



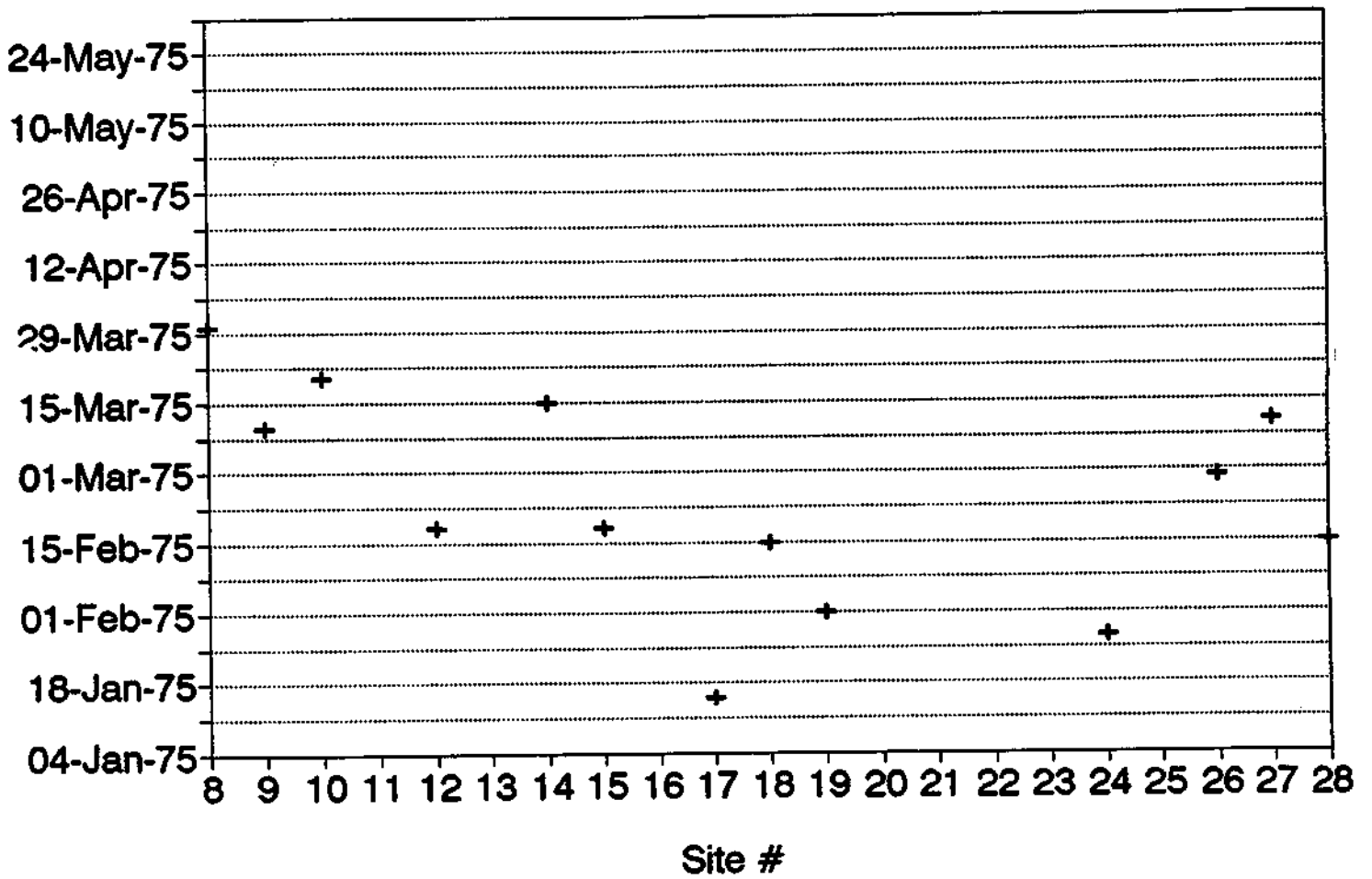
Maximum Frost Depth by Date



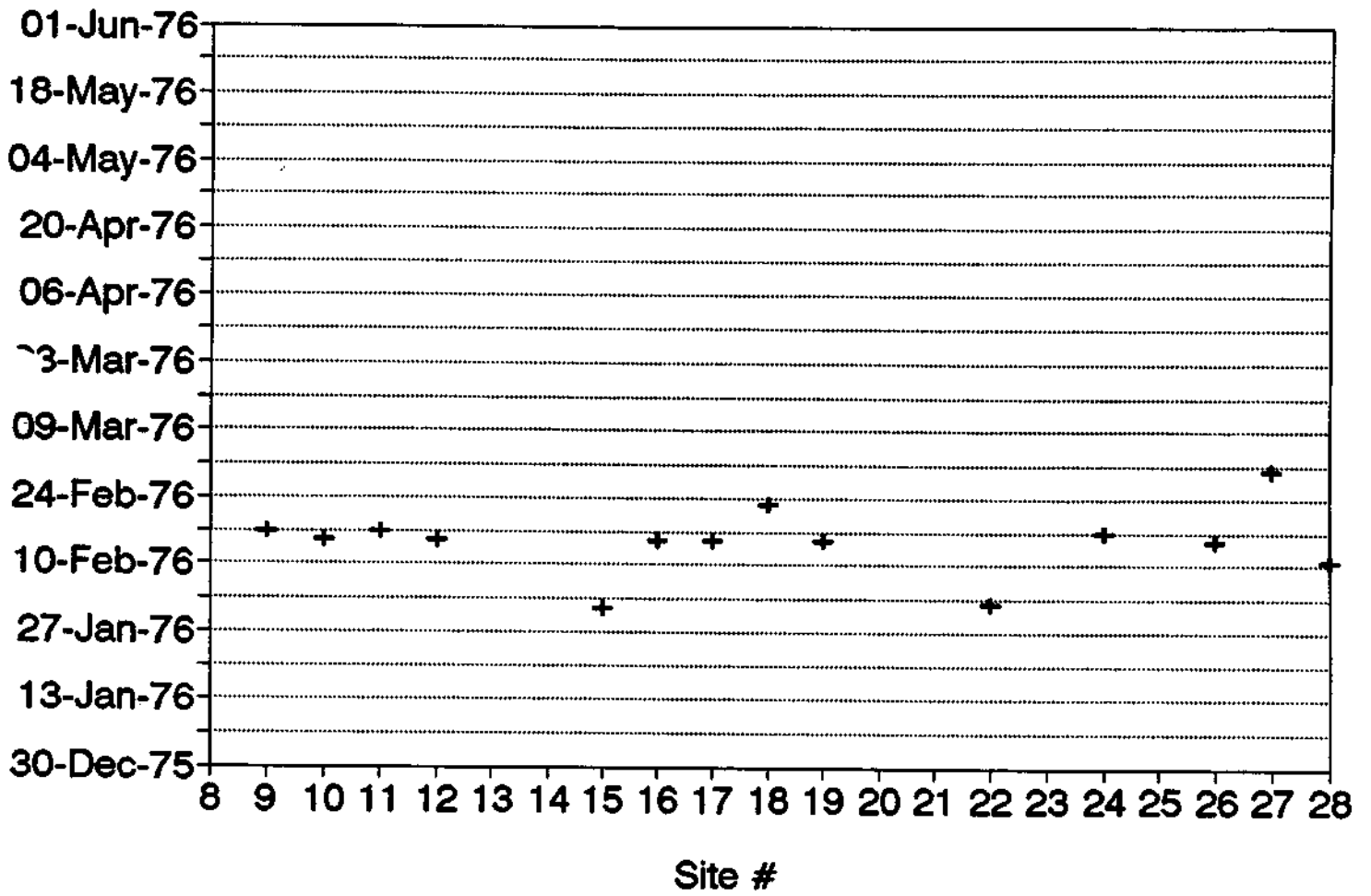
Maximum Frost Depth by Date



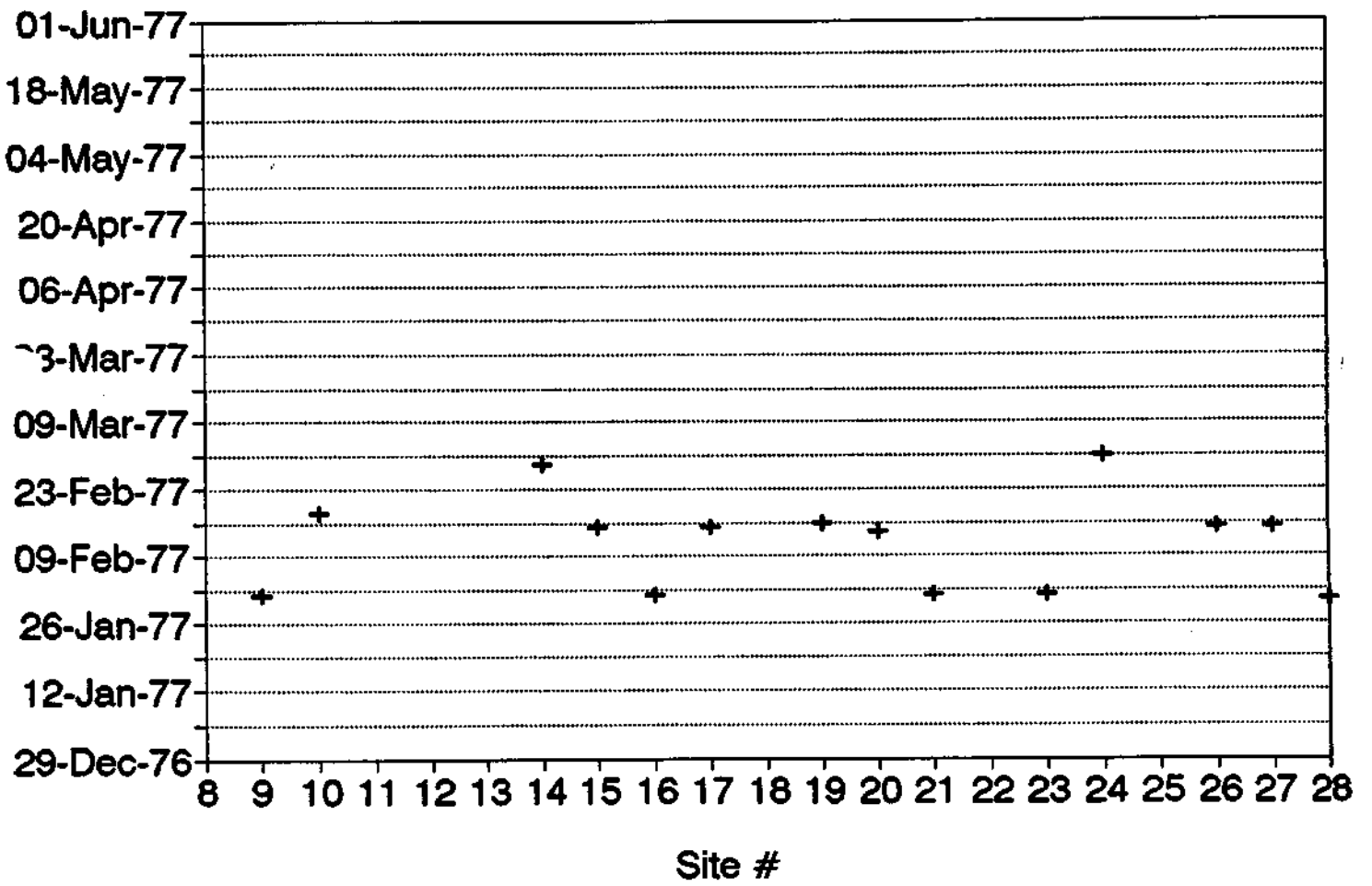
Maximum Frost Depth by Date



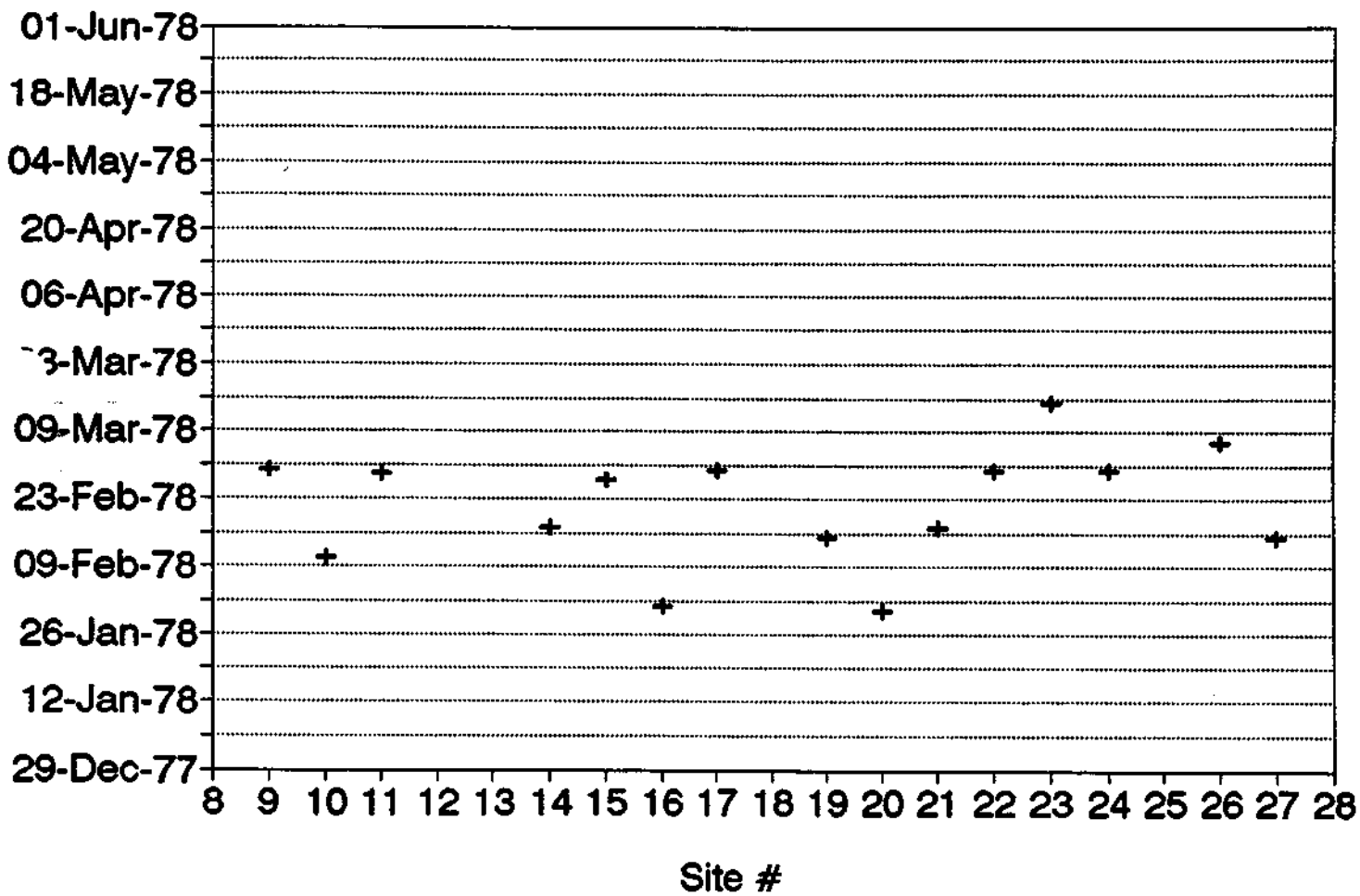
Maximum Frost Depth by Date



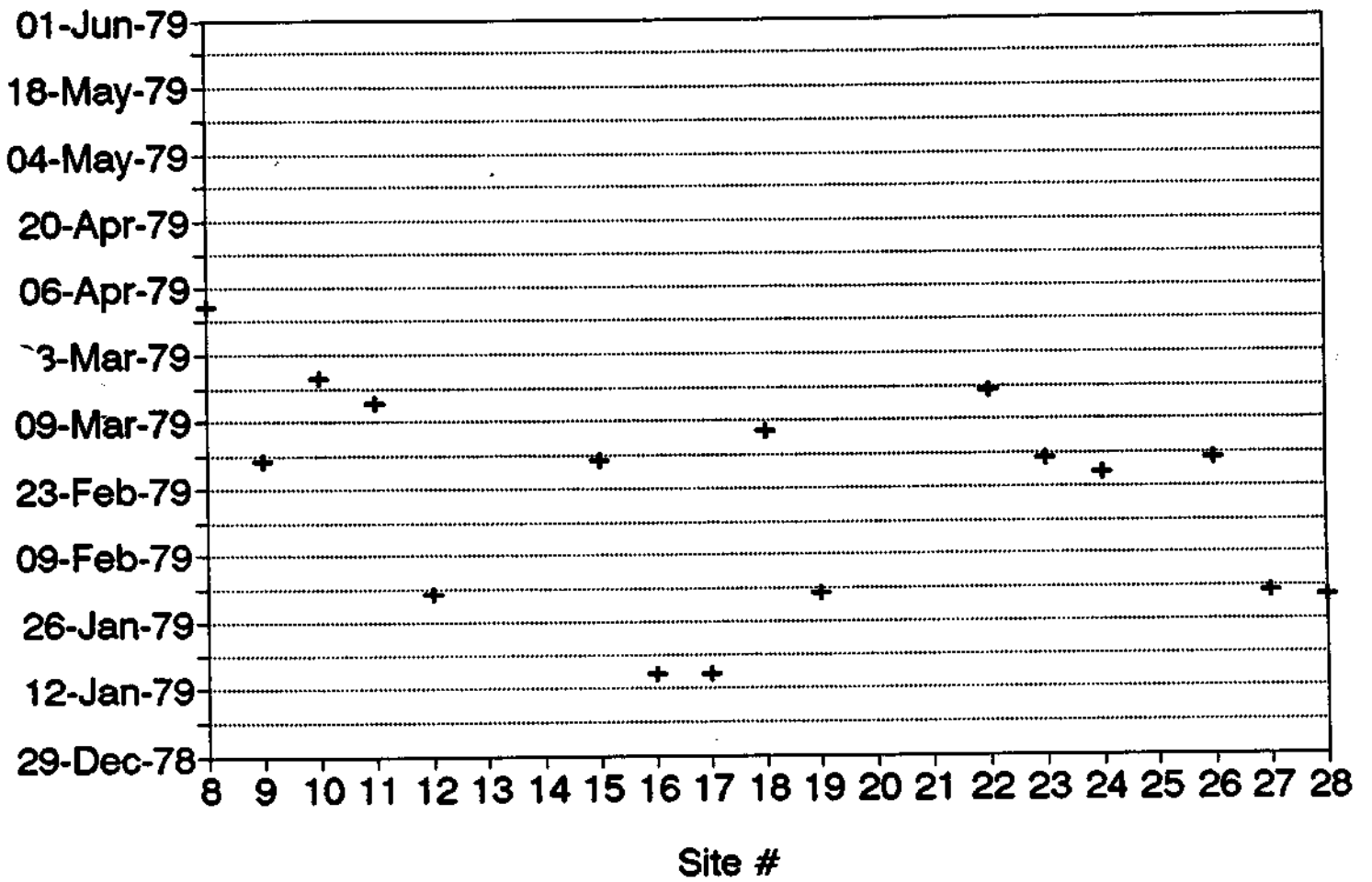
Maximum Frost Depth by Date



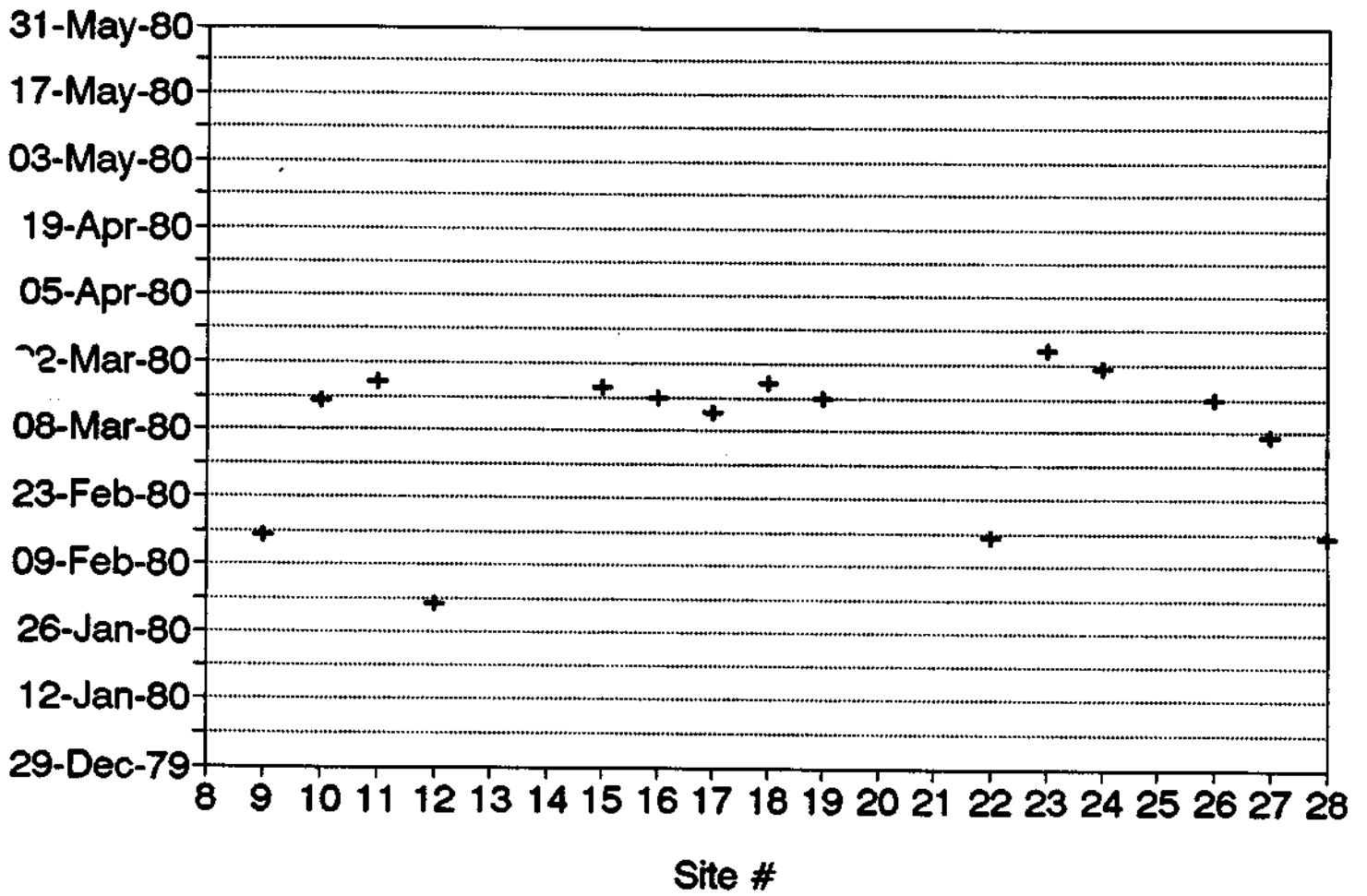
Maximum Frost Depth by Date



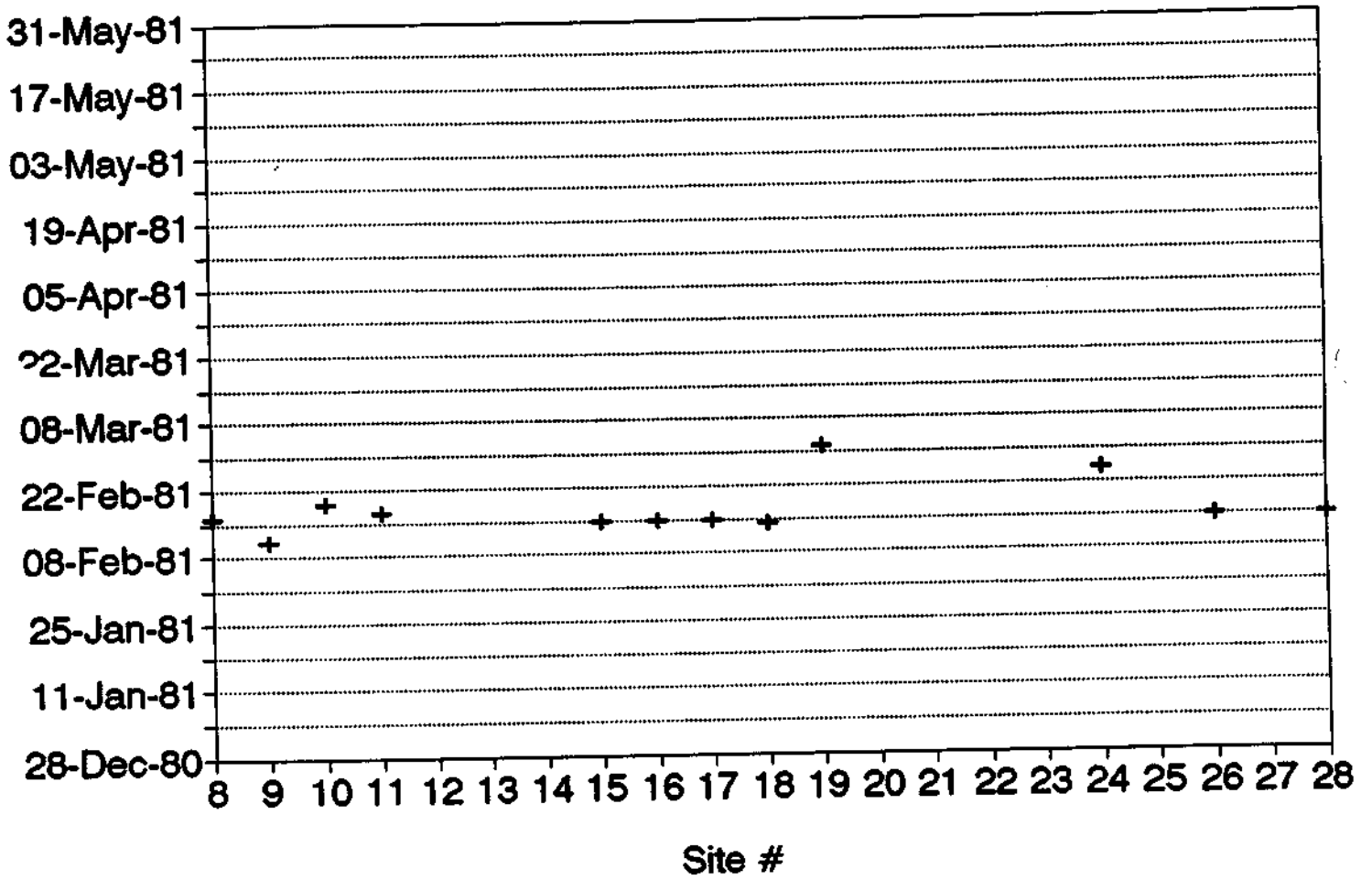
Maximum Frost Depth by Date



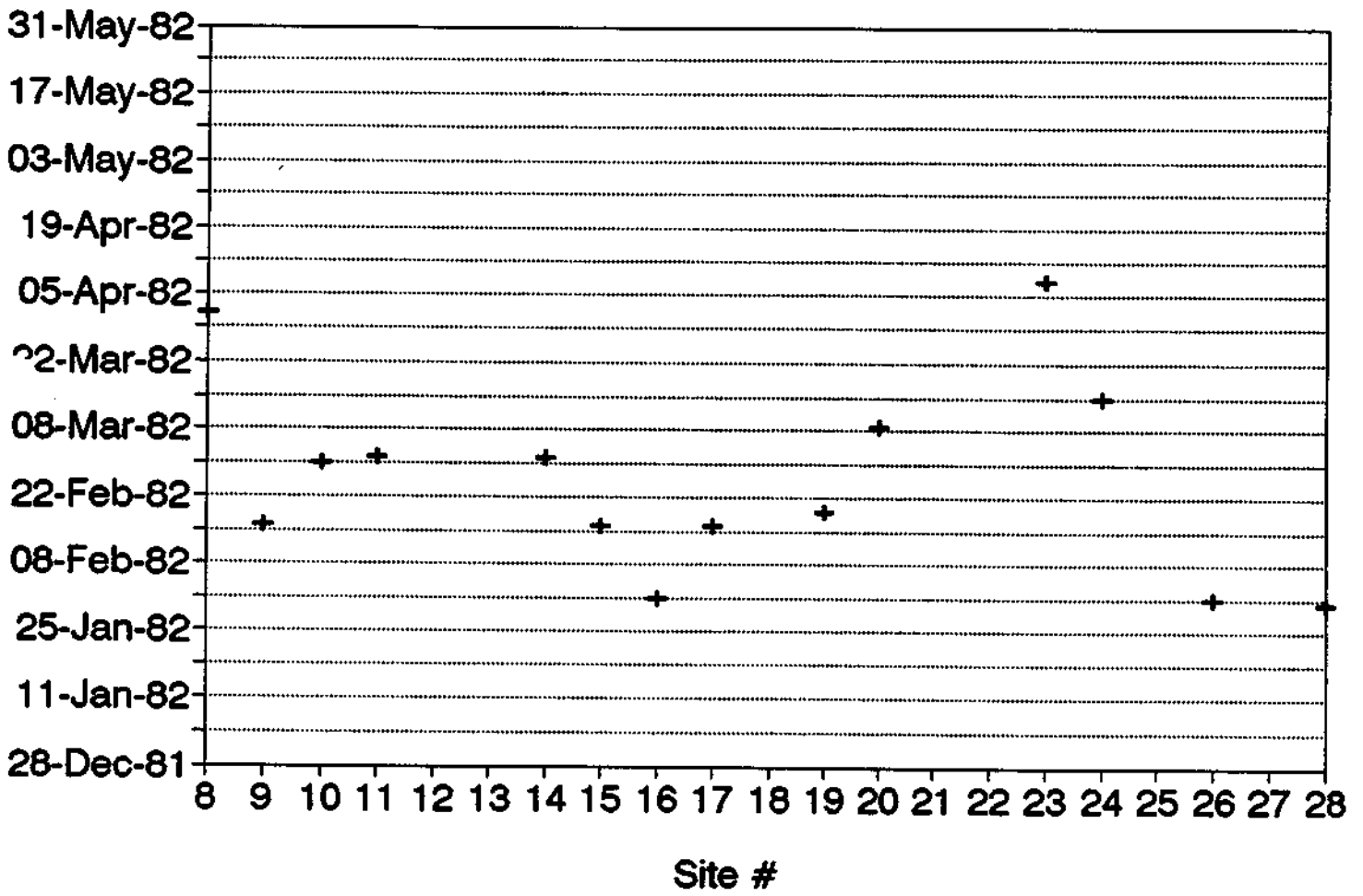
