THE CLIMATE OF THE COPPER-NICKEL STUDY REGION OF NORTHEASTERN MINNESOTA

Weather During the Project 1976-1978 and Findings Derived from Ancillary Studies

Minnesota Environmental Quality Board
Regional Copper-Nickel Study
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Chapter 1 INTRODUCTION

This report concerns meteorological findings and events from field work during the Regional Copper-Nickel Study. It is the second volume on meteorological studies made during the Study, with the first volume addressing the general climate of the Region. This volume addresses the weather that occurred during the Study. It further addresses studies of occurring weather that allow elaboration and refinement of statements on climate to be made.

Meteorological information was gathered between July, 1976, and August, 1978, with 1977 being the year of most intensive investigation. During 1977, most types of data were gathered simultaneously, while in 1976 and 1978 not all data-gathering activities took place, especially in the summer--although the winters of both 1976-1977 and 1977-1978 saw rather heavy activity.

Much of the bias toward 1977 as time of heavy activity is due to the fact that a considerable part of the weather data was gathered in cooperation with and in relationship to other Copper-Nickel Study activities. The content of this report has been somewhat influenced by meteorological needs that arose during the life of the Study. Demand for precipitation data became very heavy on the part of several activities; in response, the rain gage network was expanded and radar analysis emphasized. This report attempts to document most heavily the kind of meteorological information requested during the Study.

In addition to reporting meteorological findings per se, this report also is intended to furnish a record of the weather that occurred for the future references of those who wish to look more closely at some of the findings of the other activities. From this report, the user should be able to gain a good idea of weather that occurred during other Study investigations.

Much of the data collected were in connection with support of air quality investigations. This report does not concern itself with air quality work or air quality meteorological information, for that is covered in the report by the Air Quality Task.

Because of the great amount of data gathered, this report cannot begin to include all of the weather data obtained during the Study--much of which was gathered and assembled for the other tasks as the Study progressed. These data are available in the files resulting from the Study. Rather, the purpose of the information contained herein is to illuminate the reader's mind as to the weather and climatic conditions that did occur during the Study, and the weather and climatic conditions that can be expected to occur should copper and nickel mining activities take place in the region in the future.

Chapter 2 WEATHER DURING THE COPPER-NICKEL STUDY

2.1 INTRODUCTION

This section discusses actual weather occurrences during the period of June 1, 1976 to January 1, 1978. Although 1976 was rather atypical from the standpoint of the extreme dryness of the summer and fall, the year 1977 stands out as a year in which weather followed rather typical patterns.

The Regional Copper-Nickel Study Area (Study Area) experiences weather shaped by three kinds of air names: continental polar, maritime polar, and maritime tropical.

Continental polar air is that which has been shaped by a stay over North America. In this report, we refer to it often as simply "continental air." It may have substantial water content if it has lingered over the southern part of the

United States for several days or more, but it differs from maritime tropical air in that it never quite acquires the heat and moisture content of maritime tropical air. But this air is essentially shaped in the north of Canada. Certainly, it is air that has moved in from the ocean, but which has lost its maritime characteristics by losing heat and moisture as a result of continental visit. The land cannot supply the energy and moisture the air that the oceans can, and radiation to space is quick to remove heat while the land surface is quick to remove moisture through condensation and sublimation. In addition, the precipitation process removes moisture which the land cannot resupply, and the Canadian Rockies steal much of the moisture from Pacific air as it crosses them. Continental polar air arriving in the Study Area is cool and dry when it comes from the north; but it can be warm and sometimes even quite moist when it comes from the south. Such air is that which moved south of the Study Area but never reached the tropical ocean.

Maritime polar air which arrives in the Study Area is almost entirely from the Pacific Ocean (in this report it is referred to often as "Pacific Air"). This air is essentially that which crosses the mountains of the western United States and sometimes the Canadian Rockies. Such air is associated with a general flow of the air stream from west to east--"zonal flow," in meteorological jargon. This Pacific air is characteristically warm and dry, but not quite as dry as continental air. The warming is due to the descent of air from over the high mountains (the "polar" appendage to this air's name is thus somewhat misleading). This air is responsible generally for the warmer weather that sometimes occurs in the winter in the Study Area.

Maritime tropical air is a rare visitor to the Study Area. In order to import it this far inland, a strong southerly flow must be set up for a substantial

period of time. This essentially cannot occur in the cold season; it is virtually impossible for Maritime tropical air to reach the region except from May through September.

Figures 1 and 2 are event graphs which give the air masses present in the Study Area from June 1, 1976, to December 31, 1977. The shaded areas designate the presence of continental polar air, the unshaded the presence of maritime polar (Pacific) air, except where the designation, MT, indicates maritime tropical air. As would be expected, the continental polar air predominates, with maritime tropical air being rare. Noteworthy, perhaps, are the generally long stays of each type of air mass; interestingly, short stays of Pacific air are generally due to a storm center passing over the region, with Pacific air coming in behind a warm front rather than behind a cold front. Pacific air coming in behind cold fronts generally results in a long stay.

Note that the entire month of September, 1976, was ruled by continental air, while Pacific air ruled as long as about a fortnight in April, 1977, May, 1977, and from October 27 to November 9, 1977. The largest stay of maritime tropical air was almost 3 days in July, 1977. No maritime tropical air entered the Study Area in 1976. There does not appear to be a seasonal preference to the domination of either continental air of Pacific air from the data period of the Study; it can be said that Pacific air can enter the region at any time of the year.

2.2 SEQUENCE OF WEATHER EVENTS DURING THE STUDY

2.2.1 Introduction

The general pattern that is seen in the Study Area is a sequence of a cold air mass moving in under northwest flow aloft from northwestern Canada, crossing the

region from the northwest. The air mass may then overspread the entire United States east of the Rockies. While the air flow is still from the northwest, a minor wind-shift line may cross the Study Area, giving some short-lived cloudiness and/or brief showers. Following this, another surge of cold air may move from the northwest, along with a minor low pressure area, bringing precipitation as it passes. Several more such surges may occur.

With a shift in upper air pattern from northwest to west wind, air over the Pacific will move eastward to replace the cold continental air over the eastern portion of the continent. A large low pressure system is characteristically found at the northernmost extent of the Pacific front. This front, crossing the Study Area, has mild air behind it, which brings thaws in January. The initial Pacific surge may be a warm front, so that its arrival is preceded by southerly winds and precipitation. Fine weather with westerly winds (between southwest and northwest) follows.

Typically, the general flow of the air stream in the troposphere toward the Study Area varies from between northwest and southwest. Such large scale flow generally persists from a particular direction for periods of time varying from almost a week to a month. Changes may be shorter or longer than this, however. Typically, a cold front crosses the region about once every 4.2 days. With northwesterly flow, a series of continental cold fronts may pass, while during westerly to southwesterly flow, a series of Pacific fronts may pass. A changing pattern will see one type of air mass replace another. If a Pacific air mas replaces continental air, the leading edge of the air mass often arrives as a warm front rather than as a cold front.

Several Pacific fronts may pass over in succession, so that a warm weather regime is set up. If the storm center on the northern flank of the cold front

is strong, or if it passes close to the Study Area, cold air may be drawn into the Study Area from the northeast. Many continental polar fronts enter the Study Area in this fashion. Characteristically, they are well-marked with a sharp temperature drop, low clouds, and precipitation. They are responsible for much commentary on "sudden change in the weather."

Such a front may stall to the south, over Iowa or vicinity. The next low pressure system coming from the west may then induce the front to move north, crossing the region as a warm front, with precipitation ahead of it. Since this event is associated with an approaching low pressure area, the stay of warm air is usually for only a half-day or so, and is followed by more cold continental air from the northwest. Sometimes the storm system may move from west to east over southern Minnesota and Wisconsin. Then there is no change of air mass at the surface, but rather a backing of the wind from northeast to northwest. This situation brings rain or snow of long duration, usually resulting in copious amounts. This is a common situation in March and April and again in November, accounting for the heavy snows sometimes experienced in those months.

In the warm season, several days of low pressure in the western United States may allow maritime tropical air in ahead of a storm system. The stay of such air may be for only a few hours, if the low pressure center passes close. In languid situations, the tropical air may be around for up to one week.

One other instance merits special mention. A cold front may overtake a warm front, and the result is termed an occlusion. In an occlusion, precipitation and clouds occur both ahead of and behind the front; in contrast, a warm front has most of the cloudiness and heavy precipitation ahead of it, while a cold front has most of the heavy precipitation at and behind the leading edge.

Like a cold front, the occlusion is generally marked by a sharp wind shift from southerly to westerly or northwesterly (except when thunderstorms occur, in which case the small-scale, sharp wind systems generated by the thunderstorms overshadow the large-scale wind). Warm fronts crossing the Study Area are generally diffused, and sometimes several hours transpire before the wind shift becomes clearly evident to the casual observer.

Between cold frontal passages, a period of rising barometer followed by a crest and a succeeding drop in barometer occurs. This is due to regions of high pressure between the frontal systems. Such regions are characterized by generally sinking air, although sub-regions of rising air may exist therein.

The exact centers of high pressure systems will not usually pass right over, and often not even near, the Study Area, so a pressure "ridge" is usually experienced after a frontal passage. If the high pressure center passes to the south of the Study Area, winds will back from northwest through west to southwest and then southeast. If the high pressure center passes to the north, winds veer from northwest to northeast to southeast.

If the high pressure center passes over or near the region, the wind will be light and variable and may drop to dead calm. This gives a warm, sunny day or a cold, clear night.

On occasion, high pressure systems extending from the surface to heights of 10 kilometers or more will become stalled over the Study Area or at least somewhere in the mid-continental area. This can bring many days of hot, clear weather. High pressure over mid-continent not only favors warm, sinking air and sunshine, but also flow of Pacific air, warm and dry after crossing the western mountains.

An appreciation of the interplay of the fronts and air masses can be obtained from the following review of the weather in the Study Area from June 1, 1976, to December 31, 1977. Tab le 1 gives a synopsis of the frontal systems (with fronts occurring to March, 1978, in addition), which are numbered similarly in the text or according to cold front passages. Warm fronts are numbered in the text with the designation "W" preceded by the number of the previous cold front. On occasion, a cold front may "back up" to become a warm front, then advances once again. In such a case, the cold front retains the same number originally designated, along with the letter "R" following. Similarly, the front may back up once more, so a warm front can also have the letter "R" designating a return. Multiple Rs indicate multiple returns. Front numbers begin with the first front in June, 1976, and again with the first front in 1977, and again with the first front in 1978. The table gives the time of passage of the fronts, the kind of air mass of which they are the leading edge, and the general pattern following the front.

The table and text are not only instructional to get a handle on the kind of weather to be expected in the Study Area, but are also useful to identify weather taking place during Copper-Nickel experiments and projects, as well as for relating the data elsewhere in this report to actual weather occurrence.

2.2.2 1976 Events Between Frontal Passages

1) Continental air mass crossed 0230 June 1. Winds became southeasterly under fair skies on June 1 as front stalled immediately south of the Study Area. Winds died to calm at night.

1-W) Warm, clear all day except for a few cumulus after warm Pacific front passed early in morning June 2. Fair, warm, with little more than a few diurnal

cumulus, southerly winds by day, calm by night, through wee hours of June 6. Clouds appeared just before dawn June 7 with afternoon and night time thunderstorms.

2) Pacific cold front moved across at 0530 June 8 with initial westerlies yielding to light and variable winds remainder of June 8. Fair skies at night, but clouding up around dawn on June 9.

2-W) Front retreated as warm front, crossing around 1230 June 9. Brisk southwesterlies and hot temperatues in the afternoon.

3) Towering cumulus in afternoon June 9 grew into thunderclouds by evening, with mesoscale systems along front which passed around 1930 June 9. Variable cloudiness with limited cumulus activity June 10 with moderate westerly winds.

4) Continental front from north 0530 June 11. Cool day with only high clouds, no cumulus activity on June 11. Easterly winds through morning of June 12. Thunderstorm activity all of afternoon, early evening of June 12.

4-W) Warm air readvanced on evening of June 12, warm partly cloudy night.

5) Wrap-around Pacific front crossed 1530 June 13, coming from southwest. Brisk southwesterlies by day June 13, with stratocumulus and cirrus clouds.

6) Fresh, continental polar air mass arrived 1830 June 13. Fine day with moderate northwesterly winds June 14. Nocturnal thunderstorms June 14-15. Skies clouded June 15 with drizzle, fog as occlusion moved near Study Area; winds backed from light northeasterly to northwesterly by end of June 15. Low clouds, northwesterly winds backed to southeasterly following barometric pressure crest 100.99 KPa at 1657 June 16. Showers broke out wee hours of June 17, with afternoon thunderstorms.

7) Mesoscale systems marked leading edge of new continental polar air mass arriving around 1730 June 17. Skies partly cloudy with low clouds, rain showers, brisk northwesterly winds on June 18, followed by lighter northwesterlies and moderate convective activity on June 19. Calm night of June 18-19 with patchy ground fog. Fair skies, no cumulus, brisk southwesterlies by day, June 20, 21. High cloudiness night of June 21-22.

8) New continental front passed 1230 June 22. Mild day, light westerlies, only a few cumulus developed under broken layer of altocumulus.

8-W) New front retreated about 1730 June 22. Brisk southeasterlies, hazy, limited cumulus activity June 23, 24. Rain broke out very late on June 24 as occlusion moved toward region.

8-R) Occlusion ahead of Pacific air crossed at 0330 June 25 accompanied by heavy, steady rain.

7-R) Cold front of continental polar air returned as an occlusion crossing region 0900 June 25. Rain ended 1230 June 25. Cloudiness followed by clearing in evening. Old cold front (7) returned 0230 June 26. Variable cloudiness ended in thunderstorms in evening.

8-RR) Pacific air returned 2130 June 26. Starry night followed by fair day with cumulus. But nocturnal thunderstorms June 27-28.

8-RRR) Final return of continental polar cold front 8 at 0525 29 June. Arrived from northeast. Air unstable, with afternoon thunderstorms. Cleared off at night. Followed by fair night and day with only limited cumulus development, northerly winds. Fine day 1 July with only limited cumulus activity, northeasterly winds. After calm night, 2 July fine day with limited cumulus

activity, easterly winds, rising barometer . Barometric crest 102.60 kPa 1157 3 July followed by light northerly winds 3, 4 July with sunny skies and only small cumulus by day. After calm night July 4-5, south to west winds 5 July, fair skies. Finally, on 6 July thunderstorms broke at around dawn.

9) New Pacific front passed at 1234 6 July. Afternoon, evening thunderstorms in area. Fair on 7 July with northwesterly winds. Barometric peak 101.69 kPa at 0558 8July. Nighttime thunderstorms.

9W) Pacific warm fron barely caught region. Cumulus and cirus, westerly winds.

10) Pacific cold front moved in 1430 9 July. Noctural Thunderstorms, followed by dense fog in wee hours.

11) Fresh continental front came in 1830 10 July. Fine weather, fresh northwesterly winds 11 July. Barometric crest 101.97 kPa at 0055 12 July with calm winds and patchy ground fog. Fine skies, light southeasterlies 12 July. Increasing cloudiness, brisk southeasterlies 13 July.

12) Cold occlusion arrived 1530 13 July with thunderstorms. Followed by fair night 13-14 July with shallow ground fog. Pressure crest 101.00 kPa centered on 1357 14 July. Showers on wee hours of 15 July.

13) New continental cold front at 0730 is July followed by brisk northwesterlies, stratocumulus overcast 15 July. Clearing at nightfall. Fresh northwesterly winds, cool, with limited cumulus activity on 16, 17 July. Fine weather with winds backing from westerly to southerly on 18-19 July.

14) New continental front 2030 19 July amid thunderstorm mesosystems. Followed by variable cloudiness, northwesterlies on 20th. Skies cleared in late

afternoon, winds died to calm in evening. Barometric crest 102.13 centered at 1858 July, followed by light southeasterly winds.

14W) Warm front brought in warmer air starting around 1930 21 July. Warm with brisk southwesterlies during day of 22 July.

15) Pacific front arrived 2030 22 July amid thunderstorms. Fine day 23 July with fresh northwesterlies. Barometric crest 102.27 kPa at 0558 25 July.

16) Continental polar front from notheast at 0630 24 July. Fine day with only limited cumulus activity. Barometric crest 102.33 kPa at 0937 24 July. But thunderstorms, showers broke at just as 25 July began, lasting through the wee hours. Partly cloudy on the morning of 25 July with occasional light showers.

16W) Pacific warm front, southwesterly winds at 1730 25 July. Thunderstorms in Region all afternoon.

17) Cold front arrived amid more thunderstorms at 2130 25 July. Northwesterly winds, fine weather on 26 July yielded to general southeasterlies 27 July after barometric crest 101.50 kPa 0757 27 July. Morning thunderstorms 28 July followed by northwesterly winds. Second barometric crest 101.42 kPa 0457 29 July, followed by southerlies under partly cloudy skies. A few afternoon showers and evening thunderstorms in Region 29 July. Variable cloudiness, northwesterlies 30, 31 July, 1, 2 August, with some thunderstorm activity on afternoon of 1 August. Major barometric crest 102.71 kPa 0558 2 August, followed by fine weather, southwesterlies 3 August. Rain on 4 August with general southeasterly winds.

18) Cold front from north at 1930 4 August with low stratus, a little evening rain. Rising barometer, cool north winds, clearing 5 August. Fine weather, variable winds, barometric crest at 102.53 kPa 0858 6 August, followed by excellent day on 7 August, just a bit of cumulus activity, mild temperatures, light southwesterlies. General southeasterly winds, afternoon and evening thunderstorms 8 August, followed by brisk southeasterlies, thunderstorms morning, afternoon, and evening on 9 August until wee hours of 10 August.

19) Continental cold front followed by fog 0430 10 August, variable cloudiness, variable winds 10 August.

20) Pacific cold front 2230 10 August followed by fog during night. Scattered thunderstorms, light winds, afternoon of 11 August.

21) Continental cold front 0130 12 August followed by mostly cloudy day, light northwesterlies, showers 12 August; much the same 13 August expect for southeasterly winds. Fine day with light easterlies 14 August, with more fine weather, light and variable winds, 15 August with barometric pressure peak at 102.58 kPa 0955 15 August. Sunny skies, gentle southeasterlies 16 August, with variable cloudiness, brisk southeasterlies 17 August. Low overcast before dawn 18 August.

20W) Warm air moved in 0530 18 August. Hazy, hot high dew points on 18-19-20 August, with thunderstorms morning of 19 August.

21) Pacific cold fron 0730 21 August followed by fine day, southwesterly winds.

22) Continental cold front 1803 21 August followed by fine weather, light northerlies on 22 August.

22W) Warm front of Pacific air moved in 0830 23 August. Clear day 23-24 August. Hazy 24 August. Variable cloudiness, hazy 25 August with moderate southerlies.

23) Thunderstorms morning of 26 August with Pacific cold fron 0825 26 August. Fair hazy afternoon and evening 26 August.

24) Pacific front 0630 27 August brought partly cloudy cool, dry day with brisk westerlies lasting through night of 27-28 August.

25) Continental cold front arrived 1030 28 August. Brisk northwesterlies, broken stratocumulus clouds followed on day of 28 August. Barometric crest 103.03 at 0758 29 August, with fine day and light, variable winds. Fine weather, light winds through morning of 31 August.

26) Continental cold front from northeast on 31 August. Brought variable cloudiness, cool, dry air on 31 August. Barometer crest 102.55 kPa 0857 1 September, followed by light winds during the day. Middle cloud layer overcast early 2 September dropped to low overcast in morning.

26W) Continental polar warm front passage 1730 2 September followed by brisk southerly winds, partly cloudy skies to night of 2-3 September.

27) Continental cold front 0330 3 September followed by fine days with brisk northwesterlies on 3-4 September. Barometric crest 102.22 kPa at 0758 5 September, followed by fine weather, brisk southerlies.

27W) Continental polar warm front 0730 6 September followed by clear skies, hot temperatures, brisk southwesterlies through afternoon of 7 September. Sky smoky afternoon of 7 September from forest fires.

28) Continental cold front passage 1940 7 September, with thunderstorms. Mostly cloudy, northwest winds, 8-9 September. Barometric crest 102.71 0856 9 September. Fine with westerly winds on 10-11 September, except for smoke in air restricting visibility both days. Partly cloudy, south winds, more smoke in air 12 September.

29) Continental polar cold front passed 0630 13 September followed by low overcast, drizzle, northwest winds on 13-14 September. Cleared off by 15 September after barometric crest of 102.96 0657 15 September. Light, variable winds 15-16 September with fine weather except for morning ground fog on 16 September. Fine weather 17-18 September with light southwesterlies. Sky clouded, rainfall in advance of front 19 September.

30) Continental cold front invaded from northwest 0330 19 September. Barometric crest 2255 19 September at 101.97 kPa. Variable cloudiness, some showers, northerly winds, 19-20-21 September.

31) Continental cold front passed from northeast 1630 21 September followed by lowering clouds, rain around dawn 22 September.

32) Continental cold front 22 September followed by cold weather, northwest winds 22-23 September. Barometric crest 102.37 at 2056 23 September.

33) New continental cold front 1230 24 September. Fine weather to noon 25 September, with showers afternoon and evening on 25 September and wee hours of 26 September. Barometric crest 102.22 kPa 0155 25 September followed by gentle southerlies on 25 September.

34) Fresh continental air mass moved in at 073° 26 September, followed by low overcast, northerly winds, occasional drizzle, clearing up on 27 September. Barometric crest 102.38 kPa at 1050 27 September.

35) Completely clear sky all 24 hours 29 September with light southwesterly winds switching to northwesterly with continental cold front at 0730 29 September.

35W) Clear all day except for some morning fog, hase. Warm front passage around 0630 30 September, followed by light southwesterlies, warm temperatures into mid 80's.

36) Pacific air mass moved in 0530 1 October. Followed by clear skies, gentle northerly winds. Barometric crest 102.40 kPa 0758 2 October. Followed by sunny sky, light southeasterly winds.

37) Continental polar air mass moved in from north 2330 2 October. Followed by brisk southeasterly wind, fine weather, on 3 October, with rain before dawn October 4.

38) Sharp cold front passage 0500 4 October followed by clearing skies mid-morning, northwesterly winds backing to southwesterly, which then veered to northwest again on 5 October. Stratocumulus overcast developed from mid-morning on 5 October to wee hours of 6 October. Clouded up again before dawn 6 October, with overcast and northwesterly winds through afternoon on 7 October. First snow showers of season mid-morning 7 October. Barometric crest 103.10 kPa at 0856 7 October. Southerly winds began before dawn 8 October, with overcast skies and snow showers most of day on 8 October. Some rain showere late afternoon of 8 October.

39) Continental polar cold front passed 2330 8 October. Foggy in early hours with low overcast. Low overcast all day 9 October, with dense fog again wee hours of 10 October.

39-W) Pacific warm front passed 1130 10 October from southwest. Much warmer, with sunny skies, fresh southerly winds on 10, 11 October.

40) Pacific cold front arrived 0330 12 October. Occasional cloudiness, moderate northerly winds 12, 13 October. Barometric crest 101.80 kPa 0849 13 October. Sky became overcast late on 13 October with fresh southeasterlies before dawn 14 October.

40-W) Pacific warm front 1130 14 October. Short-lived warm spurt. Brisk southwesterlies, temperatures into 60s, fair skies.

41) Sharp continental polar cold front passed 1230 14 October. Sky partially obscured by blowing dust from Canada with frontal passage. Dust extended from surface to 2,000 ft above surface, and reduce visibility to 1½ miles. Late in the day, and into 15 October, blowing dust mixed with smoke from forest fires, reducing visibility to 4 miles. Sky became overcast in late evening with rain to early hours of 15 October, followed by drizzle around dawn and occasional snow showers rest of day, as brisk northwesterly winds blew. Snow showers, northwesterly winds through 16 October. Barometric crest 103.27 kPa 1057 17 October, followed by light, variable winds and some snow 18, 19 October, with dense fog before dawn 19 October. Sky became overcast early on 20 October, with light snow beginning 0325 20 October as fresh southerly winds blew.

42) Sharp continental polar cold front passed 1130 20 October followed by fresh northwesterly winds, low clouds, snow showers on 20, 21 October, variable cloudiness, light northwesterlies 22 October, mostly fair skies light and variable winds 23 October, variable cloudiness light northwesterlies 24 October, partly cloudy, light northlies 25 October, clear skies except for a few cumulus, light northeasterlies 26 October, with barometric crest of 103.70 kPa centered

on 0556 27 October. Brisk southwesterlies after crest on 27, 28 October, with warming temperatures, fair skies, clear with light winds 29 October, morning of 30 October.

43) Pacific cold front passed 1130 29 October followed by fair skies, light, variable winds 30, 31 October.

43-W) Pacific warm front passed 0930 1 November. Brisk southerly winds, fair skies.

44) Pacific cold front moved over at 2330 1 November followed by moderate northwesterlies.

45) Sharp continental polar cold front 0830 2 November. Heavy northwest winds with gusts to gale velocity brought in blowing dust mid-afternoon, reducing visibility to 4 miles. Some stratocumulus activity with light snow showers early evenings, with snow showers from stratocumulus most of day on 3 November to dawn 4 November. Northwesterly winds died with barometric crest of 102.74 kPa 1058 4 November. Winds backed to southwesterly in evening of 4 November, but variable cloudiness endured through morning of 5 November.

46) Continental cold front passed 1030 5 November followed by fair skies, west winds.

47) Fresh continental cold front 2130 5 November followed by fair skies, brisk northwesterlies by day through 7 November. Some overcast stratocumulus early afternoon on 6 November. Barometric crest 103.29 kPa 1057 7 November. Brisk southerly winds, variable cloudiness 8 November.

47-W) Pacific warm front crossed 0030 9 November for brief visit of mild air. Day ruled by overcast, some snow.

48) Continental polar cold front moved in 1230 9 November followed by low overcast, snow, fresh northwesterly winds, snow 9 November, yielding to clear skies, moderate northwesterlies afternoon on 10 November to near dawn 11 November. Overcast skies, frequent snow, moderate northwesterlies rest of 11 November to late afternoon of 12 November. Barometric crest 103.54 kPa 1057 12 November followed by clear skies, westerly winds through dawn on 16 November.

49) Pacific cold front passed 1130 16 November followed by clear skies 16 November, but some variable cloudiness and a trace of snow during day 17 November. Southwest to westerly winds, generally falling barometer followed frontal passage.

50) New Pacific front 0830 18 November. Strong northwesterlies following passage, with visibilities reduced to 5 to 7 miles during rest of day by blowing dust. Fair skies 18 November, with stratocumulus cloud deck developing 19 November in fresh northwesterly winds. Barometric crest 101.33 kPa, but northwesterly winds, low cloud deck continued through 20 November.

51) Pacific cold front 1330 20 November followed by scattered clouds, northerly winds.

52) New Pacific cold front 1730 20 November followed by mostly low overcast, occasional snow showers, brisk northwesterlies through evening of 23 November. Barometric crest 102.41 kPa centered on 0748 23 November, followed by winds backing to southwest by evening of 23 November. Brief clearing evening of 23 followed by overcast, snow, southerly winds till noon 24 November. Low overcast broke up evening of 24 November, but more overcast skies, snow morning of 25 November. Southerly winds, mostly light, continued to time of next frontal passage.

52-R) Pacific warm front arrived around 0930 25 November followed by continued snow, light southwesterlies.

53) Continental polar front from northwest invaded 1430 25 November followed by improving skies early 26 November. But dense fog morning of 26 November followed by daytime overcast and light snow showers. Clearing evening of 26 November; fine weather most of 27 November except for diurnal stratocumulus, very light snow showers during daylight hours; winds remained moderate from northwest to barometric crest 102.26 kPa 1557 27 November, backing then to light southwesterly. Falling barometer, cold, mostly northwesterly winds 28 November with generally fair skies but some ice fog, ice crystals in morning hours to noon. Variable cloudiness by day, very light snow, moderate northwesterly winds 29 November, followed by clearning skies, ice fog, ice crystals night of 29-30 November. Fair skies, light westerlies on 30 November with rather steady barometer. Daytime snow 1 November with winds veering to northeast, rising barometer in response to shifting high pressure system. Barometric peak 103.50 kPa 0958 2 December, followed by light southerly winds, lowering clouds, snow on evening of 2 December. Snow much of 3, 4 December with light, variable winds.

53-W) Pacific warm front 1151 4 December, followed by low overcast, westerly winds.

54) Continental polar front arrived 1630 4 December followed by clearing skies, moderate northwesterlies. Barometric crest 103.15 kPa 0758 5 December, followed by light southerly winds, nighttime snow, with strong northwesterlies following wind shift line morning of 6 December. Followed by fair weather, light variable winds through 8 December, with snow starting wee hours of 9 December. Easterly winds light during early part of 9 December becoming brisk by mid-day.

54-W) Pacific warm front at 1430 9 December by southerly winds, light snow soon after short respite.

55) Continantal polar cold front from northwest arrived 2130 9 December followed by moderate to brisk northwesterlies, clearing skies, to barometric crest 103.01 kPa 1955 10 December. Southerlies becoming brisk, after crest with mostly cloudy skies.

55-W) Pacific warm front with gentle southwesterly winds afternoon of 11 December. Partly cloudy skies, warm temperatures into 20s.

56) Sharp continental polar cold front arrived with brisk northwesterlies, low clouds at 1830 11 December. Cleared by midnight; 12 December clear, cold, with fresh northwesterlies dying to calm by end of day. Barometric crest 103.12 kPa at 0258 13 December, followed by fresh to brisk southerlies, overcast, snow by mid-morning.

56-W) Pacific warm front 2130 13 December followed by fresh to brisk southwesterlies, low overcast. Clearing in early hours of 14 December, but overcast by day 14 December. Very warm with temperatures in high 30s 14 December, brisk westerly winds.

57) Continental cold front 2330 14 December followed by fair skies, light northerly winds.

57-W) Continental front backed up, arrived as warm front 1030 15 December. Overcast mile, with fresh westerly winds. A bit of fog morning of 16 December.

57-R) Continental front returned 1930 16 December followed by low overcast, light northerly winds early 17 December, but partly cloudy with light northeasterlies during day.

57R-W) Pacific air returned as continental front backed up once again, crossing around 2030 17 December. Fair, mild, hazy southeasterly breezes through evenings of 18 December, temperature reaching 38°F.

58) Fresh continental polar cold front from northwest 2130 18 December arrived with low clouds, moderate northerly winds, some snow through rest of day. Clearing around midnight. Clear and cold with a few afternoon stratocumulus 20 December, with moderate to brisk northerlies. Barometric crest 103.13 kPa 20 December, but southerly winds did not set in until morning of 21 December. Increasing cloudiness by day 21 December, moderate southerly winds.

58-W) Pacific warm front moved in 1730 21 December followed moderate southwesterly winds, low clouds, snow.

59) Continental cold front arrived 0230 22 December. Brisk northwesterly winds, very light snow, rising barometer, falling temperatures most of day 22 December, with clearing by midnight. Barometric crest 101.92 kPa 0856 23 December, followed by winds backing to southerly under variably clouded sky. Cleared in evening. Clouds lowered during wee hours of 24 December with snow breaking out at 0439 24 December.

59-W) Pacific warm front passed 0930 24 December with winds switching to southwest, clouds breaking open somewhat.

60) Continental polar cold front passed 1230 24 December. Initial low overcast gave way in several hours to higher clouds only; winds light northwesterly through mid 26 December. Fair sky morning of 25 December with low overcast, very light snow afternoon of 25 December. Variable clouds with occasional snow 26 December. Barometric crest 101.49 kPa 1057 26 December, followed by winds

backing to southerly in evening. Snow in pre-dawn hours of 27 December, but fair after sunrise. Winds backed to northeasterly, then northwesterly, becoming brisk in evening, all in response to migrating low to the south. Generally, fair skies, rising barometers, moderate northwesterly winds 28, 29, 30, and 31 December, but ice fog mornings of 28, 29, and 30 December. Occasional snowflakes briefly on 28, 29, and 31 December.

2.2.3 1977 Events Between Frontal Passages

0) Mostly low overcast and snow showers to late morning of 3 January, clear or few clouds to late afternoon of 5 January. Low overcast with snow beginning late afternoon.

0-W) Low overcast, light snow after passage of Pacific warm front.