Maximum Frost Depth by Date



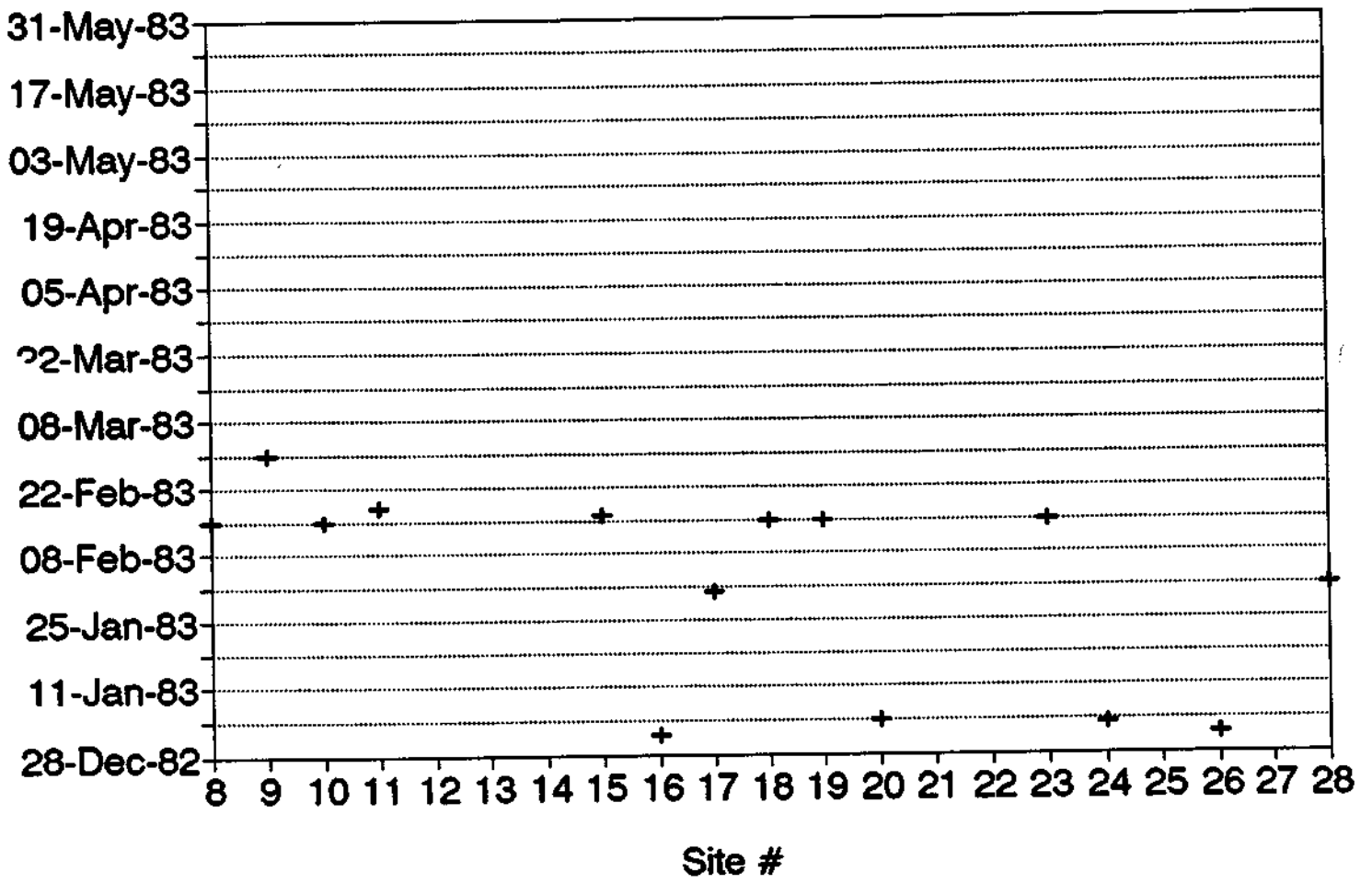
Maximum Frost Depth by Date



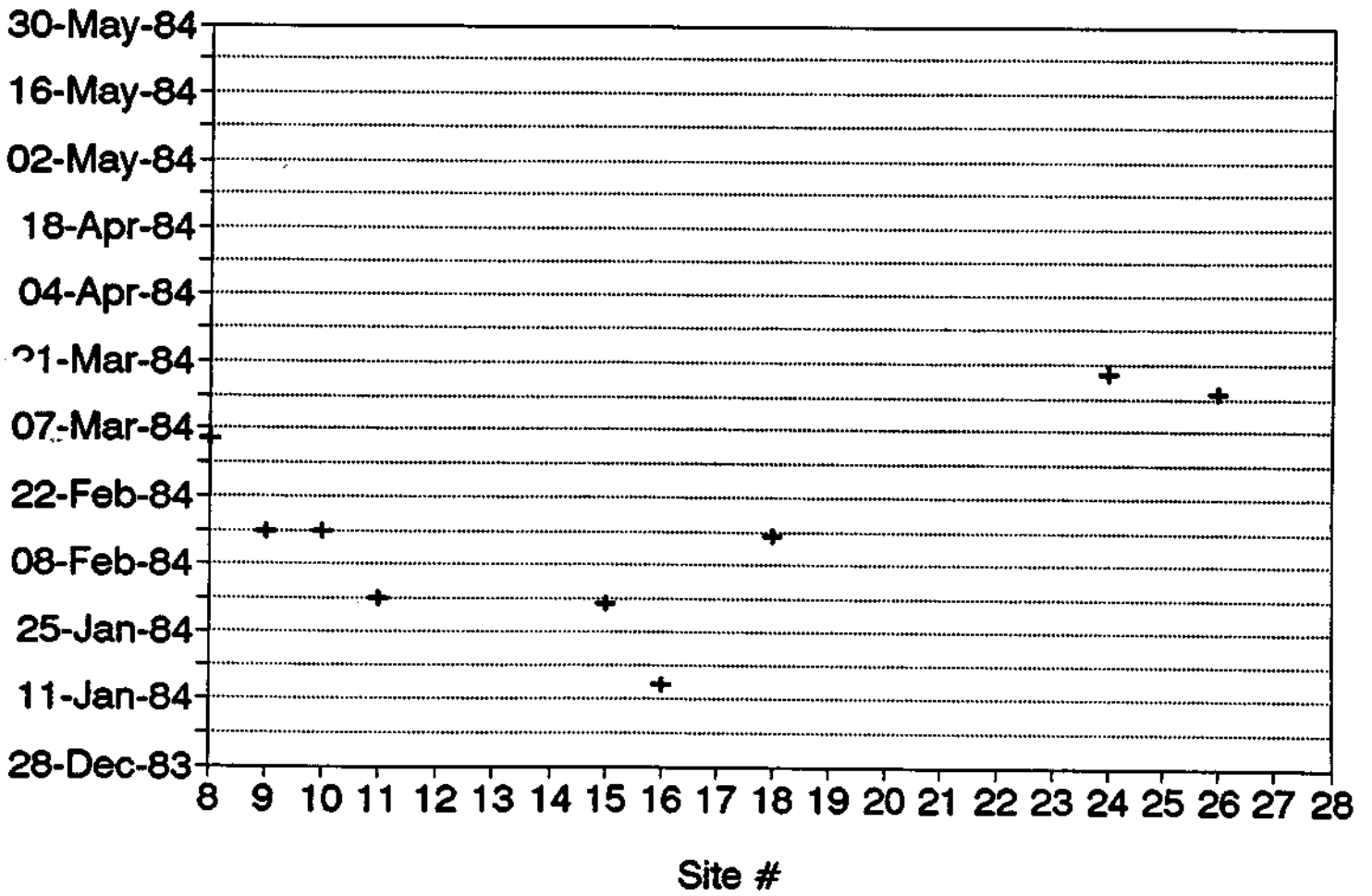
Maximum Frost Depth by Date



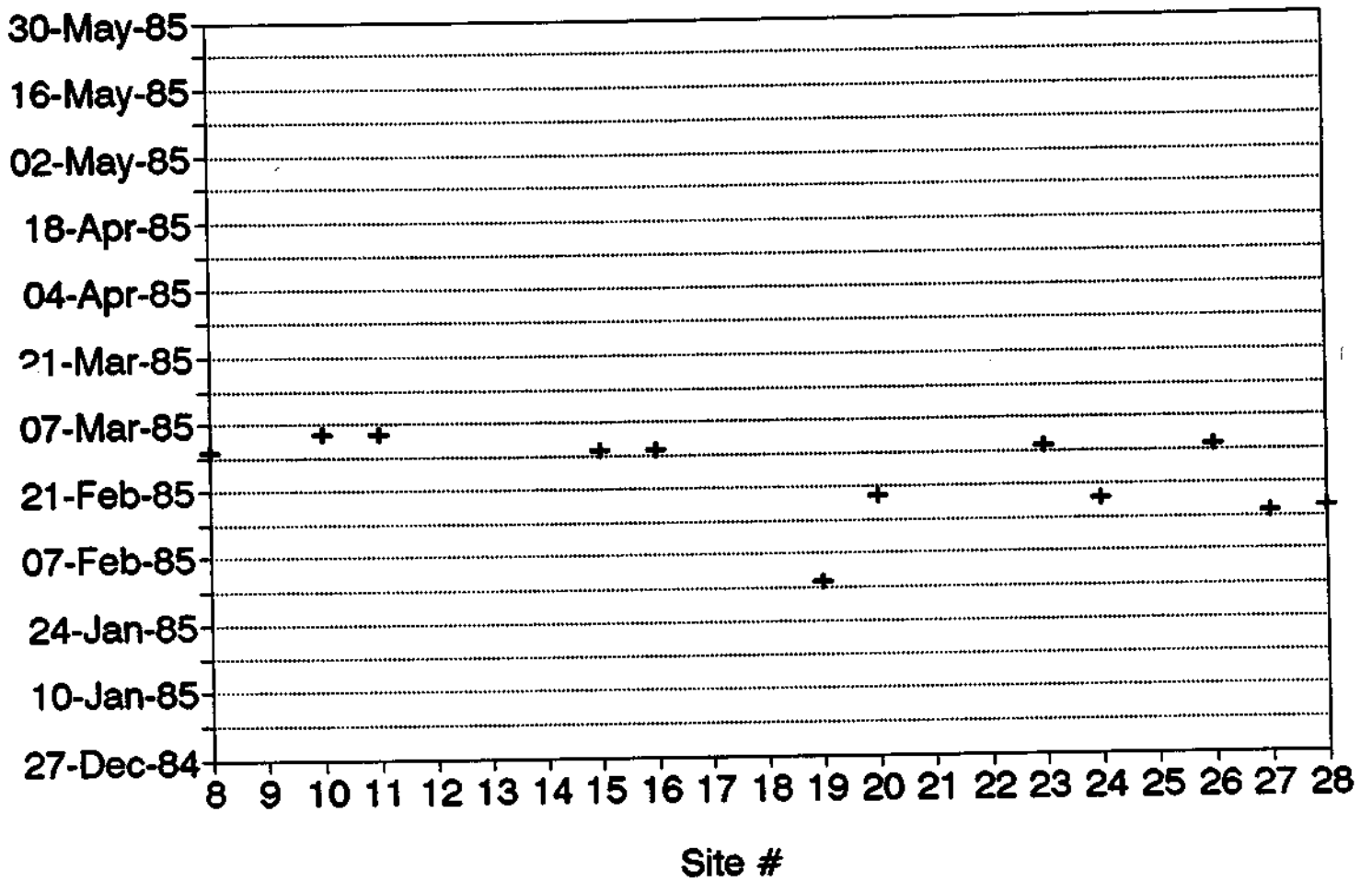
Maximum Frost Depth by Date



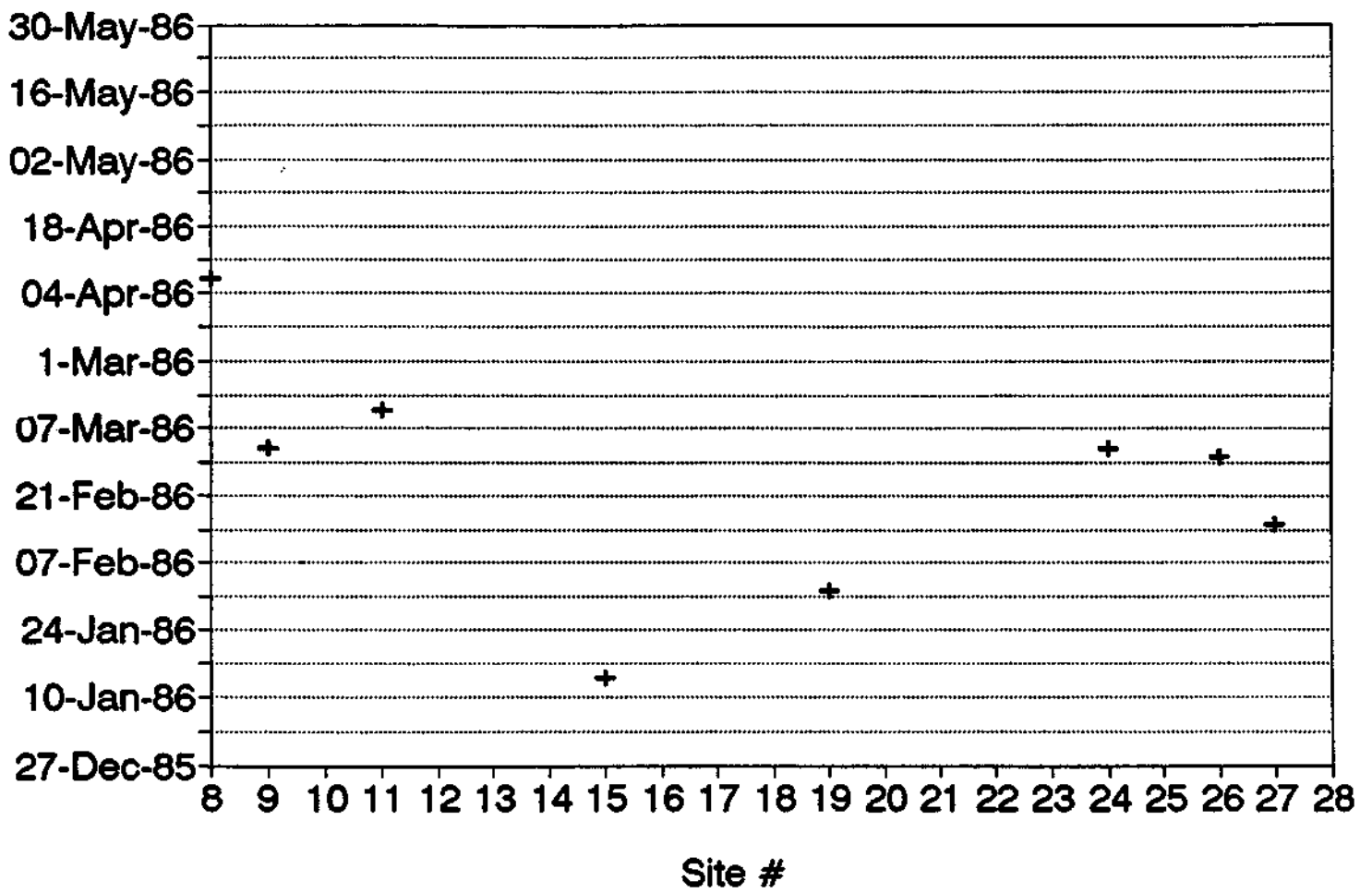
Maximum Frost Depth by Date



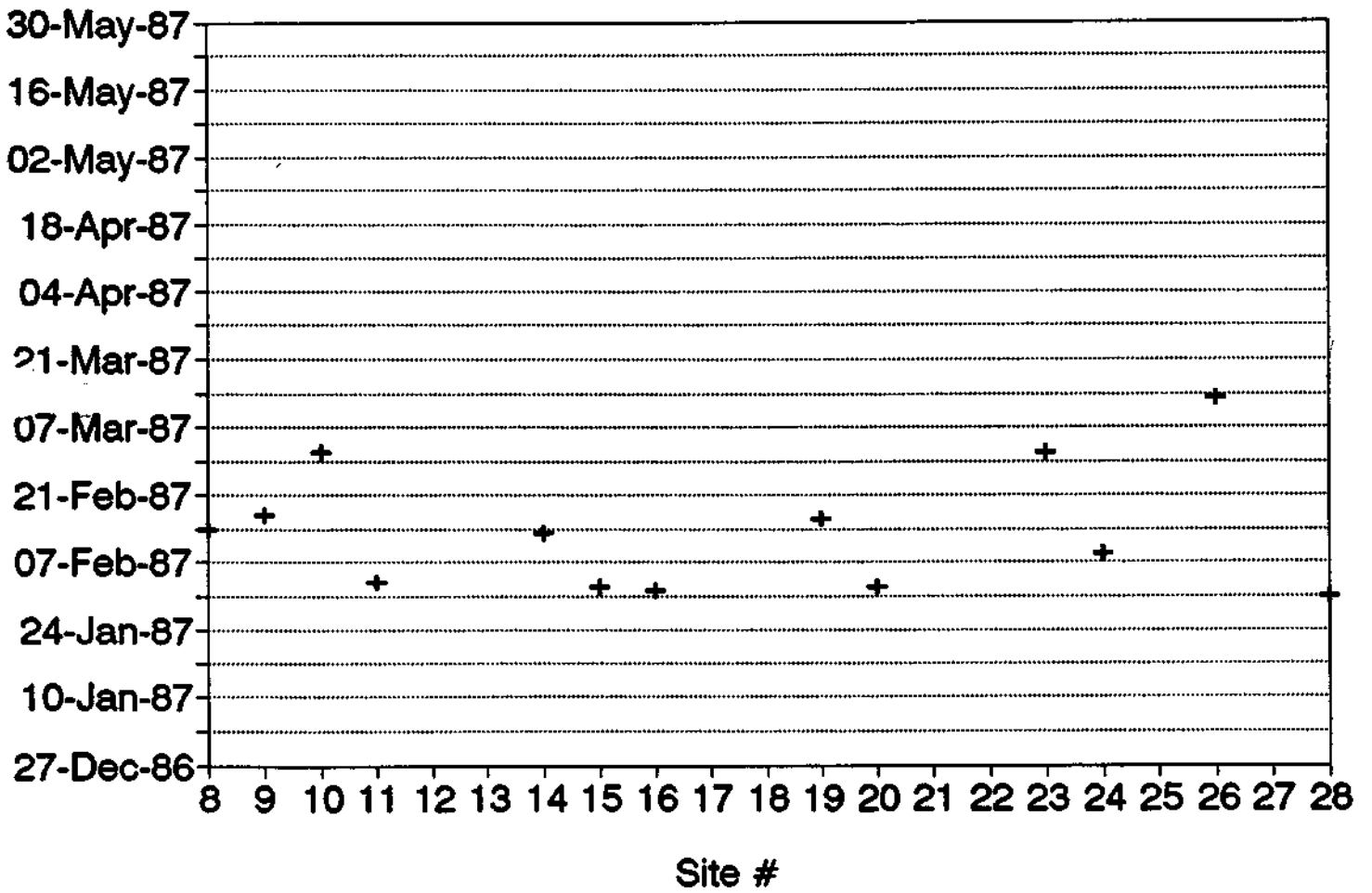
Maximum Frost Depth by Date



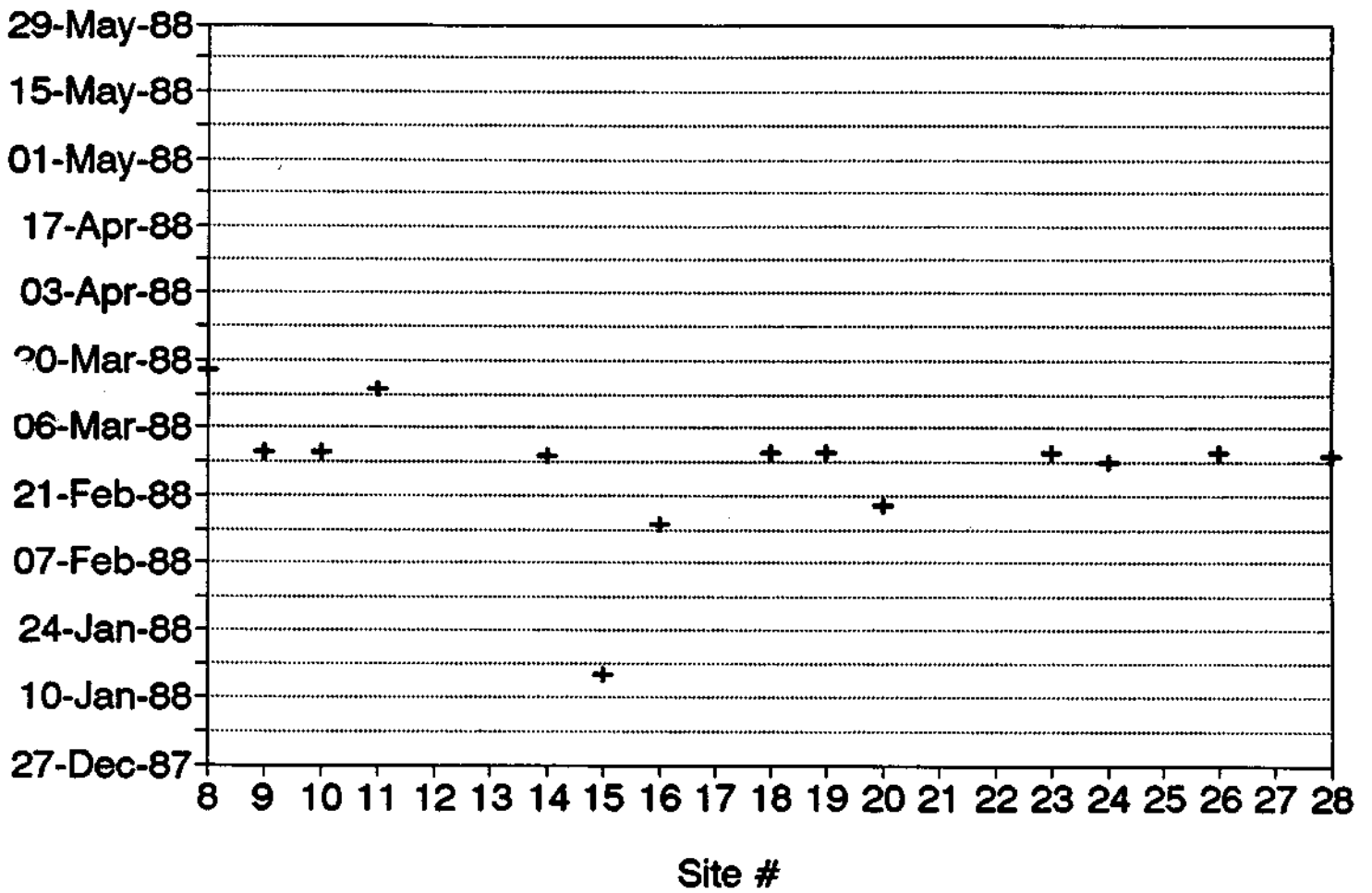
Maximum Frost Depth by Date



Maximum Frost Depth by Date

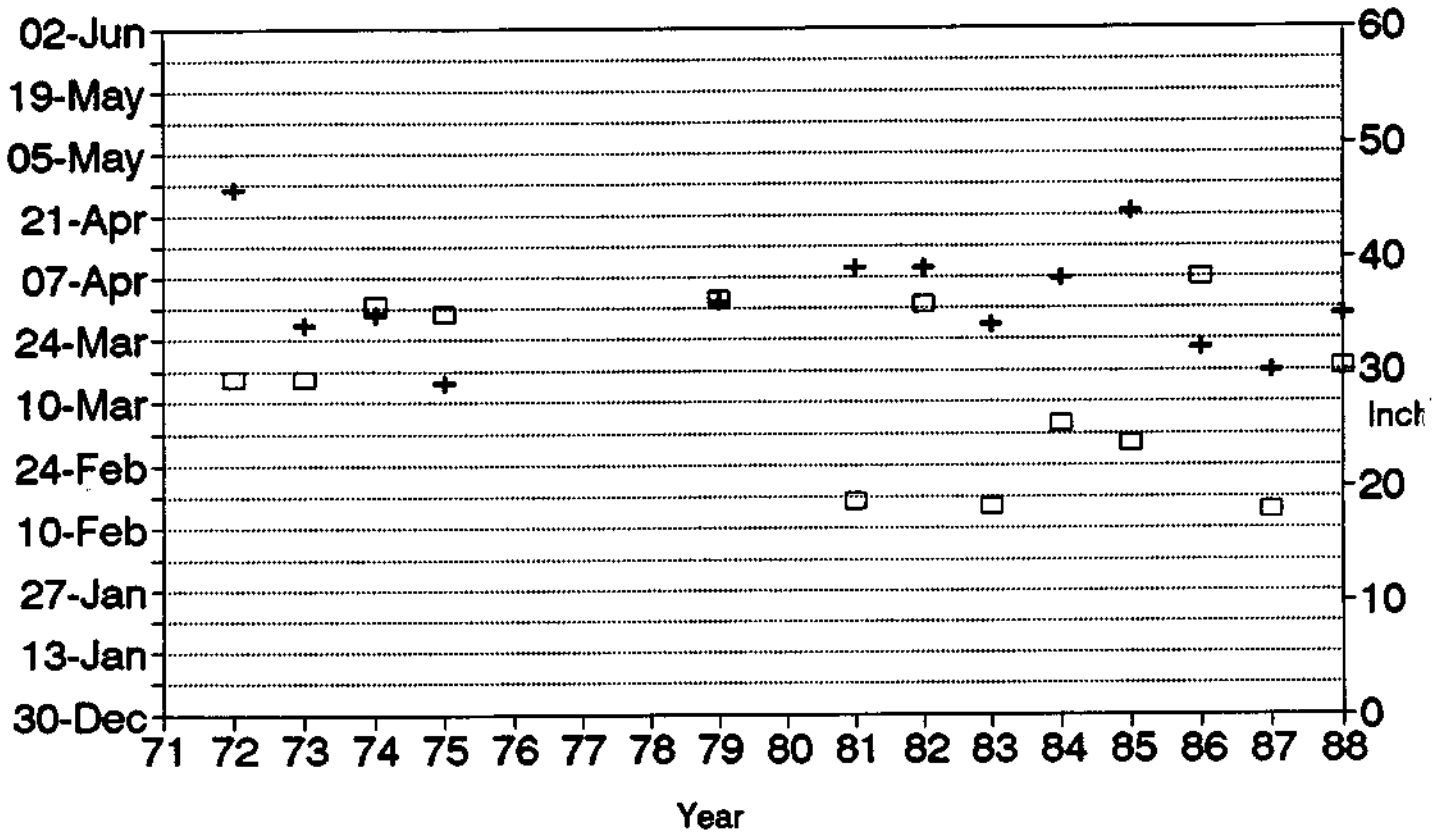