1) Frontal passage of continental air at 0812 6 January. Snow showers, strato-cumulus clouds broke up in afternoon of 6 January, yielding to clear skies at night. Winds dropped to calm before dawn with ice fog, -26F temperatures. Peak pressure 101.72 kPa at 0952 CST. Winds light, with very light afternoon snow.

2) Continental front passage 1930 7 January. Clear skies except for occasional small clouds drifting over from late on 7 January to end of day on 12 January, winds light throughout with directions responding to shifting of high pressure cells. Clear skies dominated most of time to early on 19 January, but some medium-scale systems brought very light snows on 13, 14, 17, and 18 January--all separated by clearing in between. Winds brisker on 14 and 15 in response to wave passage to south. Temperatures cold throughout, with bitter cold most nights, including -46 at Embarrass on 9 January. On 19 January, skies clouded as a warm front approached with snow breaking out just past noon.

2-W) Strong warming as relatively well-defined warm front passed at 1800 19 January. Snow ended, low clouds parted during evening at 19 January and with very light snow after midnight, region treated to first warm night all year.

3) Well-defined cold front arrived 1025 20 January with snow flurries, but clearing in late afternoon of 20 January. Mostly fair to early hours of 22

January, with maximum barometer 103.11 kPa at 2257 on 21 January with calm air. Fog formed on morning of 22 January, followed by low overcast, snow, and brisk southerly winds in afternoon through the night of the 22-23 January in advance of cold front 4.

4) Warm Pacific air from time of arrival of this front at 0630 23 January to arrival of the next. Sky low overcast with light snow through most of period with gentle to fresh northwesterly winds.

5) Sharp cold front passage at 0228 26 January, with gusts to gale velocity, blowing snow, bitter cold, strongly rising barometer on 26 January. Winds decreased to calm by 0657 on 27 January, lagging peak barometer reading at 100.33 kPa at 2358 on 26 January.

5-W) Weak, diffuse warm front at 1213 27 January followed by partly cloudy skies and not-as-bitter-cold temperatures; very short-lived.

6) Cold front 1620 27 January followed by blowing snow, clearing skies, cold. Winds strong all night on 27-28 January to early morning on 1 February. Skies altrnated between fair and overcast with light snows at times each day. Barometer rose to peak of 102.45 kPa at 0956 1 February, with wind dropping to calm by 1257 1 February; sky became overcast late at night.

6-W) Warm front passage at 0230 2 February. Sky became broken with warming temperatures in wee hours, but later became overcast with snow showers and southwesterly winds.

7) Frontal passage 1230 2 February followed by brisk northwesterlies until dark, with some blowing snow. Moderate northwesterlies, mostly cloudy skies, light snow much of the time until clearing late in morning on 4 February.

Mostly fair with moderate northwesterly winds through afternoon of 6 February. Calm on night of 6-7 February with clear skies to wee hours of 7 February. Peak pressure 103.68 at 2955 6 February. On 9 February, cloudy skies with southerly winds beginning by 0558, moderating temperatures continuing through morning of 8 February.

7-W) Marked switch to moderate winds from southwest with frontal passage around 1330 8 February. Temperatures into upper 30s.

8) Slight penetration of cold front from north about 0530 9 February. Several hours of fog.

8-W) Front retreated crossing about 1230 9 February, with spectacular temperature jump to 48F at Hibbing 1257 on 9 February. Mild throughout this period; fair skies till afternoon of 10 February, except for dense fog on morning of 10 February, followed by low overcast through night of 10-11 February, then clearing with maximum pressure 101.58 at 1050 11 February, calm at 1150. Clouded up very late on 11 February as occlusion moved near.

9) Occlusion, at 0430 12 February, brought low clouds, drizzle (first liquid precipitation of year), snow and fog throughout period.

8(R) Cold front 8 returned at 1330 13 February, bringing return of chilly air, snow; clearing at dawn of 14 February, with clear skies all day on 15 February. Maximum pressure 103.26 kPa at 0855 15 February. Calm, cold most of night of 15-16 February, with clouding-up and south winds during day.

8(R)W Warm air returned around 1130 16 February borne on south-southwesterlies. Low overcast and fog on night of 16-17 February.

10) Cold front arrival at 1430 17 February brought rapidly clearing skies. Low clouds, trace of snow, prevailed during wee hours of 18 February, followed by afternoon clearing 18 February.

10-W) Backup of front around 1030 19 February, accompanied by patchy clouds, mild temperatures.

11) New cold front at 1430 19 February initially accompanied by patchy clouds, but low clouds formed by nightfall with light snow. Cleared off by day on 20 February. Maximum pressure 102.18 kPa at 1257 20 February followed by backing winds, calm at night. Brisk southerlies formed during wee hours, with some high cloudiness.

12) Front at 1330 21 February with clearing skies. Winds became northeasterly in wee hours of 22 February as wave on front to the south influenced circulation, with low clouds ruling sky by wee hours of 23 February. Freezing rain, sleet, snow with brisk easterly winds ruled 23 February and first half of 24 February, followed by snow and northwesterlies on rest of 24 February and virtually all of 25 and 26 February. Fair skies and light northwesterlies with moderate temperatures prevailed on 27 and 28 February, with rising barometer to 0758 1 March, when peak reached at 102.42 kPa. Winds generally light to calm under fair skies through 1 and 2 March, but becoming northeasterly on evening of 2 March in response to wave passage to the south. The wave brought cloudy skies and brisk easterlies through 3 March, and snow all day on 4 March. On 4 March, the winds backed from northeast to northwest as the storm moved east, with minimum pressure 100.50 kPa at 1358 on 4 March. The snow ended at 1020 5 March, and the evening of 5 March brought clearing skies. Barometer peaked at 102.19 kPa at 0757 6 March with calm winds and partly cloudy skies.

12-W) Warm Pacific air moved in behind warm front arriving around 1630 6 March. Fair skies and mild temperatures through weeeeeee hours of 9 March.

13) Front arrived with rain 0449 9 March. Rest of 9 March marked by fair, mild weather. Followed by mild weather, patchy clouds to mid-day at 11 March, with low overcast. Rain later on 11 March, lasting through most of 13 March as wave passed to south. Rain let up as 13 March began with light northeasterlies, low clouds, and fog prevailing. Minimum pressure 99.98 kPa at 0258 13 March, followed by backing winds. South winds began late on 13 March with occasional drizzle enduring all day and into 14 March, even through peak barometer of 100.81 kPa at 1049 14 March.

14) Front invaded 2340 14 March. Low overcast throughout period.

15) Front with continental air ended long reign of Pacific air at 2145 15 March. Came in with very light snow, brisk northwesterly winds; wind died to calm, sky cleared on evening of 16 March.

15-W) Front backed up briefly on wee hours of 17 March.

15-R) Front came in with continental air, low overcast, around 0430 17 March, then snow during day of 17 March, lasting till dawn 18 March. Calm and fair during day of 18 March.

15(R)W Pacific air returned 1330 18 March with low cloudiness to morning of 19 March; fair skies thereafter.

16) Continental air came in 2030 19 March with clear sky, but same low clouds, around dawn on 20 March. Fair skies, high pressure cresting at 102.30 kPa 0658 21 March with calm air, followed by moderate southerly winds.

17) Bare penetration of new front around 0600 22 March; clear skies.

17-W) At 1030 backup of front; brisk southwesterly winds; a bit of rain and snow in late afternoon.

17-R) Strong frontal attack with violent north winds at 1745 22 March. Snow soon ended, clear by end of 22 March. Barometric maximum 102.92 kPa at 0955 23 March, with winds calm by 1357 23 March, then easterly by 1558 23 March. Easterly to southeasterly winds with occasional cloud patches moving over through 25 March, with low overcast by end of 25 March and rain beginning by 1478 26 March.

18) Front in at 2130 26 March with low overcast, drizzle, fog. Clearing around noon on 27 March, with barometric crest of 100.72 kPa at 0957 at 27 March, followed by wind switch to southerly. Easterly winds began just after midnight on 28 March as a wave to south began to influence flow. Strong easterlies, low clouds by mid-morning, and some rain just after sunset. Low clouds with drizzle and rain on morning of 29 March changing to snow by afternoon of 29 March, continuing with low clouds and some snow through all of 30 March. Clearing at start of day 31 March with calm and pressure maximum of 102.44 kPa 0757 31 March. Southeasterly winds began around noon 31 March, with fair skies until near daw 1 April. As an occlusion approached, the skies were covered with low clouds after dawn on 1 April with rain in the early afternoon and dense fog on the night of 1-2 April.

19) Skies remained cloudy and fog persisted as the occlusion passed, with some drizzle in the wee hours of 2 April. Skies cleared by nightfall 2 April, with pressure cresting with fair skies and calm air at 0656 3 April at 102.02 kPa. Southerly winds blew with fair skies throughout 4 April, but backed to

northeasterly and became brisk on 4 April, in response to a low moving eastward to the south. Variable cloudiness occurred but there was no precipitation from the low as winds backed to brisk northerly on and throughout 5 April. Winds diminished and skies cleared on the night of 5-6 April, with barometric cresting of 101.94 kPa at 0957 6 April. Nightfall brought clear skies and calm air to the wee hours of 7 April.

20) The new front arrived from the north-northeast at 0247 7 April. Clear skies gave way to daytime stratocumulus in the cold polar air, with the usual nighttime clearing on the night of 7-8 April. Fair skies and light-and-variable winds marked 8 April, with barometric cresting of 103.20 kPa at 0657 8 April. Southeasterlies began to blow as 9 April began, becoming brisk in the daytime. The night of 9-10 April was clear and calm with haze developing around dawn.

20-W) A strong warm front of Pacific air moving in around 0800 10 April boosted temperatures from freezing at Hibbing at 0558 10 April to 83 by 1252 10 April, a rise of 51 degrees fahrenheit in seven hours. The day was fair, warm and hot, with smoke from forest fires dropping visibility to 5 miles at 1252 10 April.

21) Fresh Pacific cold front moved in at 2230 10 April, bringing mild, partly cloudy day on 11 April. Wind dropped to calm at 2158 and started to blow from southeast an hour later; followed by variable cloudiness, occasional rain showers.

22) New Pacific front in at 1530 12 April followed by low clouds, some showers, dense fog, but clear, warm day on 13 April, following barometric pressure crest of 102.37 kPa at 0952 13 April. Southeasterly winds through 13, 14, and 15 April with low clouds from early afternoon of 14 April through afternoon of 15 April. Dense fog night of 15 and 16 April.

23) Weak new Pacific cold front at 1045 16 April. Mild with variable cloudiness through period, and first thunderstorms of the year before dawn on 17 April, followed by hazy day and dense fog before dawn on 18 April.

24) New Pacific cold front came in with thunderstorms on morning of 18 April with showers off and on in afternoon. Low clouds, rain, east winds, and fog dominated the scene on 18, 19, and 20 and wee hours of 21 April, as front stalled over Lake Superior. High pressure moved in, cleared the sky by dawn 21 April, with barometric crest 102.00 kP at 0758 22 April. Followed by southeast winds and variable cloudiness on 22 April to wee hours of 23 April.

25) Continental air moved in on cold front at 0630 23 April, ending nearly two weeks of Pacific air domination. Brisk northwesterlies, cold air, and mostly fair skies on 23, 24, and 25 April, with winds dropping to calm on night of 25-26 April. Morning winds on 26 April out of southeast, but variable and mostly light from afternoon of 26 April through pre-dawn hours of 27 April, all under fair skies. Nighttime thunderstorms in area night of 30 April-1 May.

26) Fresh surge of continental air from northeast as cold front passed 0730 27 April. Cool, fair weather with variable winds through morning of 29 April as high passed to north. Barometric crest 102.44 kPa at 0950 28 April. Mostly southwesterly winds, occasionally brisk rest of period with afternoon thunderstorms on 29 April.

27) Strong frontal passage at 0448 1 May, bringing in fresh but hazy continental air. Brisk northwesterlies by day under clear skies. Clear with light wind on 2 May, with barometric pressure crest 102.58 kPa at 0657 2 May. Brisk southeasterlies began morning of 3 May. Patchy cloudiness 3 May, mostly low overcast 4-5 May with showers and southeast winds through rest of period.

28) New surge of continental air at 1130 5 May, borne on strong westerly winds. Fair skies through period except for morning stratocumulus on 6 May. High pressure crest 102.71 kPa at 0658 7 May, with calm air; variable winds rest of period.

29) Intrusion of cold air from northeast brought freezing temperatures on morning of 9 May; fair skies all day.

29-W) Diffuse warm front passing 0230 10 May ahead of modified continental air halted nighttime temperature drop. Cloudy on 10 May with occasional rain, yielding to clear skies on morning of 11 May. Followed long period of warm weather with prevailing southerly winds. Fair and hazy on 12 May, with variable cloudiness on 13-14 May. Occasional thunderstorms 15, 17, and 19 May, and hazy skies on 15 and 17 May. Foggy on mornings of 16 and 18 May. Barometer varied little; between 100.96 and 101.63 kPa from 13 May to morning of 20 May.

30) Mesoscale thunderstorm system arrived at vanguard of Pacific air mass, with thunderstorm starting at 0113 20 May. Sky cleared evening of 20 May, with dense ground fog on morning of 21 May. Barometric maximum 101.65 kPa at 0754 21 May. Clouds lowered during day on 21 May, with late afternoon showers and evening thunderstorms, followed by low ceiling fog, east winds, in wee hours of 22 May.

30-W) Winds switched to southerly around 0820 as cold front backed up. Partly cloudy to cloudy on 22 May with showers and low clouds through night.

31) New Pacific arrived at 1121 23 May. Clouds broke up during day of 23 May, becoming clear in evening with dense ground fog around midnight. Winds veered to easterly around sunrise and moderate southerly with small cumulus by day on 24 May.

31-W) Warm Pacific air mass returned around 0600 25 May, starting a regime of hazy days, thunderstorms, and resulting skies of variable cloudiness for the rest of May, but ended with wave passage, heavy rain, low clouds on 31 May.

32) Pulse of continental air invaded at 0231 1 June bringing back good visibilty and colder, drier air. Convective clouds by day, clearing at night of 1 June, with patchy ground fog on morning of 2 June. Only a few cumulus and light winds on 2 June as high pressure passed over with peak pressure 101.91 kPa at 0758 2 May.

32-W) Short retreat of front with south to southwesterly winds.

33) New Pacific front arrives with showers, light fog, followed by partly cloudy skies through 5 June. Barometric crest 101.80 kPa at 1658 4 June. Winds were light throughout period.

34) Continental air arrived with thunderstorms on mid-afternoon of 5 June. High barometer of 102.30 kPa at 0955 6 June, with winds veering through rest of day to southeasterly by 2248 6 June. Wave passage to south on 7 June brought cloudy, rainy weather with inbedded thunderstorms in cloud system north of low center. After barometric minimum 100.84 kPa at 0225 8 May, skies gradually improved to clearing by end of 8 June. Fine weather on 9 June, overcast all of 10 June with brisk southeasterlies to sunset 10 June.

35) Fresh continental air invasion at 0230 11 June, from north. Partly cloudy skies with general easterly winds on 11-12 June, with pressure crest 102.44 kPa at 0857 12 June in response to high to north moving eastward. Small, cold low to north brought cool temperatures and multiple cloud layers on 13 June, but after ridge passage on 14 June, fresh southerly winds blew through 15 June under mostly cloudy skies, followed by nighttime thunderstorms on 15-16 June.

36) Intrusion of Pacific air began 0917 16 June, with rain, quickly followed by clearing skies, but dense fog at night.

37) Surge of continental air arrived 0730 17 June. Showers, clouds, thunderstorms, cool temperatures a constant feature of the regime through 23 June, except no rain on 21 June. Rain broke out with low clouds on evening of 22 June as warm front advanced with imbedded thunderstorms.

37-W) Warm front passed 1030 23 June, ending low ceilings and cool weather. Clearing skies before nightfall, dense ground fog on pre-dawn hours of 24 June.

38) Continental air invasion at 0530 24 June followed by fair weather through 25 June, with barometric crest 101.49 kPa at 0058 25 June. Nocturnal thunderstorms during wee hours of 26 June.

39) New pulse of continental air at 1530 26 June. Variable cloudiness through period with nocturnal thunderstorms on 27-28 June and 29-30 June; afternoon thunderstorms on 30 June.

40) Cold occlusion moved in 0330 30 June, with very low barometer. Afternoon thunderstorms, overcast skies through evening, becoming very windy on morning of 1 July as barometer rose rapidly. Subsiding winds, clear skies on night of 1-2 July, with calm in wee hours of 2 July leading up to barometric crest of 101.71 kPa. Southerly winds 2 July, with nocturnal thunderstorms night of 2-3 July, low clouds thereafter.

41) Pacific front arrived at 1130 3 July. Clouds variable through afternoon of 5 July, with daytime thunderstorms on 3 and 4 July. Dense fog on morning of 6 July. Winds veered to southeasterly by midday of 4 July, but became northwesterly 6 July in response to low pressure to east; dying to calm in night of 6-7 July.

42) Continental air invasion 0630 7 July. Afternoon showers, nighttime thunderstorms on 7 July. Regime of clear skies at night with daytime cumulus on 8, 9, and 10 July. Northwesterly winds through 8 July, light and variable on 9 July, southeasterly on 10 July. Barometric crest 102.70 kPa at 1053 9 July.

43) Fresh continental invasion 1130 11 July, followed by brisk southwesterly winds, scattered shower activity in evening and into morning of 12 July. Sky clear with calm air night of 12-13 July followed by fresh southeasterly winds on 13 July after pressure maximum of 101.89 kPa at 0857 13 July. Afternoon thunderstorms 13 July. Sky clouded in evening ahead of warm front with shower activity.

43-W) Warm front brought first maritime tropical air of year into region around 0330 14 July, with wind switch to southwest. Dewpoint at Hibbing 20°C (68F) at 0657 14 July. Shortlived tropical air invasion ended at 0730 14 July.

44) Continental polar air replaced maritime tropical air at 0730 14 July with fresh westerly winds. Partly cloudy skies cleared by sunset, with fine day on 15 July. Barometric crest 102.37 kPa at 0654 15 July, but northwest to west winds all day. Thunderstorms morning and afternoon on 16 July with wind backing to southerly by 0658 16 July.

45) Surge of continental air 1930 16 July. Ground fog became dense as cooler air moistened by evaporation of water from thunderstorms. Increasing cloudiness after dawn ahead of warm front.

45-W) Strongest invasion of maritime tropical air of year with warm front passage at 1030 17 July. Tropical air ruled until wee hours of 20 July. The tropical air was accompanied by the usual haze by day and by fog before dawn,

which was dense on 18 July. Dew points were in the 70s each day, with a peak dewpoint 75F at 1957 18 July. Skies were generally partly cloudy through the regime. Temperatures in 90s on 18 and 19 July; low temperatures at Hibbing 72F on 19 July.

46) Sharp cold front of continental polar air arrived at 0149 20 July. Came in with brisk north wind, low overcast, which quickly replaced clear sky. But sky again clear by late evening, with fine day on 21 July. Barometric crest 102.82 kPa at 0557 22 July, with calm air, followed by daytime southerly winds. Partly cloudy skies, westerly winds on 23 July followed by calm night with dense fog on wee hours of 24 July.

47) Fresh continental polar air surge at 1330 24 July, with brisk northerly winds; evening thunderstorms 24 July. Fine weather with northwesterly winds on 25 and 26 July, with barometric crest 102.70 kPa at 0857 26 July. Calm air night of 26-27 July followed by southerly winds, afternoon and evening showers on 27 July, with low overcast on evening of 27 July (see upper air section for upper air profile at this time).

48) Invasion of Pacific air at 0330 28 July. Sky improved during day, but clouded over with showers in evening, followed by clearing on wee hours of 29 July.

49) Continental polar air came from north at 0545 29 July with low overcast. Northerly winds veered to east and southeast during day and into evening with skies improving to clear by 2055 29 July. Barometric crest 101.70 kPa at 1556 29 July. Low overcast during day of 30 July with rain showers, southerly winds, cold temperatures.

50) Cold occlusion at leading edge of Pacific air mass, which arrived at 2230 30 July, lasted only until morning of 31 July. Fair skies after frontal passage.

51) Fresh surge of continental air moved in at 0625 31 July. Mild fine day on 31 July with brisk northwesterlies dying to calm by end of day. Barometric crest 101.30 kPa at 2258 31 July.

52) Cold blast of continental air arrived from north at 0530 1 August. Rain showers for first several hours, with cloudy skies yielding to clear by 2256 1 August. Small pressure systems moved through region 2, 3, and 4 August, with variable cloudiness, light variable winds, and nocturnal thunderstorms on 3 August.

53) New surge of continental air at 0330 5 August marked by improving skies on 5 August, fresh northwesterly winds that died to calm in evening. Barometric crest 101.78 kPa at 0656 6 August followed by southwesterly winds, afternoon showers, overcast evening.

54) New continental air mass at 0830 7 August followed by 3 days of fine weather. Light northwesterly winds by day, calm and foggy by night on 7-8 and 8-9 August. Barometric crest 101.59 kPa at 0758 9 August, as wind switched to southerly. Patchy, high cloudiness marked 9 August with virtually no rain through 10 August.

55) Cool, well marked blast of continental air arrived 0330 10 August brought cool, brisk westerlies on 10 and 11 August, which backed to southwesterly.

56) Cold, sharp blast of continental air came in at 0730 12 August. Mostly cloudy on 12 August with late afternoon showers. Northwesterly winds and fair

weather through 13 and 14 August to barometric crest 102.18 at 0456 15 August. Easterly winds, showers on 15 August in response to low, moving eastward to the south, with winds backing to northwesterly on 16 August. Improving skies after late afternoon thunderstorms 16 August; northwesterly winds and mostly fine weather on 17-18 August. Calm on night of 18-19 August followed by easterlies on 19 August into 20 August. Showers before dawn on 20 August.

57) New continental air mass 1130 20 August. Improving skies became clear evening of 21 August, followed by showers around midnight and on wee hours of 22 August.

58) Fresh continental air came in on cold front at 0830 22 August. Cool, dry, fine weather with general northwesterly winds until pressure crest at 102.29 kPa at 0955 24 August. Skies especially fair on 24 August with presence of high pressure. Southeasterly winds with skies becoming cloudy with rain and drizzle 25 August into 26 August (see the upper air section for upper air profile at this time).

58-W) Diffuse warm front in region around 1200 26 August. Dew point up to 69 at 1458 26 August. Late afternoon, evening of 26 August and most of 27 August marked by sporadic thunderstorms and showers.

59) Frontal system with edge well-shredded by mesoscale thunderstorm systems arrived around 1230 27 August. Thunderstorms from early afternoon to early evening. Northwesterly winds, mostly cloudy 28 August followed by calm; dense fog morning of 29 August after skies cleared. Barometric crest 102.19 kPa at 0757 29 August. Southerly winds began under partly cloudy skies after mid-morning on 29 August. Mostly cloudy with showers, thunderstorms on 30 August. More dense fog on night of 30-31 August.

60) Fresh continental frontal invasion 1430 31 August. Stratocumulus with light showers afternoon of 1 September, with variable winds after barometric crest of 102.45 kPa at 1159 1 September. Barometer remained fairly steady through 2 September and first half of 3 September, with maximum crest 102.64 at 0352 2 September. Southerly winds 3 September after dawn, with increasing cloudiness, followed by thunderstorms entire evening of 3 September and showers into wee hours of 4 September.

61) Cold occlusion passed 0737 4 September, with showers and northwesterly winds all day and into wee hours of 5 September. Barometric crest of 102.14 kPa with calm winds followed by southeasterlies all day on 5 September. Low cloudiness all of 5 September, however, with thunderstorms at end of 5 September; showers, drizzle, and fog all day on 6 September with east winds as low pressure wave passed to the south. Fine day with high barometer and gentle southeast winds 7 September. Barometric crest 102.57 kPa at 0858 7 September. Low overcast all day on 8 September with showers part of time and thunderstorms in late afternoon and early evening as cold occlusion approached.

62) Cold occlusion crossed just after midnight 9 September. Brisk westerly winds and low overcast and showers during day gave way to clear skies, light northwesterlies as 10 September arrived. Fine day on 10 September, barometric crest 102.07 kPa at 2157 10 September with calm air. Generally fine weather from 11 to 15 September with variable winds but a brief small thunderstorm on 11 September. Dense fog on mornings of 12 and 14 September; some shower activity on 13 September very sunny, warm, dry on 15 and 16 September as southeasterly winds picked up, but low overcast came in on evening of 16 September. Foggy on 17 September from wee hours to arrival of new front.

63) Pacific air mass arrived 1557 17 September with low overcast, fog, and haze. Overcast all day on 18 September with generally northeast winds. Some thunder activity in early afternoon.

64) Continental air mass entered from the northeast at 0030 19 September. Low overcast and northeast winds all day, with drizzle to early afternoon on 19 September. Low overcast northeast winds broke up around dawn on 20 September with barometer crest 102.07 kPa at 0856 20 September. The high pressure center started to the east, resulting in cloudy, rainy, cool weather with easterly winds through 25 September.

65) Cold occlusion leading continental air mass passed over at 0630 25 September. Pressure rise very slow, with low overcast, rains, westerly winds lingering to afternoon of 27 September. Fair with dense ground fog night of 27-28 September, followed by more low clouds and rain later on 28 September, followed by rising barometer, northerly winds, and partly cloudy skies on 29-30 September. Very fine weather and very high barometer on 1, 2, 3 October, with barometric crest of 101.37 kPa at 1059 2 October, but northerly winds through 2 October. After night of calm, light southerly winds prevailed on 3 October into 4 October. Skies clouded on morning of 4 October, with rain breaking out ahead of next frontal passage.

66) Continental polar cold front arrived 1230 4 October, with low clouds and precipitation yielding to clear skies during night of 4-5 October. Showers on evening of 5 October, with sky remaining low cloudy on 6 October. Barometric crest 103.13 kPa at 1156 6 October followed by light, variable winds for rest of 6 October, followed by light, variable winds for rest of 6 October, a fine day. Easterly winds and low clouds developed on 7 October, with rain breaking out in

the early afternoon as a low pressure wave developed to the south. With very cold air advection, the rain became mixed with snow and brisk northeasterlies blew before final clearing late on 8 October. A second barometric crest occurred at 0755 9 October at 100.99 kPa, after which winds backed to southerly.

67) A new continental polar front moved into the region at 0330 10 October. Skies remained cloudy with barometer dropping during the afternoon of 10 October in response to a cold low aloft moving over the surface low over Lake Superior. Strong northerly flow developed over the Study Area, causing high, north winds of gale velocity and heavy snow that resulted in much damage to trees. The system cleared out by the evening of 11 October after much damage had been done. The barometer rose to a crest of 101.98 at 2257 12 October with calm winds. On 13 October, clear skies and brisk southerly winds prevailed to midnight.

68) A surge of cold continental air arrived at 0030 14 October. Fine but cool weather with moderate northwesterly winds on 14, 15 October, even after barometric maximum of 102.81 kPa at 0955 15 October, as high passed to south. Fine day on 16 October with fresh southerly winds after calm night.

69) New cold front crossed 0830 17 October. Fair weather on morning, but overcast developed with rain in afternoon, evening and into wee hours of 18 October. Low clouds broke up afternoon of 18 October, yielding to clear skies in evening, followed by dense ground fog morning of 19 October. Northwesterly winds to night of 18-19 October, with southerlies following barometric crest of 101.84 kPa at 0749 19 October. Calm, clear night of 19-20 October, with southerlies resuming in the morning.

70) Continental polar air mass moved in 1430 20 October with no low clouds or precipitation. Fine weather with northwesterly winds through dawn on 22

October, with easterlies following pressure crest of 103.33 kPa on 22 October. Fine weather with easterlies through all of 23 October, with low overcast, drizzle, and fog on 24 October to midday 25 October, after which the sky cleared. Southerly winds most of the time 24, 25 October.

71) Pacific cold front moved in 0130 26 October with light westerly winds, mild temperatures. A few showers in wee hours of 27 October but otherwise generally fine mild weather on 26-29 October. Winds mostly northwesterly except for nighttime calms up to barometric crest 102.65 kPa at 1057 28 October, becoming southeasterly through 28-30 October and first part of day on 31 October. Overcast developed 30 October with rain beginning 2318 30 October to a bit past noon on 31 October.

72) New Pacific air mass at 1230 31 October. Skies cleared, dense fog developed in early evening of 31 October. Fine day 1 November, with more fog morning of 2 November. Barometric crest 101.47 1055 1 November followed by light westerlies backing to strong southerlies on afternoon of 2 November.

73) Another Pacific cold front crossed Study Area 0330 3 November after cloudy morning, skies cleared and stayed such to wee hours of 5 November. Barometric crest at 0852 4 November, 103.45 kPa, followed by moderate southeasterly winds, fine weather through 5 November to mid-afternoon of 6 November. Low overcast moved in thereafter with addition of drizzle and fog on 7-8 November.

74) Sharp continental polar cold front crossed from west at 0030 9 November with brisk northerlies. Drizzle and rain during 9 November changed to snow in evening, continuing to mid-morning of 10 November. Low overcast with northerly winds through remainder of 10 November. Fair skies, moderate northerly 11 November. Barometric crest 103.55 kPa 0758 12 November, followed by southeasterly winds and continued fair skies through 12 November.

75) Weak Pacific front 1330 13 November followed by fine, hazy days with light winds, 13-14 November. Barometric crest 102.17 kPa 1857 13 November. Low overcast with drizzle light winds arrived early 15 November.

76) Another Pacific front entered 0930 15 November, with drizzle to 1227 15 November.

77) New Pacific front in at 1530 15 November with rain which changed to snow at 1733 15 November. Snow, fresh to brisk westerly winds through night of 15-16 November, with snow ending around sunrise.

78) Continental polar front on scene at 1330 16 November with snow flurries, brisk westerlies. Low overcast, snow, and moderate to brisk northwesterlies 17-18 November, with decay of winds, clouds on night of 18-19 November. Barometric crest 102.65 kPa with calm air at 0854 19 November. Wave passage brought low clouds, brisk easterlies, snow afternoon and evenings 19 November and up to sunrise of 20 November. Barometric minimum 98.51 kPa at 1352 20 November followed by snow and blowing snow driven by brisk westerlies through pre-dawn hours of 21 November. Sky cleared by evening of 21 November with winds dying to calm, and ice crystals on night of 21-22 November. Barometric crest 103.07 kPa at 2357 21 November. Sky again clouded with southeasterlies and some mid-day snow on 22 November as low moved to south. Followed by variable cloudiness, moderate northwesterlies 20 November, and clearing with first sub-zero (Fahrenheit) temperatures on 24 November. Fair on 24, 25 November with steady barometer above 102 kPa. Sky became gradually cloudy in afternoon and evening 26 November, with gentle southeasterly winds. Snow, east winds on 27 November as wave moved south of region improving skies in wee hours of 28 November, with clear skies, light westerlies until late afternoon. Low overcast, hazy

atmosphere on evening of 28 November with low overcast and fog wee hours of 29 November.

78-W) Diffuse Pacific warm front moved over region around 1330 29 November followed by brisk southerly winds and temperature rising up to 0°C (32F) by midnight. Low clouds, mostly brisk southerlies, above-freezing temperatures before dawn.

79) Pacific cold front 0830 30 November followed by mild temperatures, low overcast, fog, south-southwest winds all day 30 November and into wee hours of 1 December.

80) Continental polar air mass arived from northwest 0430 1 December. Low overcast, snow, moderate northwesterlies through morning of 2 December, followed by clearing and rising barometer. Light northwesterlies blew on 3 December under clear skies with ice crystal activity on the morning of 3 December. Barometric maximum of 101.92 kPa 0257 4 December under clear skies with calm air. The period from 4-12 December was marked by no frontal passages, but rather the typical early December regime of general low cloudiness issuing forth very light snow most of the time. Interruption of the low clouds and/or very light snow occurred on the night of 6-7 December through the afternoon of 7 December, from the afternoon of 9 December to the wee hours of 11 December, and from the 11 December to into 12 December. Late on 12 December, in response to a low passing to the south, freezing drizzle broke out with low clouds, fog, and some snow and freezing drizzle on 13-15 December. Winds were generally northwesterly on 13 December, and generally southerly 14 and 15 December.