Maximum Frost Depth by Date



Site 8

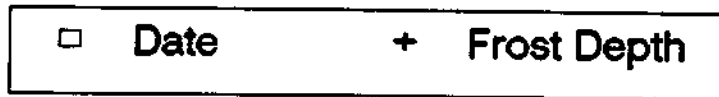
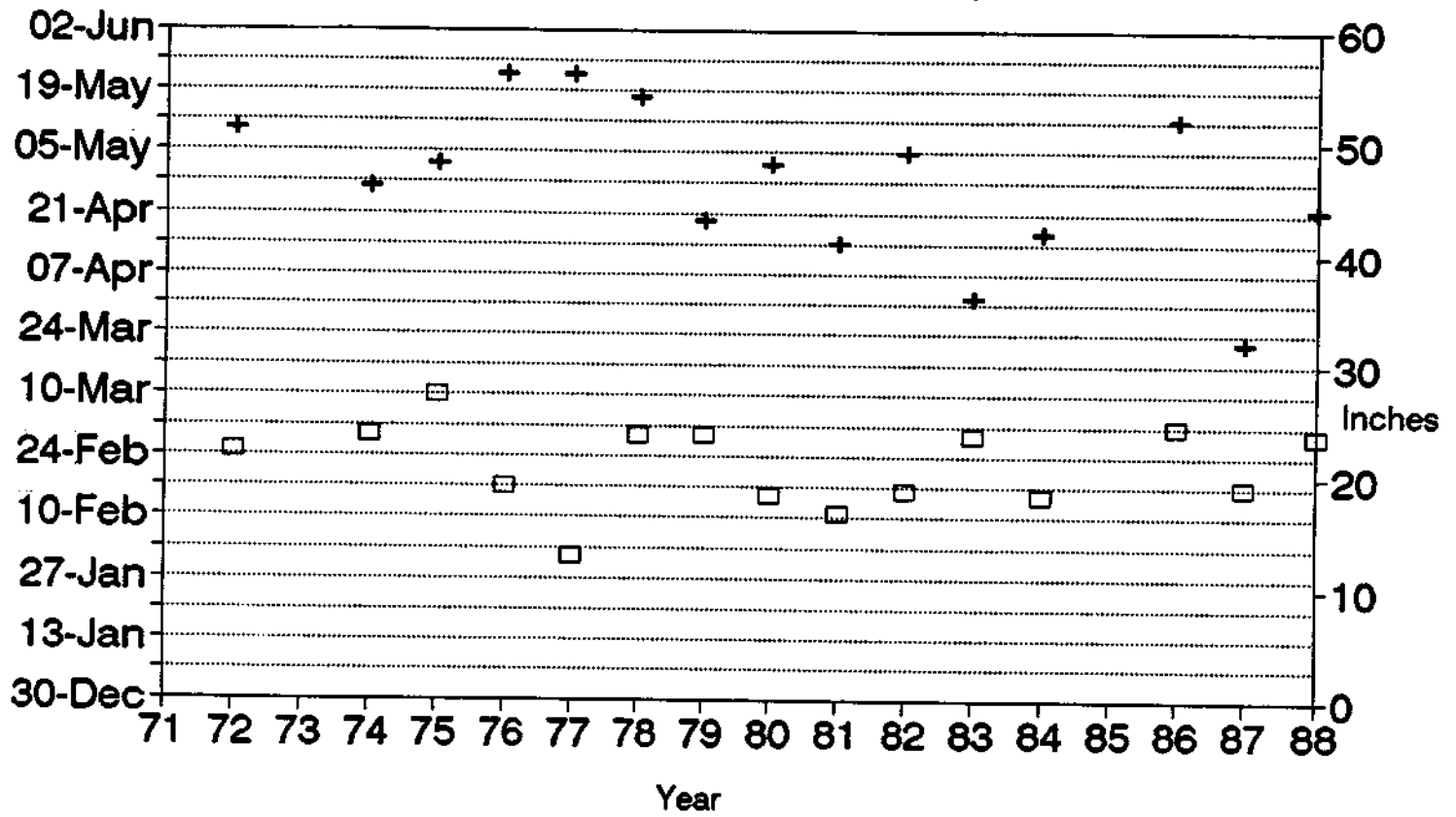
Maximum Frost Depth and Date by Year



□ Date + Frost Depth

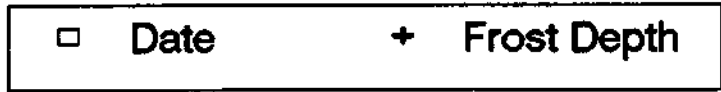
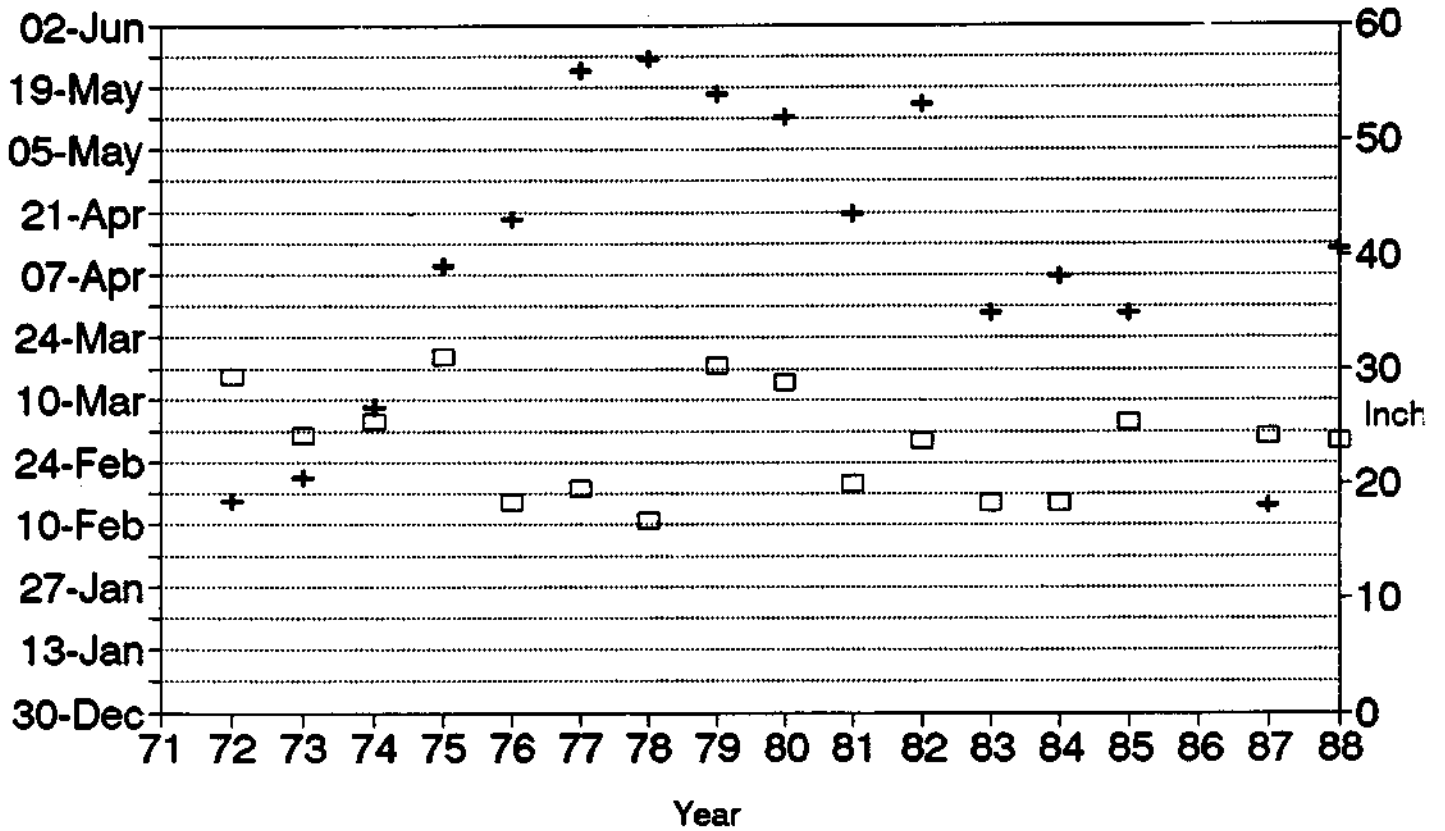
Site 9

Maximum Frost Depth and Date by Year



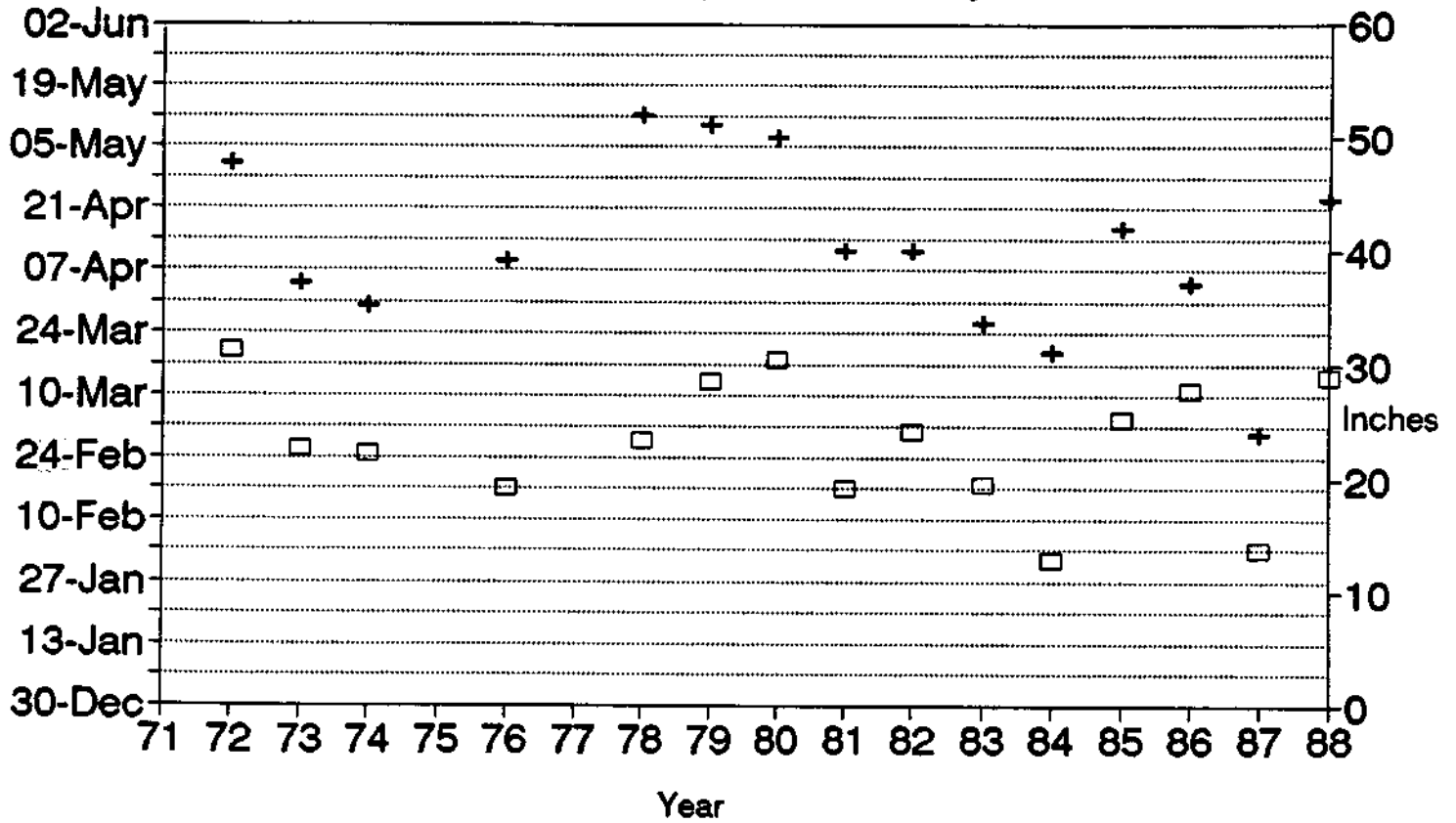
Site 10

Maximum Frost Depth and Date by Year



Site 11

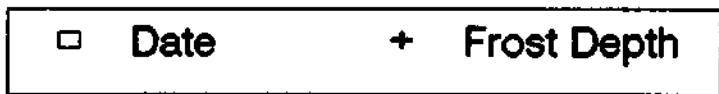
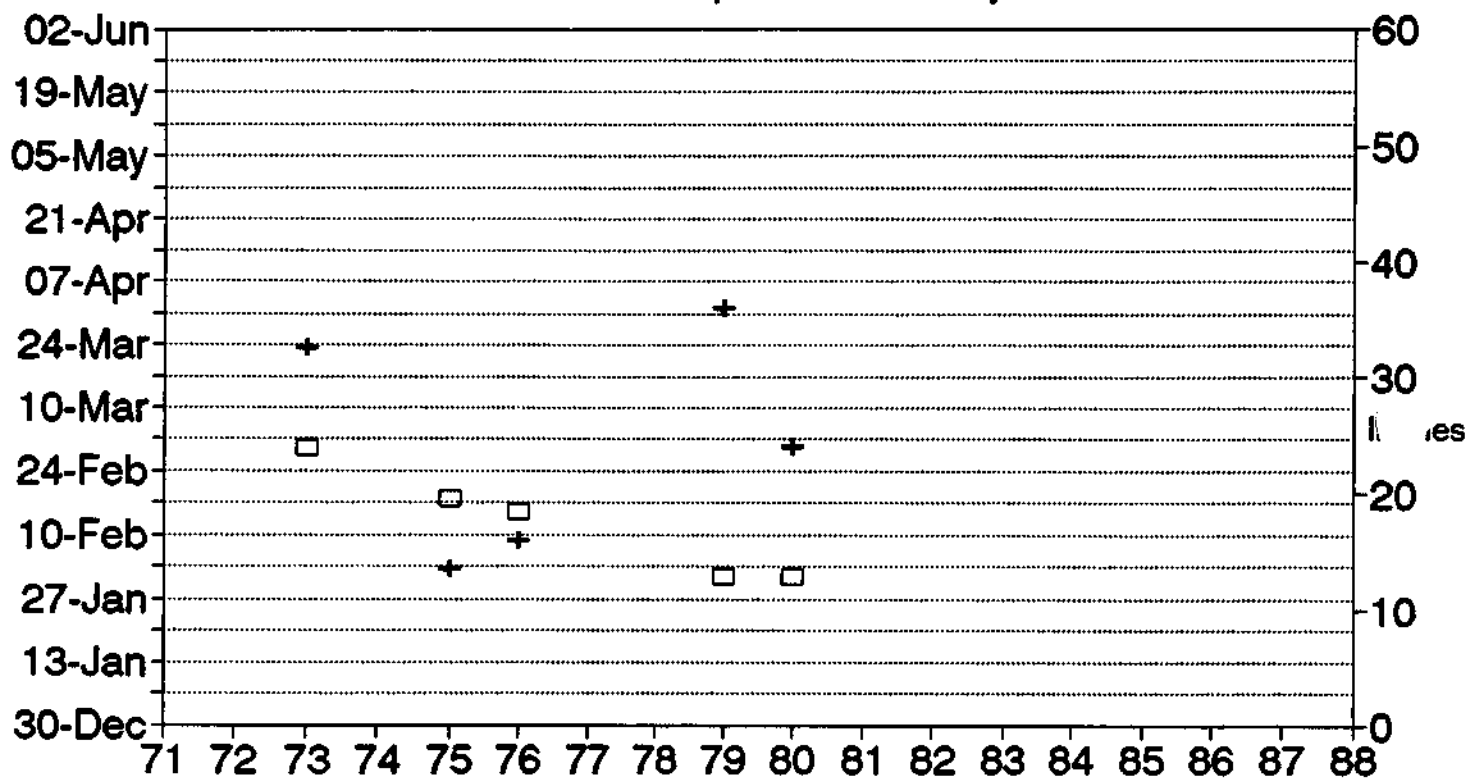
Maximum Frost Depth and Date by Year



□ Date + Frost Depth

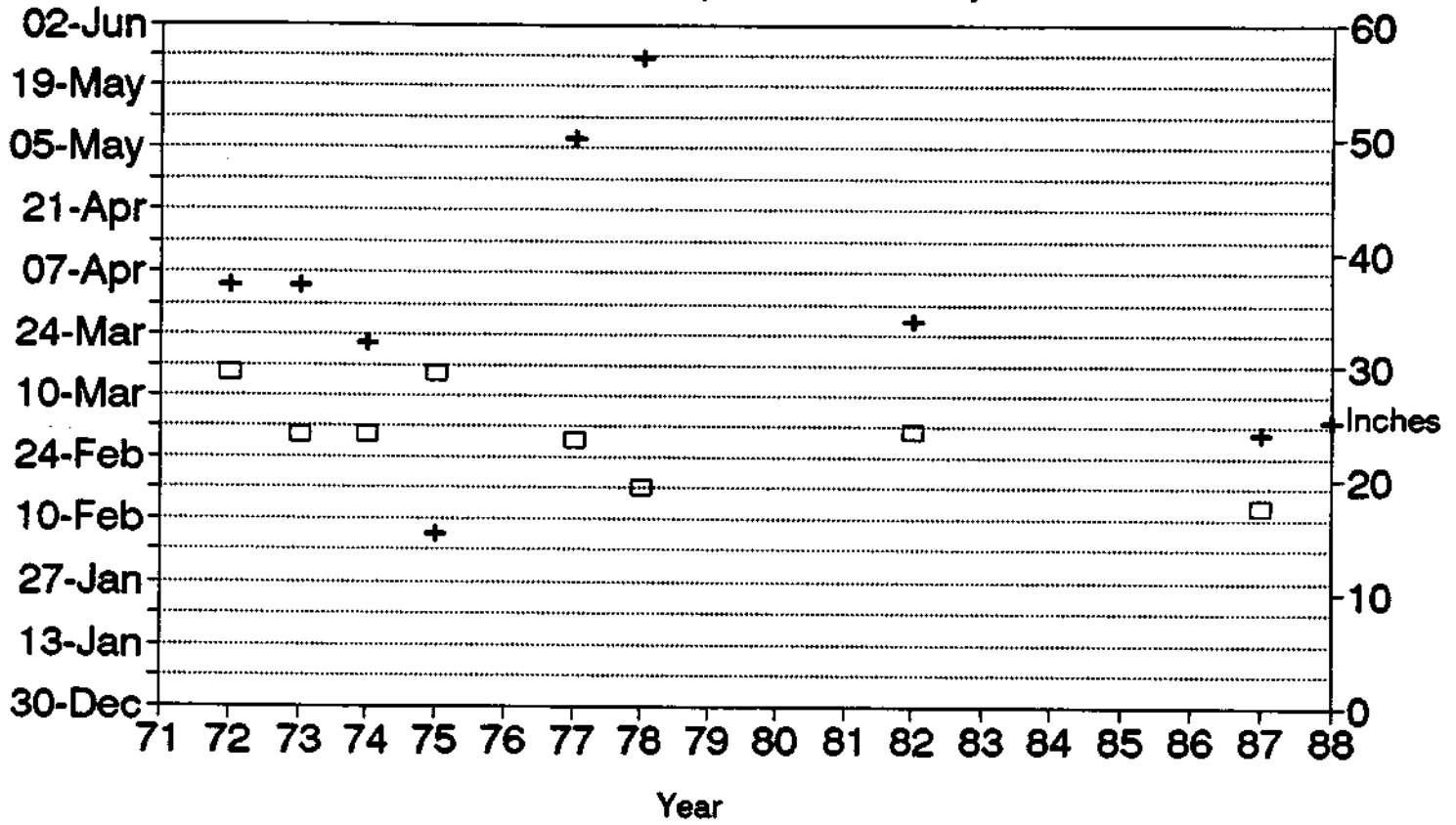
Site 12

Maximum Frost Depth and Date by Year



Site 14

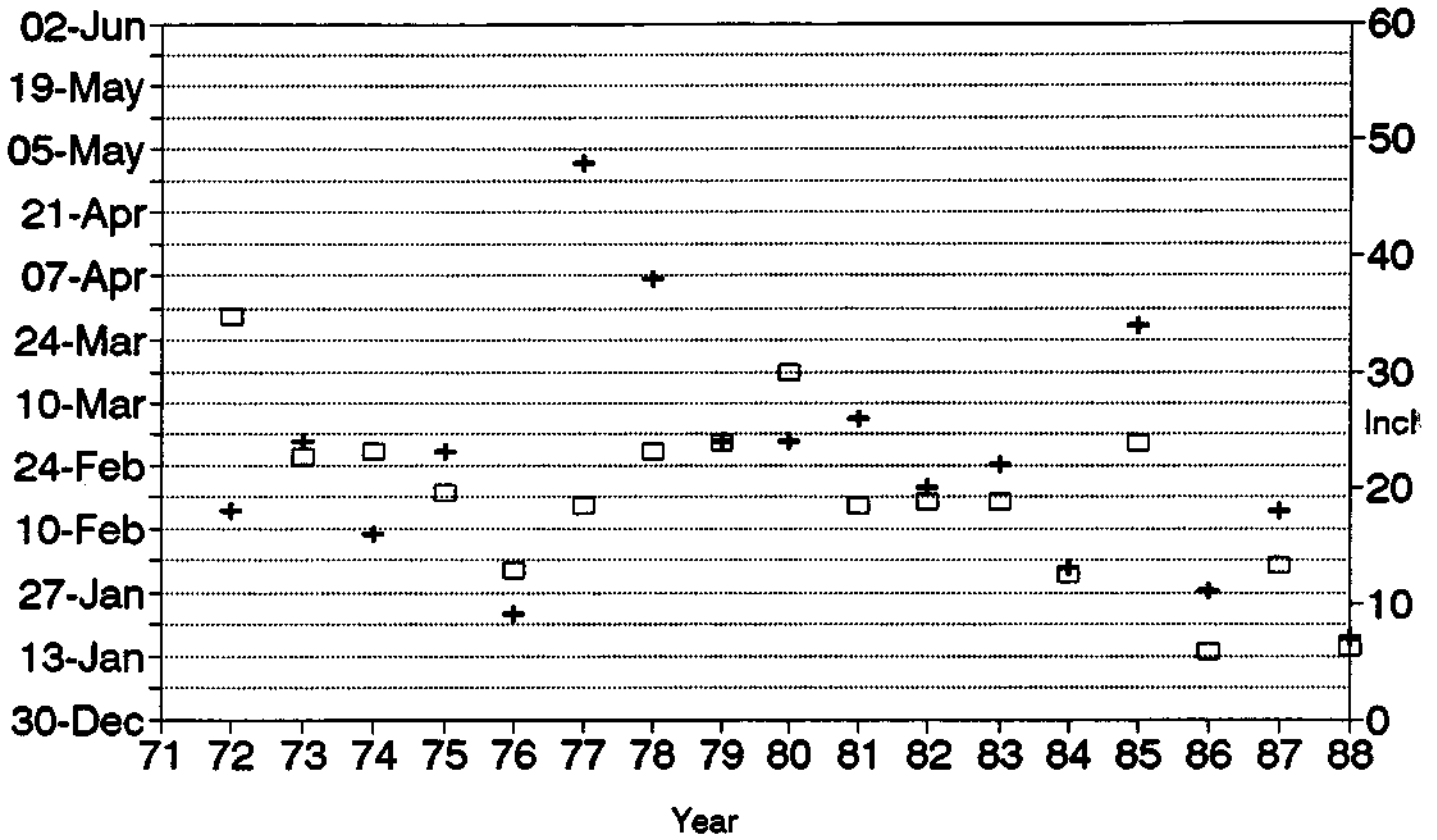
Maximum Frost Depth and Date by Year



□ Date + Frost Depth

Site 15

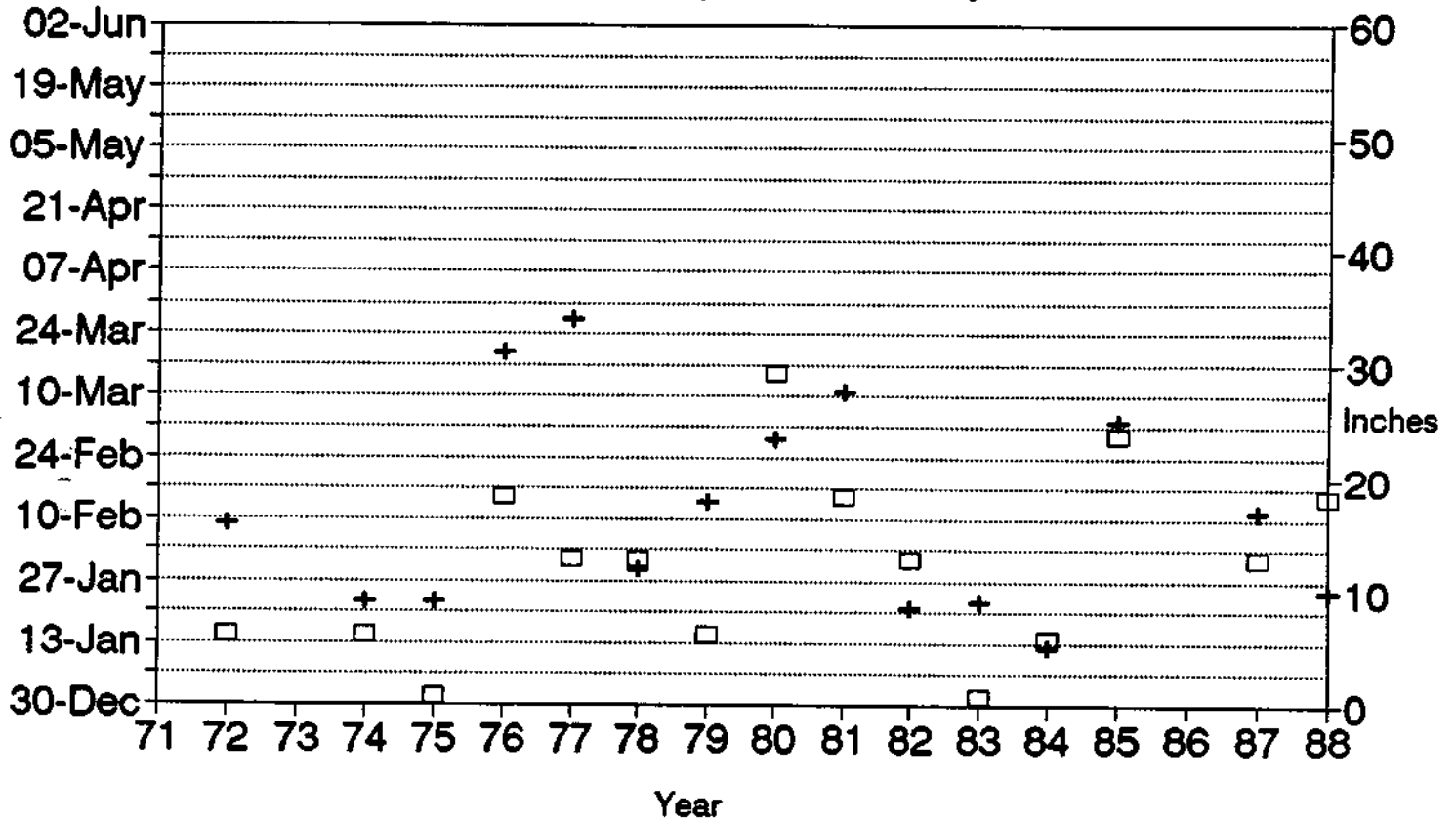
Maximum Frost Depth and Date by Year



□ Date + Frost Depth

Site 16

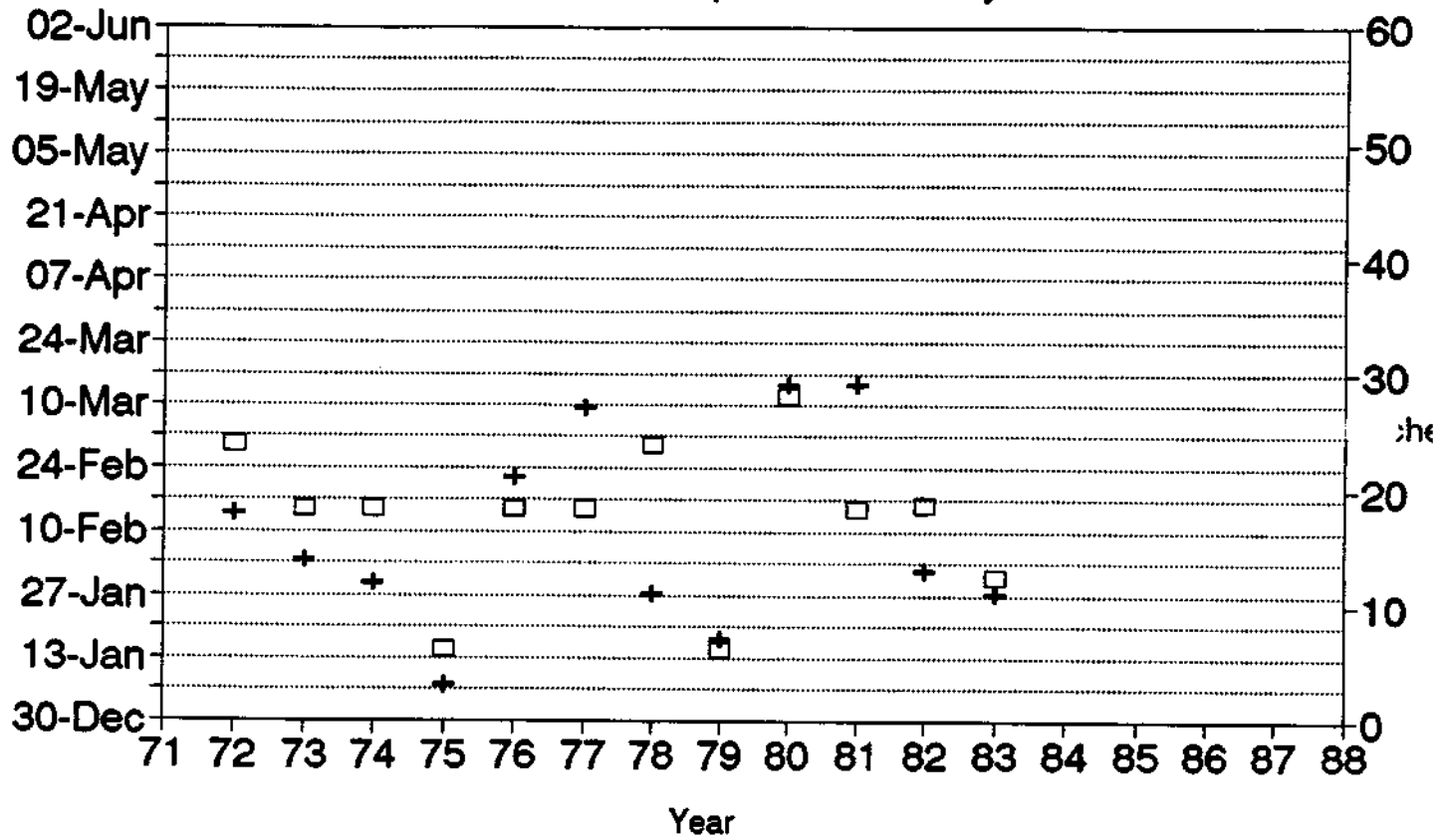
Maximum Frost Depth and Date by Year



□ Date + Frost Depth

Site 17

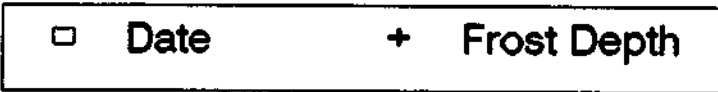
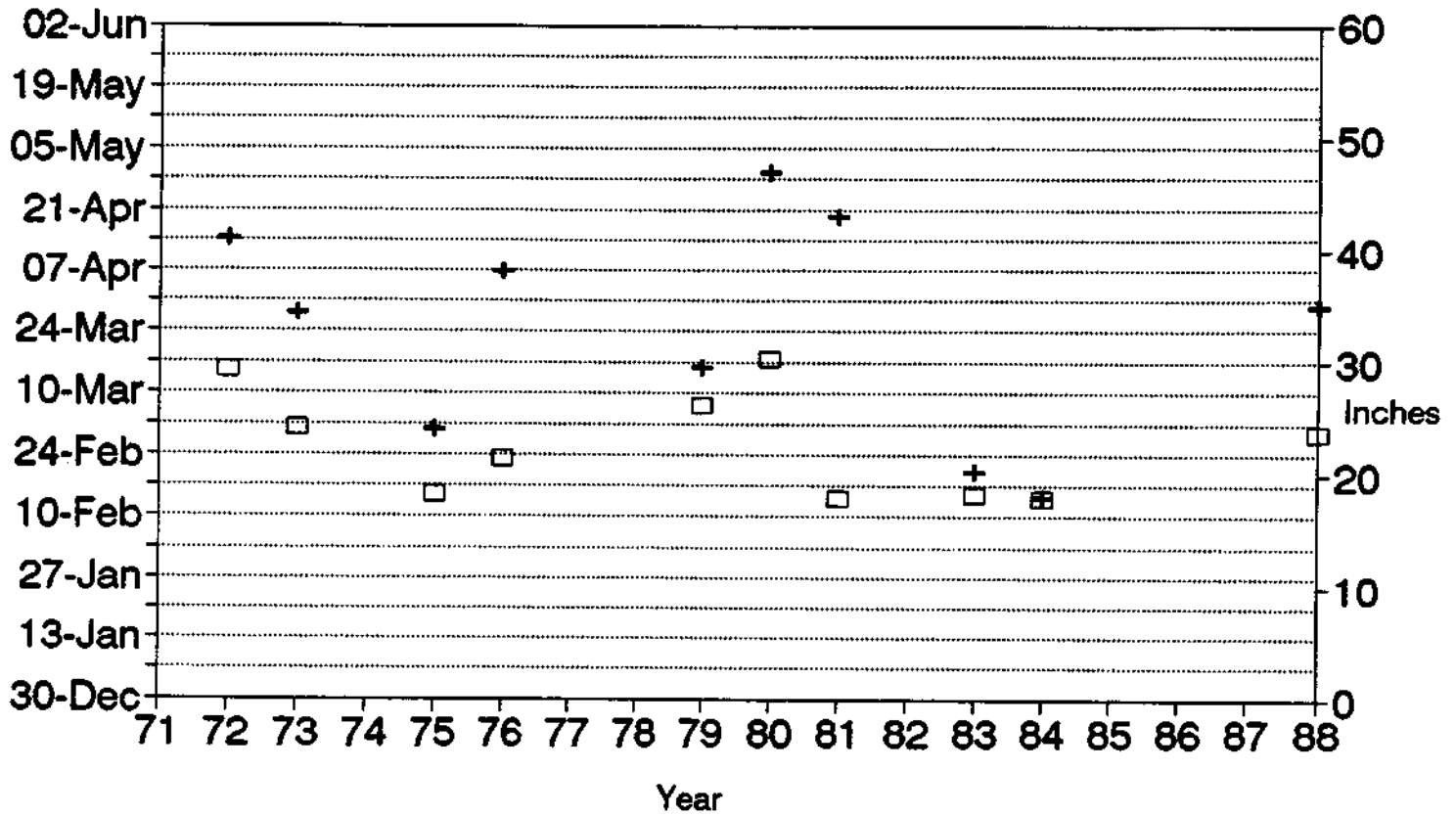
Maximum Frost Depth and Date by Year