80-W) A period of mild weather began with the passage at a diffuse warm front around 1030 15 December. The regime was marked by continual low clouds, frequent fog, and rain on much of 17 and 18 December.

81) A Pacific cold front crossed at 0210 19 December and was followed by low clouds, freezing drizzle, and then snow to the wee hours of 21 December as the storm system stalled over the Upper Great Lakes. Winds veered from westerly to northwesterly on the afternoon of 20 December, but backed to southerly with improving condition on the night of 21-22 December. Barometric crest 101.62 kPa at 0958 21 December.

82) A continental polar air mass arrived at 1330 22 December with the last air mass exchange of the year. Fair skies and rising barometer ruled most of 21-22 December, followed by variable cloudiness and occasional very light snow and continual northwesterly winds at moderate velocity to the barometric crest of 102.49 kPa at 0355 27 December. Winds on 27 December backed to southwesterly, with snow breaking out in the evening, followed by northwesterlies for most of the rest of the year. Skies were generally cloudy until the morning of 30 December, when they cleared and remained fair to the end of the year.

Table 1. Frontal passage times and interval events (values behind slashes give direction, in degrees, from which front approached).

1976 PASSAGE TIME (CST)

	Cold Front	Warm Front	Air Mass[a]	Following Weather Event
1)	0230 1 June/040		CP	
		R0600 2 June/240	MP	Domination by high pressure
2)	0350 8 June/330		MP	Front stalled south of Duluth
		R1230 9 June/190	MP	Front moved north then retreated
	R1930 9 June/1380		MP	Ridging
3)	0530 11 June/020		CP	Ridging
		R2200 12 June/210	MP	Front stalled over G. Minn., then moved north
4)	0530 13 June/240		MP	Southwesterly flew behind wrap-around
5)	1830 13 June/250		CP	Ridge passage
6)	1730 17 June/240		CP	Ridge passage
7)	1230 22 June/320		CP	Front stalled over region
		R1730 22 June/140	CP	Strong southerly flow
8)	0330 25 June/230		MP	Backed up, low formed over region
		R0900 25 June/050	CP	Moved south, old Front 7 advanced
	8R0230 26 June/360		CP	Old Front 7 advanced, then retreated
		R2130 26 June/240	MP	Control by cold low north, then old Front 7 advanced
	8RR0555 29 June/030		CP	High center slowly moved in and stalled until July 6
9)	1243 6 July/310		MP	Ridge passage
		100 7 July/220	MP	Warm sector barely caught over part of region
10)	1430 7 July/220		MP	Sector between MP, CP fronts
11)	1830 10 July/330		CP	Ridge passage--high to north
12)	1530 13 July/250		MP	Sector between MP, CP fronts
13)	0730 15 July/320		CP	Ridge passage--high to south
14)	2030 19 July/320		CP	High passage over region
		R1930 21 July/220	CP	Weak return of old Front 16
15)	2030 22 July/310		MP	Sector between MP, CP fronts

Table 1 continued.

1976 PASSAGE TIME (CST)

	Cold Front	Warm Front	Air Mass[a]	Following Weather Event
16)	0630 24 July/040		CP	Front stalled over Minn., then retreated
		R1330 25 July/220	MP	Warm sector
17)	2130 25 July/320		MP	Ridge passed slowly
18)	0430 4 Aug/010		CP	High passed over region
19)	2330 11 Aug/300		MP	Section between MP, CP fronts
20)	0130 12 Aug/760		CP	High passage over region
		R0530 18 Aug/240	MP	Warm sector
21)	0730 21 Aug/310		MP	Sector between CP, MP fronts
22)	1803 21 Aug/020		CP	At edge of high to NE
		R0830 25 Aug/240	MP	Warm sector
23)	0825 26 Aug/280		MP	Weak ridge passage
24)	0630 27 Aug/270		MP	Sector between MP, CP fronts
25)	1030 28 Aug/330		CP	Ridge passage
26)	1330 31 Aug/030		CP	Ridge passage
		R1730 2 Sept/240	CP	Warm sector
27)	0330 3 Sept/310		CP	High passage over region
		R6730 6 Sept/270	CP	Warm sector
28)	1940 7 Sept/290		CP	High passage to south
29)	0630 13 Sept/200		CP	High passage to north
30)	0330 19 Sept/320		CP	Just between fronts, high remained west
31)	1630 21 Sept/040		CP	High remained to west as new surge moved south
32)	1230 22 Sept/330		CP	Another fresh surge
33)	1230 24 Sept/360		CP	High passage over region
34)	0730 26 Sept/370		CP	High passage to south
35)	0730 29 Sept/360		CP	High to north grazed region
		0630 30 Sept/270	CP	Warm sector

Table 1 continued.

1976 PASSAGE TIME (CST)

	Cold Front	Warm Front	Air Mass[a]	Following Weather Event
36)	0530 1 Oct/320		MP	High passage over region
37)	2330 2 Oct/360		CP	High passage to northeast
38)	0530 4 Oct/280		MP	Quebec-Mexico ridge passage
39)	2330 8 Oct/290		CP	Small ridge passage
		R1130 10 Oct/250	MP	Warm sector
40)	0330 12 Oct/290		MP	Ridge passage
		R1030 14 Oct/240	MP	Warm sector
41)	1230 14 Oct/270		CP	Big high passed over region
42)	1030 20 Oct/270		CP	Enormous continental high
43)	1130 29 Oct/340		MP	Ridge passage
		R6910 1 Nov/250	MP	Warm sector
44)	2230 1 Nov/300		MP	Ridge passage
45)	0830 2 Nov/360		CP	Large high passed to south
46)	1030 5 Nov/300		CP	Ridge passage
47)	2130 5 Nov/350		CP	Large high passage to south
		R0030 9 Nov/250	MP	Warm sector
48)	1230 9 Nov/360		CP	Large high moved south of region
49)	1130 16 Nov/270		MP	Ridge passage
50)	0830 18 Nov/280		MP	Ridge passage
51)	1330 20 Nov/270		MP	Ridge passage
52)	1730 20 Nov/350		CP	Ridge passage
		R0930 25 Nov/270	MP	Warm sector
53)	1430 25 Nov/350		CP	High passage over region
		R1151 4 Dec/270	MP	Warm sector
54)	1630 4 Dec/320		CP	Large ridge passage
		R1430 9 Dec/220	MP	Warm sector
55)	2130 9 Dec/310		CP	Ridge passage
		R1230 11 Dec/270	MP	Warm sector

Table 1 continued.

1976 PASSAGE TIME (CST)

Cold Front	Warm Front	Air Mass[a]	Following Weather Event
56) 1830 11 Dec/310		CP	Ridge passage
	R2130 13 Dec/270	MP	Warm sector
57) 2330 14 Dec/360		CP	Ridge passage
	R1030 15 Dec/270	MP	Retreat, readvanced front 57
(57) 1930 16 Dec/040		CP	Ridge passage
	R2030 17 Dec/220	MP	Warm sector
58) 2130 18 Dec/320		CP	High passage to south
	R1730 21 Dec/270	MP	Warm sector
59) 0230 22 Dec/290		CP	Ridge passage to south
	R0930 24 Dec/290	MP	Warm sector
60) 1230 24 Dec/330		CP	Ridge domination

1977 PASSAGE TIME

	R2100 5 Jan/270	MP	Warm sector
1) 0812 6 Jan/320		CP	Ridge passage to south
2) 1930 7 Jan/270		CP	High pressure passage to south; slow movement; followed by wave passage to southern region on 15th; then ridge domination to 19th
	R1800 9 Jan/270	MP	Warm sector
3) 1025 20 Jan/360		CP	High pressure domination
4) 0630 23 Jan/270		MP	No ridge movement, ridge stationery to west
5) 0228 26 Jan/330		CP	High pressure passage over region
	R1212 27 Jan	MP	Warm sector
6) 1630 27 Jan/320		CP	
	R0230 2 Feb/270	MP	Warm sector
7) 1230 2 Feb/320		CP	Passage of high near region on Feb. 7
	R1330 8 Feb/270	MP	Warm sector with ridging
8) 0530 9 Feb/360		CP	Front just edge over
	R1230 9 Feb/220	MP	Warm sector

Table 1 continued.

1977 PASSAGE TIME (CST)

	Cold Front	Warm Front	Air Mass[a]	Following Weather Event
9)	0430 12 Feb/260		MP	Ridging
(8)	1330 15 Feb/040		CP	High pressure moved over region
		R1400 16 Feb/270	MP	Warm sector
10)	1430 17 Feb/360		CP	Ridging
		R1030 19 Feb/270	MP	Warm sector
11)	1430 19 Feb/320		CP	Ridge passage
12)	1330 21 Feb/320		CP	Ridging, then wave passage to south; then high passage to the south on March 1, then another wave passage to south on 4th, then ridge passage on 6th
		R1630 6 Mar/220	MP	Warm sector
13)	0449 9 Mar/270		MP	Ridging
14)	2030 14 Mar/270		MP	Ridge passage
15)	2145 15 Mar/330		CP	Ridging
		R 17 Mar/200	MP	Ridging
(15)	0430 17 Mar/360		CP	Ridging
		R1330 18 Mar/200	MP	Warm sector
16)	2030 19 Mar/320		CP	High passage over region
17)	0600 22 Mar/330		CP	Ridging
		R1030 22 Mar/190	CP	Front 17 retreated then advanced
(17)	1745 22 Mar/360		CP	Large ridge passage
18)	2130 26 Mar/290			Ridging then passage to southern 18-30 then high passage to south
19)	0030 2 Apr/270		CP	Ridging then low passage to south
20)	0247 7 Apr/020		CP	High passage over region following low center passage over region
		R0600 10 Apr/220	CP	Warm sector
21)	2230 10 Apr/320		MP	Ridging
22)	1530 12 Apr/300		MP	High passage over region
23)	1045 16 Apr/290		MP	Ridging

Table 1 continued.

1977 PASSAGE TIME (CST)

	Cold Front	Warm Front	Air Mass[a]	Following Weather Event
24)	0930 18 Apr/290		MP	Front stalled over Wisconsin, Lake Superior until 21st; then on 22nd high passage over region
25)	0630 23 Apr/320		CP	Passage of large high to south
26)	0730 27 Apr/360		CP	Passage of high to north
27)	0448 1 May/320		CP	High passage over region, then wave to south on 5th
28)	1130 5 May/020		CP	High passage over region
29)	2230 8 May/020		CP	Ridging from high passing to NE
		R0230 10 May/290	CP	Strong domination by deep ridge of high pressure
30)	0113 20 May/270		MP	Ridging
		R0830 22 May 150	MP	Warm sector
31)	1121 23 May/220		MP	Ridging
		R0600(w) 25 May/220	MP	Long stay in warm sector due to drop high over Lake Superior followed by wave passage to south ?
32)	0430 1 June/020		CP	High passage over region
		0730 3 June/280	MP	Short warm sector stay
33)	1430 3 June		MP	Small high passage over region
34)	1530 5 June		CP	High passage to south, then passage to south, then high passage over region
35)	0230 11 June/320		CP	High passage to north, then small, cold low, then ridge passage
36)	0917 16 June/280		MP	Ridge passage
37)	0730 17 June/200		CP	Slow high passage
		R1030 23 June	MP	Warm sector
38)	0530 24 June/310		CP	High passage over region
39)	1530 26 June/320		CP	High passage to south
40)	0330 30 June/270		CP	High passage to south

Table 1 continued.

1977 PASSAGE TIME (CST)

	Cold Front	Warm Front	Air Mass[a]	Following Weather Event
41)	1130 3 July/300		MP	Front stalled over central Minn., Wisconsin until July 6
		R0330 14 July/220	MT	Warm sector
42)	0630 7 July/250		CP	High passage over region
43)	1130 11 July/260		CP	High passage to south
		R0330 14 July/220	MT	Warm sector
44)	0730 14 July/290		CP	High passage over region followed by several small systems
45)	1930 16 July/300		CP	Ridging
		R1000 17 July/150	MT	Warm Sector
46)	0149 20 July/320		CP	High passage over region
47)	1330 24 July/320		CP	High passage over region
48)	0330 28 July/320		MP	Ridging
49)	0545 29 July/350		CP	High passage to north; front stalled over Iowa
50)	2330 30 July/240		MP	Ridging
51)	0675 31 July/300		CP	Ridging
52)	0530 1 Aug/030		CP	Small systems
53)	0330 5 Aug/320		CP	High passage over region
54)	0830 7 Aug/330		CP	High passage over region
55)	0330 10 Aug/270		CP	High passage to south
56)	0400 12 Aug/300		CP	High passage to south, followed by wave to south on 15th; then slow high passage to south
57)	0100 21 Aug/330		CP	Ridging
58)	0830 22 Aug/310		CP	Large high passage over region
		R1100 26 Aug	MT	Warm sector
59)	1230 27 Aug/300		CP	High passage to south
60)	1430 31 Aug/310		CP	High passage over region

Table 1 continued.

1977 PASSAGE TIME (CST)

	Cold Front	Warm Front	Air Mass[a]	Following Weather Event
61)	0737 4 Sept/320		CP	High passage to north, followed by wave passage to south on 6th
		Psbl R1800 8 Sept/220	CP	Warm sector
62)	0030 9 Sept/230		CP	High passage to south
63)	1588 17 Sept/290		MP	Front stalled over Lake Superior for a day, then moved east
64)	0030 19 Sept/240		CP	High passage over region which stalled to east
65)	0630 25 Sept/180		CP	Very slow mover, over region until 29th, finally followed by high passage to south on Oct. 3
66)	1230 4 Oct/280		CP	High pressure ridge moved over region, followed by wave to south on 8th; then ridge moved to south
67)	0330 10 Oct/290		CP	Cold low aloft moved over surface low over Lake Superior, causing intense deeping, cold flow from north; followed by high passage to south
68)	0030 14 Oct/300		CP	High passage to south
69)	0830 17 Oct/280		CP	High passage to south
70)	1100 20 Oct/30		CP	High passage over region
71)	0200 26 Oct/310		MP	High passage over region
72)	1230 31 Oct/260		MP	Ridging
73)	0400 3 Nov/300		MP	High passage over region followed by formation of huge low over southeastern U.S.
74)	0030 9 Nov/280		CP	Front stalled over region as low center crept northward along the front; then slow high crossed region on 12th
75)	1330 13 Nov/290		MP	Ridging

Table 1 continued.

1977 PASSAGE TIME (CST)

	Cold Front	Warm Front	Air Mass[a]	Following Weather Event
76)	0930 15 Nov/220		MP	Ridging
77)	1530 15 Nov/270		MP	
78)	1330 16 Nov/270		CP	Deep low lingered a day then moved out followed by ridging on 19th; then deep wave moved from south of region to northeast of region; followed by another low moving south on 23rd then high passage to south on 26th; low passage to south on 27th; high passage to south on 28th
		R1330 29 Nov/200	MP	Warm sector
79)	6830 30 Nov/290		MP	Ridging
80)	0430 1 Dec/320		CP	Ridge passage, then low center passage over south part of region on 13th, followed by ridging on 14th
		R1030 15 Dec	MP	Warm sector
81)	0210 19 Dec/220		MP	Low stalled over Upper Great Lakes till 21st; followed by ridging on 22nd
82)	1330 22 Dec/300		CP	Ridging followed by low center passage to south on 24th followed by high center passage to south on 27th; then east-west ridge dominated region for rest of year

1978 PASSAGE TIME

1)	1100 2 Jan/020		CP	Ridging
2)	0100 3 Jan/270		CP	East-west ridge dominated to 7th, when wave moved to south; then strong high passed to south on 11th and stalled
3)	0800 15 Jan/280		CP	Strong high center passage over region followed by a second pulse on 19th
		R1400 22 Jan/210	MP	Warm sector

Table 1 continued.

1978 PASSAGE TIME (CST)

	Cold Front	Warm Front	Air Mass[a]	Following Weather Event
4)	1200 23 Jan/290		CP	Ridging
5)	1100 23 Jan/220		CP	Deep low center moved over region; then at Yukon-Gulf ridge dominated until Feb. 3, then moving east; followed by new pulse moving north of region on Feb. 6, becoming quasi-stationary over region until Feb. 22
		R1100 22 Feb/270	MP	Warm sector
6)	1700 22 Feb/290		CP	Ridging
7)	1000 24 Feb/260		CP	High passage to south; then small low, then high pulse on Mar. 1, and another on Mar. 4 and again on 6th
8)	0300 10 Mar/020		CP	Ridging
		R0800 10 Mar/240	CP	Warm sector
(8)	1200 12 Mar/020		CP	Lingered on south part at region through much of 13th, followed by ridging on 14th
9)	0700 15 Mar/270		CP	Ridge passage on 17th
10)	1300 18 Mar/290		CP	High passage to south
11)	1100 20 Mar/280		CP	Ridging
12)	0300 22 Mar/290		MP	Ridging
13)	1000 22 Mar/360		CP	High passage over region

[a]CP=continental polar air mass
MP=maritime polar (Pacific) air mass
MT=maritime tropical air mass

Chapter 3 TEMPERATURE

3.1 SUMMARY

Temperatures during the Copper-Nickel Study shared the unusually cold winters, unusually warm springs, and unusually cool falls that have marked recent years in Minnesota. Summers were mixed, with August, 1976, being exceptionally warm and August, 1977, being exceptionally cold. At Babbitt, where records have been kept atop the Embarrass Range since 1921, the most anomalous month warm-wise was May, 1977, over 11° above normal. The most anomalous month, cold-wise was January, 1977, 8° below normal.

Table 2 gives the temperature statistics over the life of the Study for Babbitt. This station was chosen because of the long record in a similar location, quite free from air drainage effects, as will be seen. The data, however, are based on observations taken at 1700 CST from November to April, and at 1600 CST from May to October, so that the actual absolute values of temperature are "too warm," both with respect to "normal" values and the values observed over the length of the Study--midnight-to-midnight observed maxima and minima are needed to calculate approximately correct mean temperatures. This is done for Study stations, as will be seen below. However, the departures of temperatures given in the table here are approximately correct, since most of the Babbitt data are similarly based.

3.2 CLIMATIC RECORDS AND CHARACTERISTICS

The various weather stations can be seen to have certain characteristics with respect to the local topography and vegetation. Figure 3 gives a presentation of temperature variability. At two extremes are the Babbitt station, high on the Embarrass Range, and Embarrass, on the flat Embarrass plain.

The Embarrass Range is a line of small mountains (or high hills, as the reader may prefer) between 1,800 and 1,900 ft above sea level oriented WSW-ENE from a cut on the western end made by the Embarrass River just east of Biwabik to another cut made by the Dunka River on the eastern end. Hills continue in the same orientation to the east and west of the river cuts.

To the north lies the great flat plain of the Embarrass River, which is bounded on the north by a ridge at 47°40'N. The plain is marked by a few occasional hills but mostly by marshland. The western end of the plain is bounded by a north-south ridge about one mile west of Embarrass center, where the Embarass River is forced to flow south instead of westward. The eastern portion of the plain is marked by the irregular hills just west of Babbitt. The plain, surrounded on all sides, is an ideal cold air trap, and very likely is the coldest place in Minnesota. Even in July and August, all that is needed for a frost is a continental polar air mass with clear skies and near-calm air.

The two temperature stations (Embarrass and Eagles Nest) with thermographs maintained by the Copper-Nickel Study are of special interest with respect to the microclimate when compared with other standard and special stations in the area. Data were reviewed for these stations on a daily basis, along with data obtained from the EPA Tertiary Treatment Plant in Ely and data from Filson Creek. In addition, data were obtained from the Reserve Mining station at the Babbitt mine, from the Minnesota Power and Light Company station at Winton, and from the Federal Aviation Agency station at Hibbing. Values of temperatures for all these stations except Babbitt are from midnight to midnight. Except for the Winton station, which always observes at 12AM on local legal time, the values for all midnight-to-midnight stations were in terms of Central Standard Time, a necessity for valid comparison with first-order National Weather Service stations.

Since the Babbitt station thermometer is read by the Reserve Mining Company guards at 5PM local legal time, a special reduction of the Embarrass data was made to be consistent with the station. Comparison of the Embarrass and Reserve data are of special interest since they represent microclimatic extremes to be found in the Study Area. The other stations are in intermediate microclimates.

Before discussing the information from the stations, let us discuss a microclimate model classification scheme derived by the author.

The microclimatic classification system has been designed to be compatible with a landform and vegetation classification system derived by the Minnesota Department of Natural Resources. The basic microclimate classification is defined in terms of vegetation type, with sub-classifications made in terms of landform type. In all cases, the surface of the earth is considered to be the interface between the air and the surfaces of shrubs, grasses, crops, soil, asphalt, etc. Trees here are excluded as constituting the surface.

Vegetative effect is basically due to tree cover, and therefore vegetation is defined in terms of tree effects on the microclimate. Shrubs and grasses are for the most part below eye-level of persons, and are considered to constitute the greater part of the surface.

Enclosed vegetation is used to denote the most sheltered class. Here the trees essentially lift the earth surface to heights above the sphere of persons. Protected denotes that class where trees give partial sheltering from the meteorological elements. Open denotes the class with so few (or none) trees that persons are essentially exposed fully to the weather.

Tables were prepared listing the differences in the key meteorological variables in the micrometeorological realms. The reference realm is class C1, which is

the open, flat, dry region devoid of trees which has as its greatest example the prairie flatlands of western Minnesota.

Differences arising from vegetation are listed in the table at the top of the page, while differences arising from topography are listed in the lower table or tables. One lower table is given when warm season-cold season differences are unimportant; two lower tables are given when the cold and warm seasons produce dissimilar effects on the microclimate.

The upper, vegetation table gives values in refrence to departures from values in the upper table of class C1; the lower table gives adjustment values in reference to the upper table. Thus, if the daily range of temperature over a given period is 10°C in the realm of class C1, the daily range on the flat for class A1 would be 8.5°C. However, if class A1 vegetation exists on a high promontory, the daily temperature range would be 10% less than 8.5°C, or 7.65°C (ignoring the unreality of such precision).

At the bottom of the page, characteristics of the snow cover and evaporation are given. Snow distribution refers to the evenness of the snow, which tends to be very unequal over flat areas due to wind drifting, but rather equal in heavy forest, where drifting due to wind is minimal.

3.2.1 Class A Microclimates: The Enclosed Microclimates

Class A microclimates are the most sheltered from the meteorological variables. There are two vegetative categories in this class: A1, deciduous-conifer covering over 40% of the surface; and A2, conifer covering over 40% of the surface. Deciduous alone over 40% is not considered to be a part of type A, or enclosed, category since a great deal of shielding is lost in the winter when the trees are devoid of leaves.

In class A, microclimates, wind, temperature range (the difference between the daily maximum and daily minimum), and sunshine are considerably diminished as comapred to that experienced in the open.

3.2.2 Class B Microclimates: The Protected Microclimates

Class B microclimates are those which offer some protection from the meteorological elements. Four vegetative categories are in this class. B1 is a region of over 40% deciduous. In the warm season, this clas is essentially an enclosed vegetative type, but is only a protected type in the cold season, when the trees are not in leaf.

B2 is mixed deciduous and conifer covering 10-40% of the surface; B3 is conifer covering 10-40% of the surface; and B4 is deciduous covering 10-40% of the surface.

In the B class, the meteorological elements of wind, sunshine, and temperature range are reduced somewhat as compared to the open.

3.2.3 Class C Microclimates: The Open Microclimates

Class C microclimates are those which are essentially fully exposed to the meteorological elements. Two categories are in this class. Class C1 is the open, dry region, exemplified by prairies and brushland. Up to 10% of the land in trees is permitted in the classification. This class includes the "representative observation site" where the National Weather Service prefers to locate its instrumentation for macrometeorological purposes.

Class C2 is open, wet places which include lakes, rivers, bogs, and swamps. With little exception, these places are frozen through much of the cold season in Minnesota.

The meteorological stations used here are in the following microclimatic zones:

STATION	ZONE	MODIFYING FORMS
Embarrass	C1	Deep depression
Hibbing	C1	None
Ely Water Treatment Plant	C1	Shallow depression
Babbitt	B1	High promontary
Filson Creek	B2	Low promontary
Winton	B3	Shallow depression
Eagles Nest	A2	South slope

All of the stations are in different microclimatic regions when modifying forms are considered.

Tables 3a to 3h give observed temperature data from the stations under consideration. Embarrass is listed twice, with data first analyzed for observation with reference to 5PM local legal time for comparison with Babbitt, and in the next column with data analyzed for observations with reference to midnight, Central Standard Time (CST), for comparison with the other stations.

It can be observed that values of monthly mean temperature, temperature range, etc. are influenced by time of observations. Means are "cooler" when observations are made from midnight-to-midnight than when made from 5PM to 5PM (actually 4PM to 4PM CST during the Daylight Time months). In standard U.S. meteorological practice, means are calculated by the formula of adding the high for the 24-hour period to the low for the 24-hour period and dividing by 2. It should be noted that this is actually a method of approximating the mean temperature, rather than truly calculating it. The values of temperature vary by observation time, and all have a systematic error. In Europe, means are calcu-

lated by adding together the readings at 7AM, 2PM, 9PM, with 9PM added in a second time before division by 4. If the clock time is close to the correct local mean time (LMT), then there is virtually no systematic error except as some local microclimatic anomaly may create.

In this discussion, we shall use Embarrass as the standard since calculations were made for both observing times.

Comparison of Embarrass with the Reserve site shows that the mean daily range of temperature at Embarrass is 1.5 times that of Reserve. Further, the mean annual temperature for the year April, 1977, to March, 1978, at Embarrass averages 4.3°F cooler than at Reserve. The mean maxima for the full-year period were virtually the same, being 0.3°F warmer at Embarass, while the mean daily minimum temperature at Embarrass over the year was 8.8° colder at Embarrass than at Reserve. Thus, the difference in the mean temperature is accounted for in the extreme minimums at Embarrass due to cold air entrapment in the valley, plus the lack of cold air buildup at Reserve since it is on a slope not far from the crest of the hill. The slightly warmer maxima at Embarrass are likely due to the fact that it is in the open, while the Reserve Babbitt station is on the north slope with trees around. The south slope near the crest is an open area on the Embarrass Range would present even more contrast with the Embarrass Valley station.

Note that in the summer (May to August, 1977) the maximum at the Embarrass Valley station ran 1.1F higher than at Reserve due to heating in the open in the Valley.

The northly mean minima is also of interest. Note that in February, 1978, the mean minimum temperature at Embarrass was -18.6F, a full 17.5° colder than at

Reserve, where it ran only -1.1F. The average daily range of temperature at Embarrass that month was 33.6°F, as compared to 19.5°F at Reserve.

It is also informative to contrast Embarrass with the Eagles Nest Lake station. The latter station is in a forest not far from the north shore of the lake, on a south-facing slope. In summer when the lake is warm, minima averages about 10°F warmer than at Embarrass, but in the winter months when the lake is frozen, the difference in minimum temperatures is only about 3°F.

The Ely Water Treatment Plant station is located near the bottom of a north-facing slope not far from the lake, but with the water treatment plant between the station and the lake. The station is in a treeless area. Although it is 5° F warmer than Embarrass, it is much cooler than the downtown area of Ely, which repeated temperature surveys show is the warmest spot in the region, due to the urban heat island effect. The extent of the warmth of Ely, however, is pretty much confined to the downtown area, while the higher ground of the Embarrass Range (and the other high hills of the region) is a region of substantial warmth.

The Filson Creek station, operated only in the summer, was located in a rather large clearing (over several acres); it was on a slight promontary in the area. It is warmer by day than Embarrass, very likely due to heat trapping in the clearing by the surrounding forest, but substantially warmer than Embarrass by night since Filson Creek is not in a deep valley. However, Filson Creek runs about 6° cooler than Eagles Nest in the summer, the difference reflecting the benefits of proximity to water and the forest canopy at Eagles Nest. The forest canopy also helps keep Eagles Nest a bit cooler by day.

The Hibbing station is somewhat similar in climate to the Ely Water Treatment Plant. The Ely station runs a bit cooler in the winter when cold air drainage is a little more effective.

3.2 DAILY TEMPERATURES

Tables 4a to 4h give daily maximum and minimum temperatures for stations associated with the Copper-Nickel Study. Values for the Embarrass, Eagles Nest, Ely Water Treatment Plant, Hibbing, Winton Dam, and Filson Creek stations are midnight-to-midnight values, except that readings at Winton Dam are 2300-2300 CST from May to October inclusive, when local legal time is CDT.

In addition, maxima-minima values for Embarrass are given from 1700-1700 CST from November to April inclusive, and from 1600-1600 CST from May to October, inclusive, for comparison with the baseline Babbitt station, which observes at those times (5PM, local legal time).

The Winton Dam station is quite similar to the Eagles Nest station, being near a lake. However, it is in more of a cleared area with no forest canopy in the immediate vicinity of the thermometer, although the forest is very close. The slightly greater warmth of the Winton station in summer perhaps reflects its more open location. Minima are a bit cooler likely due to the fact that the station is more in a depression not far from the lake rather than simply on the slope, allowing some cold air entrapment.

The above discussion points out the strong effects that microclimate has on temperature. If we take the average Babbitt annual temperature of 39.1 for the 12-month period April, 1977, to March, 1978, and compare it to the normal for Babbitt of 38.5F, we find the period was 0.6° above normal. If we estimate

that the departure from normal at Embarrass was similar, we can estimate that the annual normal mean temperature for Embarrass is 34.4°F, only 2.2° above freezing.

Chapter 4 PRECIPITATION

4.1 GENERAL SUMMARY

The general precipitation pattern during the Copper-Nickel Study was one of extreme dryness from July 1, 1976, to February 23, 1977, and was followed by very wet and rainy weather for the remainder of 1977. The first half of 1978 was near normal in precipitation. The extreme dryness of the second half of 1976 was preceded by a very wet June.

Table 3 gives monthly values of precipitation for all available operating rain gages in the Study Area for all months from April, 1976, to June, 1978, where month-long readings were made. The most abundant data are from July, 1976, to October, 1977, with scarce data before the beginning of the Study and since January, 1978. The data in the table have been adjusted to midnight observation time so that the totals for each month are comparable between stations. The adjustments were made from use of the weather radar in determining precipitation times. Figures 5a to 5k illustrate the observed monthly totals during the Study for selected stations against normal values given in the climatology report.

Table 4 calls out the maximum and minimum observed precipitation, by month, at the various stations. The table gives an idea of the variability of precipitation over the region in a month's time. (Tofte and Wales are excluded due to the unreliability of the gages.)

The variability of precipitation arises from the random way in which precipitation-bearing clouds move and from the non-random, geographical effects. The heaviest precipitation in most cases is formed in the highlands between Lake Superior and the western plains of St. Louis County, the lightest amounts are generally near Lake Superior or on the plains.