□ Date + Frost Depth

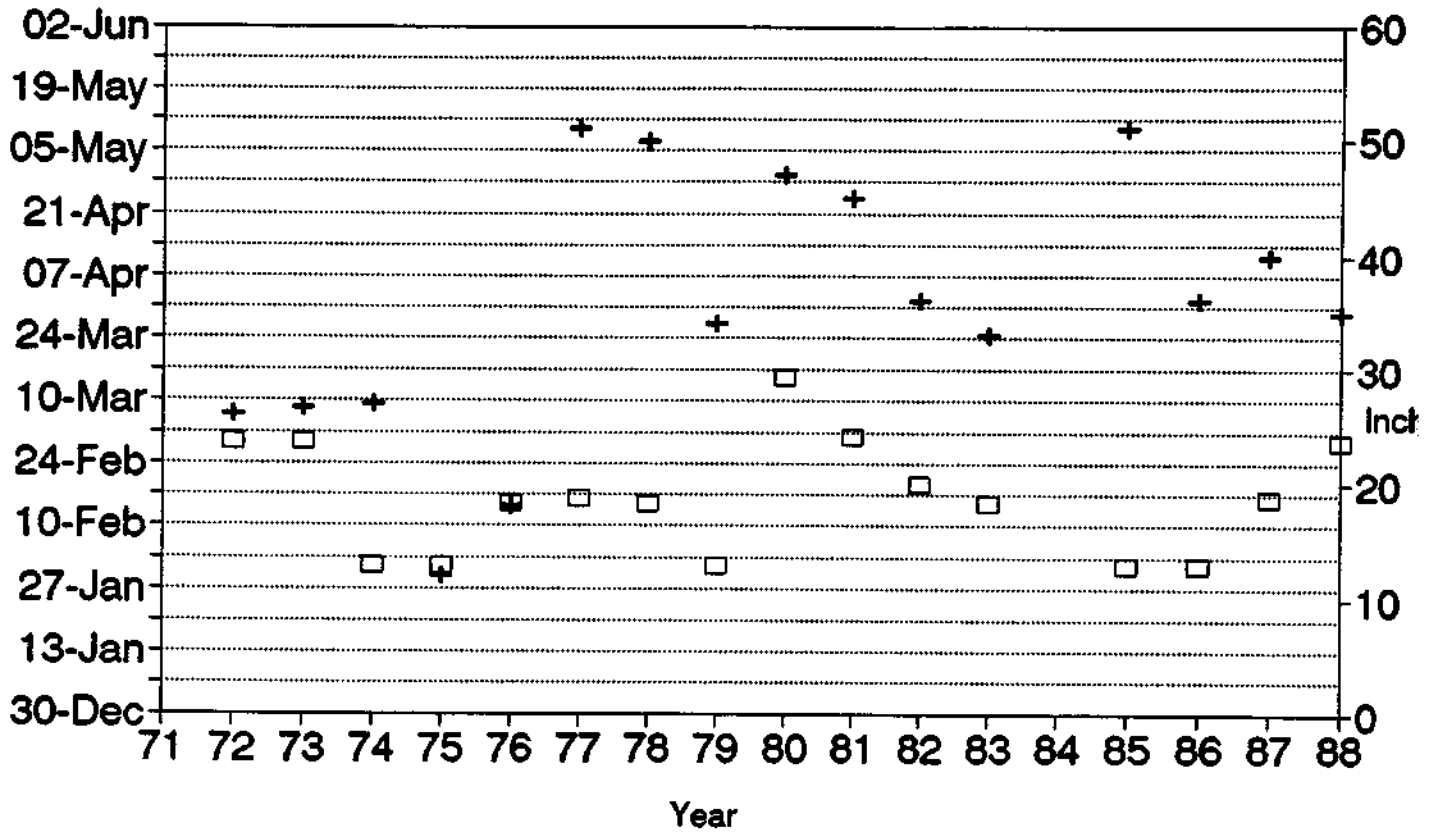
Site 18

Maximum Frost Depth and Date by Year



Site 19

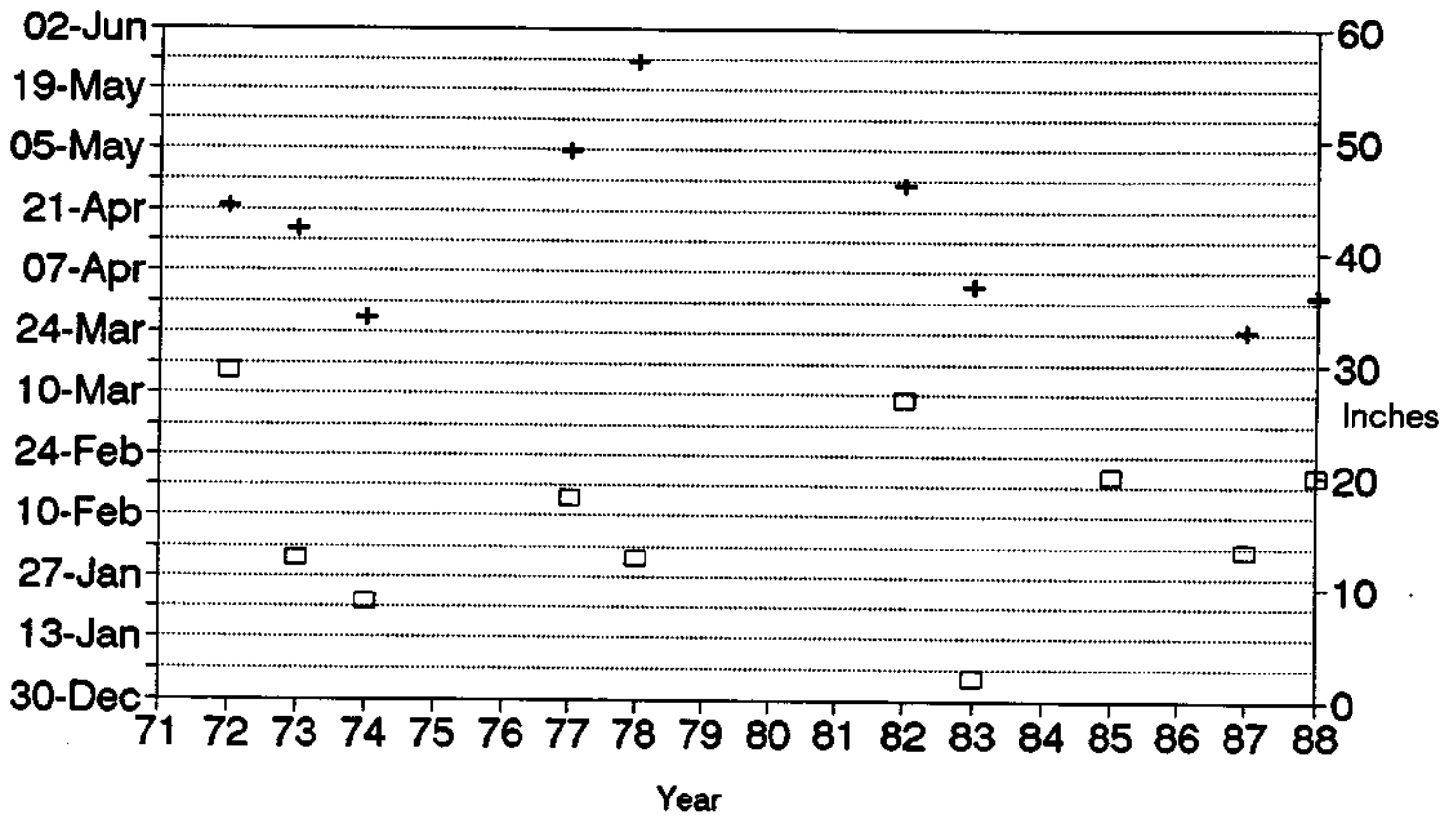
Maximum Frost Depth and Date by Year



□ Date + Frost Depth

Site 20

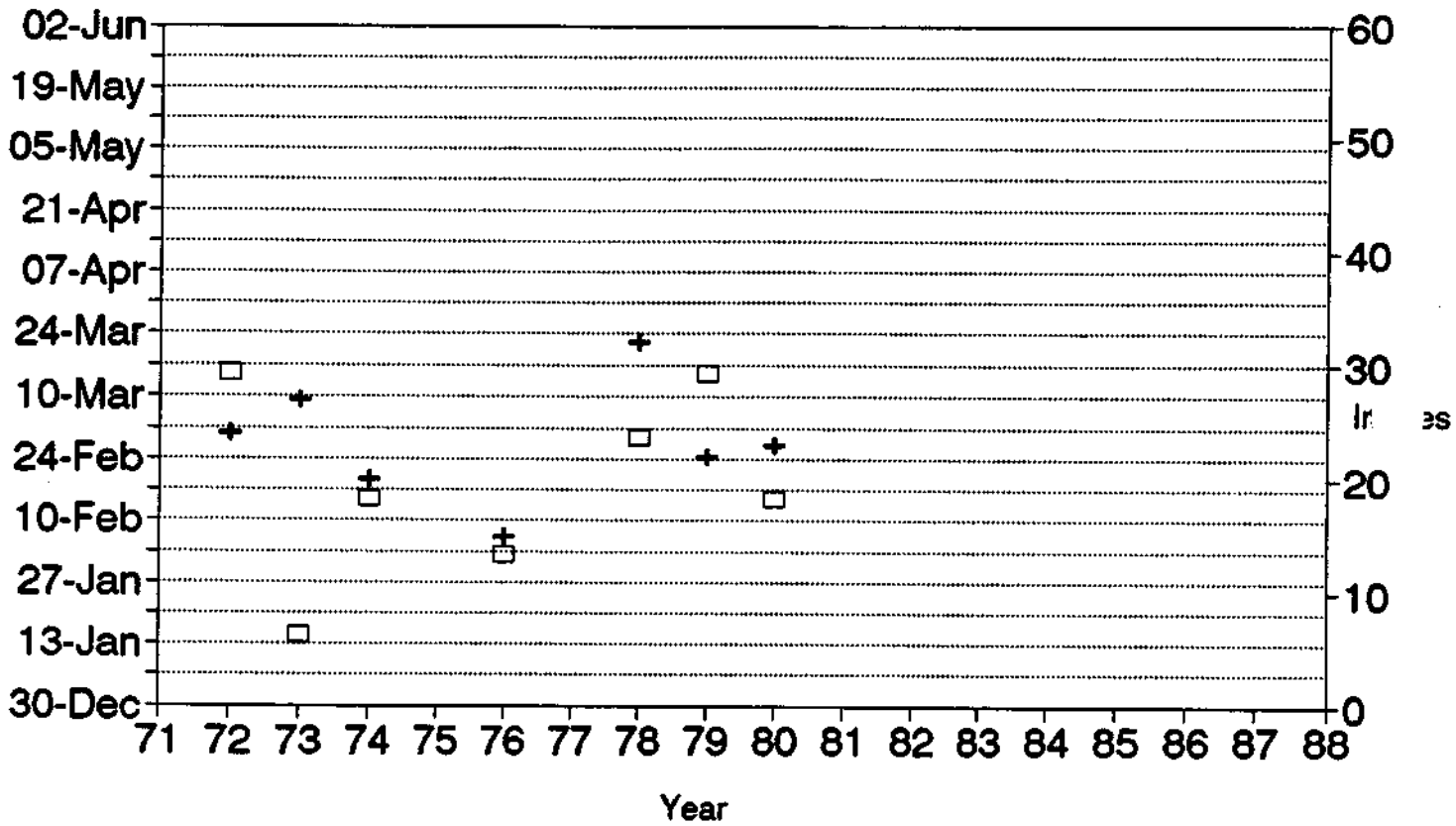
Maximum Frost Depth and Date by Year



□ Date + Frost Depth

Site 22

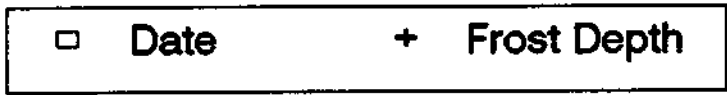
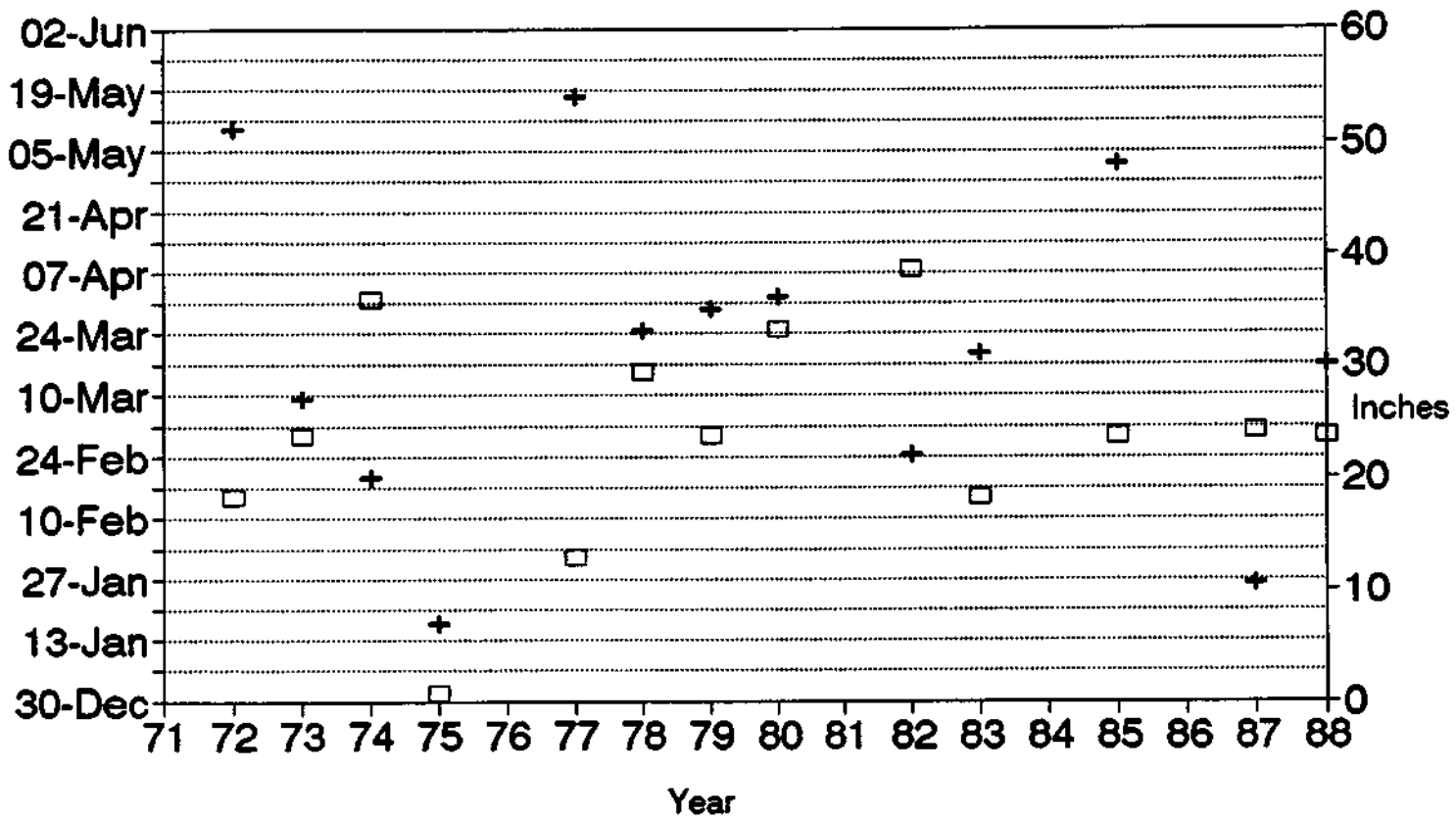
Maximum Frost Depth and Date by Year