Table 3. Total monthly precipitation

MONTH		06 FAIRBANKS	07 EMBARRASS	07 EAGLES NEST	07 WATER HEN	07 BRIMSON	07 ISLAND LAKE	0730 NORTH SHAGWA	0730 VERMILION COLLEGE	08 LOG CABIN	08 HIBBING CITY	08 COTTON	08 FINLAND	08 MINNIMAX	0815 ISABELLA ELC	09 STONY RIVER	09 SKIBO	09 TOWER 39	0930 WHITEFACE	11 VIRGINIA	13 ISABELLA RS	13 ELY USFS C	16 GRAND MARAIS	17 SNOWBANK LAKE	17 BABBITT	17 COTTON 3NE	17 CRANE LAKE	17 GUNFLINT LAKE	17 MEADOW-LANDS	18 OLSON BAY	24 HIBBING AIRPORT	24 HOYT LAKES	24 WINTON	24 KAWISHIWI	24 FILSON CREEK	24 DUNKA CR	24 WALES	24 TOFTE
1																																					
2	1976																																				
3	APRIL					61	67				64	~~49~~						43	43	53	171		93		99	49	163	86	~~74~~		80	107	56					
4	MAY					38	23				122	~~24~~						77	48	42	101		35		30	24	53	26	41		61	73	40					
5	JUNE					680	581				841	~~585~~						841	598	820	819		530		570	585	692	720	767		622	669	722					
6	JULY			198		185	286				385	207	127			110		198	217	137	178	241	138		142	331	246	358	356		386	147	182				190	60
7	AUG			35		145	189				129	61	94			60		48	112	59	70	101	72		59	137	56	126	183		98	47	120			171		80
8	SEP			120		130	78				55		89		111	80		138	43	73	150	97	92		161	74	57	115	81		62	99	76			94		
9	OCT			79		98	83				57		30			70		81	78	39	114	109	105		132	86	101	116	87		42	141	111		99	95	70	50
10	NOV					28	37				17		12					35	24	13			13		24	27	32	28	14		19	15	26	40	39	88		30
11	DEC			58		71	153				78	~~72~~	47	31				61	73	30			45		66	72	61	61	76		32	71	66	80	74			70
12																																					
13	1977																																				
14	JAN			54		75	96				54	~~18~~	27	29	58			29	67	22			51		52	18	65	105	73		48	51	68	70	68			20
15	FEB		48	66		30	54					~~22~~	86	86	46			70	85	14			43		24	22	56	94	37		71	21	65	80			80	70
16	MAR		168	163		231	384				202		309	220	242			202	180	159			192		170	170	89	187	286		90	161	140	~~80~~			430	170
17	APR		143	139		126	141						127	122	122			196	121	136	136		61		120	156	131	121	112		120	115	98	110			130	140
18	MAY		438	617		393	403	505							398			526	389	400	349	622	225	397	550	425	515	242	494		305	564	427	520			380	
19	JUNE	430	418	474	401	471	414	444	343	~~47~~			268		571	663	486	488	490	402	513	435	209	534	551	402	540	215	305	411	424	421	364	450			310	380
20	JULY	372	435	375	420	436	398	311	335	472			205		349		422	525	353	323	381	348	238	179	321	340	261	317	322	334	219	320	289	300			430	250
21	AUG	503	752	651		491	350	672	970	993	578		388		~~524~~		759	789	540		526	721	769	771	667	405	475	578	308	731	~~728~~	794	783	590			760	610
22	SEP	683	534	585		732	561	659	701	489	403		275		589		691	676	600	547	751	600	747		567	507	747	960	470	~~636~~	492	621	568				760	
23	OCT		207	201		263	292	216	173		236		331		355		178	222	191	201	483	328	301		162	203	153	275	254	236	235	208	209					
24	NOV		339	319		399	239	443			320		226		297		275	283	290				192		450	219		269	306		358	328	270					200
25	DEC		130	125		146	188				147		264		186			131	144	108	222		148		112	103		214	133		100	133	140					
26	1978																																				
27	JAN					92					65								69		77		84		78	48		59	40		43	52	56					
28	FEB		39								58								40	15	24		16		28			34	72		52	39	31					
29	MARCH					68					72							86	84	41			59		71	49		108	73		72	67	84					
30	APRIL					147					154								168	126			132		106	189		105	183		134	138	113					
31	MAY					400		339			408							441	338	400	403		316		452	244		357	286		392	476	375					
	JUNE							258			255							348	363		217		298		233	426		406	361		195	308	199					

MONTH
APRIL 1976

	FAIRBANKS 06	EMBARRASS 07	EAGLES NEST 07	WATER HEN 07	BRIMSON 07	ISLAND LAKE 07	NORTH SHAGWA 0730	VERMILION COLLEGE 0730	LOG CABIN 08	HIBBING CITY 08	COTTON 08	FINLAND 08	MINNIMAX 08	ISABELLA ELC 0815	STONY RIVER 09	SKIBO 09	TOWER 39 09	WHITEFACE 0930	VIRGINIA 11	ISABELLA RS 13	ELY USFS C 13	GRAND MARAIS 16	SNOWBANK LAKE 17	BABBITT 17	COTTON 3NE 17	CRANE LAKE 17	GUNFLINT LAKE 17	MEADOW-LANDS 17	OLSON BAY 18	HIBBING AIRPORT 24	HOYT LAKES 24	WINTON 24	KAWISHIWI 24	FILSON CREEK 24	DUNKA CR 24	WALES 24	TOFTE 24
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14					32					t	12	16						18	t	24		t		8	27	63	8			1	2	t				
15					7					t		4										1				2				52		7				
16										45	1	2					10		43	105		36		49	1	66	46			2	65	6				40
17												5						t						t						t						
18										t	17							4	2			39		32	16	18	26			16	35	27				50
19					22					17		36					26	21	8	31		2		2		2	6				t					
20										2																t				1	t					
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31																																				

MONTH
MAY 1976

Day	06 FAIRBANKS	07 EMBARRASS	07 EAGLES NEST	07 WATER HEN	07 BRIMSON	07 ISLAND LAKE	0730 NORTH SHAGWA	0730 VERMILION COLLEGE	08 LOG CABIN	08 HIBBING CITY	08 COTTON	08 FINLAND	08 MINNIMAX	0815 ISABELLA ELC	09 STONY RIVER	09 SKIBO	09 TOWER 3S	0930 WHITEFACE
1					26					★	16	23					44	32
2					12					★	t	41		63			18	12
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27											1							
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29											7							
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31												14						

Day	11 VIRGINIA	13 ISABELLA RS	13 ELY USFS C	16 GRAND MARAIS	17 SNOWBANK LAKE	17 BABBITT	17 COTTON 3NE	17 CRANE LAKE	17 GUNFLINT LAKE	17 MEADOWLANDS	18 OLSON BAY	24 HIBBING AIRPORT	24 HOYT LAKES	24 WINTON	24 KAWISHIWI	24 FILSON CREEK	24 DUNKA CR	24 WALES	24 TOFTE
1	15	20	17	14		22	11	6	0			6	55	12					20
2	8	19	12	t		5	t	10	M	M		3	16	15					10
3	1	60	5			t		2	0										
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MONTH
JUNE 1976

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFSC	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 2NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
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8				61		67					12								46	168	138	71	9		66	42	37		14			25	34					
9																					t	23	26		4		6					55	64					
10				40		28					61								33	39	13	24	3		27	36	44		45			5	16					
11																					14	13			3		2										
12				53																	50				15	19	75		38			102	68					
13				55		73					98		57						60	62	83	55	110		36	62	51		82			14	3					
14				70									15																			25	15					
15				5		101					94								86	83	137	82	112		145	126	64		210			33	101					
16				6		☆					5								6	2	70	9	92		9	7	15		13			5	t					
17				130		☆					11		45						11		52	12	33		12	26	65		12			88	132					
18				6		204					177		11						66	98	109	130	43		65	30	80		65			11	6					
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24																																					
25				110		157					192		83			110			165	141	62	96	58		59	105	172		160			199	118					
26				20							★								56	49	42	56	13			47	4					10	4					
27				18		10					☆								11	45		17	t		16	25	42		62			9	16					
28				24							174								13	17	7	28	7		t	11	35					21	34					
29				10		★					10		6			20			6	103	4	21	2		7	49	t		66			20	19					
30						40					4					20			35	20	35	4	22		·	t												
31																																					

MONTH
JULY 1976

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
1																																					
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6											3							3		5	10	19	9		31	17	76	40	8		25	16	57				20	2
7				60							33	28	7			10		66	7	4	17	48	26			6	t	11	19				t				
8																						38	1					8			t						
9				37							24	5	20			40		55	17	23	37	42	17		42	64	9	32			42	28	34				30	
10													4						t				t					5		t							
11																																					
12											t																										
13				1									t								4	9	4		1		2	48			52	1	8					2
14											52		t			10			44		9	2	2		t	47		t									
15				t							7								t	1	10	t	t			3	7	t	13		13	12	4					
16											t					10					3	9	t					12										
17																																					
18																																					
19																															74	26	49				100	
20	22			50							77	142	23			20		42	74	M	18	53	20		35	138	90	90	118									
21																																					
22																															34	6	3				10	
23				t							31		4					t	12	29	2	2	1		t	48	[illegible]	10	149								
24																												t									
25				30								32						10	9	18	27	14	17		18	8	48	50	18		116	42	19				30	
26				20							129		44			20		19	54	28	41	5	33		t			10			7	9						
27																																					
28													10							1	t		4		14		9		t		23	7	7					
29				t							29		15					4										47	26		t		1					
30				t							t		10														5											
31																							4														

MONTH

AUGUST 1976

	FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFSC	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
	06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
1												5												t	43			2		2							
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10			15		M	16				26		10			10		13	6	25	53	21	30		22		13	8	15		7	27	7			☆		16
11					M	31						11						11		3		5		16	7		t	25		t		71			☆		50
12					M	5				30		41			10		6	33	2		49	35		3	14	t	22			5					133		
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27						20				10	34	3					2	15				t		t	4	3		t		t	5	1					
28											1																										
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31																																					

MONTH
SEPTEMBER
1976

	FAIRBANKS 06	EMBARRASS 07	EAGLES NEST 07	WATER HEN 07	BRIMSON 07	ISLAND LAKE 07	NORTH SHAGWA 0730	VERMILION COLLEGE 0730	LOG CABIN 08	HIBBING CITY 08	COTTON 08	FINLAND 08	MINNIMAX 08	ISABELLA ELC 0815	STONY RIVER 09	SKIBO 09	TOWER 39 09	WHITEFACE 0930	VIRGINIA 11	ISABELLA RS 13	ELY USFS C 13	GRAND MARAIS 16	SNOWBANK LAKE 17	BABBITT 17	COTTON 3NE 17	CRANE LAKE 17	GUNFLINT LAKE 17	MEADOW-LANDS 17	OLSON BAY 18	HIBBING AIRPORT 24	HOYT LAKES 24	WINTON 24	KAWISHIWI 24	FILSON CREEK 24	DUNKA CR 24	WALES 24	TOFTE 24
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13			15			26				17					10		26	2	28	11	27	3		18	22	9	26	10		29	16	25			☆		
14			11							19		47		17			6	7	2	27		4		1	1	1	t			t	2	1			☆		
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20			2			6				2		2		11	10		11	9						1		t	7			4	22	2			☆		
21			4							t		2		11			4	2	2	8	4	4			8		6	9							94		
22			9							t				7	10		10	5	2	10	6	1		16	1	11	t			t	7	9					
23			1							t				2								1				2										
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25																					t						25		4	2	3					
26			26			4				☆		5		18	10		26	6	10	28	28	17		20	3	16	25	3		4	22	21					
27			1			7				9		10		7				t		11	4				1		t	2		t		t					
28																																				
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MONTH
OCTOBER
1976

	FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
	06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	18	24	24	24	24	24	24	24	24
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4			28		76					28		7	70		40		40	65	27	18	70	30		87	69	16	58	87		29	107	65	60		66	60	40
5			14							10		17					11	2		41																
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8			t		7																3	7		6	3	23	8	t		3	13	10	10		☆		10
9			3										10				9		4	5		40													☆		
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15			16							10			20		10		14	4	4	9	12	t		12	t	10	12	t		2	5	8	10		☆	10	
16			3									6	10		10			1		9				4	t	6	t	t		1	6	8	10		☆		
17			3															t	1	11	4	t		t	2	t									☆		
18										3										t					t			t		1			10		12		
19					10					2								2		1		7		1	7		10	t						☆		
20			1							t			35				3	4	2	20	6	10		15	3	21	20	t		6	10	18	10		☆		
21			8							4			10				4	t	1		14	t		7	2	24		t		t	t	2	10		☆		
22			6							t			5		10		t	t				t		t						t	t				17		
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31																																				

MONTH
NOVEMBER
1976

	FAIRBANKS 06	EMBARRASS 07	EAGLES NEST 07	WATER HEN 07	BRIMSON 07	ISLAND LAKE 07	NORTH SHAGWA 0730	VERMILION COLLEGE 0730	LOG CABIN 08	HIBBING CITY 08	COTTON 08	FINLAND 08	MINNIMAX 08	ISABELLA ELC 0815	STONY RIVER 09	SKIBO 09	TOWER 39 09	WHITEFACE 0930	VIRGINIA 11	ISABELLA RS 13	ELY USFSC 13	GRAND MARAIS 16	SNOWBANK LAKE 17	BABBITT 17	COTTON CNE 17	CRANE LAKE 17	GUNFLINT LAKE 17	MEADOW-LANDS 17	OLSON BAY 18	HIBBING AIRPORT 24	HOYT LAKES 24	WINTON 24	KAWISHIWI 24	FILSON CREEK 24	DUNKA CR 24	WALES 24	TOFTE 24
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10					8	16				3		7	7				9	2	2					t	t	1					t	t			☆		
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21						t											2	t	1			t		2	t	2		t		t	1			☆		
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24						2				t			t					t	t			1		t	t	t					t			☆		10
25						t						5							1			4		t	18	t		14			1	t		☆		
26					13	11				11			7					16	1						t					t				☆		
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31																																				

MONTH
DECEMBER 1976

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 3S	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
1							T											T	T						T		T		T		T	T	T					
2							T				T								T							T				2	5	T	10				
3				2		10	7				12	9		8				5	7	5			4		3				12		3	7	3					20
4				4			6					T							1	T			T		7		8				T	5	3	10				
5				1			T												T	T			T		T						7	9	10	☆				
6				17		16	16				17	14		3				13	18	10			13		15		12	30	14		2	6	5	☆				
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9						9	23				2	3							3	9			4		10		10	12	11		4	16	15	☆				10
10				13			25				10	1	20	2				21	5				T		T		11	19	T		T	T	2	☆				
11				T																			T				3						T	☆				
12							T											T	T	T			T								T		T	☆				
13				T							T			T									7				T				T	1	2	☆				10
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23				6		☆	8												T				T				T							☆				
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25							5					T							T				T								1	1	T	☆				
26				4		☆	T					T							T						9		T		5		T	T	T	☆				
27				11		36	26				35	33	19	4				13	20	4			3		22		12	T	21		9	16	19	☆				10
28				T			T				T		1						T												T			☆				
29				T			1				T	T		2					1				T		T		T		T		T	3	60					10
30																																						
31																															T		T					

MONTH
JANUARY
1977

	FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 33	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
	06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
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3			4		8	10				7			1					9	6			5			2	7		7		5	5	6	10				
4			1			t				t																t											
5																						t			t	t		t		1	4	4					
6			8		7	18				7			7	6			5	8	7			8		15	1	9		2		3	3	5					
7			1			6								1				t	1						t		t	t		t							
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9														t																t							
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11																			t									t		t							
12						2				t								t	t			t								t							
13			1			5				5		6	6	4			t	6	1			3		4	t	8		25		2	4	6	☆				
14			2			3				t		2					4	3	1			5		4	4	6	t	6		6	5	8	☆				10
15			11		21	25						6		8				2	t			t		t		t	t						☆				
16												6		1								t											☆				
17										7			t					t				t		t		t				t	t	2	☆				
18			2			t				t			t	2				3						t		t				t		t	☆				
19						t																		t	t	3		6		6	t	3	☆				
20			2			5				8			12	2			t	4	3					3	t	5		2		1	t	1	☆				
21			t			t				t				1				t												t			☆				
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23			5			3											13	7	1			12		9	5	12	☆	4		5	9	7	☆				
24			4		15	6				12			2	15				6	1			t		6	5	4	90	8		3	3	4	☆				
25			3		☆	2				8		7	1	6			11	3	t					t		t		5		2	2	3	☆				
26			6		12	5				t				1				7	1			18		8	3	5		4		6	9	9	☆				
27			1							M									t						t	t	15	t		t	1		☆				
28			1			3				M								2	t						t	t				t	☆	6	☆				
29			2			2				M				4				2							t	6	t			6		t	☆				
30			t			1				M				4				1							t	t				t			☆				
31										M			t	3												t				t	t	t	60				

MONTH
FEBRUARY
1977

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
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2			t				t												t				4		3	t	5	15	t		t	2	7					10
3			4	9		3	3							20	7			15	3	7						4	5	t	t		5	2	3					
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12			t	1			2												t	t			t		2	t	5	15	2		6	1	4					
13			2	5			2							4	13			t	1	t					3	t	1	t	t		t	t	t					
14			t	2			1								4				t	1					t						t	t	1					
15																																						
16			1																						t	t					t	1	1					
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18			t				t												t	1			t		t	t		t			t							
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24			20	23		24	27						71	t	14			21	65	4			28		15	13	31	52	22		14	8	30	☆			10	20
25			11	13		3	15						15	60	1			17	2	t			2		t	2	9	12	6		7	2	3	☆			10	
26			5	6			4								1			11	t	t			t		t	2	t		t		3	1	3	☆				
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MONTH
MARCH 1977

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON ONE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
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5			14	26		25	5								3			11	2	10				t		t	1	6			1	t	4	☆			30	
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8			3																									t						☆				
9				1		2									13			5		10			t		t	1	3		2		t	t	t	90			10	
10			17																																			
11			14																												4	t	t				10	
12			21	38		62	144						63	63	25			48	59	50	110		65		63	87	25	51	142		47	60	55	60			170	160
13			2	17		30	27						132	65	55			21	6	9			33		2	1	t	15	2		t	3	3					10
14				4		3	2							13	3			10		2			3		t	1	t				t	1		10				
15				1										5	2								t		t	t		t			t		5					
16			t	1										t	1			3					t		t						2		1					
17							22																		t	2	t		16		6	8	t				10	
18			9	6			t							15	4			16	7	20					6	1	7		t		3	t						
19			t															t		1			t			t					1							
20																										2	t		5		1							
21			t																																			
22																					3				t	t	t		t		3	7	2	10			10	
23			8	9		20	15							10	14			6	8	1	5		t		t	10	5	11	12									
24																							t															
25																		3																				
26							t																		t		7	t			8	31	29	20			50	50
27			8	7		31	38							65	45			22	27	10	45		51		24	15	14	37	19				3					
28				1			t						47																		t					40	10
29			1	1		22	30							5	17			6	13	6	19		32		33	24	3	31	21		7	33	26	60			50	40
30			46	49		36	44						31	35	52			30	41	20	M		8		23	20	14	28	14		3	6	3				10	
31			t	1			t						36		1			5	t	10					t		t	t			t							

MONTH APRIL 1977

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
1																				1			t		t			t			1	1	3					10
2			t	3			t							3	1			29	t	1		6	t		t			t			t		t					
3																																						
4																												t									
5																																					
6																														t	t	1					
7			t	1			t							2	2			t	t	t		t	t		t	1	2	t	t		t		t	10				
8			t	1																					t													
9																																						
10																																						
11							3																							t							
12			5	2		23	10							5	1			6	t	1	t		t		t	10	32	t	8		3	1	t			20	20
13			2	2									11	2	5			2	5	1	17	2	5			2			t								
14						5	7														5					7			8		2	t	t					
15			5	4										4	3			21	5	4	5	3	t			1	2	5				2	1					
16																																						
17			19	13		15								19	13			28	15	31	13	8	t		17	27	28	33			19	18	28	20				
18			2	19		12									t			12	t	2		14	t		20	32	25	69	20		40	20	12	10			30	20
19			42	27			35						38	25	25			22	20	35	16	29	4		21	18	32	6	13		3	5	13	10				
20			11	10			1						4	2	3			16	4	10	2	15	7		2	3	7		7		49	51	37	50			60	50
21			57	57		71	63						74	60	69			60	62	50	78	52	45		60	55	3	79	50		3	14	3	10			20	40
22															t																						
23																					t		t										t				
24															t			t			t		t		t			t										
25																																					
26																												t									
27																							t														
28																																					
29														t					t						t	t	t		t		t	3						
30			t				17												10	t								10	6									
31																																						

MONTH

MAY 1977

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
1			3	4			5								1				t	2	1		t	M	t	1	6		4	M	1		t					
2																																					
3																																					
4																				t			t								t	t				10	
5			18	15		30	22	M	38				35	65	21			20	25	46	25	45	67	M	75	26	47	43	48	M	47	38	34	60			60	
6			21	18		8	t								24			10	15	10	11	2	t	M			t	5					t				
7			t												t																						
8																																					
9																																					
10																					5	3			8	t	8	5		M	t	18	25	20			20	
11			14	27		26	10						9	35	9			19	14	6		31	t	M	31	12	9				t	2					
12																																					
13																						t															
14																						196					25						1				
15			46	159		24	18	107	159				M	22				10	59	10			2	t	30	60	40	t	38	M	9		48	40				
16			4	15			15	38	M				M		2			2	2	32					t	36			44	M		110					
17																					22			10	7	4	20		8	M	t	5	45	60			70	
18			6	4		41	24	2	M				M	8	18			3	2		2	2	4															
19			t				10								t			t	4		2		1	t		12	28	9	6	M	t	2					
20			50	21		★	1	30	M				M	M	21			23	37	70		70	t	68	71	62	31	12	81	89	73	88	71	60			65	
21			58	51		55	51	54	M				M	M	1			50	36	10				21			t				7	1	1				7	
22			42	31		40	39	23	M				M	M	16			55	31	21	20	27	66	19	31	20	36	24	29	34	t	73	42	50			8	
23			54	6		6	30	t	6				M	M	57			40	11	16	26	26	6	19	10	13	21	9	26	24	4	11	22	20				
24			14	22			1	27	25				M	M	9			13	t	t	3	28		12			4			t				20				
25				1																																	
26																											t									1	
27		23	11	26		12	10	6	1									15	t	1		t							15	3	5	t				
28																t										t	21		t								
29				t	3		t									t	5			1		t		t		4	4		41	t	21	4	t				
30		1	5	4	t	81	t	6								t	3		3	★		4	7				t				47		1	10			18	
31		71	86	91	185	70	95	62	71				48	M	54	55	89	125	63	104	56	67	37	170		125	157	76	140	131	93	200	128	160			121	
																																	510				

MONTH
JUNE 1977

	FAIRBANKS 06	EMBARRASS 07	EAGLES NEST 07	WATER HEN 07	BRIMSON 07	ISLAND LAKE 07	NORTH SHAGWA 0730	VERMILION COLLEGE 0730	LOG CABIN 08	HIBBING CITY 08	COTTON 08	FINLAND 08	MINNIMAX 08	ISABELLA ELC 0815	STONY RIVER 09	SKIBO 09	TOWER 39 09	WHITEFACE 0930	VIRGINIA 11	ISABELLA RS 13	ELY USFSC 13	GRAND MARAIS 16	SNOWBANK LAKE 17	BABBITT 17	COTTON CONE 17	CRANE LAKE 17	GUNFLINT LAKE 17	MEADOW-LANDS 17	OLSON BAY 18	HIBBING AIRPORT 24	HOYT LAKES 24	WINTON 24	KAWISHIWI 24	PELSON MCREEK 24	DUNKA CR 24	WALES 24	TOFTE 24
1	6	122	121			72	112	124	M		50			165	195	117	141	87	71	178	121	36		92	50	57	85	29	61		7	9					
2																			1																	
3				10							23	93									3		t	t	23			24		27	9	t				20	
4	7	3	3	21		28	2		M		22			6	5	12	3	25	17	5		3		9	22			23	t							
5		2		4										2	30	t	2			47	t	t	51	36		10	10	t	26	19	29	40	50				40
6	2	9	38	26		7	52		M		8			37	40	34	23	20	15	3	56	21	8	11	8	8	75	2	31			6	30			20	50
7			t	10	85	t	27		M		9	27		3		2	1	2	1		22	7	12	3	9	10	11	2	20	26	9	15				10	
8	18	36	27	23	7	25	28		M		19	6		7	20	28	20	37	26	2	28	t		28	19	12		9	21	11	14	18	20			10	
9		t	t											t						t									1						20	
10		3	t		41	17	t		M		11				5	2	6	2	1		2			9	11	t		17		1	5	t	10				
11	2		4				t		M		3			2	t		t				t	t			3	5										
12															t				1								t									
13																																				
14	2	2	8	2			4		5					4	5	2	5	t		1	4	9	6	4		12	32		6	t		5				
15	6			15		4													1		t	4		t		t	4	4	t	t	2	5	10			
16	34	58	62			25			9		9			65	85	20	78	28	97	66	98	29	113	70	9	173	28	35	94	92	57	121	50			40	20
17	3	t	2	4		2												t	3		5		t					2		34	27	23	40			20	10
18	42	54	30	24		24			65		41			59	35	58	55	57	37	76	21	26	120	80	41	173	91	27	46	28	37	14	20			20	
19	15	11	50	101	99	8	160		11		30	21		15	80	17	6	25	22	13	11		t	61	30	7	8	11	8	10	9	t			10	40
20	14	10	78	25	158	6	29		4		10	15		103	20	18	55	71	38	70	32			21	10	t	t		11	t	7					
21																																				
22																												3		32	14	10	20				
23	154	66	53			81	46	136	32		110			23	133	93	70	114	75	80	43	40	60	72	110	28	28	54	44	81	95	32	50			80	70
24	2					2								1					1	t		t							t							20
25																																				
26		15	t				1		M								5			t		t	44			9	6					4				
27				13		t					22			3						29	t				22			24		5		t	10				70
28	21	32	28	73	7	90	11	12	M		21	8		130	50	127	46	38	1		13	2	16	76	21	17	30	2	33	12	25	19	60			10	20
29	8	19	15		58	10	25		M			45		39	40	15	23	3	15	26	18	t		t		5		t	4	36	17	25	20	47		30	
30	69	33	33	9	16	72	29		M		55			19	115	M	44	52	42	22	32	14	20	43	55	38	15	53	32	10	56	21	40	6		20	30
31																																				
																																440				

MONTH JULY 1977

IGNORE

		FAIRBANKS 06	EMBARRASS 07	EAGLES NEST 07	WATER HEN 07	BRIMSON 07	ISLAND LAKE 07	NORTH SHAGWA 0730	VERMILION COLLEGE 0730	LOG CABIN 08	HIBBING CITY 08	COTTON 08	FINLAND 08	MINNIMAX 08	ISABELLA ELC 0815	STONY RIVER 09	SKIBO 09	TOWER 39 09	WHITEFACE 0930	VIRGINIA 11	ISABELLA RS 13	ELY USFSC 13	GRAND MARAIS 16	SNOWBANK LAKE 17	BABBITT 17	COTTON ONE 17	CRANE LAKE 17	GUNFLINT LAKE 17	MEADOW-LANDS 17	OLSON BAY 18	HIBBING AIRPORT 24	HOYT LAKES 24	WINTON 24	KAWISHIWI 24	FILSON CREEK 24	DUNKA CR 24	WALES 24	TOFTE 24
1		31	65	43	*	52	13	30	*			9	53		53		20	45	16	8	73	47	54	84	28	9	33	24	13	34	5	7	6	20	20			10
2			6	7	*	52	11	2	*	110		6			6		74	3				3			5	6				3							10	
3		96	100	93	*		49	89	*	50		40			76	20		100	42	97	122	99	61	70	106	40	49	97	26	73	65	98	87	80	70		90	40
4	185					32				76		21	10								19	5	4	t	14	21	9	t	19	10	16	15	10	10	25		20	
5	186		63	25	*		20	54	*	18					29	M	37	125	22	25		65	18	t	44		119	78		80		6	80	100	100			10
6	187	2	t	89	*			30	*				1			M	8	6	t		22	23	3				2	t				t					
7	188					8						t	2		1										2	t	t	t		2	6	1	1		17			☆
8	189	13	2				3	1				5			2		14	t	14	2	3	1	t		t	5	t	8		t		1			1			☆
9	190																																					☆
10	191					32	2	3	*										30																			☆
11	192	8	15			7	23	3	29			27				20	27	6	30	9	30	7	30	14	4	27	3	15	4	6	1	16	3			20	☆
12	193		2	6	*			10	*	5		10			7	M	10	3	2	3	7	8	7	t	12	10	11	11	3	20	6	19	10	10	40			☆
13	194	8	15	7	*		4	13	*						14	M	10	13	10	2	6	13	5		1												☆
14	195												20															t	62								☆
15	196					63							5																								☆
16	197	36	4		192	145	67			80		47			86	35	18	33	51	25	48	31	37	34	64	47	1	23	89	28	40	80	30	40	82		160	☆
17	198	121	148	38	30	↓	89	28	*			75	46		46		155	110	84	40					4	75	t		16									☆
18	199				140								3		9						25																☆
19	200									10																					t		t				☆
20	201			2					*									2			8									2							☆
21	202																																					☆
22																																						☆
23	204														t							7											t				☆
24	205		5	24	t	60		2	*						t	40		16				2	t		t		18	t		20	4	20	7			10	☆
25	206	5	2	1			13	18	71			21			3	40	7	4		12		5	t		t	21	22			6				8			☆
26	207																				40																	☆
27	208				14							5										42			t	5	t		2		22	30	17	20	54		30	☆
28	209	34	37	40		37	7	24	*	85		21			39		27	45	38	55			21	27	33	21	10	58	16	38	t	3	11	10	6		10	☆
29	210			3	15			1	*	8			44		t			t	1	8	3		t		t		6	t		2		1					☆
30	211		t	t	64			*	*			60			t	40			16	23	9	23	21	22	25	60	18	20	85	36	54	21	31	30	27		80	200
31	212	49	36	40	5		112	33	47	30		2	74		31		35	59	43	22	39	14	31	12	7	2	3	6		10	t	9	2		2			

Ignore all values below IGNORE

MONTH
AUGUST 1977

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFSC	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON CONE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	ELSON MCREEK	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
1	213	17	4	7			3	8	7			7			9		11	2	2		t					7			13		7	5			8		10	
2	214	8	t			75	10	t		t			2						15												15	11	9	10			10	
3	215	25	19	5		42	42	8	5	t		38			29		41	14	51		37	6	6		t	38	29		17	21	16	47	1		83		40	☆
4	216		t				5											t					3							t	28	3	38					☆
5	217	17	3	18			t	25		35							4	6	26			7	1	44	24		17	56		30		3	5					☆
6	218		4	t				1									13	18			17	t						t		2	t	12			7		10	☆
7	219	14	5	3		35	4	4							15			4	11				10	4	3		5		8	5	6	1	10			1			☆
8	220	7		t			6					33	7				4		8				6			33				t							10	☆
9	221																														t							☆
10	222		7	1			t														t	t	t	t	1	6		t		t		t	t					☆
11	223		4	t				t							t			9							3		t	t							3			☆
12	224			t															1								2			11	5	8	4	10	5			☆
13	225	8	6	9		4	8	5				6			10			6	3		9	7	4		t		2		3									☆
14	226		t	t											2						t		t		5		1											☆
15	227											13									2	t	t	t	6	13	6		15	13	15	15	16	20	6		20	☆
16	228	17	23	23		15	31	22	22	22		4			32		18	29	15		30	22	27	30	★	4	21	30	13	19	20	6	10	10				☆
17	229	5	9	5			11	4				16	9		2		20	19	6		t	4	t		25	16	24	6	5	11	1						÷
18	230		t					t																													☆
19	231																						t									8					☆
20	232	36	32	20		48	14	15	53	53		15			12		27	56	30		28	19	33	33	62	15	5	12	5	36	58	125	55	40	81		60	☆
21	233	25	41	16			11	36					93		26		222	28	81		5	28	9		t		1	18			t							☆
22	234		3	7		5	9	14				4			8		3	6	6		10	10	12	18		4	6	10	11	21	7	3	22	10				☆
23	235		t					4										1																				☆
24	236							t																														☆
25	237	55				58						22													8	22	3		21	☆	101	81	60	80	86		50	☆
26	238	5	66	52			39	60	62	62		39	69		43		79	70	63		52	76	64	226	100	38	41	172	11	☆	79	130	230	130	55		20	☆
27	239	34	187	199		48	55	198	435	435		45	32		66		39	225	34		56	226	62	214	223	45	145	131	91	449	282	260	209	190	294		30	☆
28	240	7	259	222			61	222	275	275		7	38		125		145	201	41		68	206	167	113	129	7	49	81	36	4	t	2	2	10				☆
29	241		t	1				2							2						t				7						1							☆
30	242	12				98	5		51	51		130					t		5		58	23	104	50	39	130	8	28	44	42	58	62	48	40	25		70	☆
31	243	211	80	63		63	36	44	60	60		25	138		123		133	95	142		154	87	261	39	32	26	110	34	15	67	23	19	56	40	18		30	610