□ Date + Frost Depth

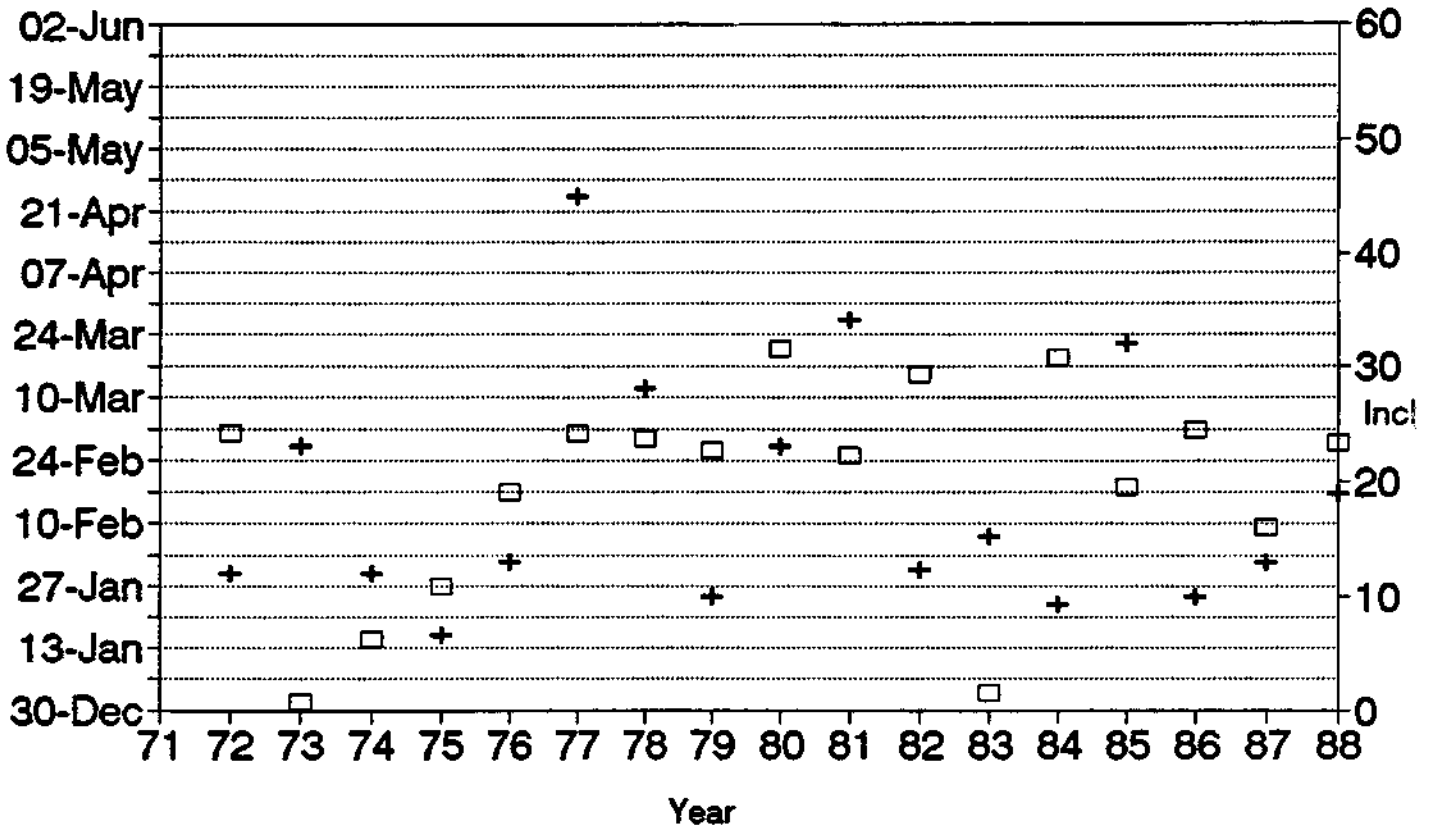
Site 23

Maximum Frost Depth and Date by Year



Site 24

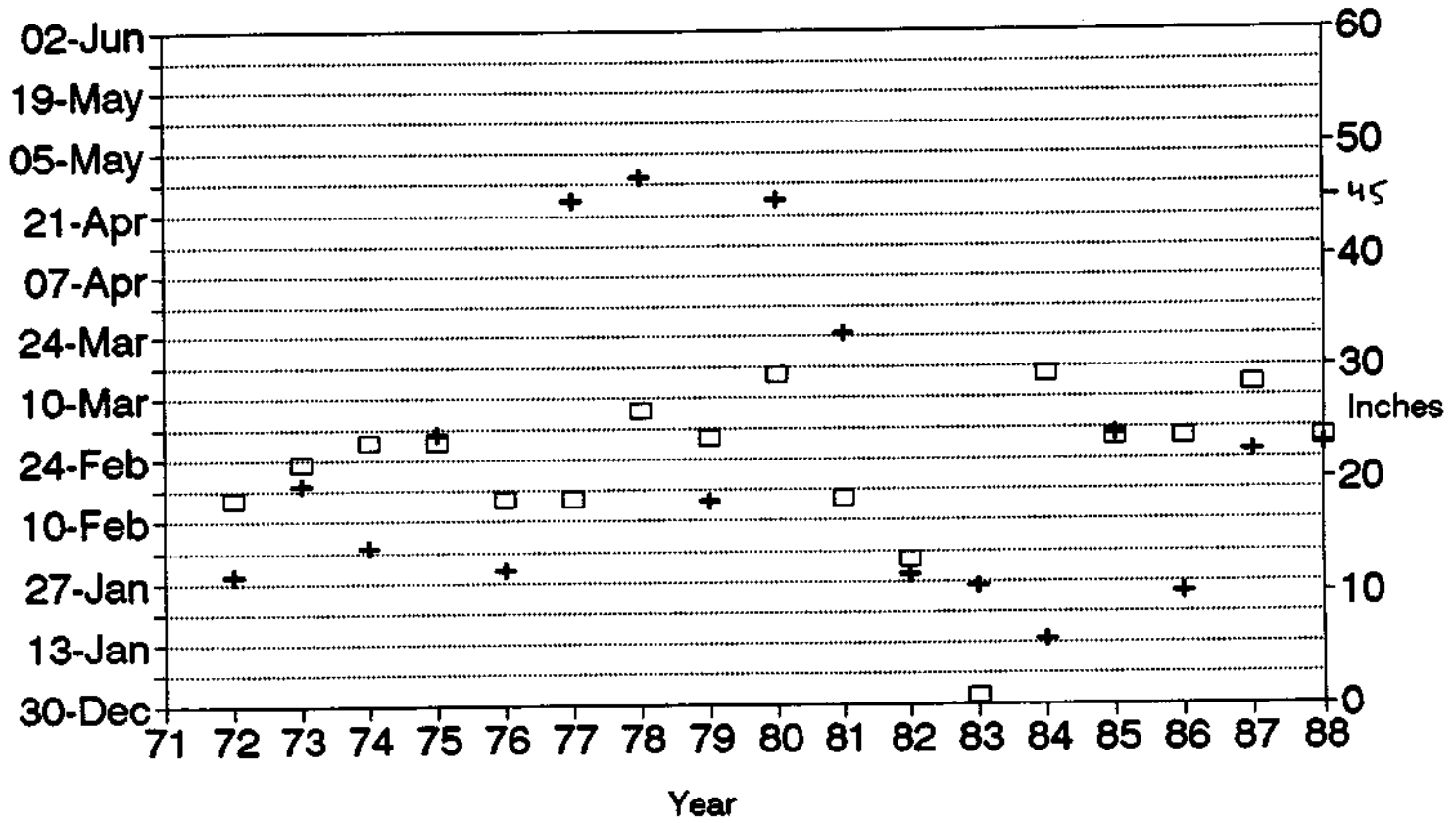
Maximum Frost Depth and Date by Year



□ Date + Frost Depth

Site 26 *St. Paul*

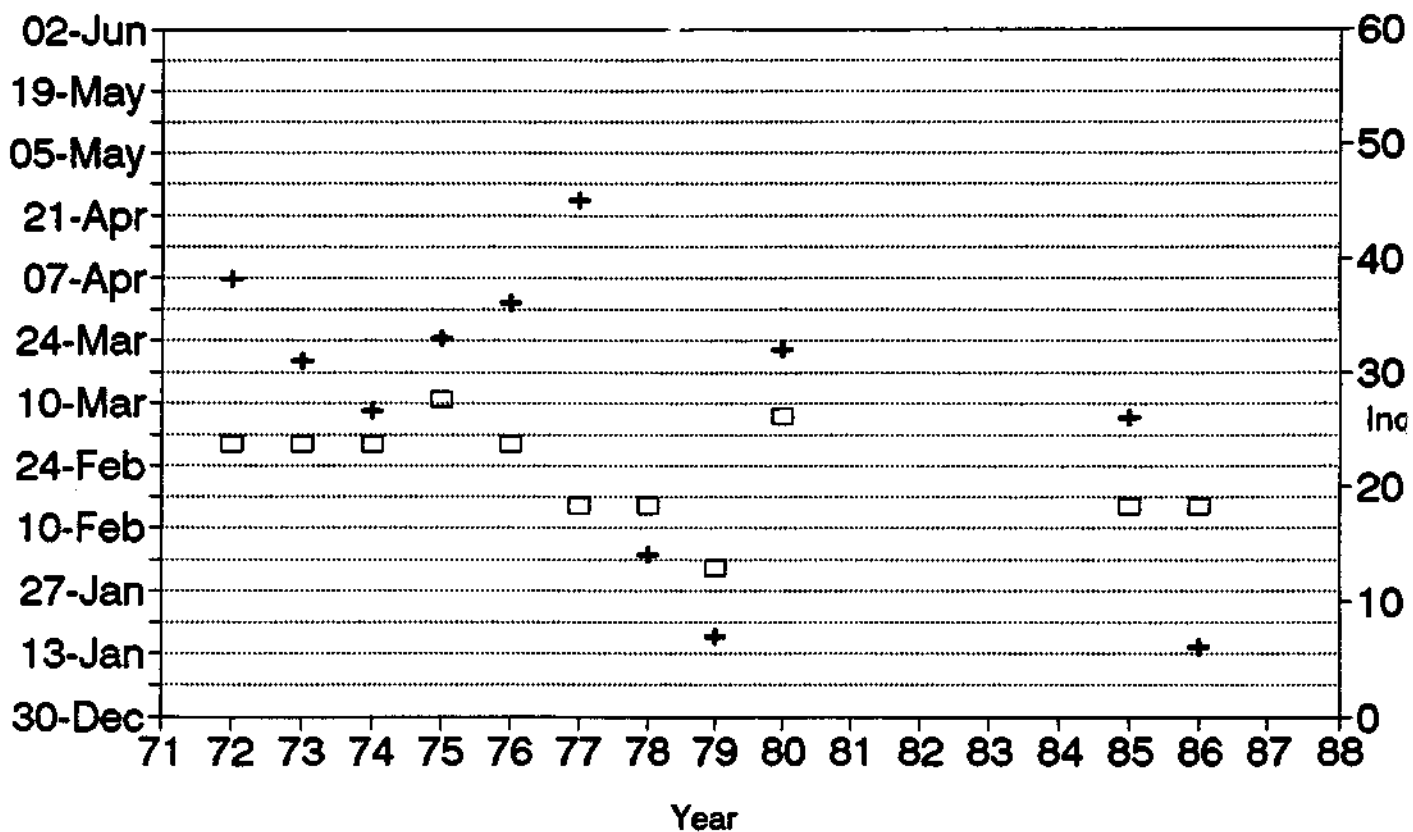
Maximum Frost Depth and Date by Year



□ Date + Frost Depth

Site 27

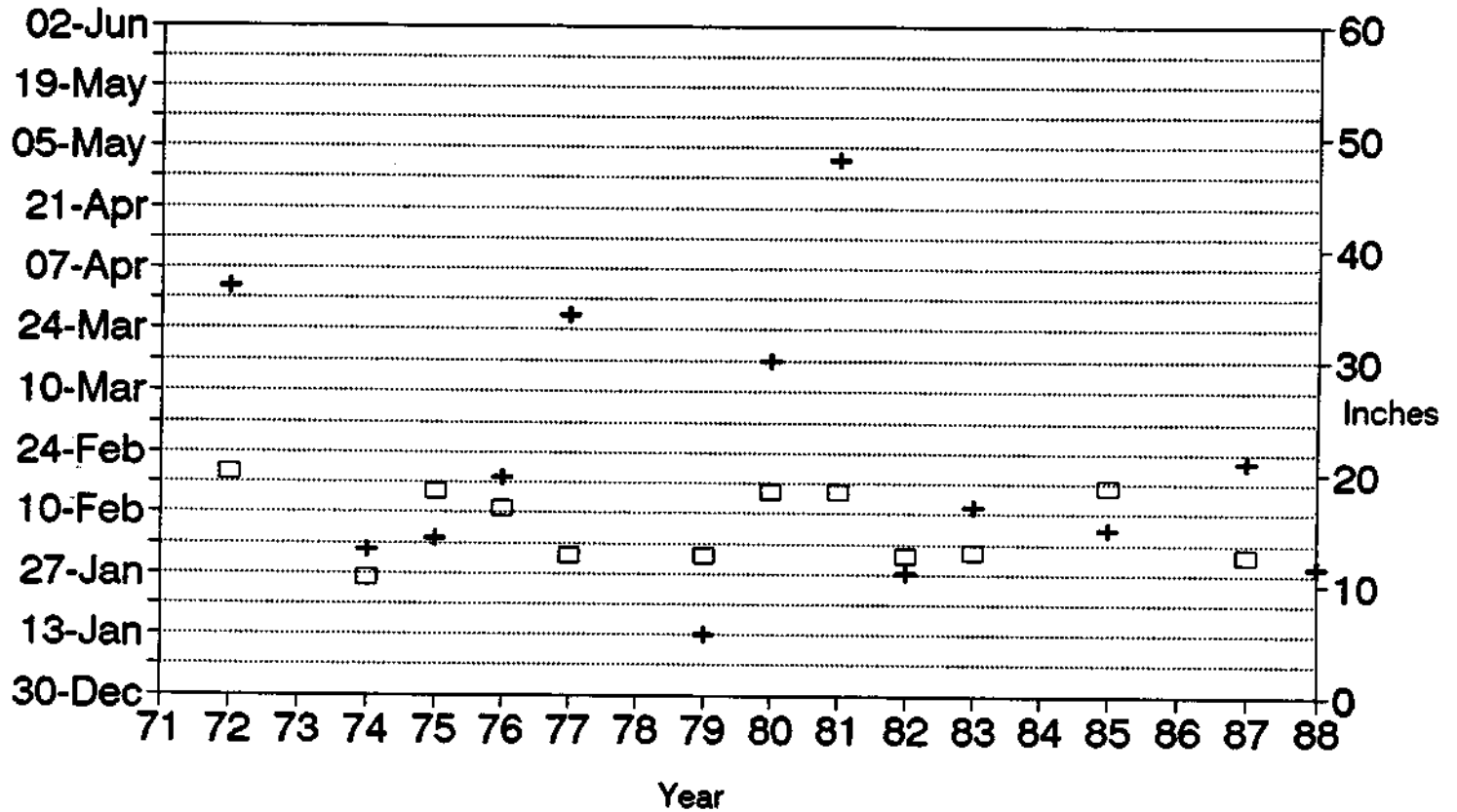
Maximum Frost Depth and Date by Year



□ Date + Frost Depth

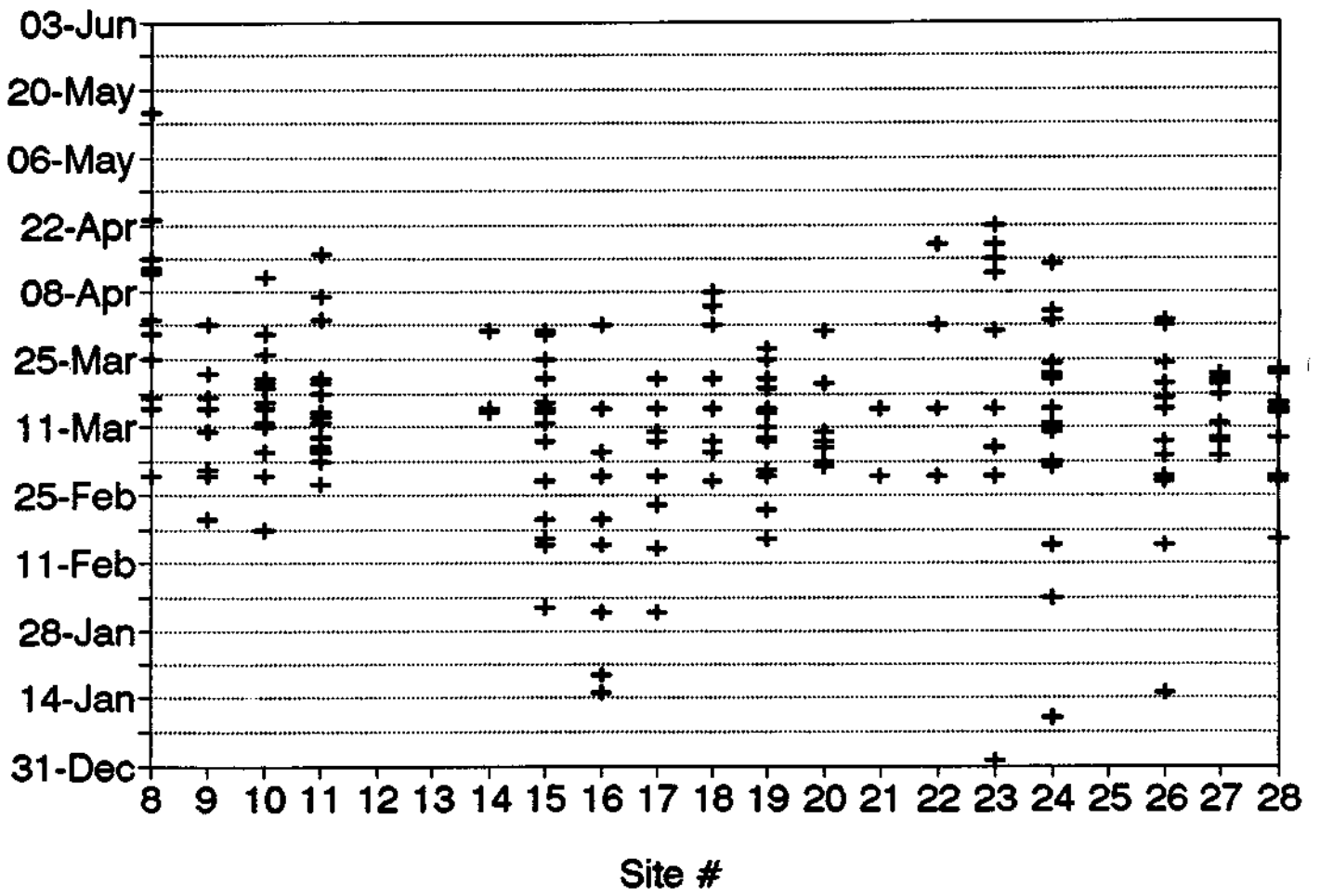
Site 28

Maximum Frost Depth and Date by Year

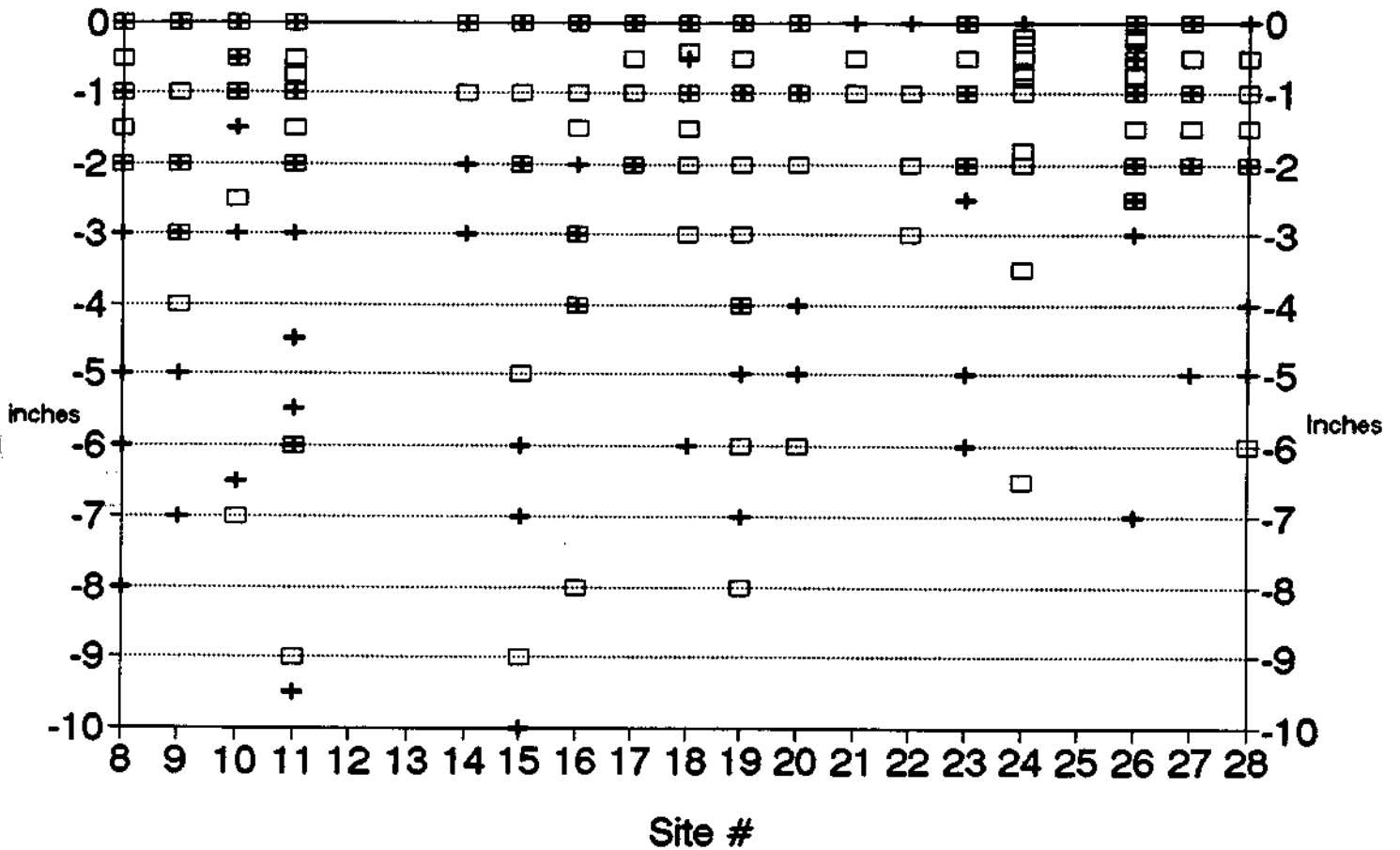


□ Date + Frost Depth

Initial Date of Ground Frost Melt

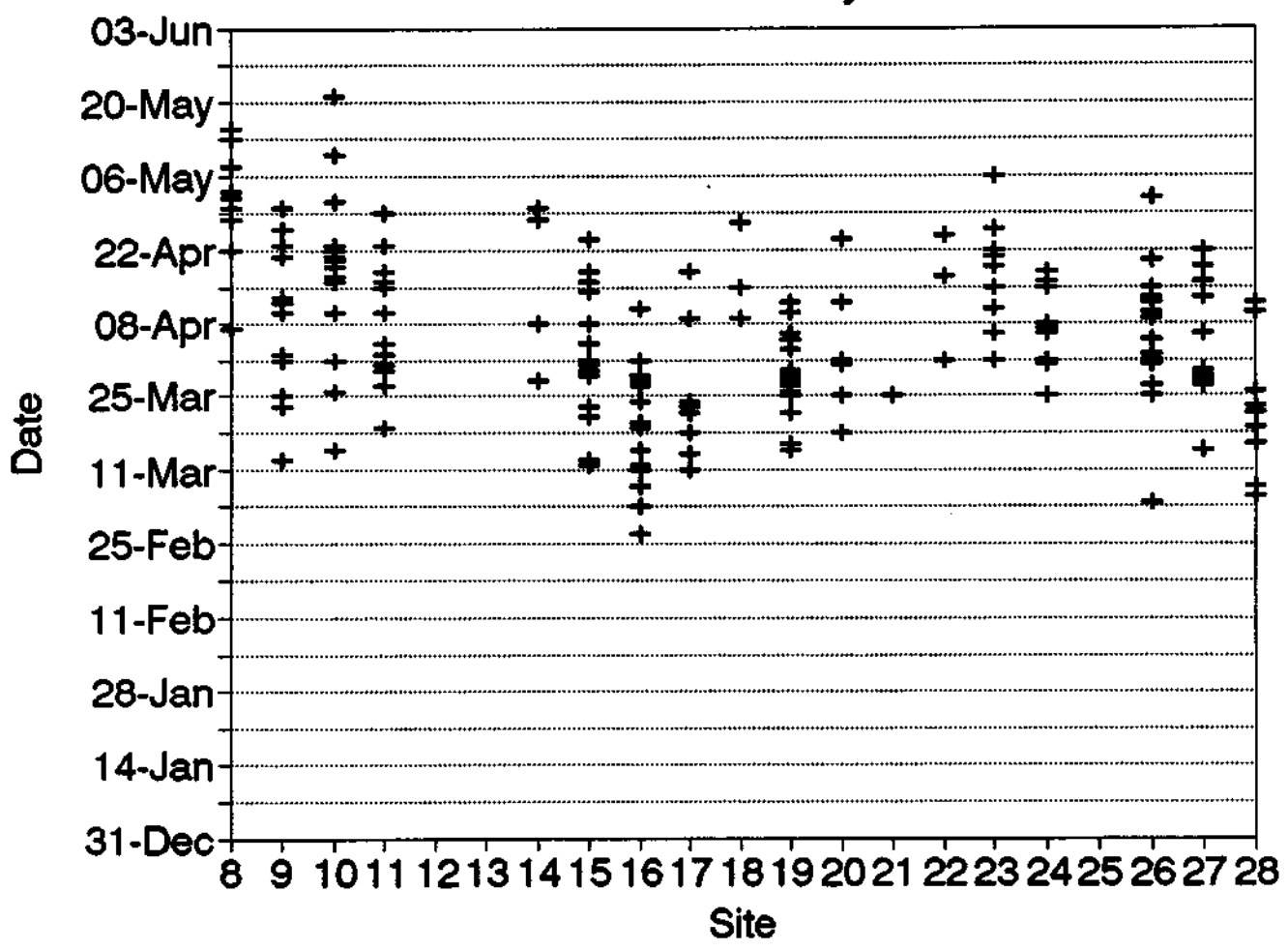


Surface Melting of Frost



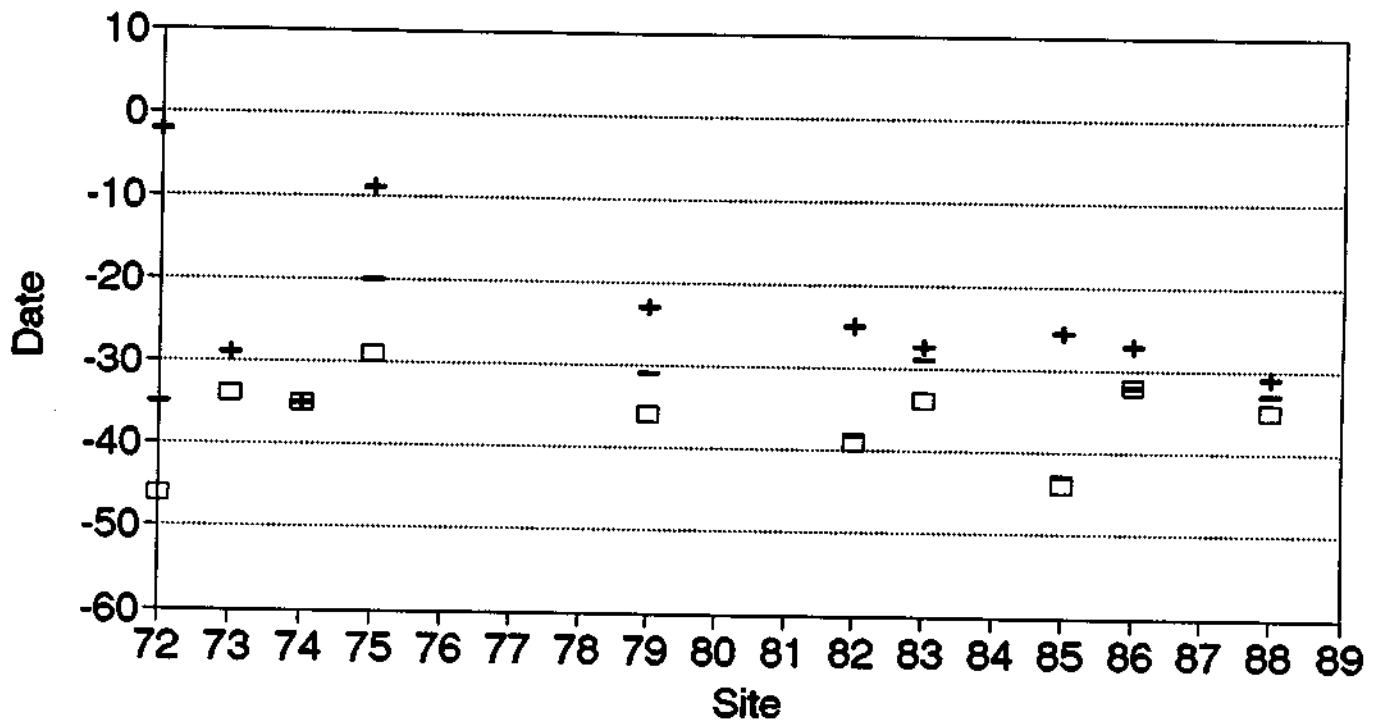
+ Surface Melting □ Subsurface Melt

Final Frost Dates By Site



Final Frost - Site

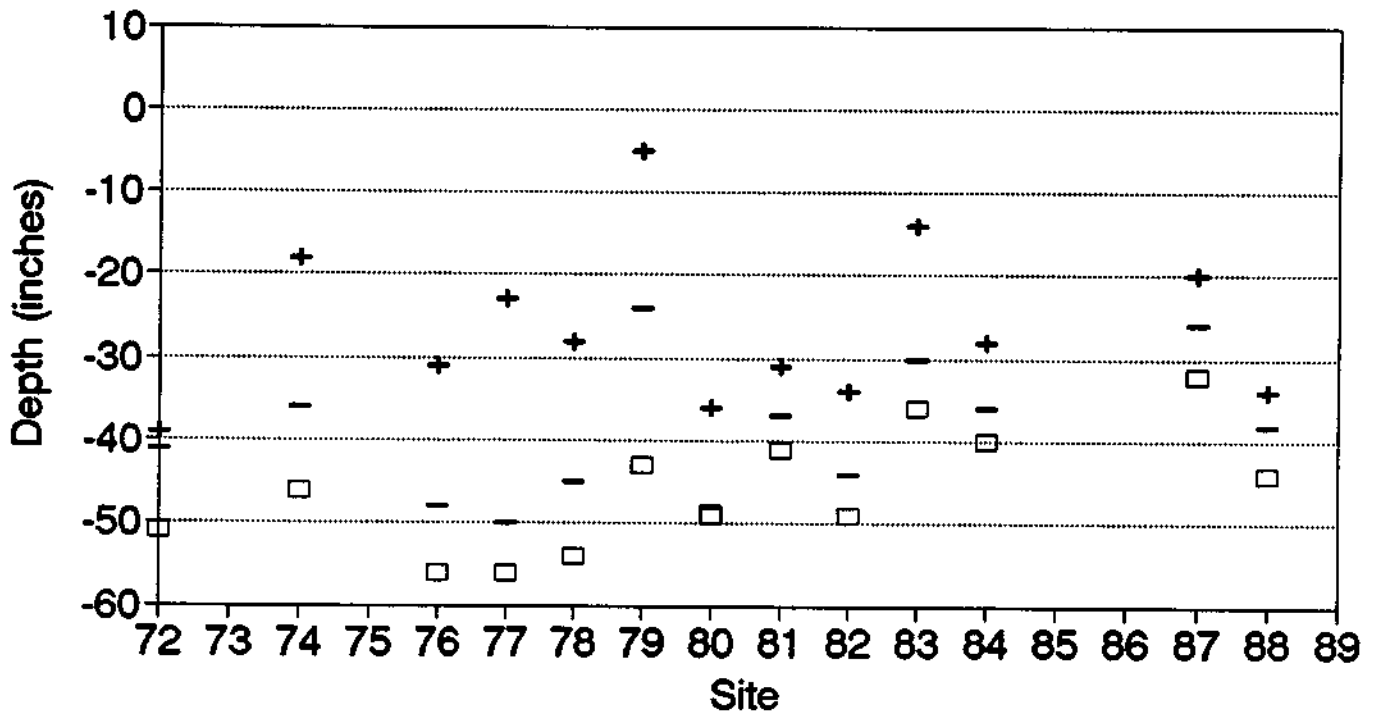
Site #8



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

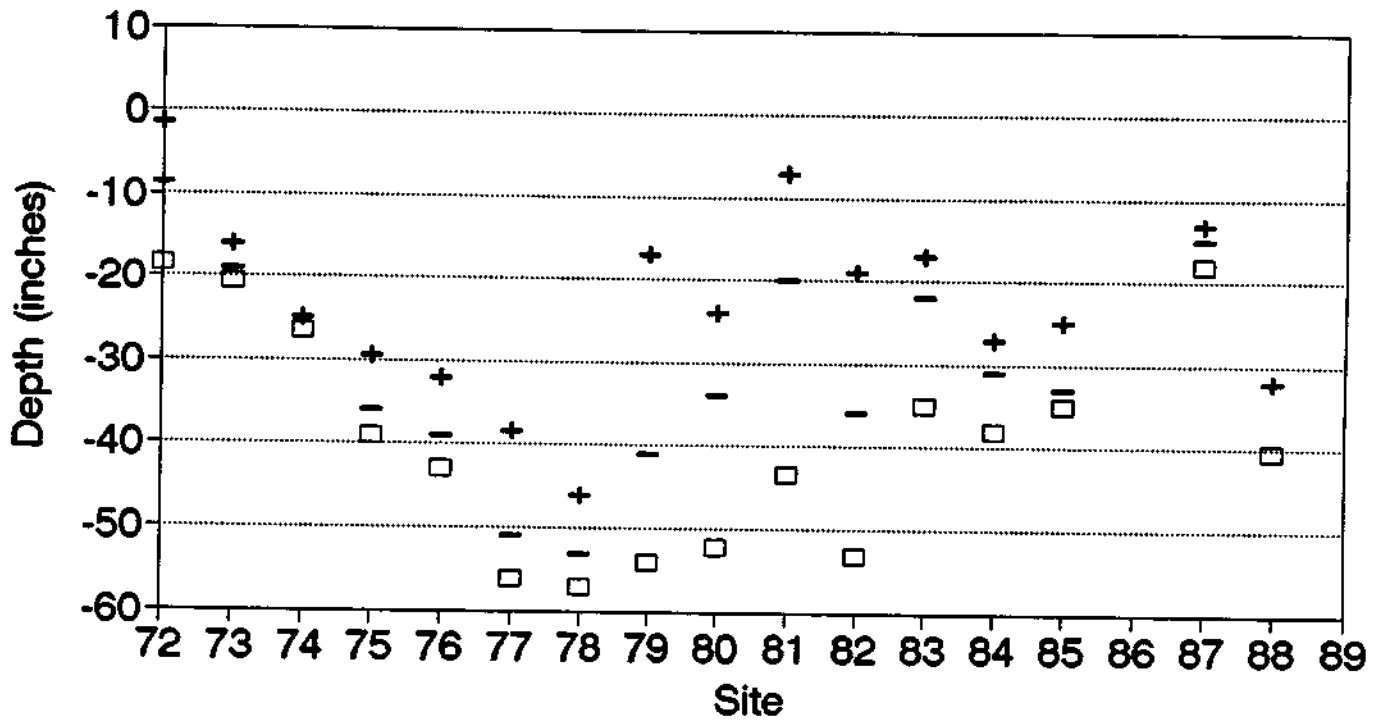
Site #9



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

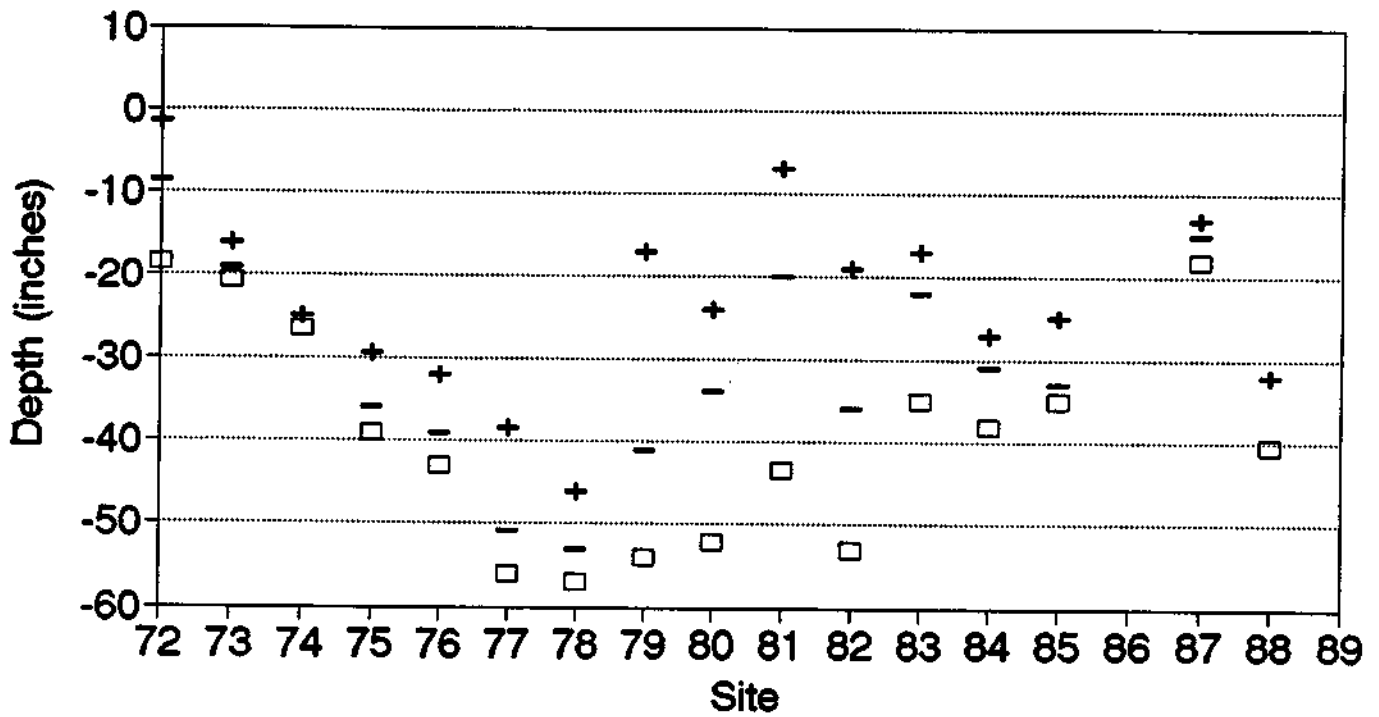
Site #10



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

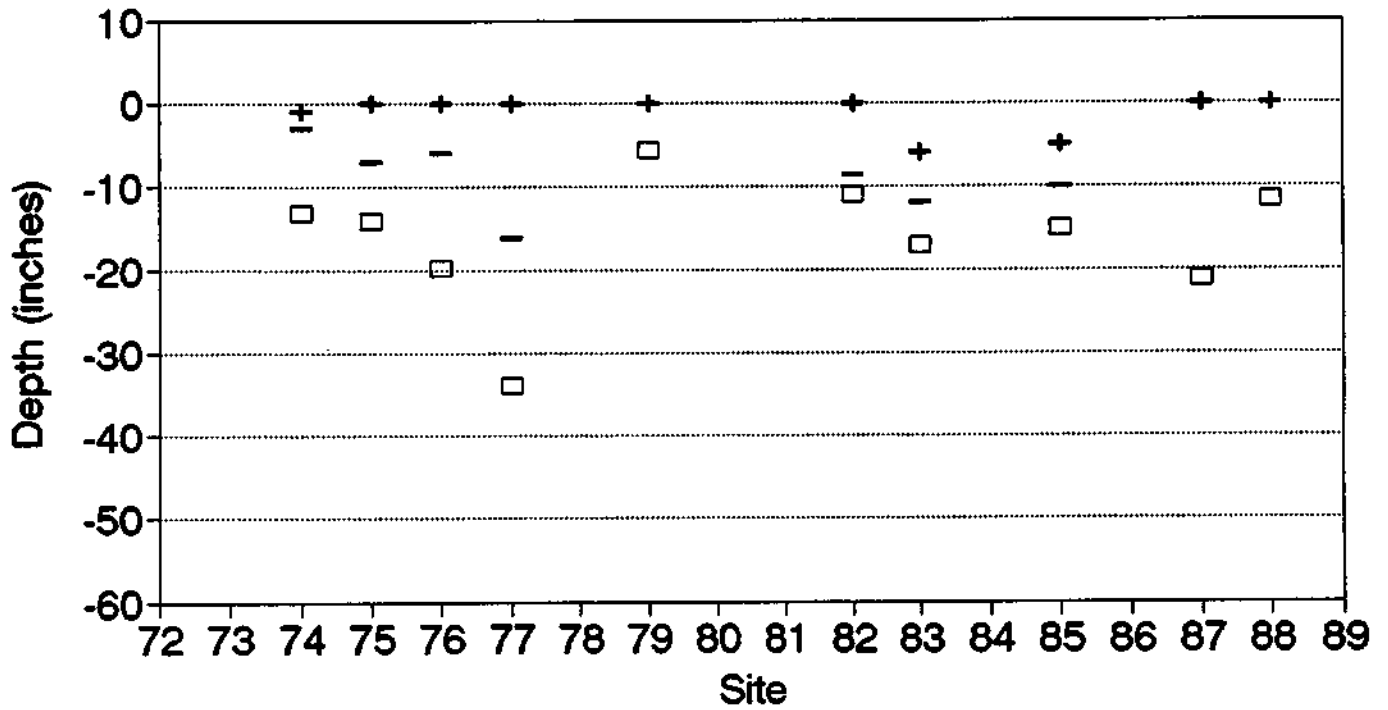
Site #10



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

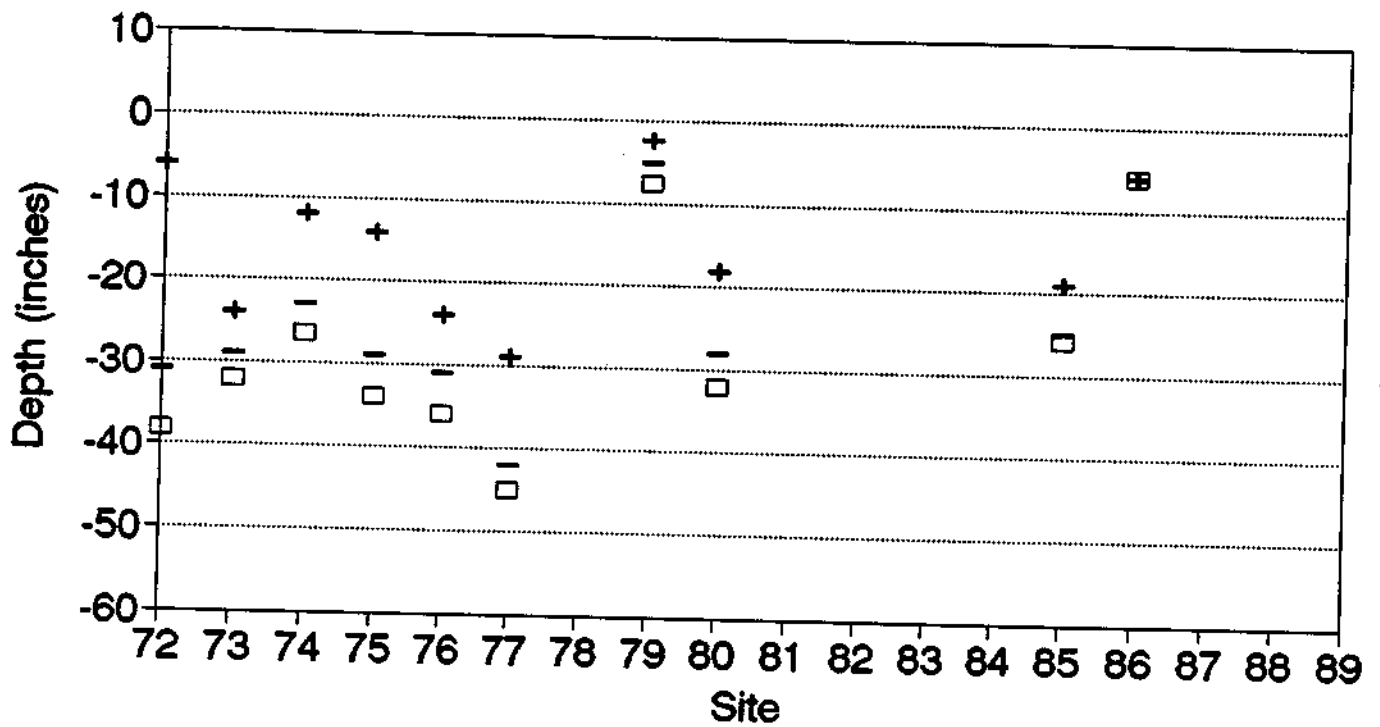
Site #28



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

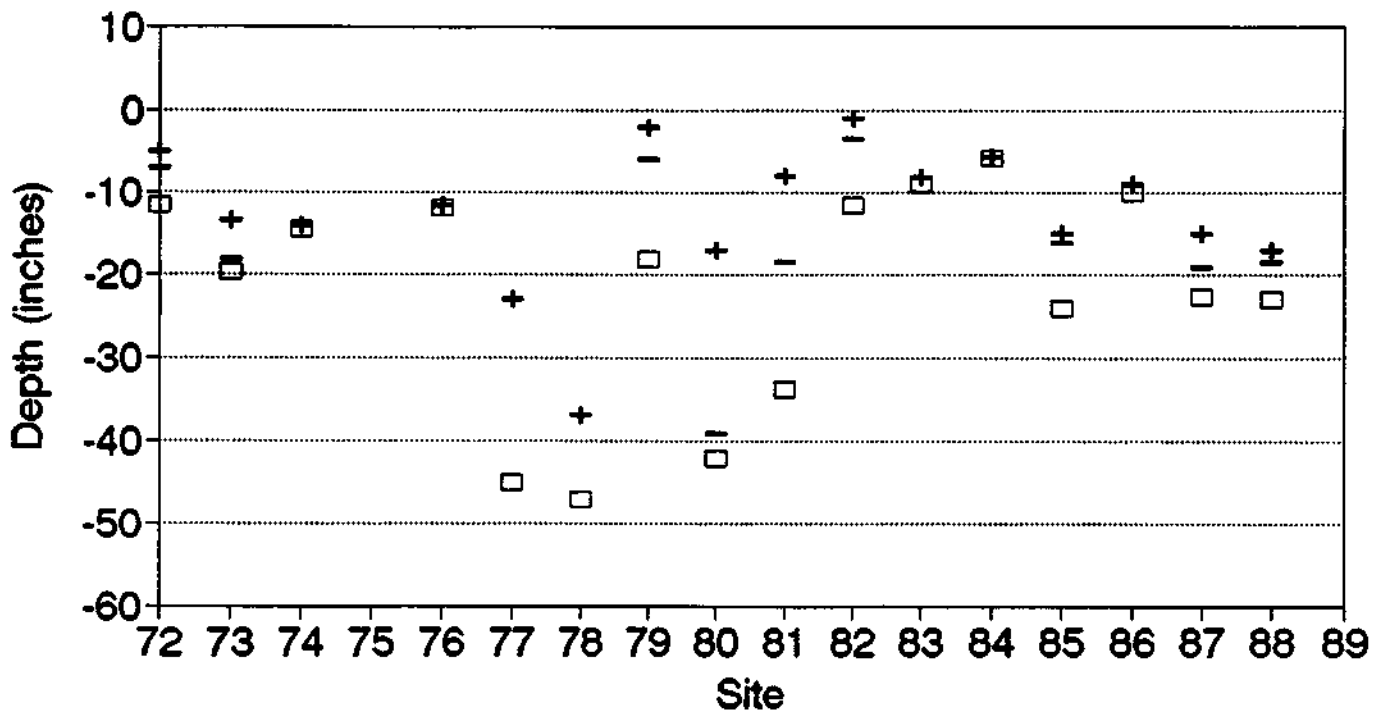
Site #27



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

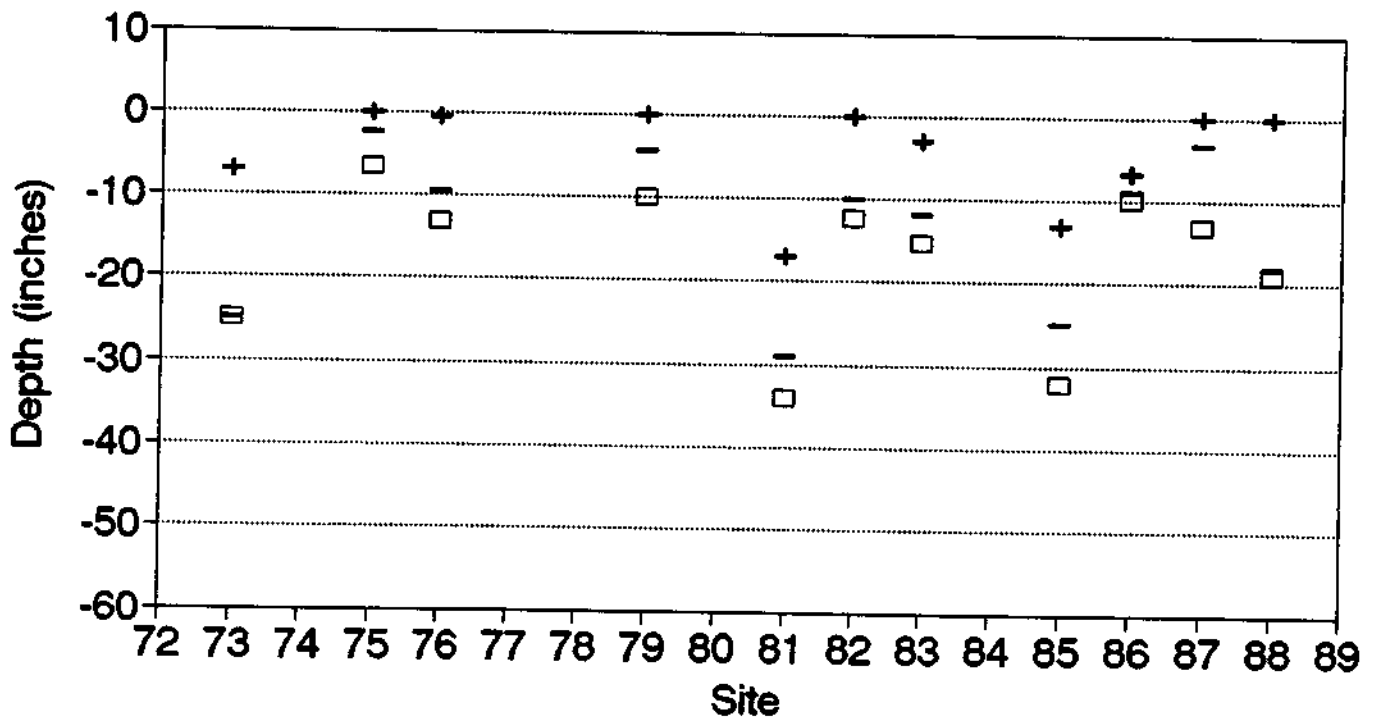
Site #26



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

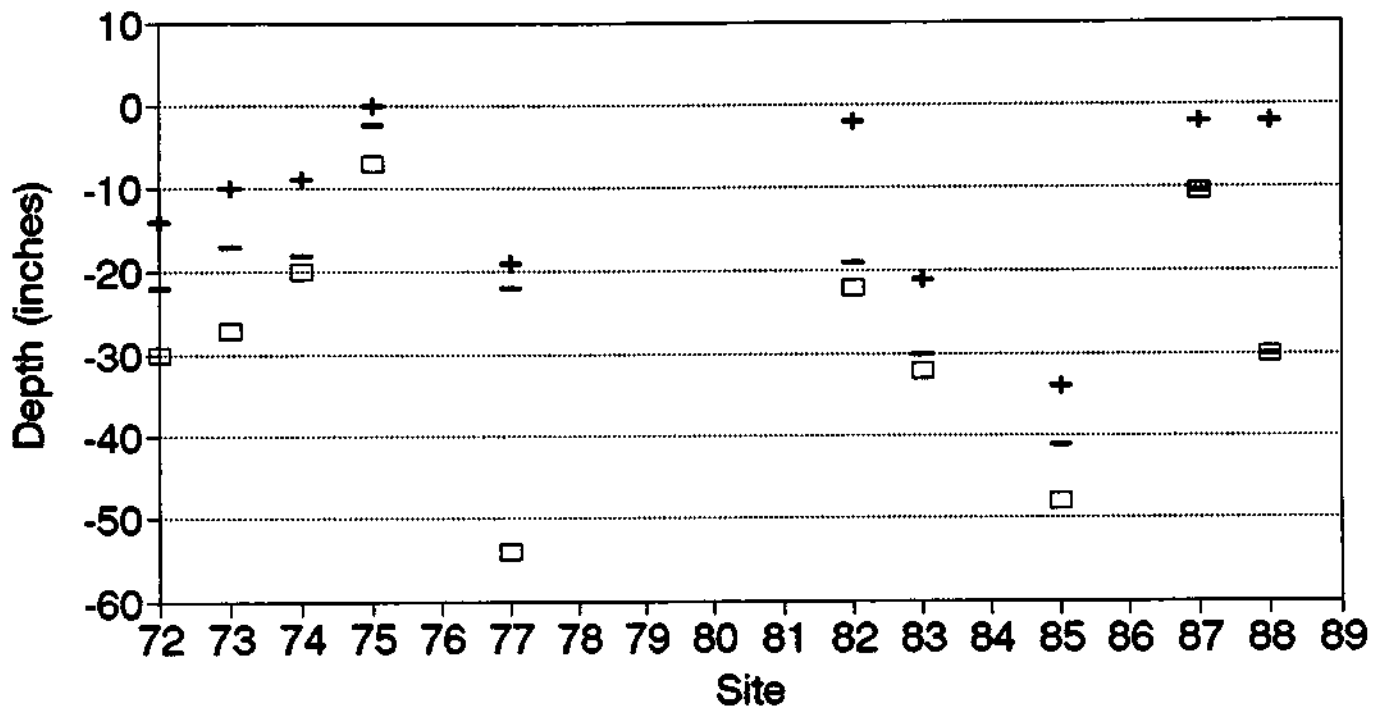
Site #24



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

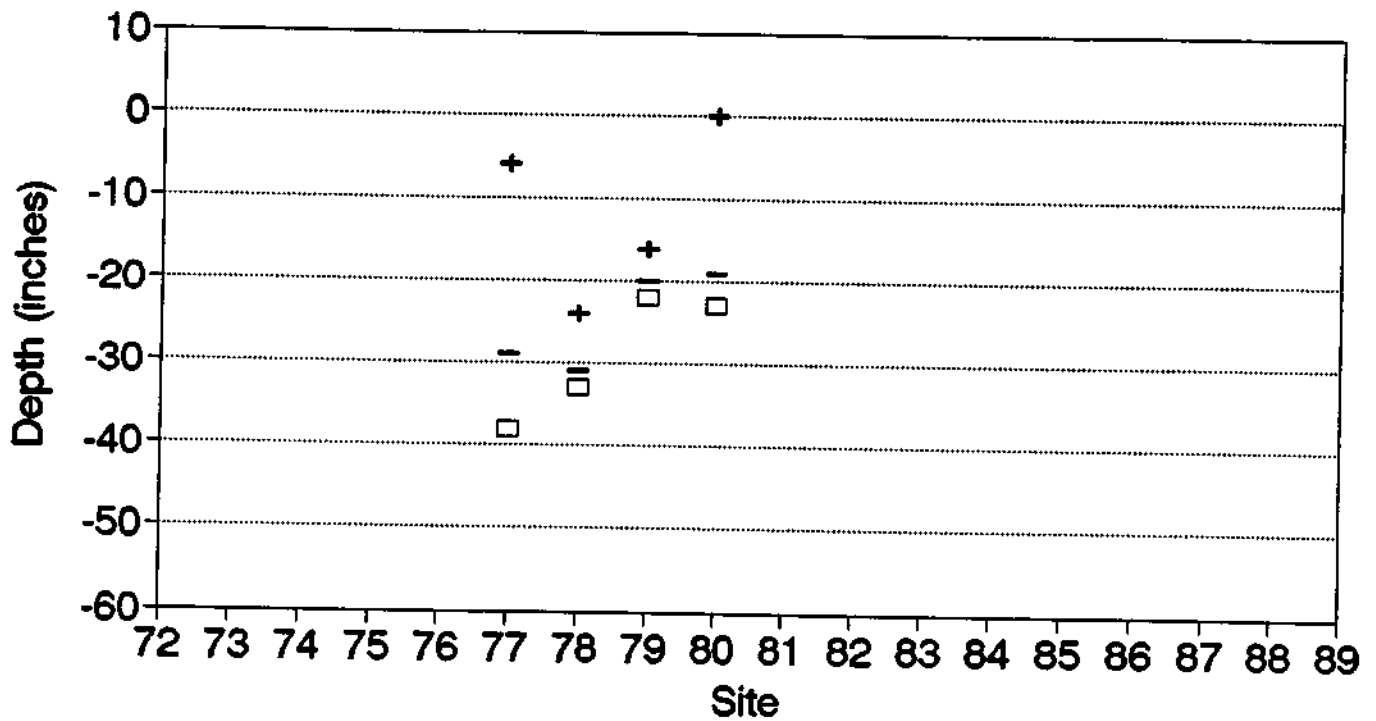
Site #23