MONTH SEPTEMBER 1977

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FIESTA MCREEK	DUNKA CR	WALES	TOTALS
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
1	244	20	8	55		5	2	78	19	t		11			11		9	38	13	2	11	27	t		t	11	t			14	15	26	10	20	27			10
2	245		17	12			5	15	☆	t		1			15		12	15	14	27	10	13	1		22	1	6		10							0	
3	246																						68				t				96	55	29	60	100		80	40
4	247	☆	122	90		☆	89	72	☆	88		120			79			150	107	130	76	75	65		82	120	79	35	74	75	12	106	45	30	73		40	
5	248	☆	2	1		☆		3	92	18		1	96		6		145	6		1	4	6	t		t	1	9	7		t	8	4	5	☆	8			10
6	249	136	12	18		145	79	27	☆			88	5		11			14	10	10	8	20	15		14	88	25	22	81	43	17	7	15	30	2		10	
7	250	2	2	3			1	t	☆						t		12	t		2	t				t		3										
8	251	12	t	t				t	☆		t				1			2		t	8	15	13				138	170	t	☆	48	47	112	☆	42		10	☆
9	252	93	59	140		71	7	125	☆	125	55	54	53		98		2	115	81	49	111	113	116		83	54	128	475	19	165	17	32	32	200	17		20	☆
10		10	32	22			13	28	☆			1			26		124	25	8	19	12	8			2	1	t	t	t		t							☆
11			1				t	t		t		14			2			t		1	t	1	15		27	14	15	t			28	22	4		27		30	☆
12		30	11	11		40	15	2	164	t	47				40		42	13	35	56	25	6	11					t			t		t					☆
13							t	1				2						5		t	3	t			5	2	6		4	10	18	37	1	10	16		10	☆
14		13	18	2		8	10	1	1	15	15				4		19	6	2	1		t											t		3			☆
15																																			1			☆
16																																						☆
17															t								t				t			☆	t	t	t					☆
18			1	1								7			t		5	1	2		t		t		2	7	2	10	12	☆	30	17	58	50	5		20	☆
19		41	33	39		74	14	52	63	85	66	19	67		19		12	22	43	42	80	57	135		105	19	117	117	56	51	35	25	15	10	18		50	☆
20		7	3	7			27	t	3		8	1	28		20		4	1	2	2	15	3	6		1	1	t		8						2			☆
21								1																							1	2			2			☆
22		11	6	4		30	9	2	☆	60	6	2	M		13		18	8	13	24	14	7	2		21	8	2		31	☆	13	28	9		23		30	☆
23			13	6		☆	11	5	☆		6	t	M		11		☆	9	3	2	26	4	3		5	t	t	t	2	☆	28	13	10		7		60	☆
24		200	83	59		☆	212	80	☆	95	☆	158	M		89		☆	90	142	123	215	134	274		85	87	158	98	118	183	80	94	175		91		330	☆
25		37	56	44		☆	33	107	☆	8	☆	31	M		74		☆	90	54	26	40	45	47		36	55	31	12	29	☆	13	37	20		13		30	☆
26		28	2	7		310	15	12	207		167	11	M		5		225	10	33	19	26	18	2		26	9	11	t	6	☆	8	6	4		1		10	☆
27		7	7	13		☆	4	13	☆		5	16	M		11		8	10	4	7	10	11			6	2	16	8	t	89	t	6	3		1			☆
28		2	4	9		☆	t	8	☆		t	2	M		8		4	6		1	6	8	1		10	1	2		2	☆	24	58	18		38		20	☆
29		34	42	38		39	13	25	52	35	28	t	26		45		50	40	34	3	47	29	41		35	26	t	6	17	24	t		3		3		10	280
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31																																					

MONTH
OCTOBER
1977

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	+ WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	McRIGHT	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
1																																						
2																																						
3																																						
4															14		2	13			14	t			t	5	9	6	20	☆	3	9	10		3			
5			7	10		11	25	8	9		4		8				3	18	16	1	10	10	13		4	7	8	10	6	☆	3	1	t		2			
6			3	4			1	☆	2		3				2		4	18	2	2	6	t			2	1				☆		t	t					
7			t	t				☆	☆		☆	20			t		2	5	t		t				13	6			18		47	27	33		31			
8			45	39		90	148	☆	☆		☆	X	183		53		28	63	34	70	35	39	67		25	31	25	29	72	☆	18	12	13		13			
9			5	7			9	50	52		88	105	25		2		4	7	t	1	6	5	t		☆	1				☆								
10												X					t					2		13	6			7		24	38	21		34			
11			86	85		120	33	106	85		48		91		158		85	87	90	66	308	220	122		91	86	87	185	65	☆	57	77	106		91			
12			35	35			8	38			13		24		109			11	84			21	13				1	20		207					1			
13								1																														
14																																1						
15			t									X								1	t																	
16																																						
17																									t	10			5		41	3			5			
18			2	2		7	14	2	4		30				7		11	4	9	1	6	3	t			9	7		27		2	3	3					
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25			t	t			t				t						2		t			1			9	1	1				t		t					
26			t	1			t										1		t																			
27			t				3				t						4		3				t		t	4					2							
28																																						
29																																						
30																							t								t							
31			18	8		35	48	11	21		44				6		29	17	33	4	51	29	82		29	36	15	25	34	29	38	37	23		29			

MONTH

NOVEMBER 1977

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	MCRIVER	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
1			6	10			4				5				6		3		t				2		2													
2																																						
3																							t												X			
4																																						
5																																			X			
6							t																								6	2		6			
7			10	6			t	t			3	2			3		2	4	t				t		3	2		3			t	6	1					
8			2	1			4	2			2	1			1		3	2	3		7		2		t	1		t			t	3	2		3			
9			45	23		65	37	☆			70	105			11		78	78	78		t		9		195	105		32	128		130	133	65		121			
10			108	116		25	37	158			63	2	31		65		32	64	37		32		9		103	2		82	15		10	25	25					
11			4	15			t	8					16		20										t			t										
12																																						
13																																						
14																																						
15							1				2	t					25		t				t			t		1			41	24	10					
16			40	45		90	22	☆			32	43			46		30	55	67		M		23		88	43		52	37		33	29	54		83			
17			25	35		97	4	☆			12	10	14		53		t	16	10		M				14	10		5	22		10	37	12					
18			5	6			t	190			t	t			9		t	5	t		M				1	t		9	t		1	t	1					
19			2	3			t	☆				3					20		t						t	3		t			39	2	16					
20			38	41		75	96	☆			☆	43	103		50		M	32	78		66		131		44	43		57	78		73	56	72					
21			52	25		37	28	☆			123		62		36			20	5		89		15		t			21			10		4					
22			t									5							t				3			5		1	14		6	1	3					
23			3				6	85			5	1			t				7							1		t	t		t	t						
24							t								t				t									t			t							
25																																						
26																												t										
27			t				2				☆	4			3				3				t		t	4		t	12		5	5	3					
28			5	3		10	2				7	t						7	2		6		t		t	t		6			t							
29							t	t															t								t							
30				t			t				1	t							t		t		t		2	t					t	1	t					
31																																						

MONTH
DECEMBER
1977

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 33	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
1			t	–			t					t								t	t						t		t			t	5	2					
2			3	3			t					t						8	2	5						t		3	t		t	1	2					
3			t			13	t								2						5							t			t							
4											开	3														3			6		7	4	2					
5			6	8			13				14	3	7					14	7	9	40		17		17	3		23	1		2	14	9					
6			3	5			t				2		9		39			3	t	t	98		5		t	2		22	t		3	4	5					
7			2	4			t				田				2			t	2	t			t		t	t		t			2	3	t					
8			9	9			7				11		32		5			11	8	10	10		13		18	11		25	10		10	15	15					
9			12	18			12						48		22			11	10	1			12		09	5		16	8		2	5	3					
10			1	t			t						17		1				t									t			t							
11													7						t		2		12		7	1		16	t		4	7	10					
12			6	2			1				21				7				2	1			4								1	t	11					
13			32	27		10					15				17			9	t	19	26		11		29	t		35			1	25	22					
14				t			t				t								t				t			t		t				1						
15			t	1			t				t								t	1						t					t							
16				t			t												4									t			t							
17				3		★	5								3			9	17	19	60		61		9	19		43	50		38	20	26					
18			34	13		123	130						118		60			43	74	30	70		4		5	51		4	42		20	14	10					
19			t	2			9				83		26		t			10	4	t			8		t	t		2			t	2	10					
20			11	11			2								8			t	5	6			1		13	2		11	10		7	11	10					
21			8	11			7				13				20			9	6	5			t		t	5		14			t		t					
22			t	t			t																															
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25			1	1			t								t				t	t					t	t					t		t					
26																															t							
27											t																				2	2	2					
28			2	6		70	t				2				t			4	2				t		5	t			6		t		t					
29																															t	t						
30							1												1							1			t		1							
31																																						

MONTH
JANUARY 1978

	FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 33	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 2NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
	06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
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2																	t	3	t			3			t			t		2	1	1					
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5										t							2	1	t	10		t		9	1		6	5		1	8	6					
6					42					25							M	32	22	12		6		25	24		26	22		20	20	13					
7																		t	3			t			t		2	t		1	2	5					
8																		1							t		t			t							
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10																														t							
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13																	t	1						t	t			t		t	t						
14																		2	t			t		t	1					3	t	t					
15																		t	t			4		t	t		9	t		2	1	4					
16										3								1	t			t		t													
17										7												4															
18					☆					2							5	6	t	20					11		10	13		6	5	7					
19					★													2							t											
20					18													t				t								t		t					
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25					★					12							27	14	M	23		67		39	11		6	12		8	15	19					
26					32					8							8	6	M	12		~~1~~ t		2				33		t	t						
27																						☆						t									
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29																																					
30																														t		t					
31																		t							t			t		t							
					42					65								69		77		84		78	48		59	40		43	52	56					

MONTH

FEBRUARY 1978

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
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4			3			7											7	3	6	7		10		8	7		17	12		11	8	11					
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6											17																										
7											t							t	t			t			t			t		t	t	t					
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9			t								2							t	t									t		t							
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13						8													t					t						2	t						
14			1								2						2	t	t	2		t		6	t		t	t		4	2	t					
15											t							t									t			t		t					
16											t								t						t		t			t		t					
17			t								t							t						t	t		t			t	t	2					
18			t														3	t	t						t					t	t						
19																		t	t						t			t		t	·						
20																																					
21																																					
22																								t						1	1	2					
23			4								4						3	1	t	1		t		2	t		t	t		1	t	1					
24			11			26					28						14	18	2	★		6		12	20		12	24		32	28	15					
25			16								5						11	14	7	13		t			10		5	20		t	t	t					
26			t															t	t						t					t		t					
27			t																													t					
28			t															t		1																	
29																																					
30																																					
31																																					
											58							30	35	34		16		28			34	30		32	39	1					

MONTH

MARCH 1978

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 39	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
1																																						
2						9														t					t	4			6		5	8	2					
3							7				10						3	4	9	1			t			t					t							
4																																						
5																	2	t							t													
6																		11																				
7																																						
8																																						
9																																						
10																							t															
11																																						
12																															1	t	1					
13						40	20				12						5	13	24	20			13		20	21		29	51		35	28	38					
14						6	46				28						40	13	23	10			7		18	7		11	5		t		t					
15							5				2						t	5	8	t			8			8		t			2	4	7					
16							2				t						7	5	5				17			1		22										
17																																						
18																							t		t			7			t	t	t					
19																	2		t						A	t												
20																		t	t	10			14		22	10		29	11		19	27	26					
21						13	8				18						15	28	13				t		7	t		t	t		5		10					
22							t				2							7	2	t			t		t			10				t	t					
23																																						
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30																									t								t					
31																												t			t		t					
																	84			11			159		71	47		159	13		30	67	74					

MONTH

APRIL 1978

		FAIRBANKS	EMBARRASS	EAGLES NEST	WATER HEN	BRIMSON	ISLAND LAKE	NORTH SHAGWA	VERMILION COLLEGE	LOG CABIN	HIBBING CITY	COTTON	FINLAND	MINNIMAX	ISABELLA ELC	STONY RIVER	SKIBO	TOWER 33	WHITEFACE	VIRGINIA	ISABELLA RS	ELY USFS C	GRAND MARAIS	SNOWBANK LAKE	BABBITT	COTTON 3NE	CRANE LAKE	GUNFLINT LAKE	MEADOW-LANDS	OLSON BAY	HIBBING AIRPORT	HOYT LAKES	WINTON	KAWISHIWI	FILSON CREEK	DUNKA CR	WALES	TOFTE
		06	07	07	07	07	07	0730	0730	08	08	08	08	08	0815	09	09	09	0930	11	13	13	16	17	17	17	17	17	17	18	24	24	24	24	24	24	24	24
1																	2		t				t		t	t		t			t		t					
2																									3	20			14		38	9	12					
3						29					44						25	26	24	t			18			30		6	6		15	8	8					
4											12							8	18	15			10		16	18		11	14		t		t					
5																															7							
6						67					58						M	27	73	61			61		42	68		38	70		47	67	51					
7																		t							t												
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9											*						15	9	18	4			17		t	12		20	23		23	23	20					
10						30					21						20	7	10	t			21		30	9		11	8		t	5	7					
11											t						+	t	2	12			t		t	6		3	2		t	t	t					
12											3						21	10	3	5			5		16	11		11	14		4	23	15					
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14																									t	t		t			t		t					
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29																																					
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31																																					
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MONTH MAY 1978

FAIRBANKS	06
EMBARRASS	07
EAGLES NEST	07
WATER HEN	07
BRIMSON	07
ISLAND LAKE	07
NORTH SHAGWA	0730
VERMILION COLLEGE	0730
LOG CABIN	08
HIBBING CITY	08
COTTON	08
FINLAND	08
MINNIMAX	08
ISABELLA ELC	0815
STONY RIVER	09
SKIBO	09
TOWER 3S	09
WHITEFACE	0930
VIRGINIA	11
ISABELLA RS	13
ELY USFS C	13
GRAND MARAIS	16
SNOWBANK LAKE	17
BABBITT	17
COTTON 3NE	17
CRANE LAKE	17
GUNFLINT LAKE	17
MEADOW-LANDS	17
OLSON BAY	18
HIBBING AIRPORT	24
HOYT LAKES	24
WINTON	24
KAWISHIWI	24
FILSON CREEK	24
DUNKA CR	24
WALES	24
TOFTE	24

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31		

MONTH
JUNE 1978

	FAIRBANKS 06	EMBARRASS 07	EAGLES NEST 07	WATER HEN 07	BRIMSON 07	ISLAND LAKE 07	NORTH SHAGWA 0730	VERMILION COLLEGE 0730	LOG CABIN 08	HIBBING CITY 08	COTTON 08	FINLAND 08	MINNIMAX 08	ISABELLA ELC 0815	STONY RIVER 09	SK180 09	TOWER 39 09	WHITEFACE 0930	VIRGINIA 11	ISABELLA RS 13	ELY USFSC 13	GRAND MARAIS 16	SNOWBANK LAKE 17	BABBITT 17	COTTON 2NE 17	CRANE LAKE 17	GUNFLINT LAKE 17	MEADOW-LANDS 17	OLSON BAY 18	HIBBING AIRPORT 24	HOYT LAKES 24	WINTON 24	KAWISHIWI 24	FILSON CREEK 24	DUNKA CR 24	WALES 24	TOFTE 24
1										62						20	110	66	62	27		51		50	61		56	53		20	53	62					
2										13							17	14	t	9		t		6	1		12	t		t	2	4					
3																						t								t		t					
4																	2	2	t	t		8		1						t	6	2					
5																			4			t															
6																														32	85	34					
7										48						108	65	92	56	107		83		87	121		88	100		26	28	2					
8										11								21	t	t		t					21			1	1						
9										2								1						t													
10																5		2	3	t		t			9			14		2	10						
11																7	4	51	t	3		28		9	52					t	12	t					
12										t							5	t	t	t				t	3					t	6						
13																		t	t									51									
14										31								11	6						57			64		25							
15										6								1	t						2		9	16		2	t	4					
16										12						5	29	7	6	12		39		11	5		10	12		10	24	1					
17																														t							
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24										☆							2	t		8				t	1		58			1		2					
25										☆									M			5			3		36	6		8	9	68					
26										13						22	13	26	M	17		45		29	50		97	8		18	6	16					
27										30						25	36			9		38		30			5					2					
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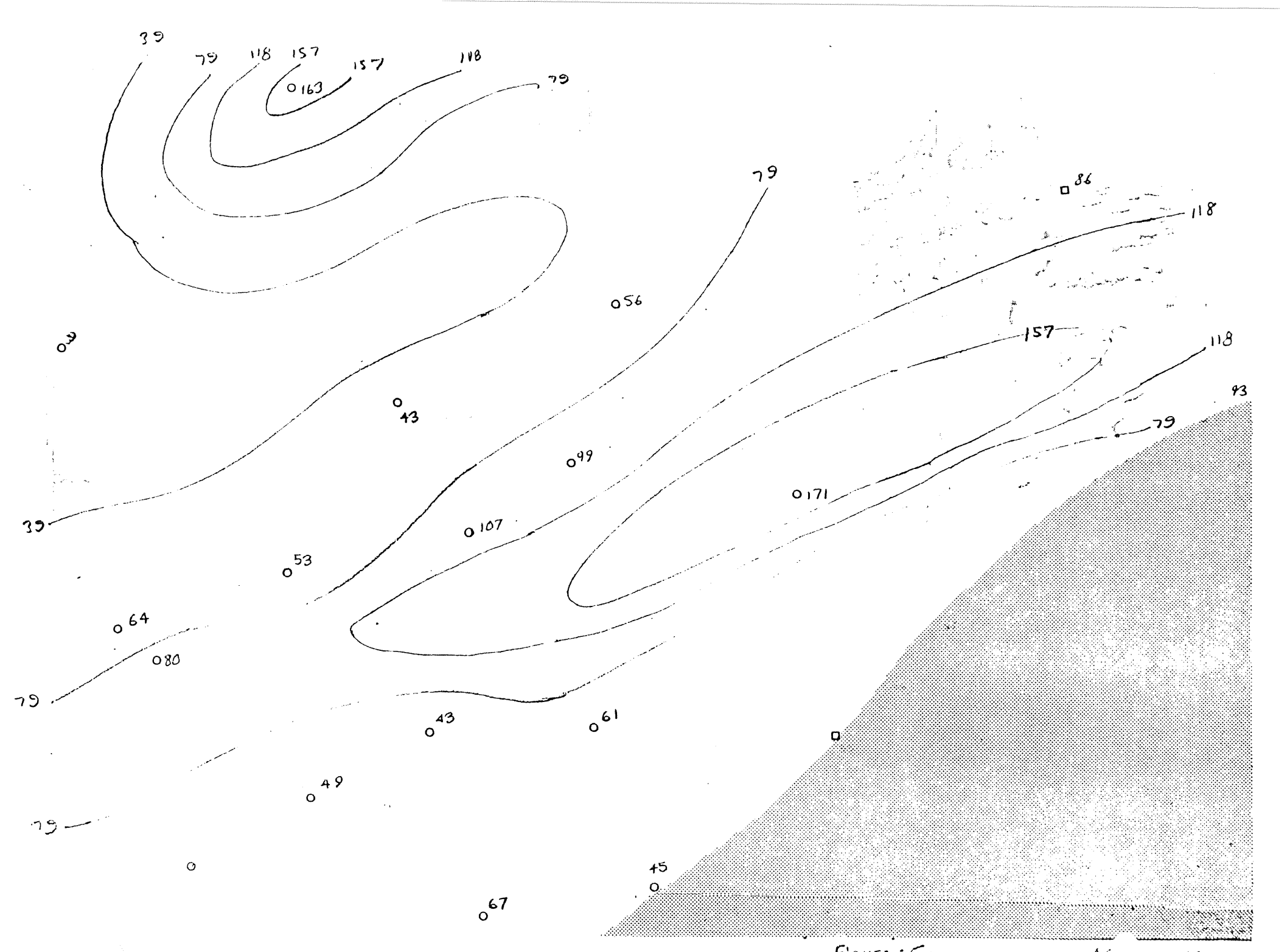


Figure : 5a

A[illegible] 1976

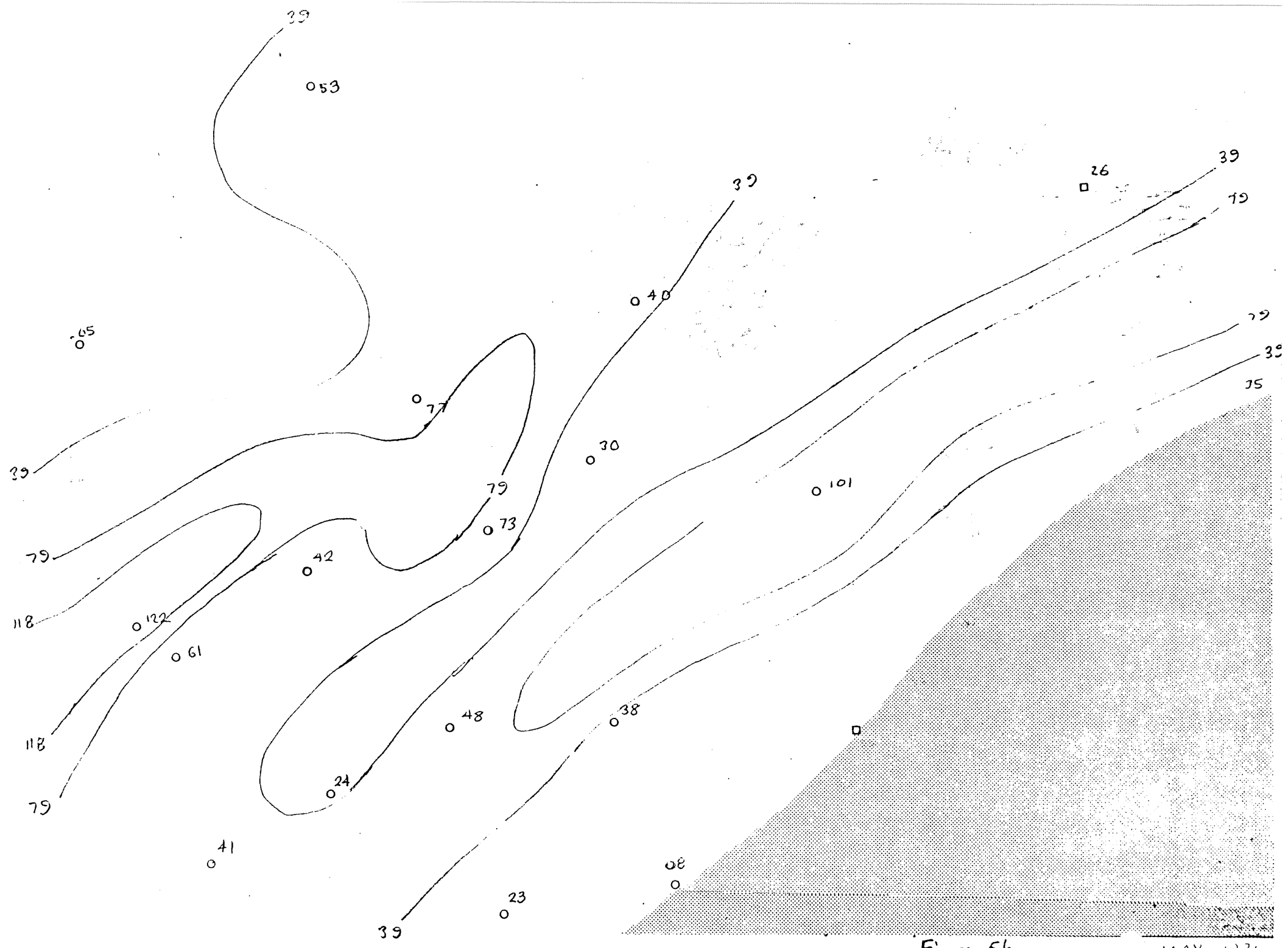


Figure 56

MAY 1976

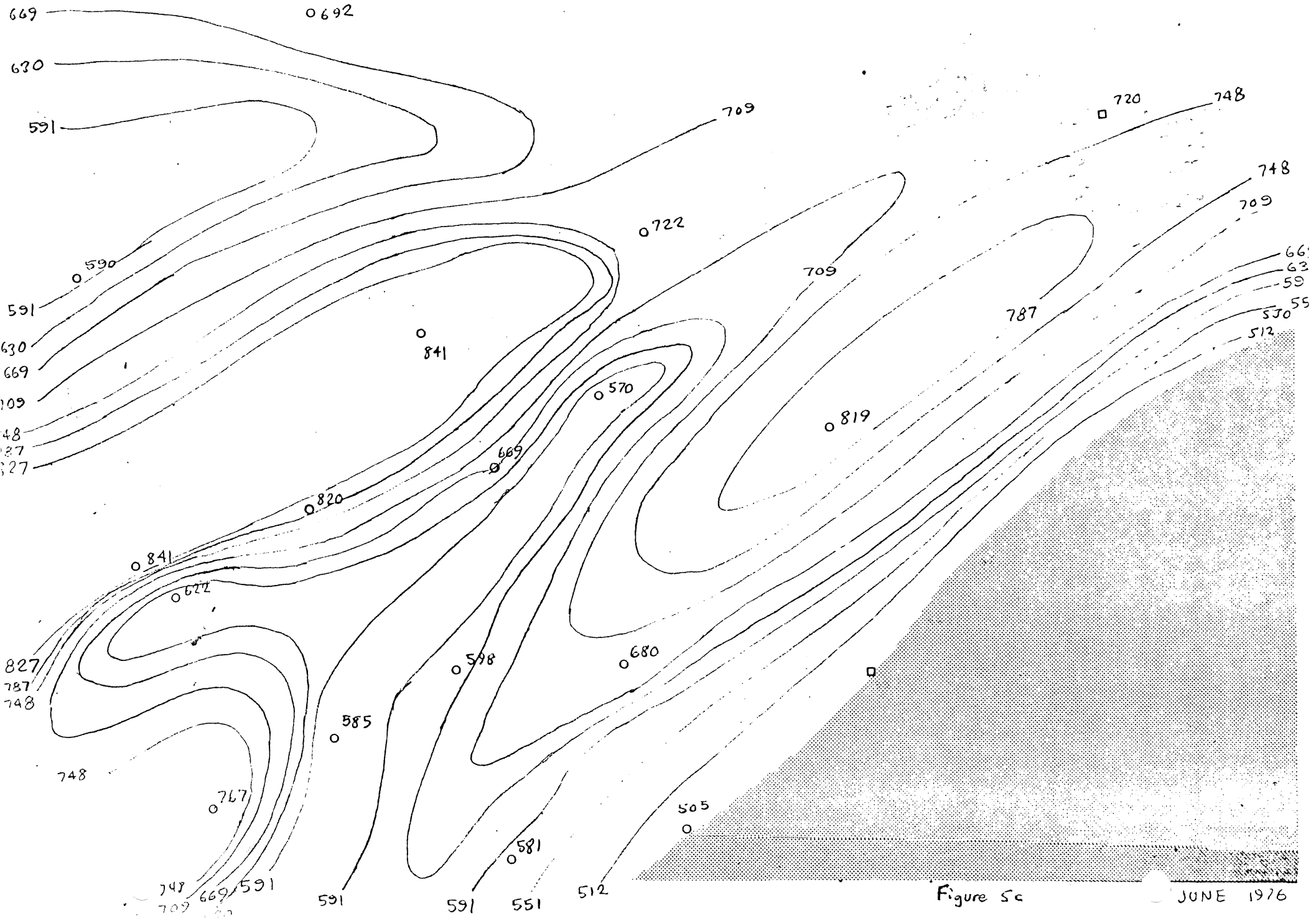


Figure 5c JUNE 1976

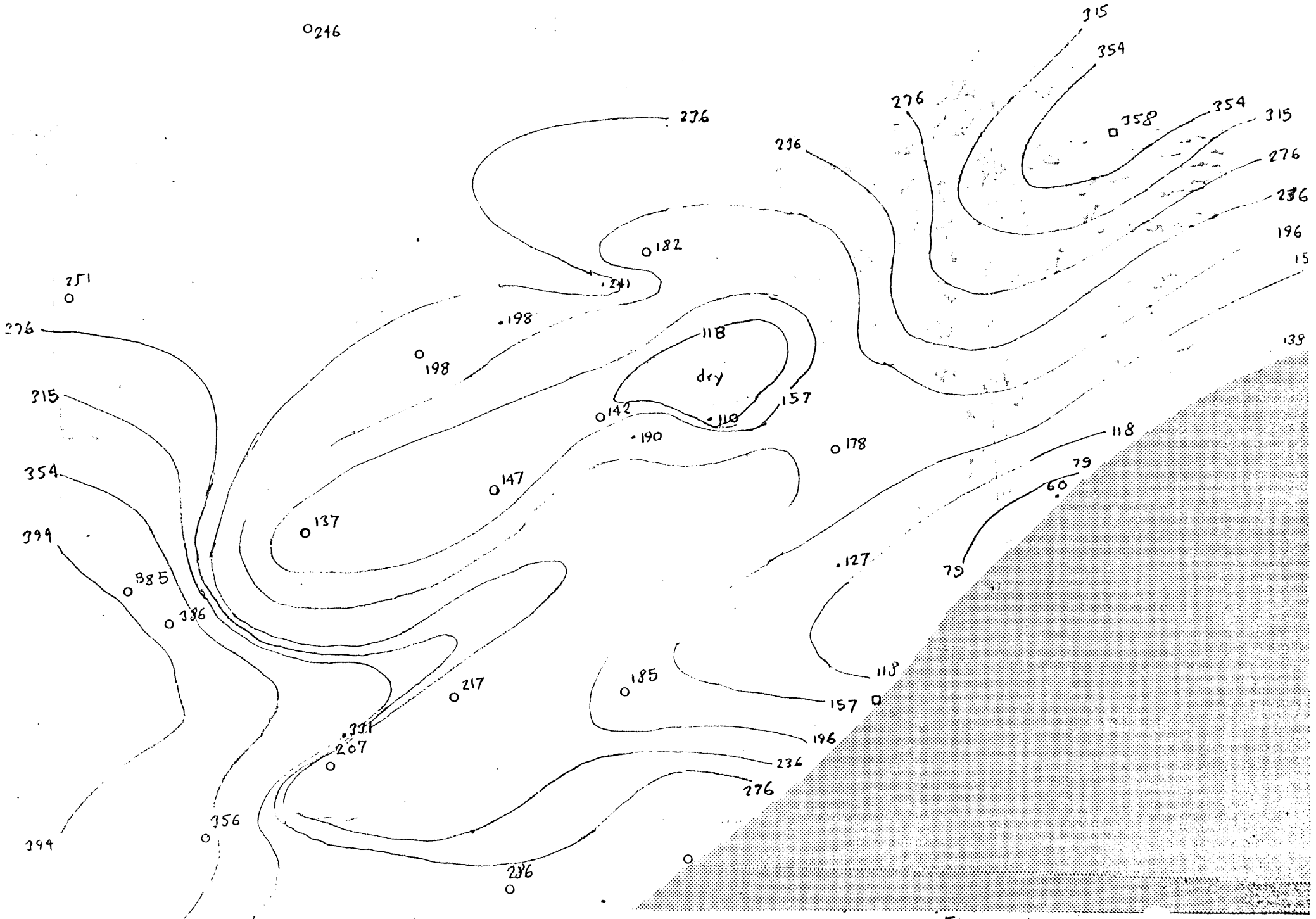


Figure 5d JULY 1976

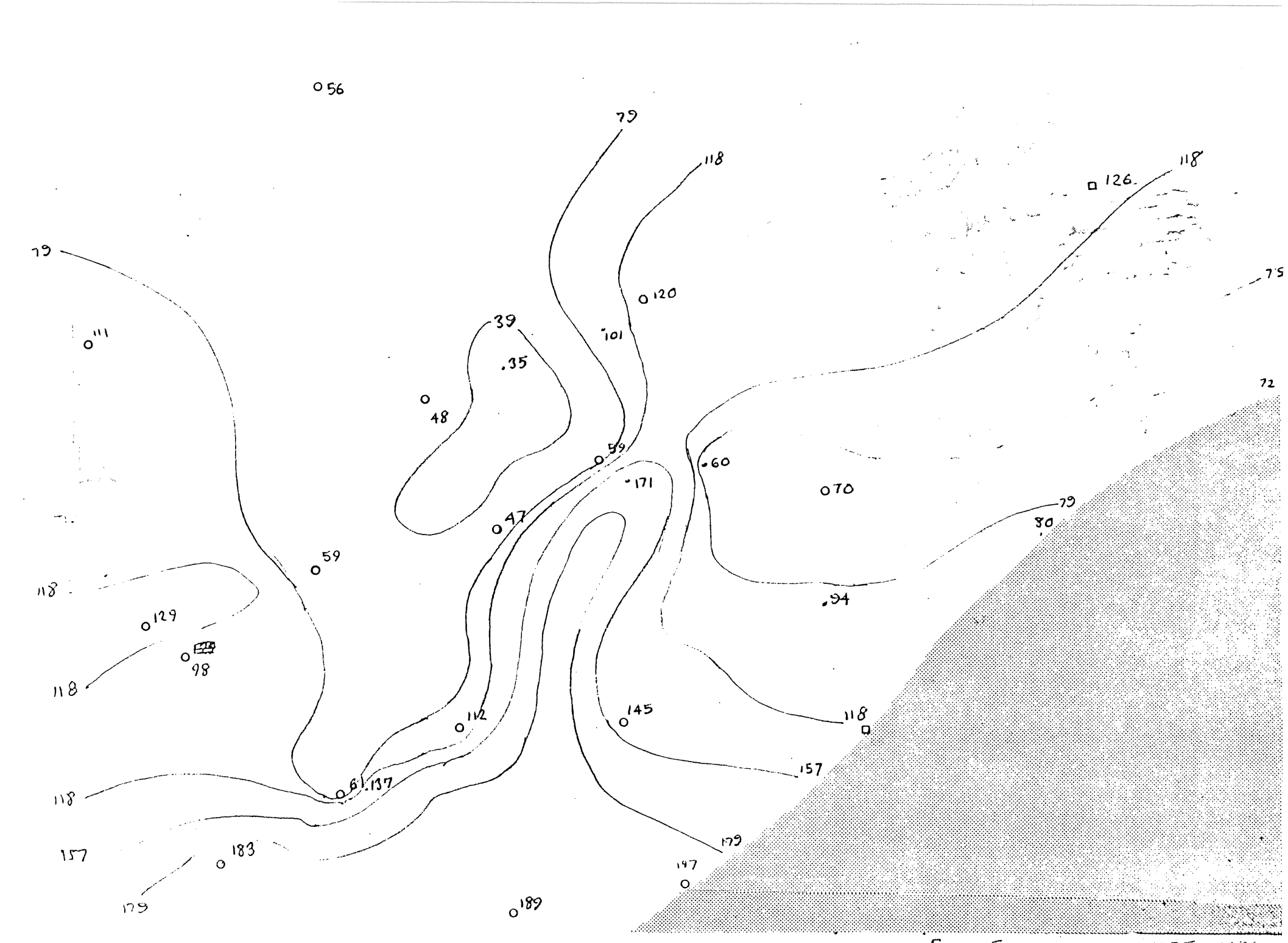


Figure 5e GUST 1976

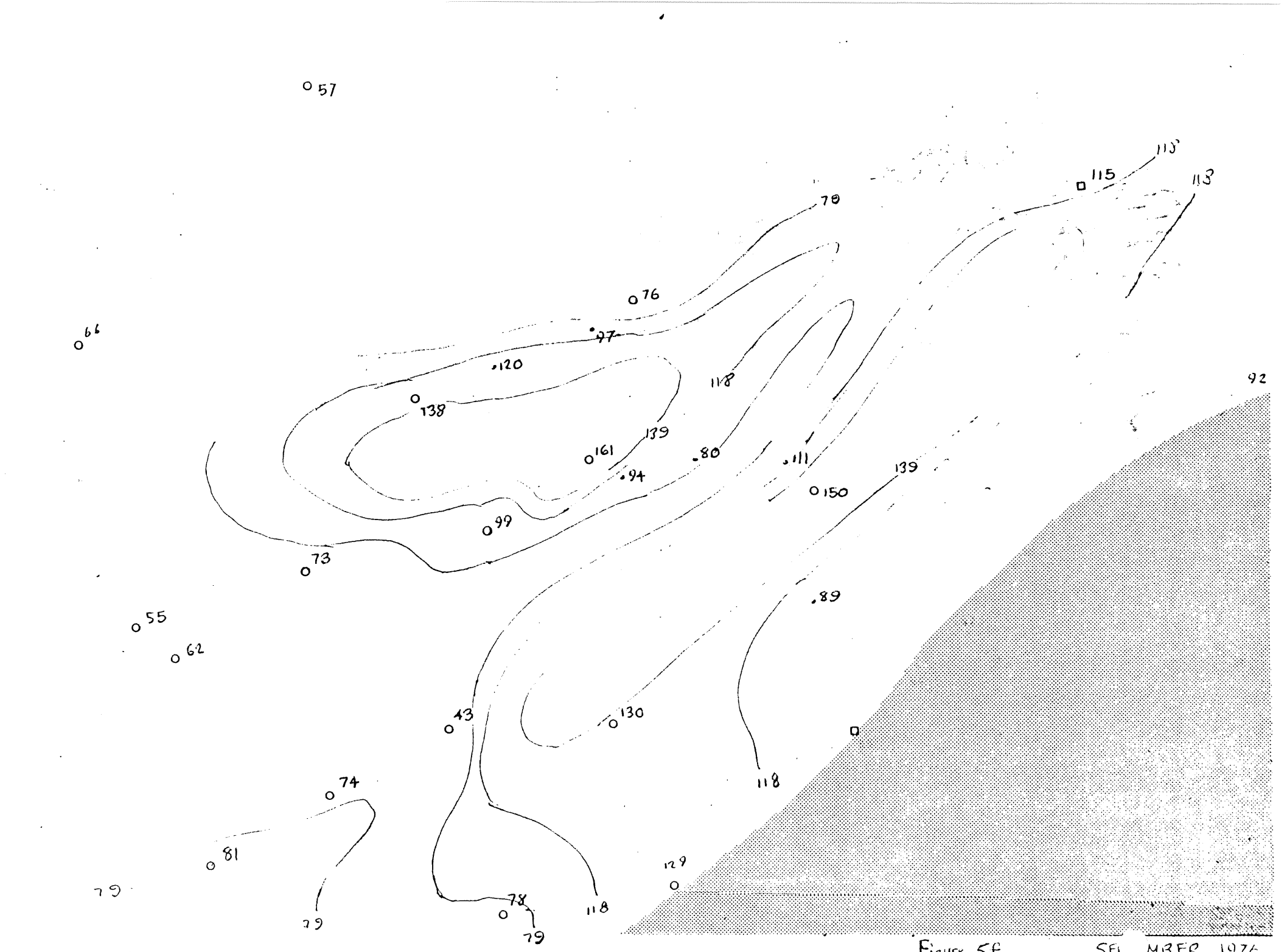


Figure 5f SEPTEMBER 1974

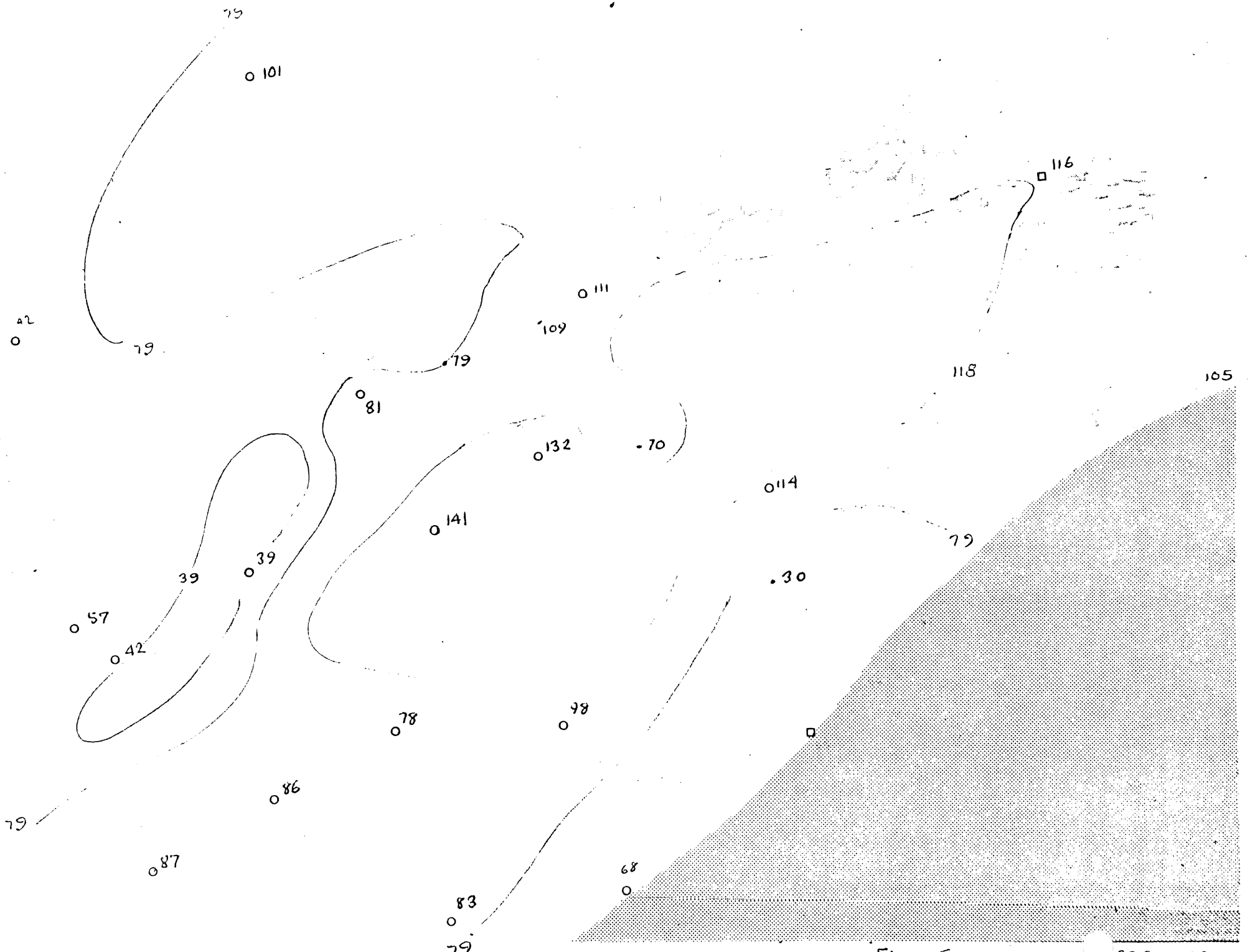


Figure 5g OCTOBER 1976

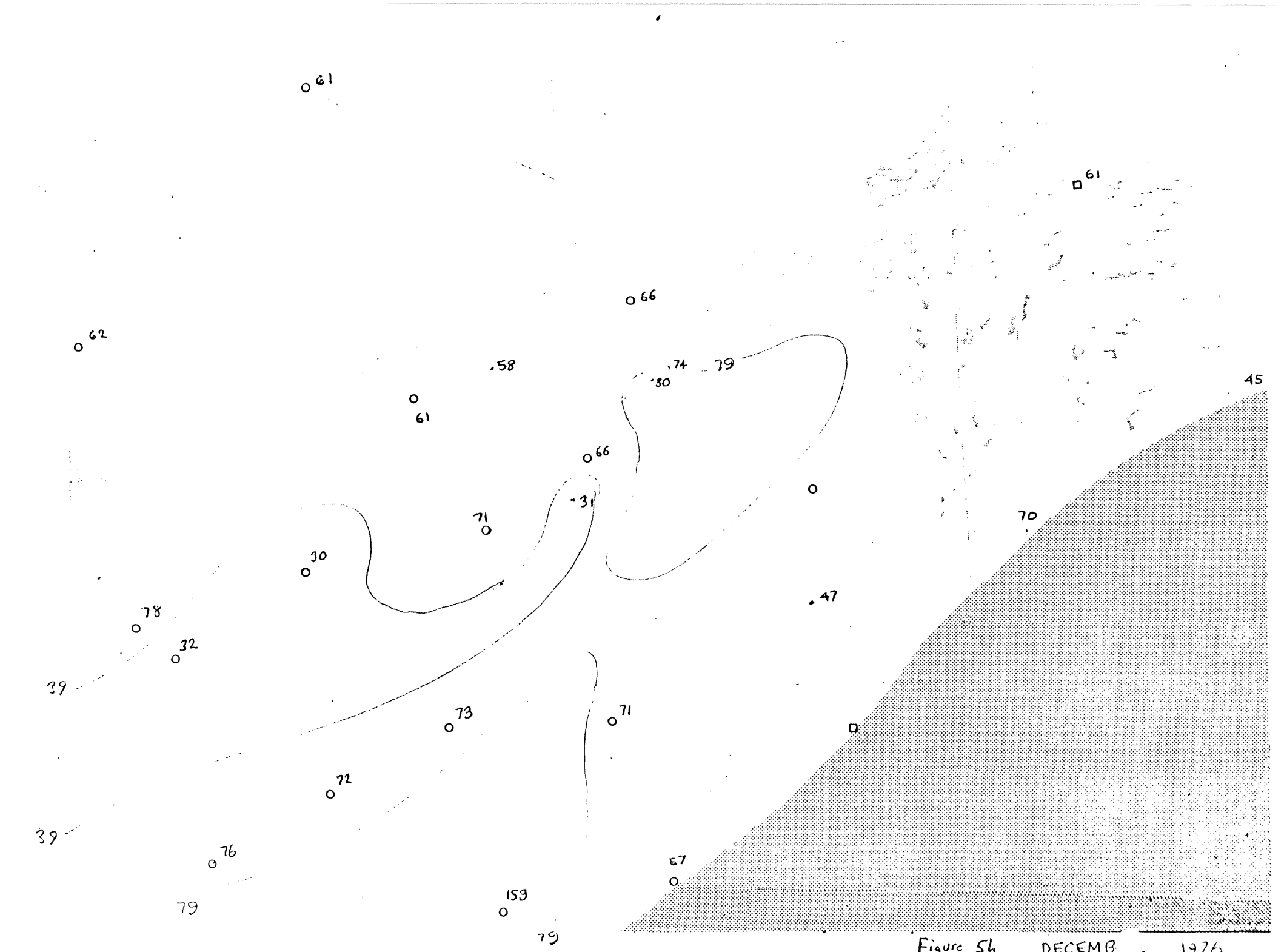


Figure 54 DECEMB . 1976

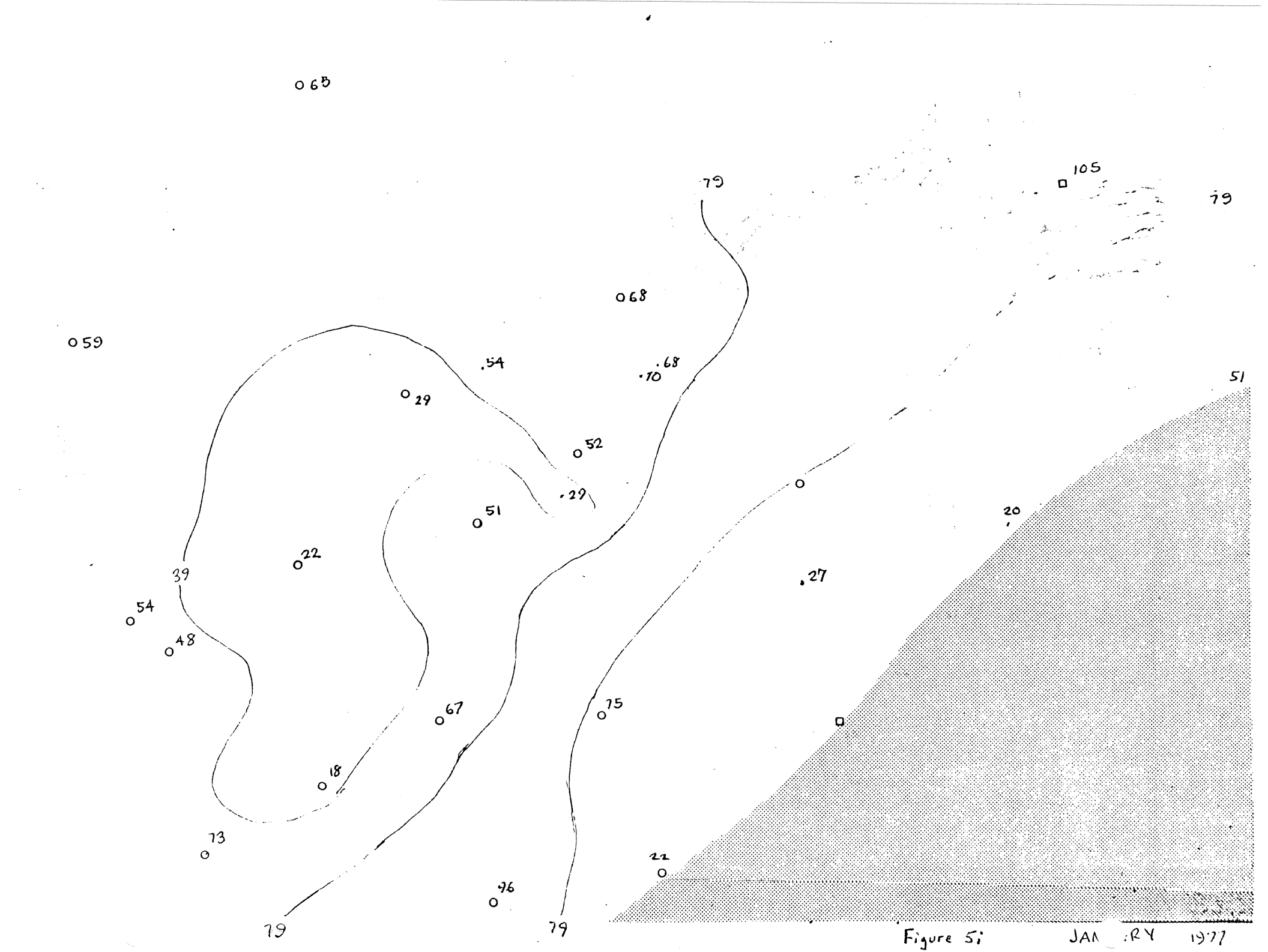


Figure 5: JANUARY 1977

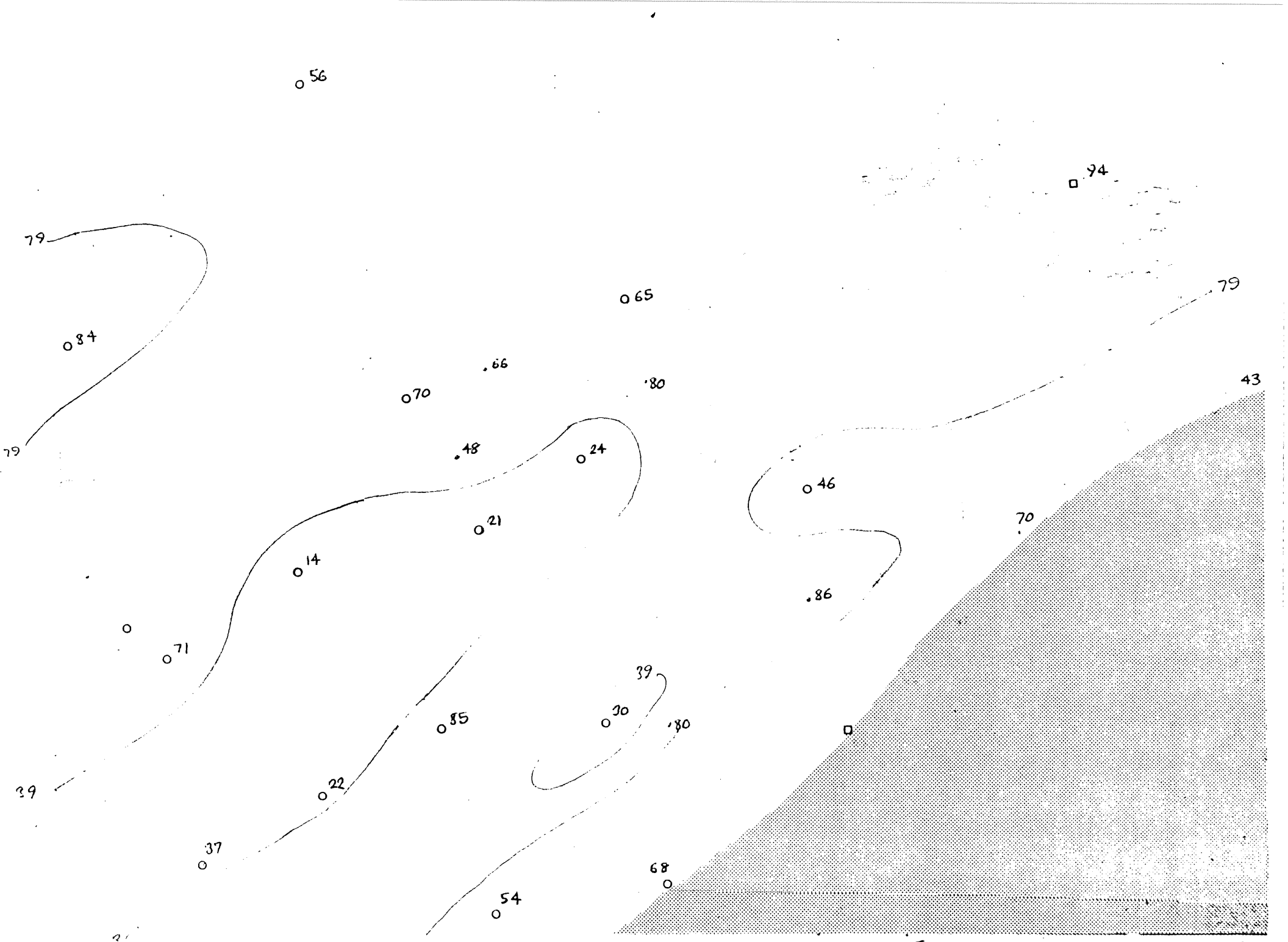


Figure 5j FEBRUARY 1977

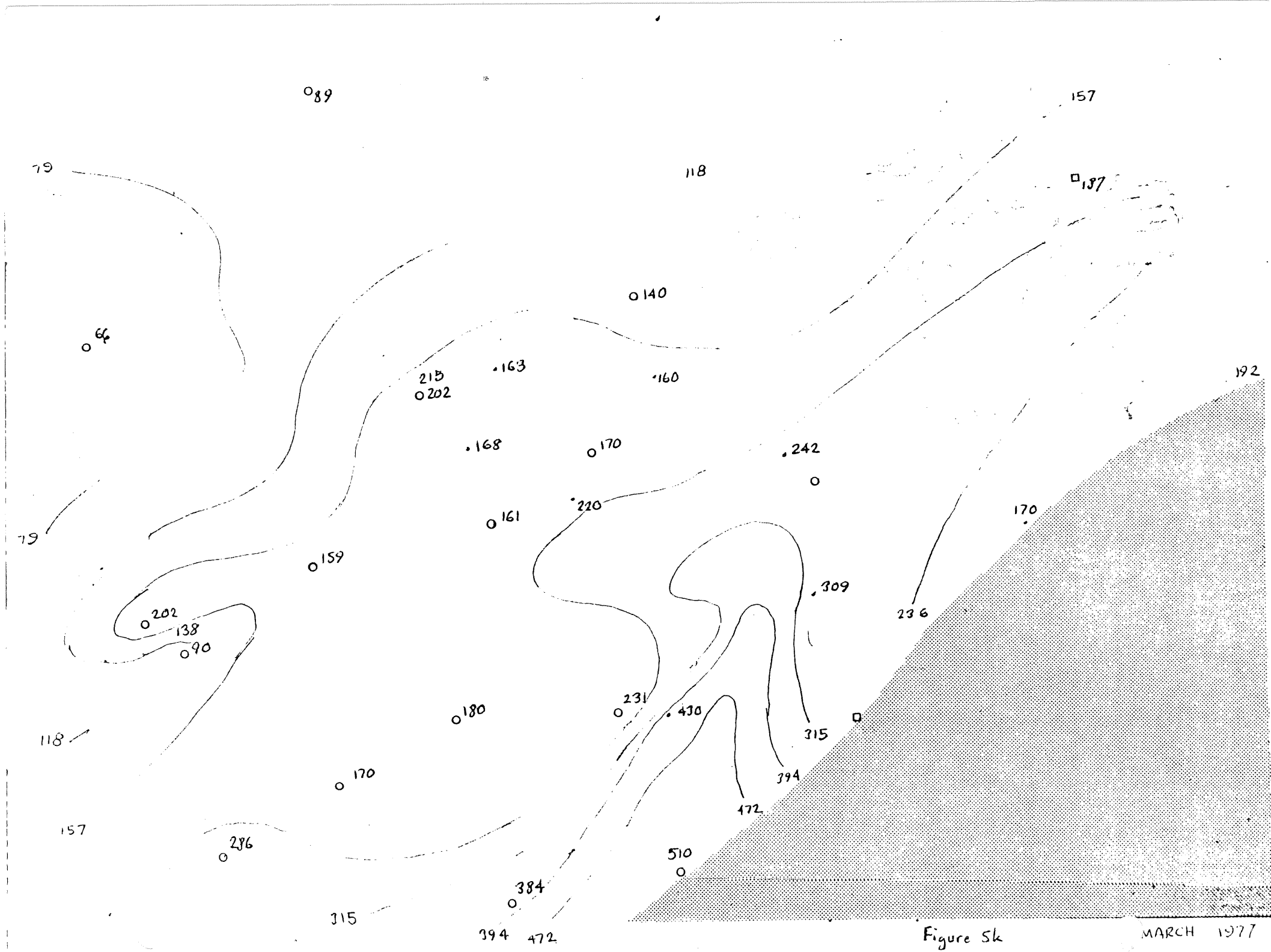


Figure 5k

MARCH 1977

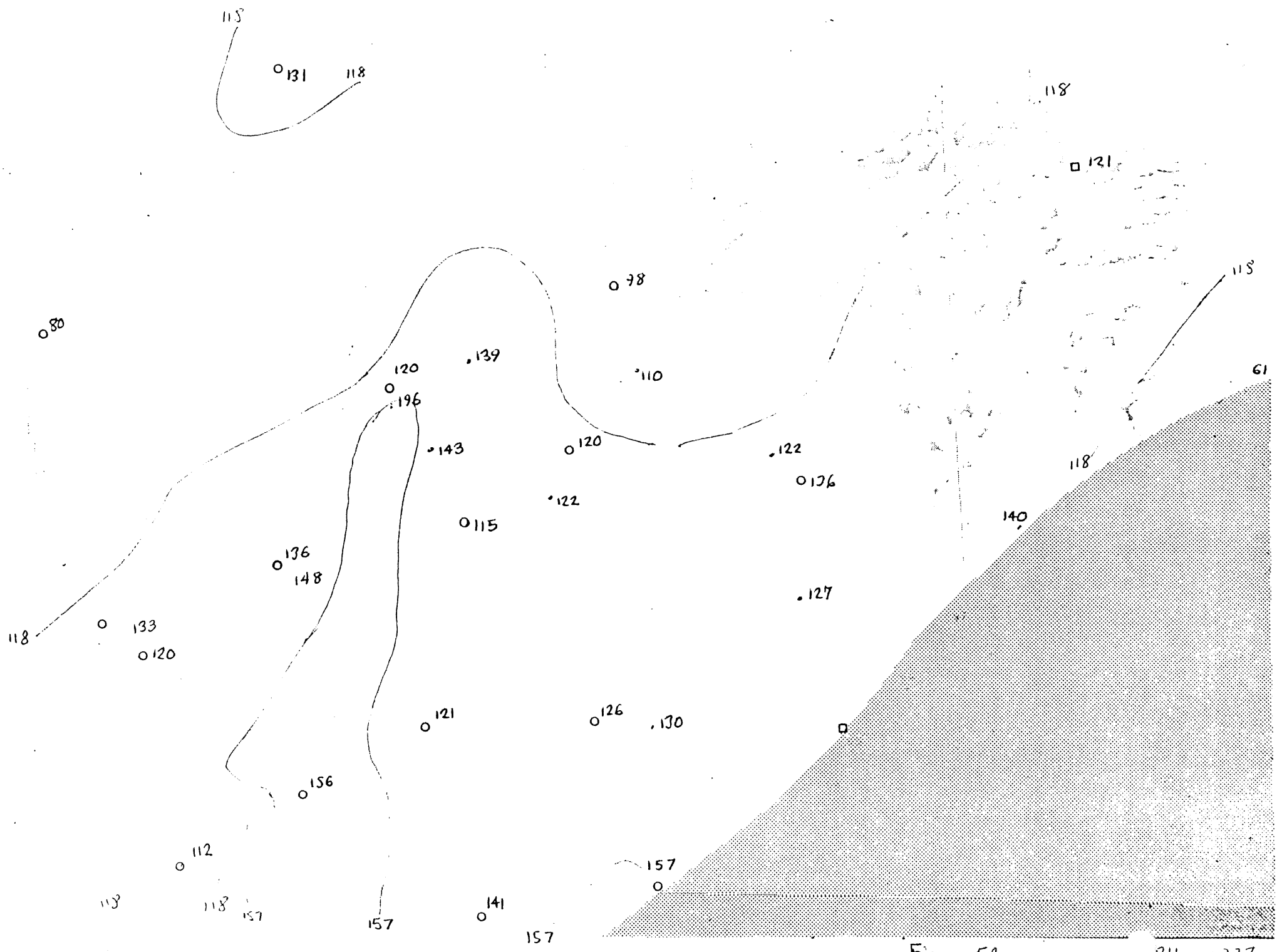


Figure 5L

RIL 1977

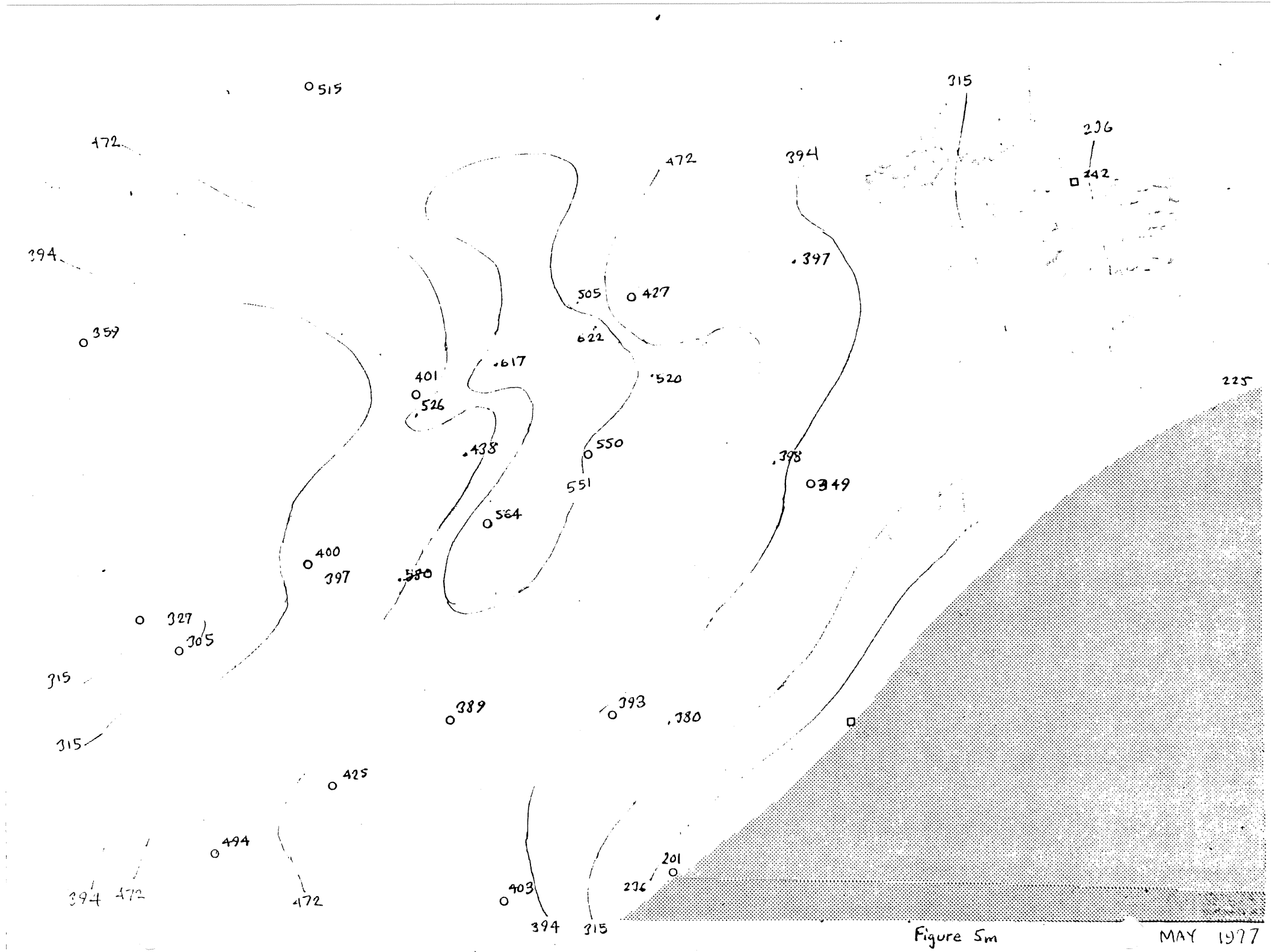


Figure 5m

MAY 1977

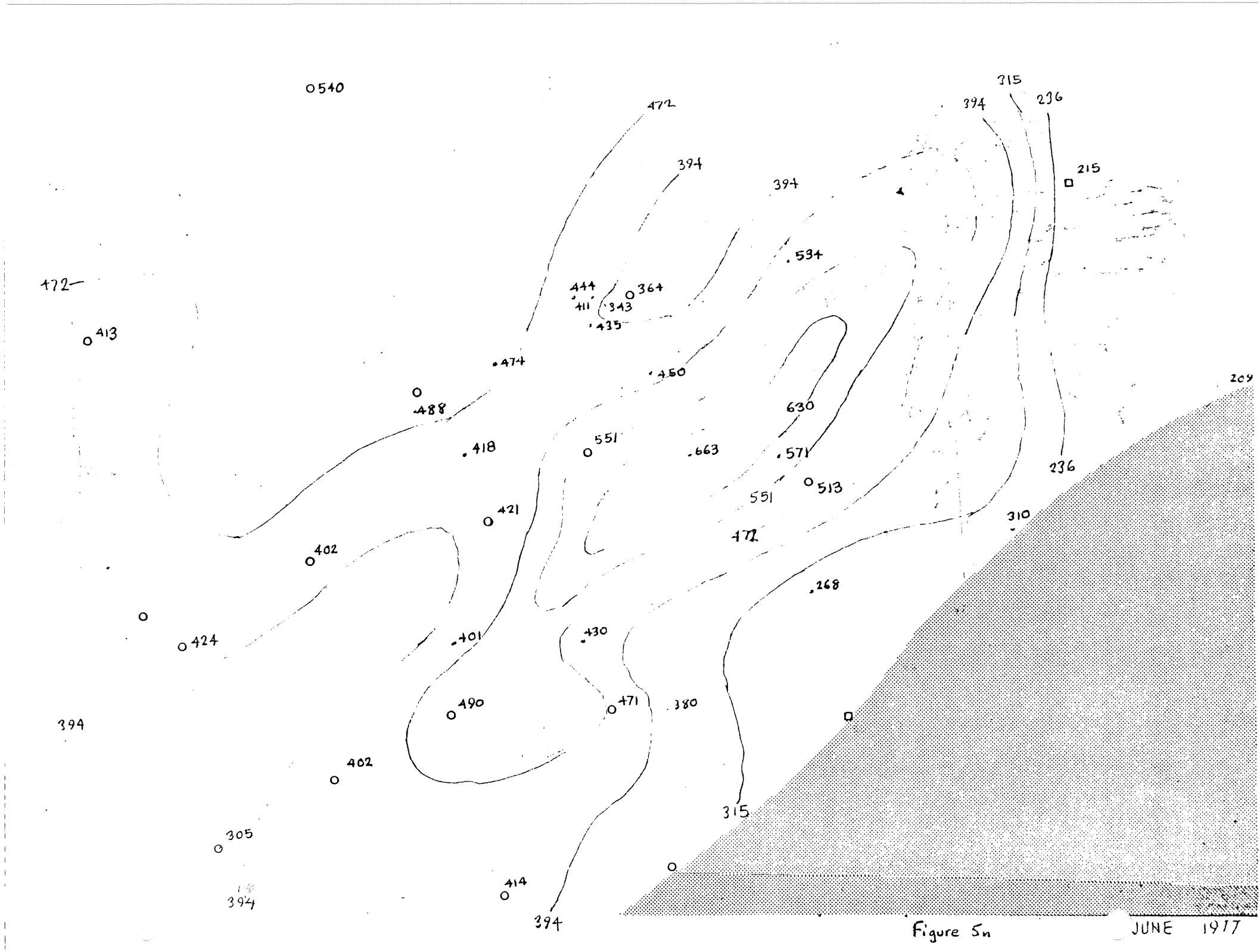


Figure 5n JUNE 1977

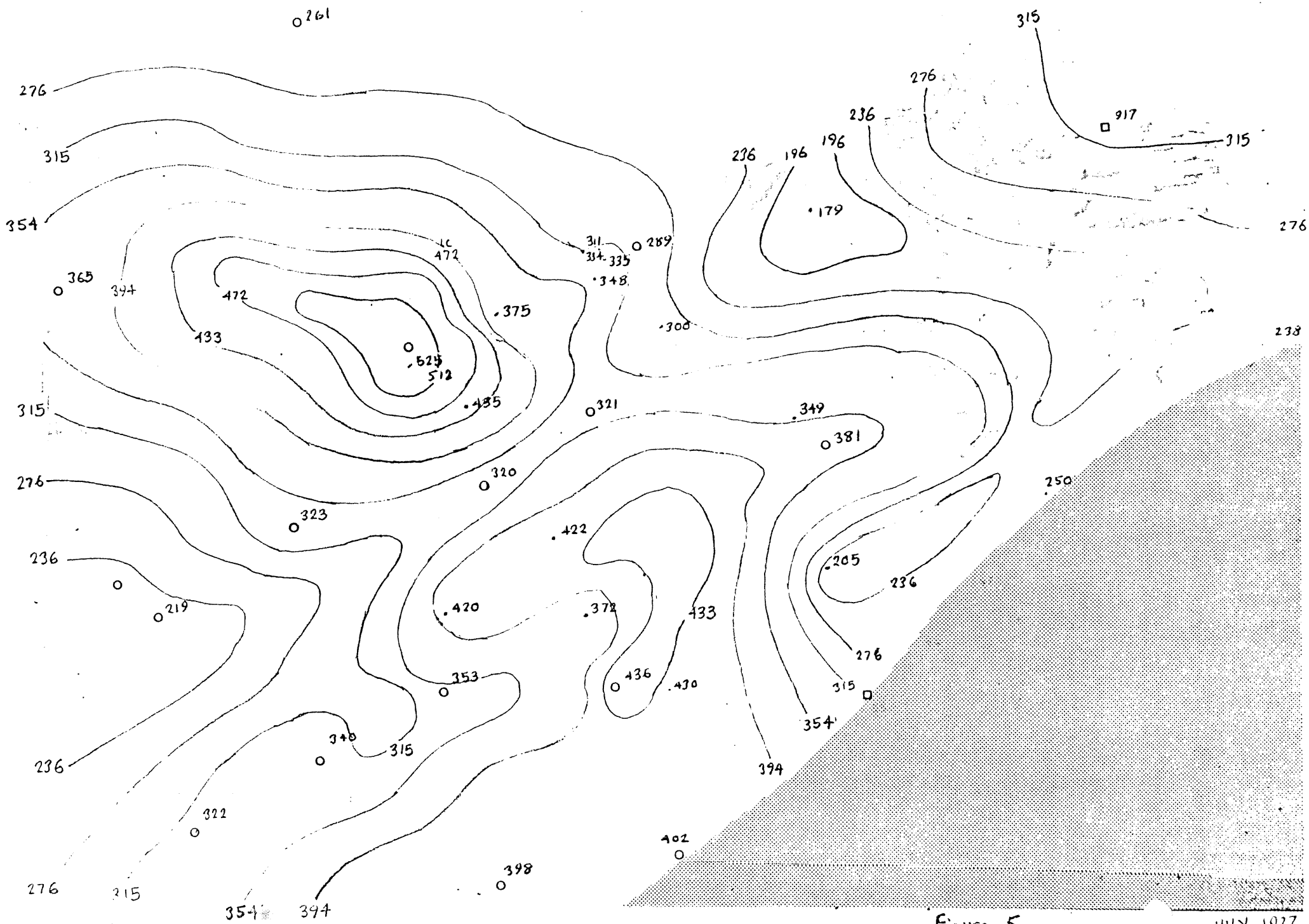


Figure 5a

JULY 1977

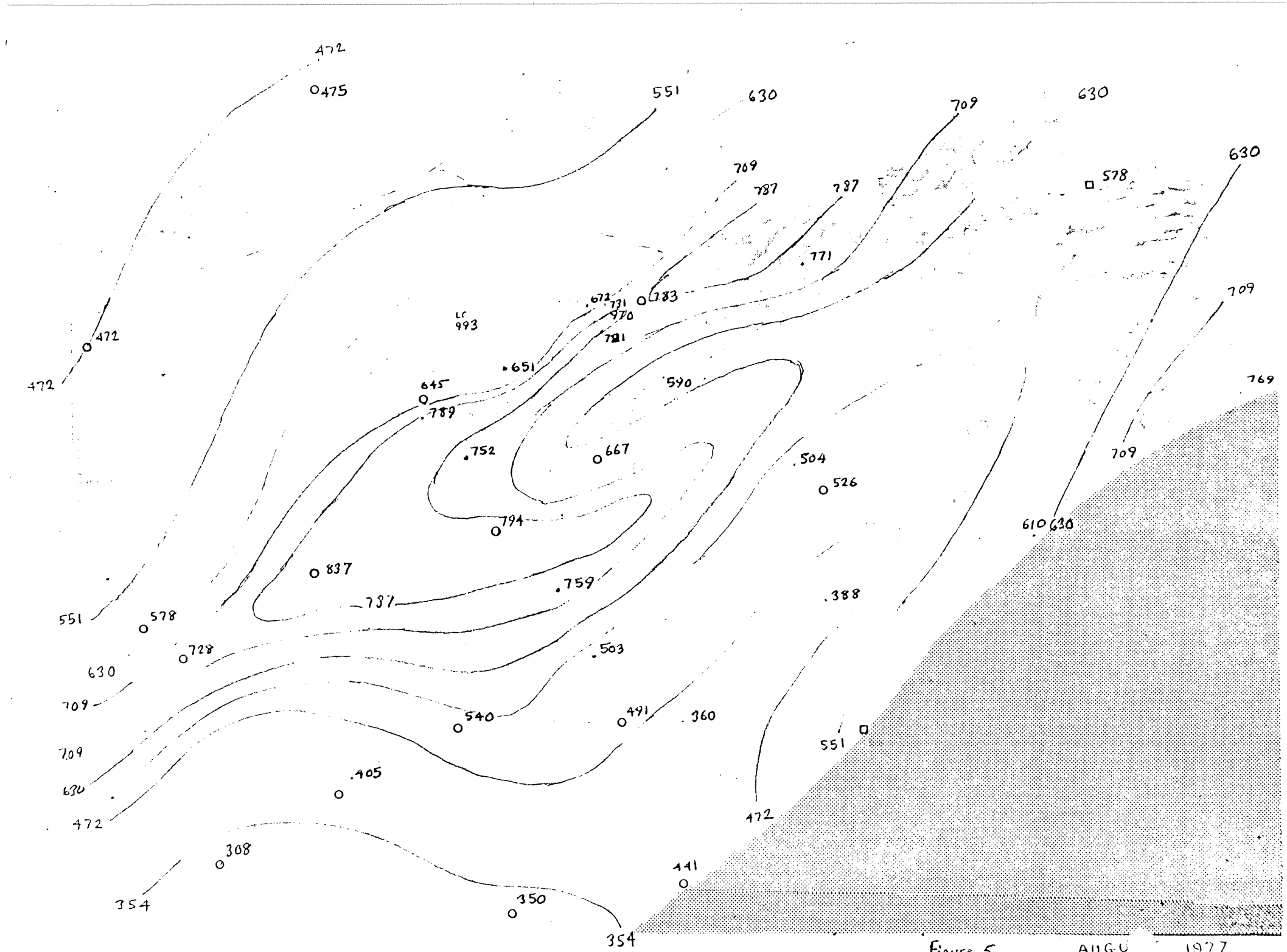


Figure 5p AUG 0 1977

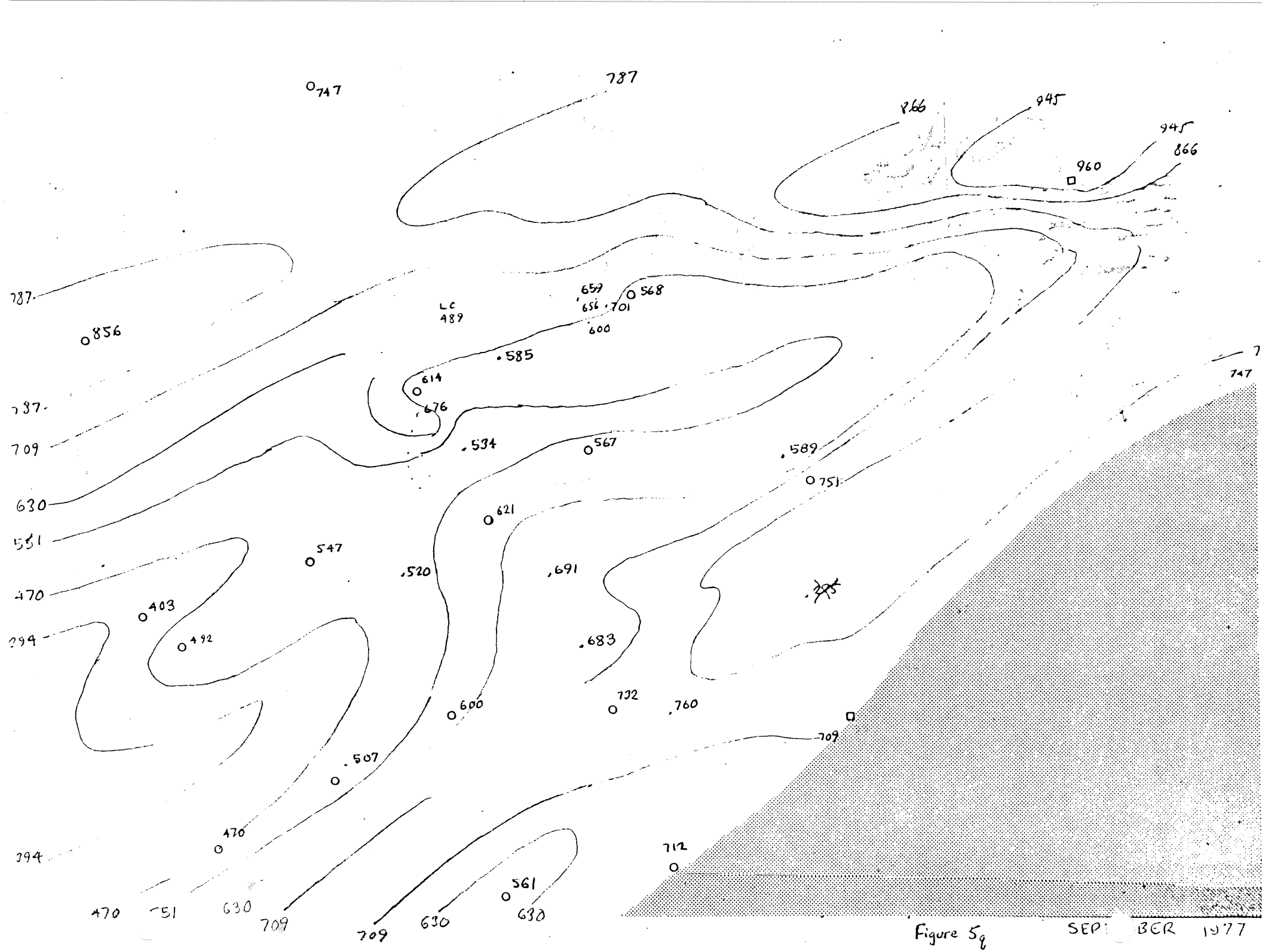


Figure 5g SEPTEMBER 1977

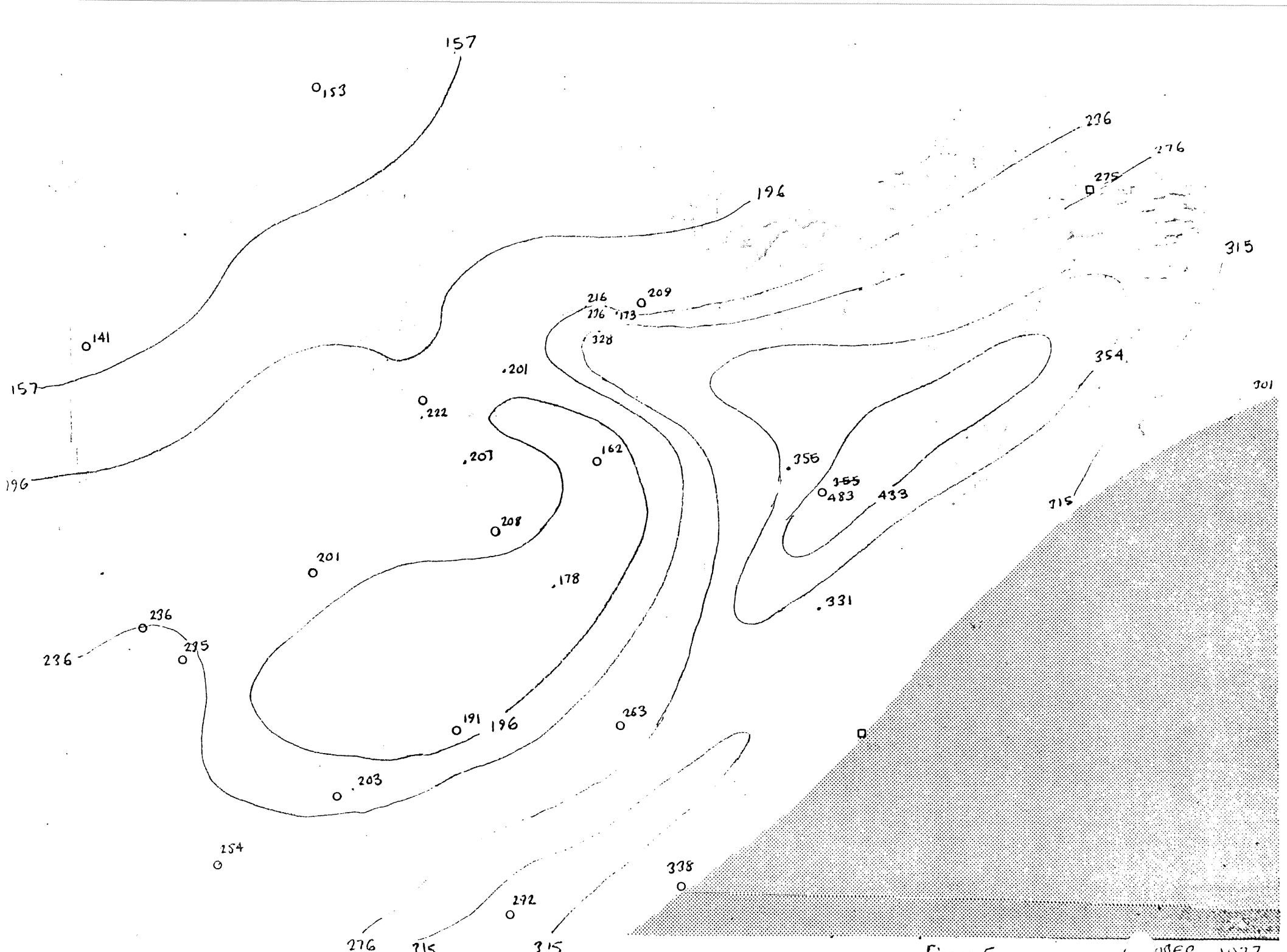


Figure 5r

OCTOBER 1977

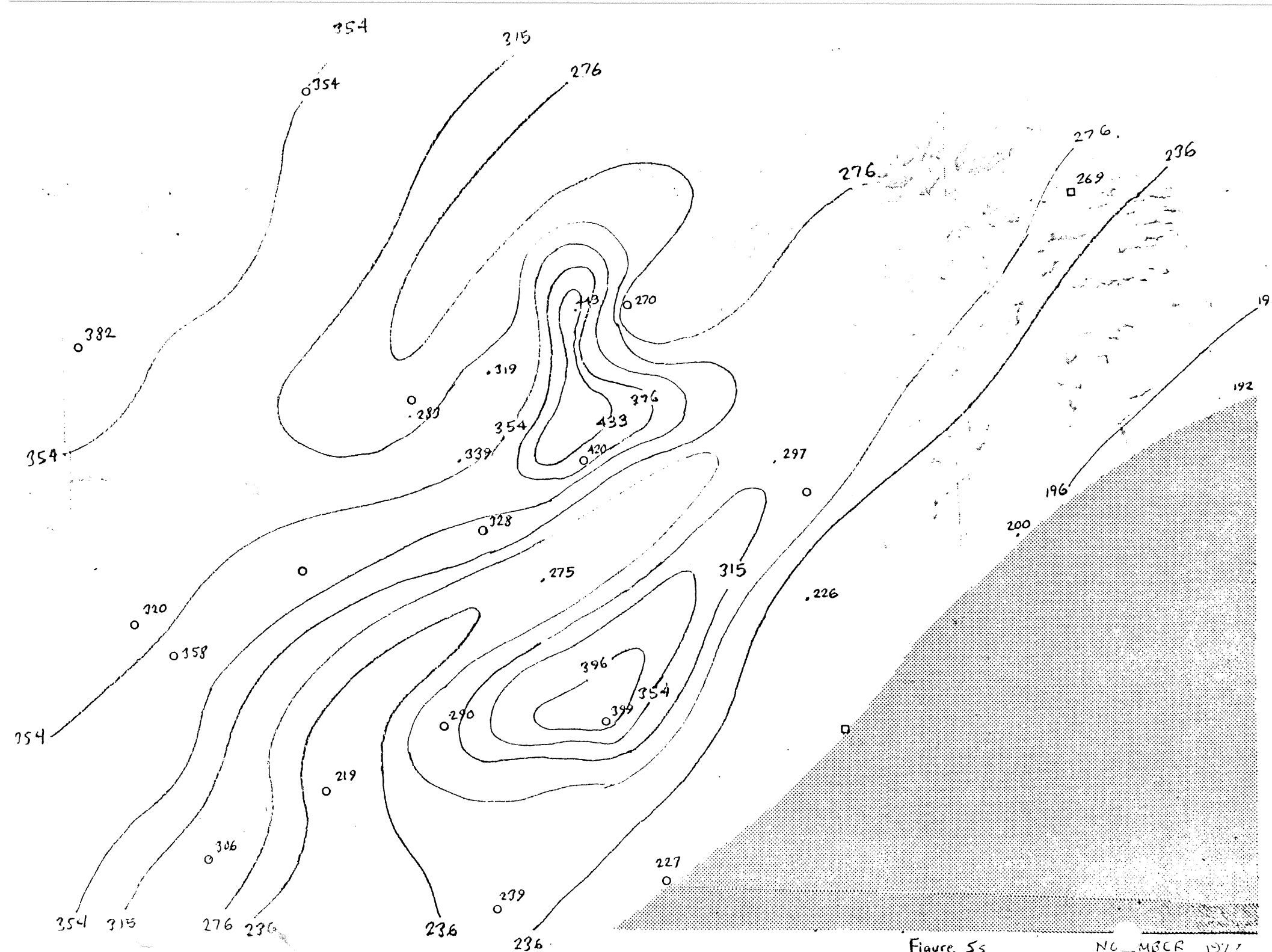


Figure 5s

NOVEMBER 1977

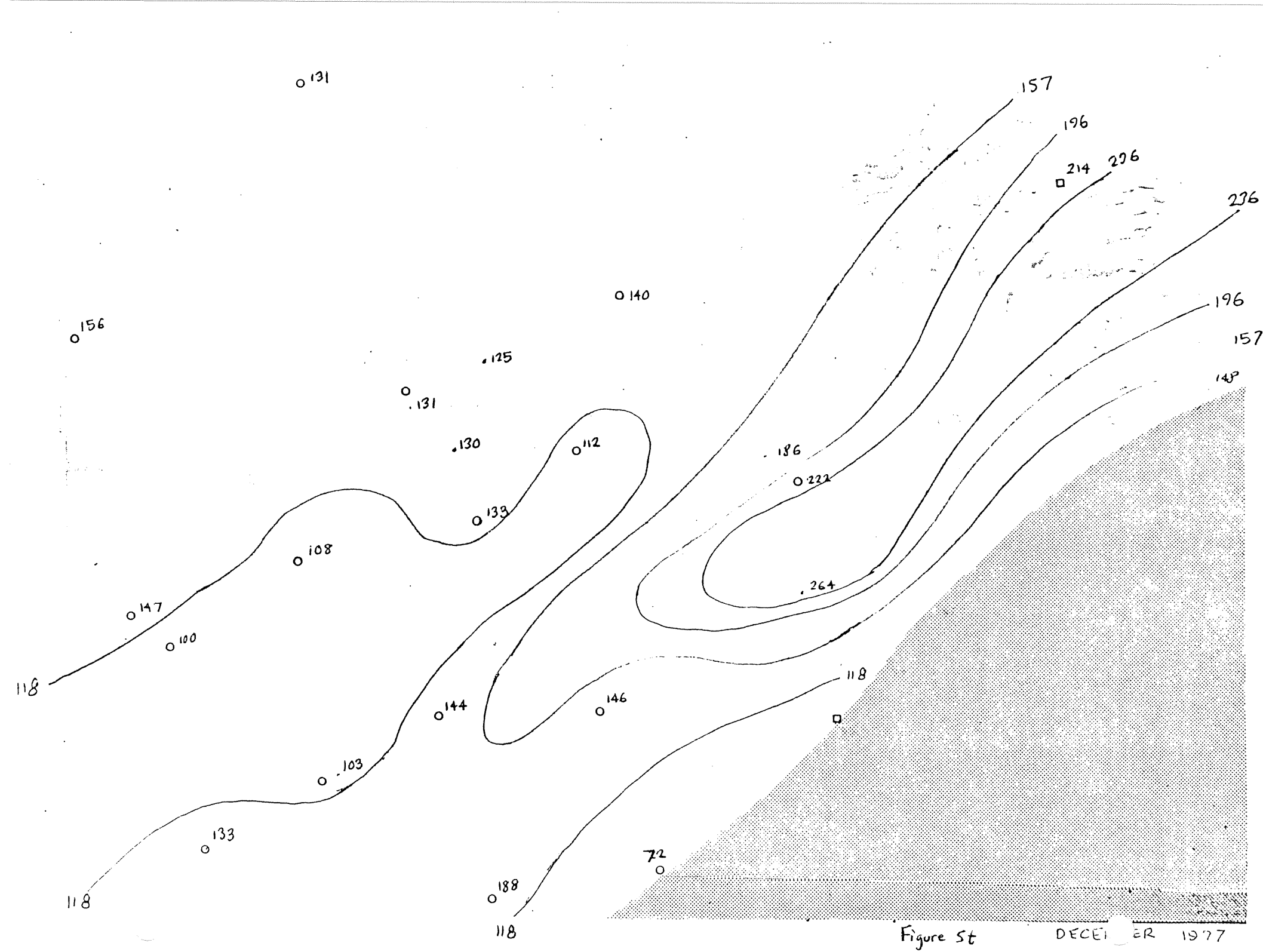


Figure 5t DECEMBER 1977

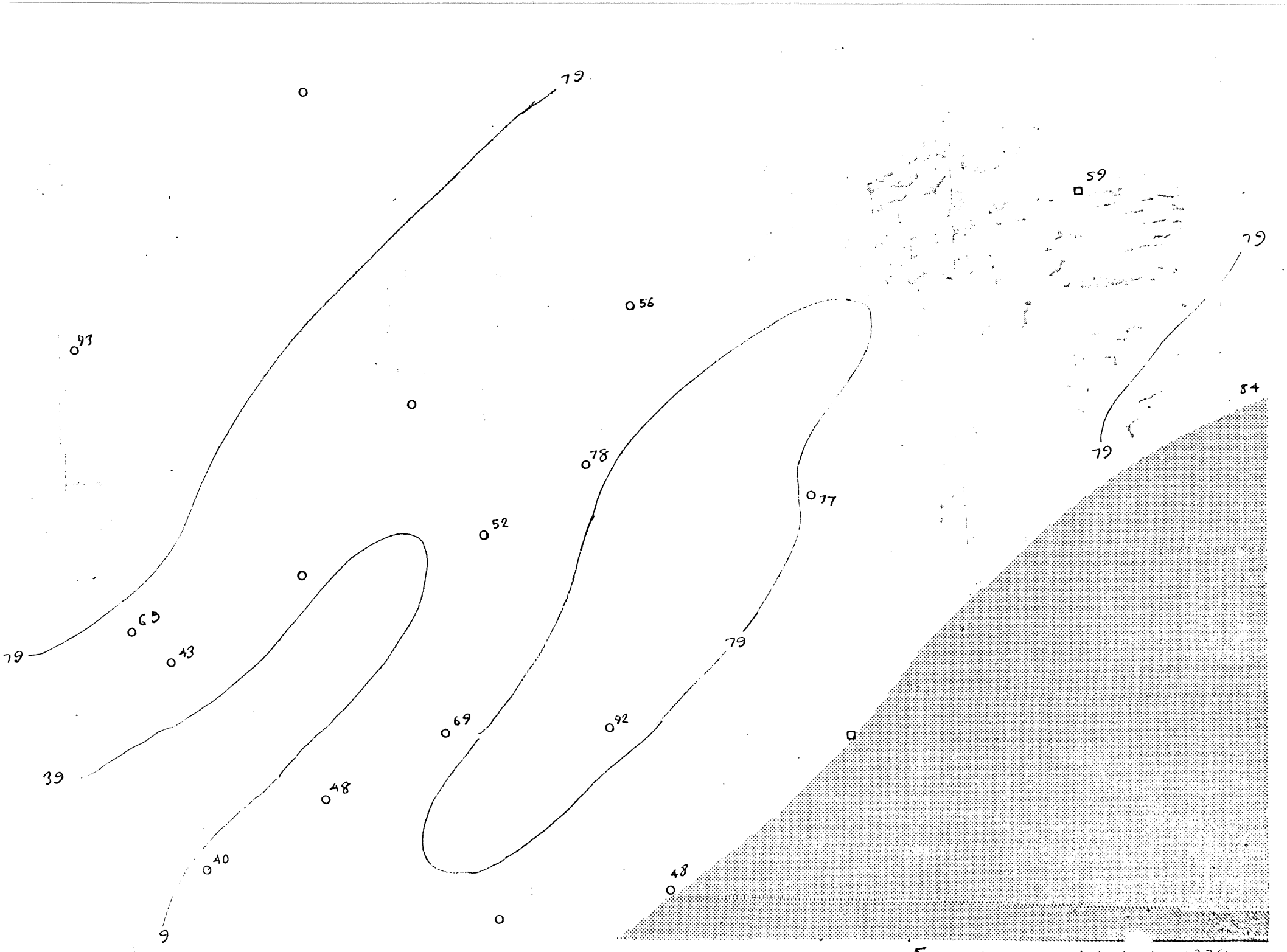


Figure 5a JANUA 1 1978

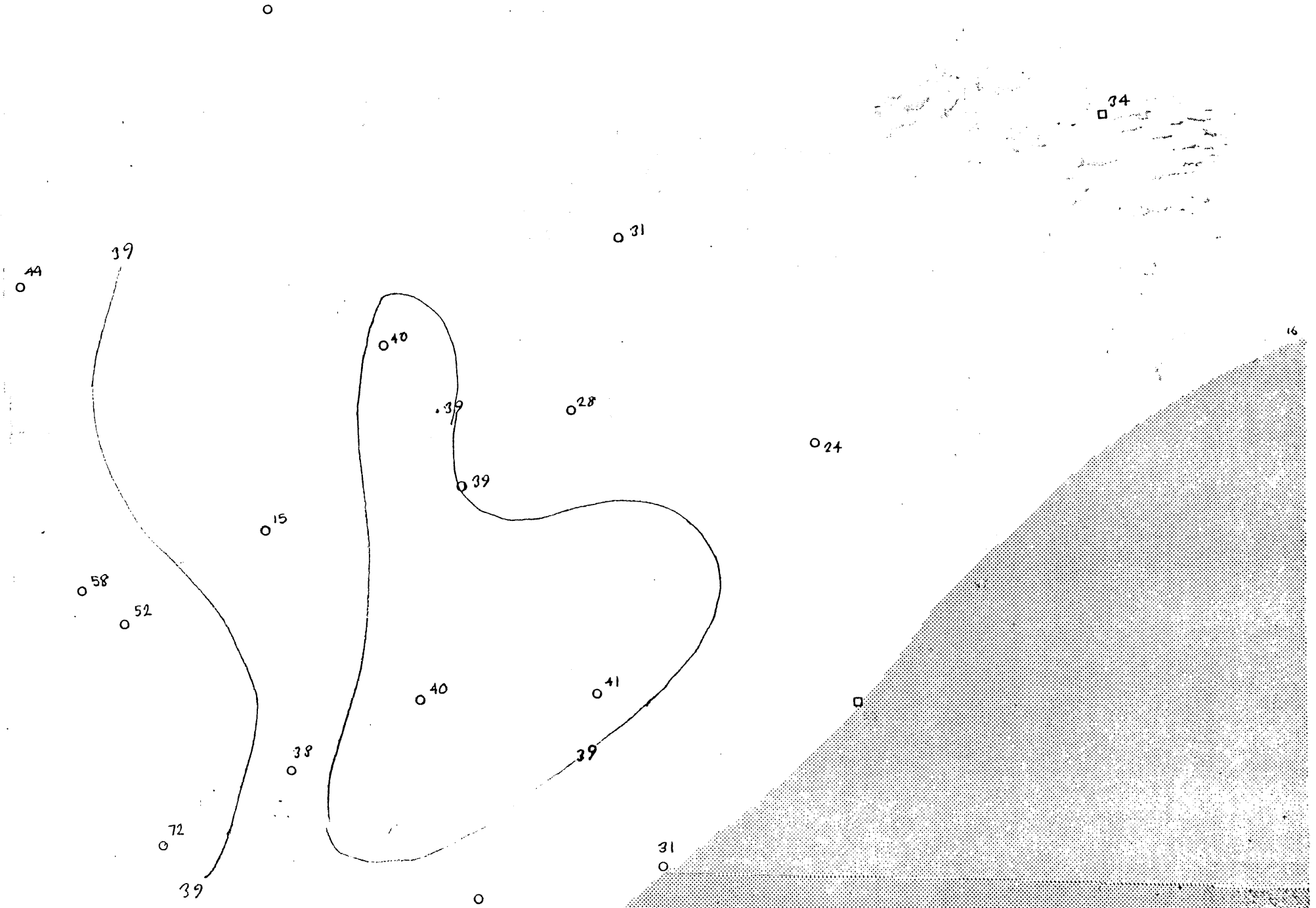


Figure 5v FEBRU Y 1978

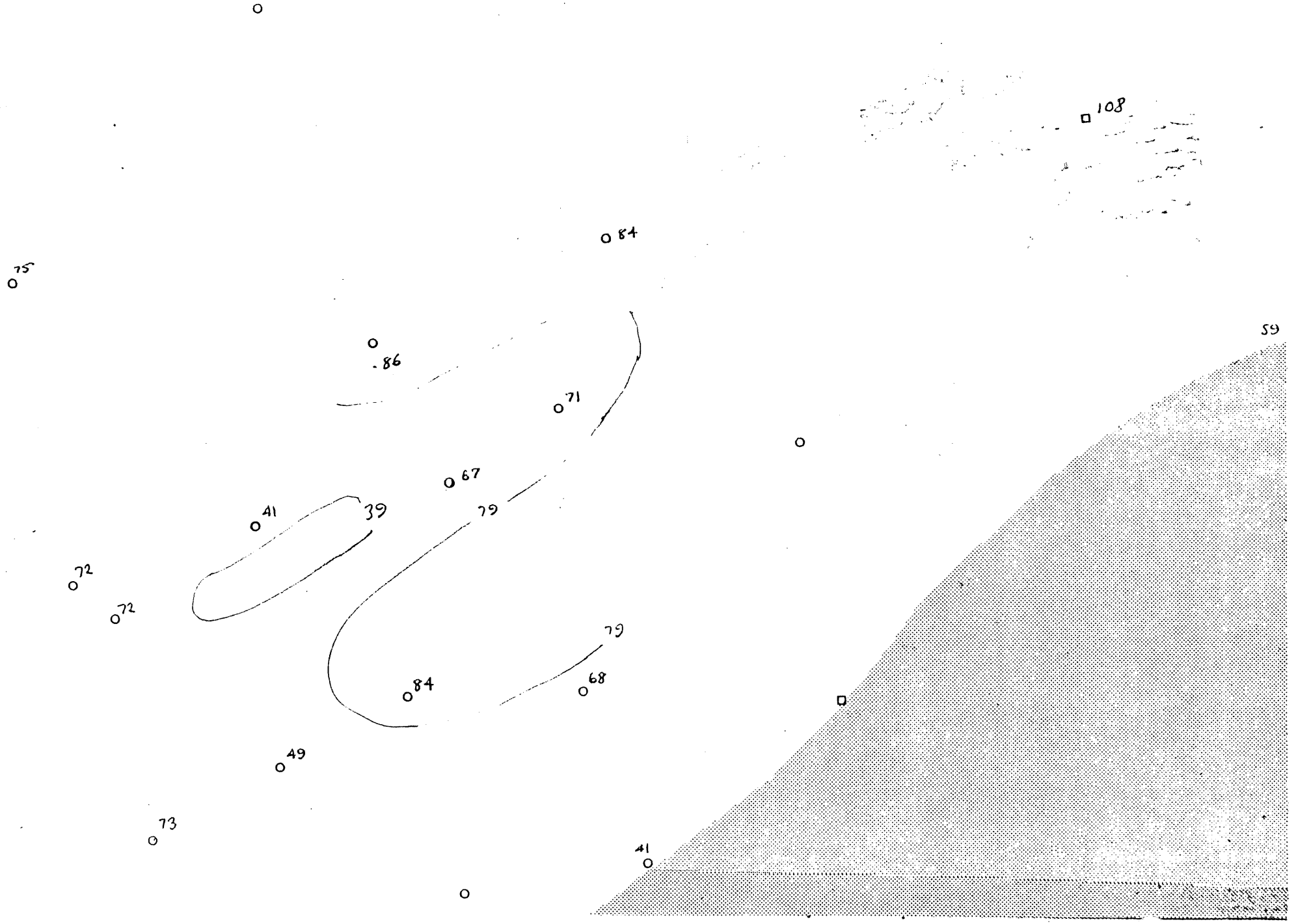


Figure 5w MARCH 1978

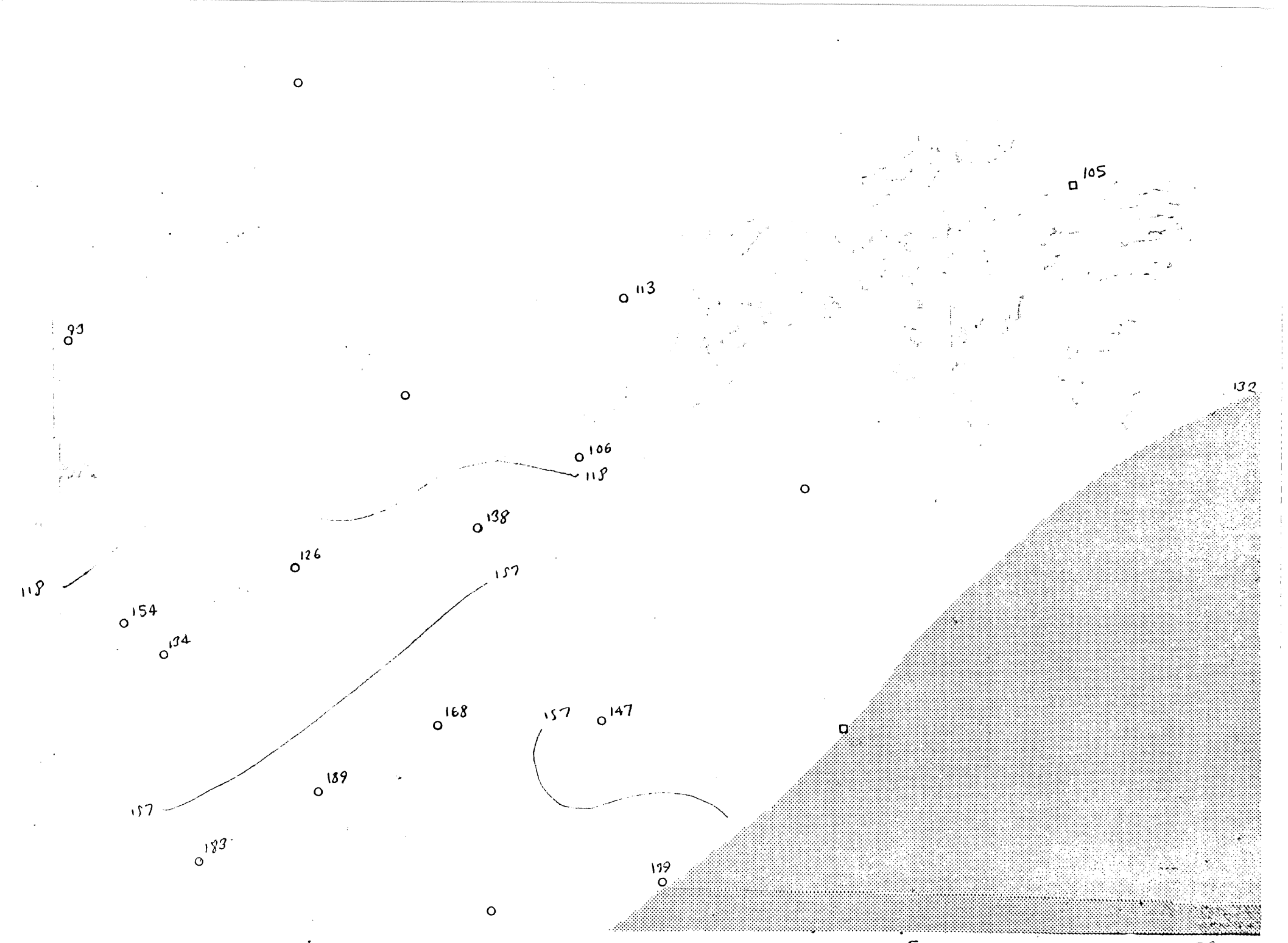


Figure 5x API 1978

Clearly, the table shows that the variability between the station with the most precipitation and that with the least is of a ratio of about 3 to 1 over the Study Area. This underscores the need for taking rainfall measurements at or near a Study site for almost every application.

Figure 6 gives the times each day of occurrence of precipitation at Hibbing. The chart has 365 segments, each divided into 4 parts. Each segment represents one day, and the lines creating far divisions in each segment represent 0600, 1200, and 1800 hours clock time. Snow occurrences are shaded dark, rain or drizzle are shaded light.

Figure 7 similarly shows thunderstorm occurrences at Hibbing in 1977.

4.2 PRECIPITATION EVENTS

In current meteorological practice, precipitation is measured daily at the same time every day, although the time of observation varies from station to station. However, precipitation occurs in association with eastward moving regions of general low atmospheric pressure which may have a transit time on the order of days. Thus, many observations of rainfall occur while it is still raining, and the total rainfall occurring during the storm in progress is cut into 24-hour segments. With different observation times at the various stations, daily rainfall totals may become very confusing to relate to storm totals.

Further, the eastward-moving regions of general low atmospheric pressure from various structures to them. They may contain warm fronts, cold fronts, mesoscale thunderstorm systems, vorticity maxima, and shower convergence systems induced by differential advection of air from different regions. Between these features, small regions of high pressure or descending air may cause precipitation to cease at times while the general low pressure system passes over.

The purpose of this section is several-fold. The main purpose is to identify the precipitation events that occurred during the main part of the Study, from June 1, 1976, to December 31, 1977, to establish what happened precipitation-wise.

Another purpose is to enable the reader to gain a deeper understanding of the precipitation regime in the Study Area. The general patterns remain the same from one year to the next, although the intensities of the precipitation systems may vary. Reading of this section should familiarize the reader with what "goes on" precipitation-wise. Yet another purpose is to enable users of the information to relate what may have happened to flora, fauna, leaching processes, etc. as a result of the precipitation patterns and intensities.

Finally, a purpose is to provide a guide that might be useful for any further studies. The section is arranged by months. Following a description of the total rainfall distribution for each month, each rain event is described as follows:

1) Intensity of the event. Whether an event is a minor, intermediate, major, or a very major event. A minor event is one in which very little precipitation fell--not enough to have much impact on most applications. An intermediate event is one which has substantial precipitation totals to impact at least numerous applications. A major event is one which has an impact on a great many applications, and generally requires at least one inch (2.54 cm) at one of the stations, or alternately, the better part of an inch at many stations. A very major event is one which features 2 or more inches of rain at several stations and/or nearly that much almost everywhere in the Study Area. The events are numbered in order, and the event intensity described after the event.

2) The type of rain event. The event types are described as follows:

T - basically thunderstorm-produced precipitation

S - basically convective showers not from thunderstorms

R - basically widespread general rains not from convective activity, in plain language, general rainstorms or general snowstorms.

In some cases, the events may be a combination of the above. In these cases, the event types are listed in the judgment of the author in order of their contribution to the rainfall total.

3) The days on which the event occurred.

4) A description of the event with the heavier totals and the lesser totals of the various stations reporting. In a few cases, values from some stations were not included because of inapplicability (such as event gages) or possible observer error. Nearly every precipitation occurrence in the Study Area during the period is included herein, including some observed on the radar which passed between the observing stations. There were a few instances of traces of rain reported that are not included. Some of these are likely due to observer error, while others are due to a few sprinkles from isolated clouds.

In reading this section, the reader may wish to consult the monthly precipitation maps, the daily precipitation records, and the radar echo track charts.

4.2.1 Event Descriptions

June 1976

This was a month of heavy rains, with over 8 inches along the high ground from Greenwood Lake northeastward and from Hibbing to southwest of Ely. A drier

region, 5-6 inches extended from Cotton to Babbitt and along the shore of Lake Superior. The heavy rains were associated with frequent frontal passages from 8 June to 17 June and lingering frontal systems from 25 June to 29 June.

1) Major T, 7-8 June, afternoon, nighttime, the thundershowers on 7-8 June in vicinity of a Pacific cold front passing over after sunrise on 8 June. Heavier system totals included Babbitt 1.71, Virginia 1.68, Isabella Ranger Station 1.38, Winton 1.2; only .09 at Grand Marais.

2) Intermediate T, 9-10 June. Afternoon, nighttime thundershowers 9-10 June attending front passing on evening of 9 June. Heavier totals Winton .80, Hibbing .61, Hoyt Lakes .60; least Isabella Ranger Station .13.

3) Minor T, 10 June. Some light showers late on 10 June reported at Isabella Ranger Station .14, Ely USFSC .13, Babbitt .03, Crane Lake .02.

4) Major T, 12 June. Thunderstorm activity ahead of warm front on afternoon of 12 June and night of 12-13 June. Heavier system totals Isabella Ranger Station 1.33, Crane Lake 1.26, Eagles Nest 1.23, Meadowlands 1.20, Hoyt Lakes 1.16, Grand Marais 1.10; least .52 at Virginia.