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

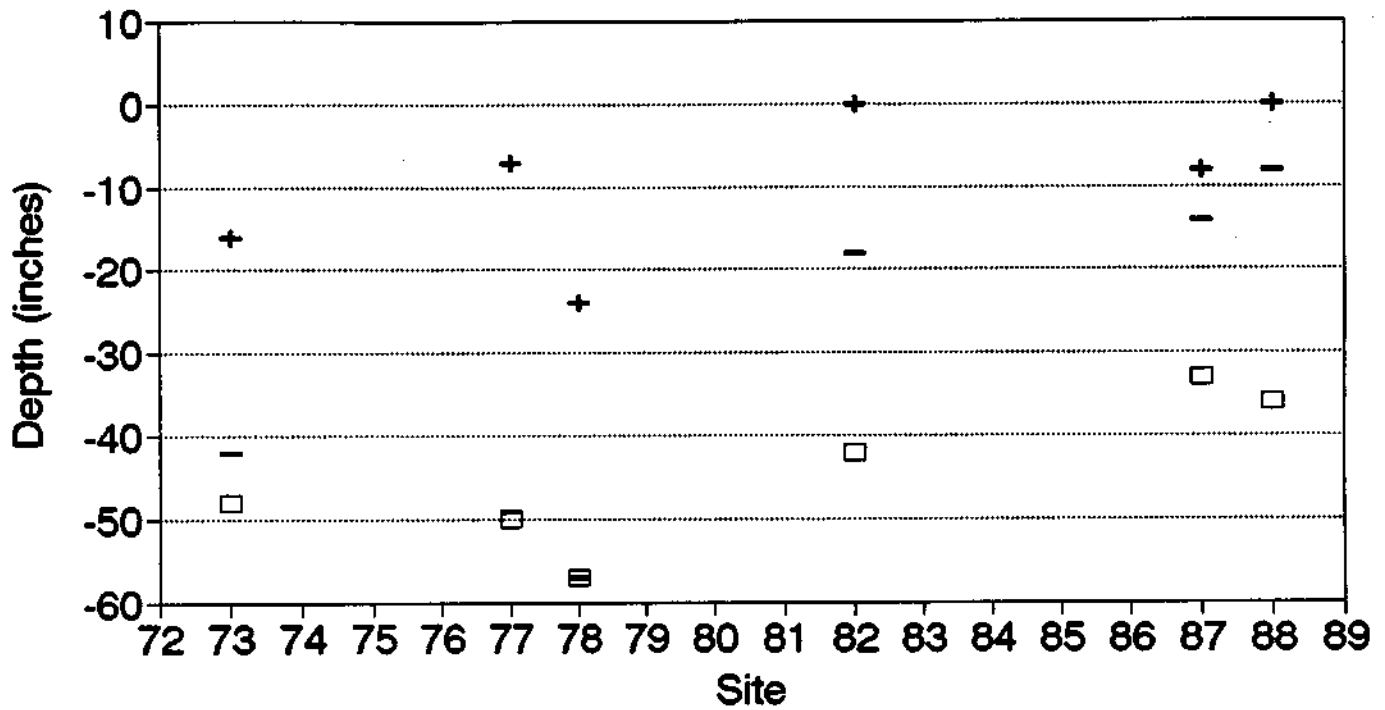
Site #22



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

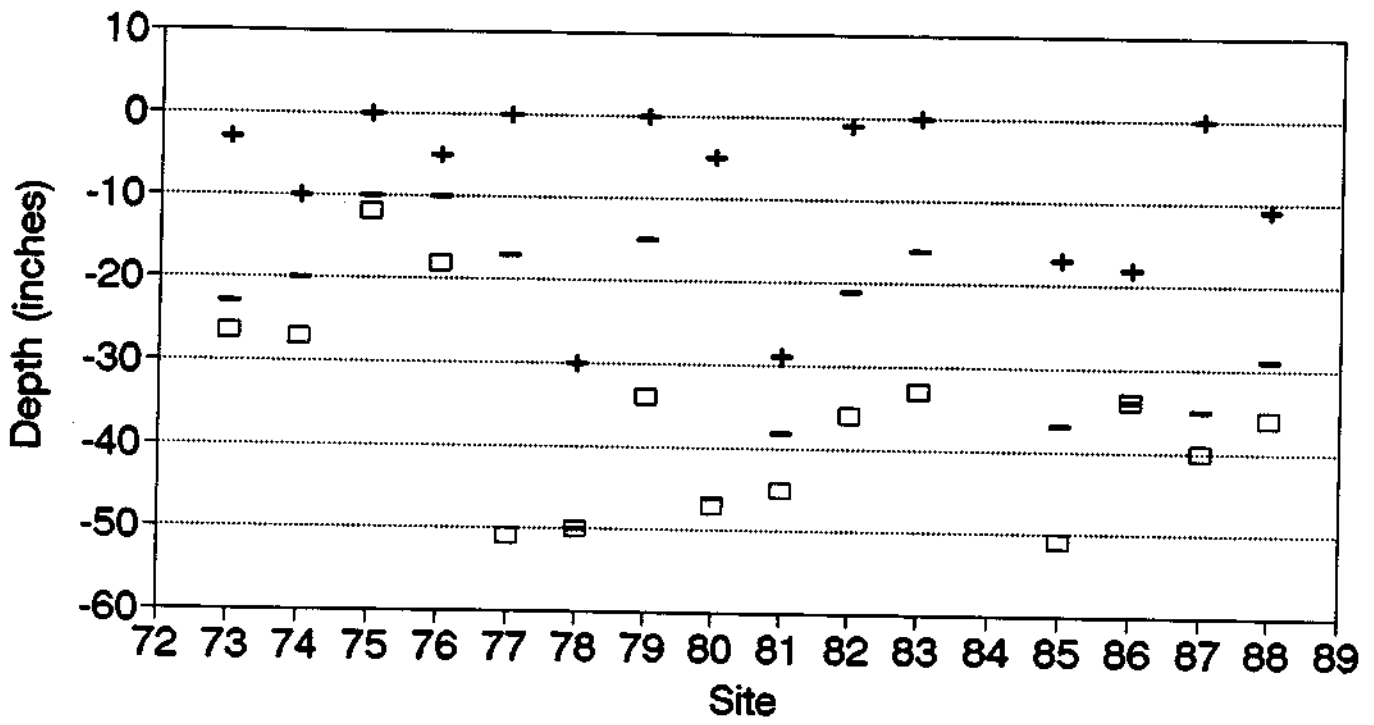
Site #20



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

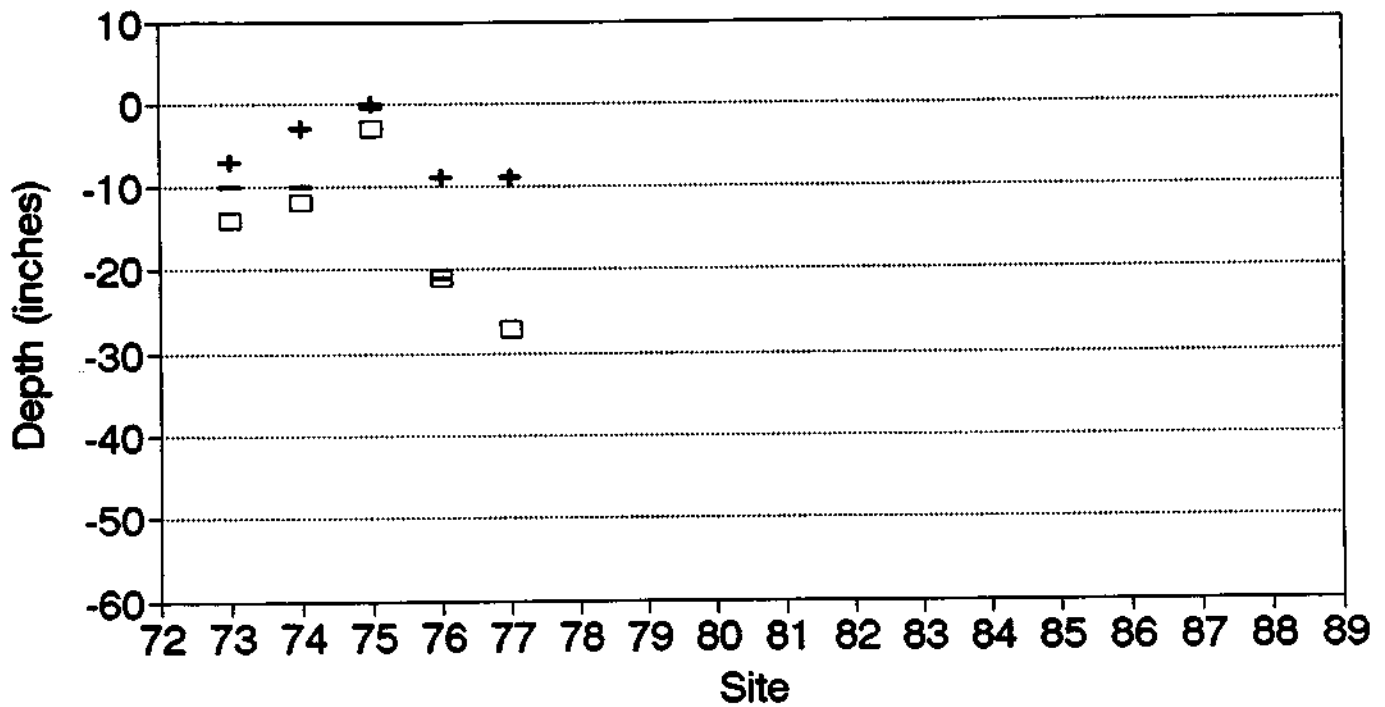
Site #19



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

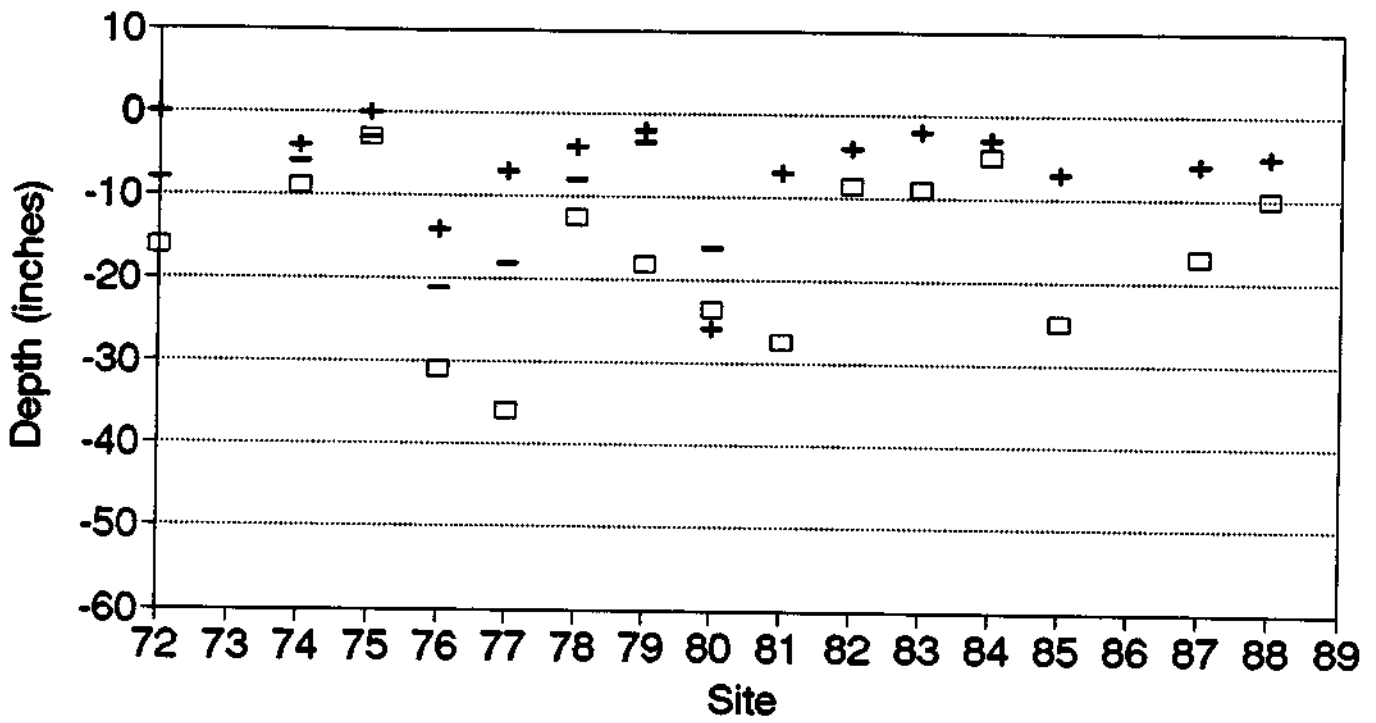
Site #17



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

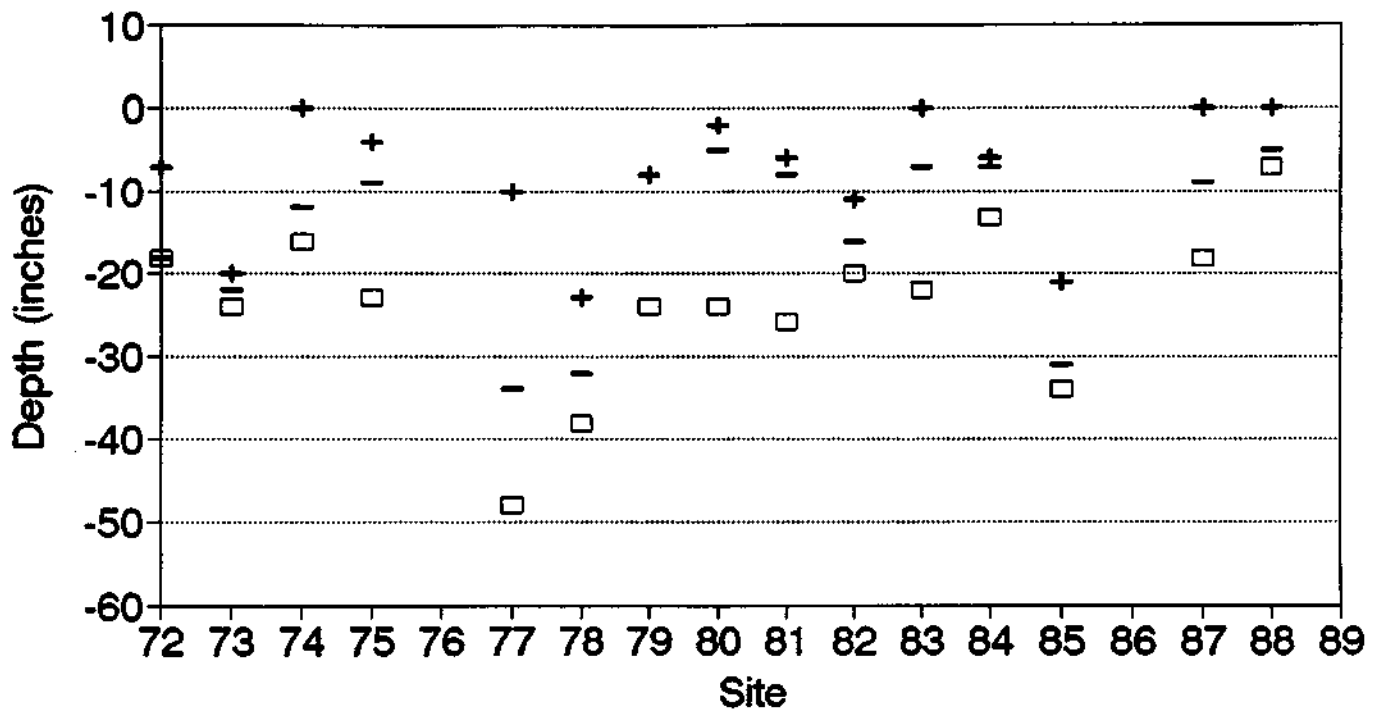
Site #16



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

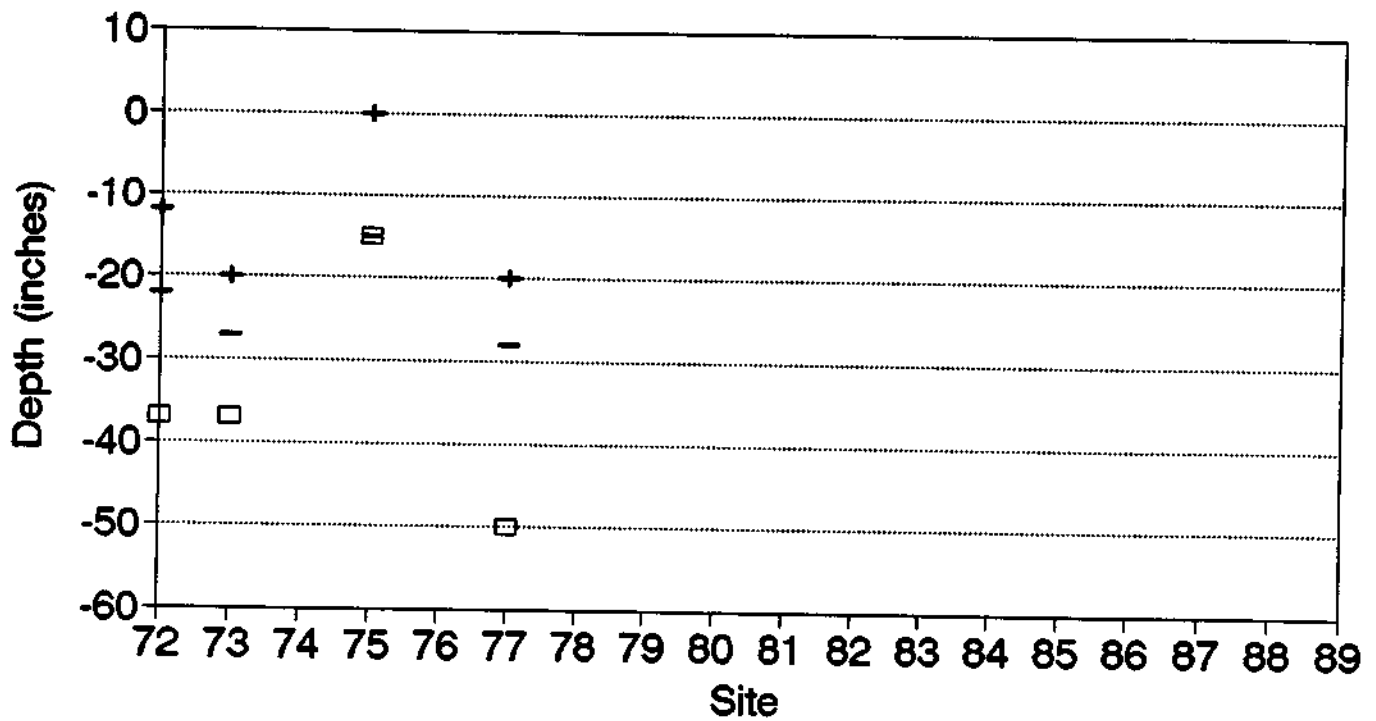
Site #15



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

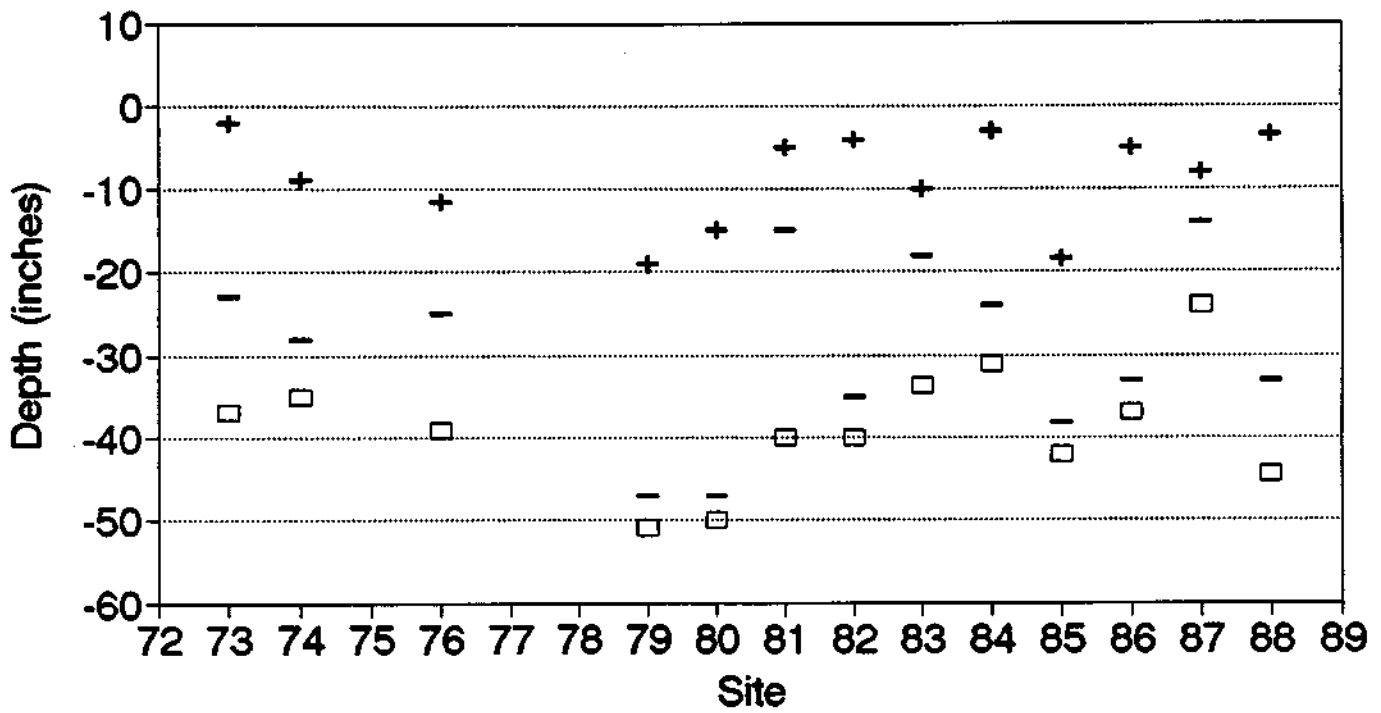
Site #14



□ Max Frost Depth - Lower Frost Line + Upper Frost Line

Final Frost - Site

Site #11



□ Max Frost Depth - Lower Frost Line + Upper Frost Line