5) Major T, 14-15 June. Nocturnal thunderstorms night of 14-15 June in northwesterly flow. Totals added to by rain, drizzle associated with nearby occlusion on 15 June. Heavier totals Meadowlands 2.13, Isabella Range Station 2.07, Grand Marais 2.04, Babbitt 1.54, Cotton 1.33, Winton 1.16, Brimson 1.01; least .11 at Eagles Nest, only .58 at Hoyt Lakes.

6) Major T, 17 June. Showers broke out in southerly flow on wee hours of 17 June, with occasional thunderstorms all day and into evening of 17 June, continuing to a bit after midnight. Heavier totals, Brimson 2.04, Hibbing City

1.88, Isabella Range Station 1.61, Crane Lake 1.45, Ely USFSC 1.42, Winton 1.38, Eagles Nest 1.36; least .56 at Cotton, Finland.

7) Minor S, 18 June. A few light showers with cloudy skies on afternoon of 18 June. No totals over .04.

8) Minor S, 19 June. A few light showers on afternoon. Most .20 at Stony River, none most places.

9) Major R, 24-25 June. Occlusion passage followed by cold front passage, brought heavy, steady rain from late on 24 June to late afternoon of 25 June. Storm totals, Whiteface 2.21, Hoyt Lakes 2.09, Virginia 1.90, Crane Lake 1.76, Meadowlands 1.60, Brimson 1.57, Cotton 1.52, Ely USFSC 1.42, Eagles Nest 1.30, Winton 1.22, Stony River 1.10, Isabella Ranger Station 1.04; least Babbitt .59.

10) Minor T, 26 June. Nocturnal thunderstorms late on 26 June as cold front returned. Heavier amounts, Meadowlands .62, Virginia .45, Crane Lake .42; none at Isabella Ranger Station; only a trace at Grand Marais.

11) Minor T, 27-28 June. Nocturnal thunderstorm; heaviest totals, Crane Lake .35, Winton .34, Ely USFSC .28, Eagles Nest .24; none at Meadowlands, Brimson, only a trace at Babbitt.

12) Minor S, 28 June. A few showers after nocturnal storms of 27-28 June brought small amounts .10 or less.

13) Major T, 29 June. Thunderstorms on 29 June. Heaviest totals Virginia 1.23, Meadowlands .66, Cotton .49, Whiteface .41, Isabella Range Station .39; least .06 at Finland.

July 1976

A very dry month, the beginning of a long drought. There was a center of dryness between Birch Lake and Stony River, and general dryness west of a line from Snowbank Lake to Tofte to central St. Louis County.

1) Intermediate T, 6-7 July, evening thundershowers on 6 July behind Pacific fron, with additional minor amounts on morning of 7 July ahead of frontal passage. Heaviest totals, Crane Lake .76, Tower 3S .69, Ely USFSC .67, Eagles Nest .60; least .07 at Whiteface, Finland, only .10 at Stony River.

2) Minor T, 7-8 July. Nighttime thunderstorm on; precipitation at only a few stations, Ely USFSC .38, Gunflint Lake .08, Grand Marais .01, Hibbing a trace, rest none.

3) Minor T, 8-9 July. Thunderstorm on 8-9 July. Heaviest amounts, Cotton .64, Tower .55; least .09 at Crane Lake.

4) Minor T, 13 July. Thunderstorms broke on afternoon, is connection with occlusion outbreak. Heavier totals, Hibbing City .52, Hibbing Airport .52, Gunflint Lake .48, Cotton .47; none reported at Eagles Nest, Tower 3S, Virginia, and Crane Lake.

5) Minor S, 15 July. Showers fell on wee hours of 15 July ahead of cold front and during that day from stratocumulus over east. Heaviest totals, .13 at Isabella Ranger Station, Meadowlands, Hibbing Airport; .12 at Hoyt Lakes, Gunflint Lake; none reported at Babbitt, only a trace at other stations.

6) Major T, 19 July. Heaviest rain of month in connection with cold front; arrival on evening of 19 July. Heavier totals, Cotton City 1.42, Cotton 1.38,

Meadowlands 1.18; least .18 at Isabella Ranger Station, only .20 at Stony River and Grand Marais, and only .26 at Hoyt Lakes and Babbitt.

7) Intermediate T, 22 July. Scattered thunderstorms with cold front on evening. Heaviest totals, Meadowlands 1.49, Cotton .48, Hibbing City .31, Virginia .29; least a trace at Eagles Nest, Babbitt, and Tower 3S.

8) Major T, 25-26 July. Thunderstorms all day on 25 July and into wee hours of 26 July as Pacific warm front moved in on 25 July, followed by cold front on wee hours of 26 July. Heaviest totals, Hibbing City 1.29, Hibbing Airport 1.23, Isabella Ranger Station .68; least .08 at Cotton, only .18 at Babbitt and Meadowlands, and .19 at Ely USFSC.

9) Minor T, 28 July. Morning thunderstorm; heaviest total, Hibbing City .29, Hibbing Airport .23, Finland .15, Babbitt .14; none or a trace at some stations.

10) Minor T, 29-30 July. Scattered afternoon and evening showers on 29 July. Heaviest totals, Gunflint Lake .47, Meadowlands .26, Crane Lake .35; none or a trace most stations.

August 1976

August 1976 was a very dry month with about half of the Study Area recording less than one inch of precipitation. A relative wet maximum occurred north-south from east of Winton southward to Island Lake.

1) Minor T, 1 August. Afternoon thunderstorms in northwesterly flow. Heavier amounts, Cotton .43, Island Lake .42; less than .05 elsewhere, most stations had none.

2) Minor R, 4 August. General rain in southeasterly flow ahead of front. Heaviest totals, Meadowlands 1.24, Island Lake .65, Hibbing Airport .51, only .02 at Grand Marais, .03 at Winton, .08 at Hoyt Lakes, .10 at Babbitt, .11 at Isabella Ranger Station.

3) Minor T, 8-10 August. General thunderstorms from afternoon 8 August to wee hours of 10 August. Heavier amounts, Gunflint Lake .88, Isabella Ranger Station .59, Island Lake .57, Babbitt .46, Winton .42; only .14 at Tower 3S.

4) Minor. Scattered showers afternoon of 11 August; only light amounts.

5) Minor T, 12 August. Scattered thunderstorms in afternoon. Heavier amounts, Winton .71, Tofte .50, Ely USFSC .49, Finland .41; least trace at Hibbing Airport, Crane Lake; only .02 at Virginia.

6) Minor S, 13 August. Light showers afternoon in southeasterly flow; light amounts.

7) Minor T, 19 August. Scattered thunderstorms in morning; only light amounts registered.

8) Minor T, 26 August. Scattered thunderstorms moving behind Pacific cold front. Heavier amounts, Cotton .35, Whiteface .25, Brimson .20, Island Lake .20, Cotton .16; none or a trace at some stations.

September 1976

September 1976 was the third consecutive dry month of the year. Heavier amounts centered over Birch Lake, Isabella Ranger Station, separated by dry area from Stony River to Dunka River.

1) Minor T, 7-8 September. Thunderstorms with cold front passage on evening of 7 September, wee hours of 8 September. Heavier amounts, Gunflint Lake .26, Babbitt .25, Virginia .22, Tower 3S .18; least .01 at Grand Marais.

2) Minor R, 11-14 September. General rain and drizzle with hail after passage of cold front morning 13 September. Heavier totals, Finland .47, Isabella Ranger Station .38, Ely USFSC .37, Hibbing City .36, Tower 3S .32; least .07 at Grand Marais.

3) Minor S, 19-23 September. General shower activity for four days following cold front passage morning of 19 September. Heavier totals, Babbitt .97, Isabella Ranger Station .73, Grand Marais .68, Tower 3S .62.

4) Minor S, 25-27 September. Afternoon and evening shower on 25 September into wee hours of 26 September. Heavier totals, Gunflint Lake .50, Ely USFSC .28, Isabella Ranger Station .28, Eagles Nest .26, Tower 3S .26; least .03 at Meadowlands, Cotton.

5) Minor; some light drizzle on 26 September following cold front. Heavier amounts, Isabella Ranger Station .11, Finland .10; none reported at many stations.

October 1976

The fourth very dry month in a row. Slightly less dry along higher ground from Gunflint Lake to Skibo.

1) Intermediate R, 4 October. Most of the precipitation for month fell in connection with cold front passage in morning. Heavier amounts, Hoyt Lakes 1.07, Babbitt .87, Meadowlands .87, Brimson .76, Ely USFSC .70, Minnamax .70, Cotton .69, Whiteface .67, Dunka River .66, Winton .65, Kawishiwi .60; least .16 at Crane Lake, only .24 at Finland, .29 at Hibbing Airport.

2) Minor S, 7-8 October. Snow showers, rain showers 7-8 October in cold air. Heavier totals, Grand Marais .47, Crane Lake .24, Hoyt Lakes .13; only .03 at Eagles Nest, Ely USFSC Cotton, and Hibbing Airport; just a trace at Meadowlands.

3) Minor S, 14-16 October. Instability snow showers 15-16 October. Behind Continental front passing midday 14 October. Heavier amounts, Ely USFSC .29, Minnamax .30; least was trace at Meadowlands.

4) Minor S, 19-22 October. Snow and snow showers ahead and behind cold front passage during day on 20 October. Heavier totals, Crane Lake .45, Babbitt .23, Isabella Ranger Station .21, Ely USFSC .20, Winton .20, Kawishiwi .20; many stations reported less than .10.

November 1976

Very much below normal precipitation for fifth month in a row. Only Dunka River reported more than .40 inches--and the reading there is probably too high due to the possible snow blowing into the gage. All precipitation from snow showers.

1) Minor S, 1-4 November. Light snow showers, following frontal passages 1-4 November. Heavier amounts, Winton .14, Tower 3S .13, Crane Lake .12; most stations less than .05.

2) Minor S, 9-12 November. Light snow showers following frontal passage on 9 November. Heavier totals, Minnamax .19, Island Lake .18, Tower 3S .16.

3) Minor S, 17-30 November. Light amounts almost daily 17 November to end of the month at most stations. Heavier totals through entire period, Gunflint Lake .18, Cotton .18, Whiteface .16, Brimson .16; very light amounts at most stations.

December 1976

Sixth straight month of below-normal precipitation. Maximum over high ground, less along Lake Superior and west.

1) Minor R, 2-4 December. Snow began ahead of Pacific warm front on evening of 2 December. Snow lasted to arrival of front at midday 4 December then quit or tapered off. Heavier totals, Kawishiwi .20, Tofte .20, Hoyt Lakes .17; lesser amounts .04 at Grand Marais, .05 at Hibbing Airport and Tower.

2) Minor S, 5-6 December. Snow began in southerly flow ahead of vorticity maximum on late evening of 5 December into evening. Heavier totals, Gunflint Lake .30, Eagles Nest .18, Whiteface .18, Hibbing City .17; only .03 at Minnamax, .09 at Hibbing Airport.

3) Minor R, 9-10 December. Snow began early on 9 December ahead of Pacific front, continuing to passage of continental polar cold front late on 9 December. Heavier totals, Island Lake .48, Gunflint Lake .31; only .02 at Minnimax, .04 reported at Hibbing Airport, Grand Marais, and Cotton.

4) Minor R, 11 December. Light snow ahead of Pacific warm front. Maximum .03 at Crane Lake, trace or none elsewhere.

5) Minor R, 13 December. Light snow began midmorning ahead of Pacific warm front. Heavier totals, Grand Marais .07, Winton .02, Hoyt Lakes .01; trace or none elsewhere.

6) Minor S/R, 21-22 December. Snow in association with cold front passage wee hours on 22 December. Heavier totals, Grand Marais .08, Crane Lake .05, Tower .05; lesser amounts elsewhere.

7) Minor R, 24-25 December. Snow ahead of Pacific warm front passage; some after on 24 December. Heavier totals, Eagles Nest .48, Whiteface .16, Meadowlands .13; lesser amounts elsewhere.

8) Minor R, 26-27 December. Snow on 26, 27 December in response to low passage to south of Study Area. Heavier totals, Brimson .36, Hibbing City .35, Cotton .33; only trace at Gunflint Lake, .03 at Grand Marais.

January 1977

This was the seventh straight month below normal precipitation in the Region. All falls of snow were minor. No liquid precipitation fell. Heaviest precipitation was along the higher ground parallel to the lake, as it is most of the time, while higher totals either side.

1) Minor S, 1-3 January. Light snow on 2-3 January. Heavier totals Kawishiwi .10, Island Lake .10. But only trace at Babbitt, .01 at Minnamax.

2) Minor S, 5-6 january. Snow showers ahead of, behind cold front during day on 6 January. Heavier totals island Lake .24, Babbitt .15. Lighter amounts Cotton .01, Meadowlands .02, Tower .05.

3) Minor S, 12-14 January. Showers brought by small-scale systems 12-14 January. Heavier totals Island Lake .35, Meadowlands .31, Brinson .21. Only a trace at Cotton, Gunflint Lake, Tower.

4) Minor R, 19 January. Snow on afternoon of 19 January ahead of Pacific warm front. Heavier totals Minnimax. 12, Hibbing City .08; only a trace at several places.

5) Minor S, 20 January. Light snow flurries behind cold front during day of 20 January. Isabella ELC recorded .01; other places trace or none.

6) Minor R/S, 22-26 January. Snow most of the time ahead of Pacific front arriving on 23 January. Heavier totals Brimson .27, Winton .27, Hoyt Lakes .23, Babbitt .23. Smaller amounts Minnimax .03, Virginia .03.

7) Minor S, 27-31 January. Small systems behind frontal passage of afternoon 27 January brought light scattered snow showers to end of north. Heavier amounts Isabella ELC .11, Island Lake .06, Hibbing Airport .06, Crane Lake .06. none reported or a trace at some places.

February 1977

Storm late in month started the end of the long dry period since July and began a wet period lasting for the rest of the project. Precipitation from the storm pretty well reflected the pattern for the month. Heaviest precipitation was along the high ground, the least along Lake Superior and to the west of the high ground.

1) Minor S, 2-9 February. Snow behind cold front passage on afternoon of 2 February. Heavier totals Minnimax .20, Tower .15, Gunflint Lake .15, Winton .10, Crane Lake .10. Least .03 at several places.

2) Minor R, 7 February. Light snow in southerly flow on 7 February. Most .06 at Isabella ELC, trace at most other places.

3) Minor R, 11-12 February. Drizzle and fog in connection with occlusion passage on 12 February. heavier totals Gunflint Lake .15, Isabella ELC .13, Hibbing Airport .06. Only a trace at Tower, Virginia, Grand Marais.

4) Minor S, 13 February. Snow with return of cold front from northeast. heavier amounts Isabella ELC .04, Eagle Nest .02. None reported or a trace at most places.

5) Minor S, 16-18 February. Warm front followed by cold front, brought light traces of snow to most places, with Babbitt reporting only measurable precipitation at .01.

6) Minor S, 19-20 February. Light snow on evening of 19 february from low clouds behind passing cold front. Heaviest fall Virginia .01, trace or none reported elsewhere.

7) Major 4, 23-26 February. Biggest storm of the winter signaled the beginning of a wet era, ending the long drought that prevailed since July 1976. By far most of the precipitation falling this month occurred during this storm. Heavier storm totals Finland .86, Whiteface .81, Wales .80, Gunflint Lake .64, Hibbing Airport .60, Tofte .60, Minnimax .60. Virginia reported only .04, Babbitt .15, Hoyt Lakes .15.

March 1977

March 1977 was a wet month nearly everywhere in the Region, and especially wet towards the southern Lake Superior north shore. The high ground area was very wet.

1) Intermediate R, 3-5 March. A large storm passes to the south of the Region 3-5 March, bringing snow those dates. Heaviest totals Wales .70, Island Lake .62, Meadowlands .53, Eagles Nest .27, Tower .27, Embarrass .26. Least a trace at Grand Marais, .05 at Hibbing Airport.

2) Minor R, 9 March. First rainstorm of year on 9 March with frontal passage. Heaviest total .13 at Isabella ELC; .10 at Virginia.

3) Major R, 11-14 March. Heavy rainstorm borne on northeasterly winds as a storm passed to the south. Heaviest totals Wales 1.80, Finland 1.74, Island Lake 1.73, Tofte 1.70, Isabella Ranger Station 1.10. Lighter amounts Crane Lake .25, Embarrass .46, Hibbing Airport .51, Eagles Nest .60.

4) Minor S, 17-18 March. Snow following cold front on 17-18 March. Heavier totals Island Lake .22, Virginia .21. Trace at Grand Marais, Winton.

5) Minor R, 22 March. Snow accompanying strong cold front passing on afternoon of 22 March. Heavier totals Brimson .20, Island Lake .15. Lighter totals Grand Marais trace, Babbitt trace, Virginia .01.

6) Intermediate R, 26 March. Rain and drizzle with cold front passing on evening of 26 March. Heavier totals Minnimax .65, Grand Marais .51, Wales .50, Tofte .50, Finland .47, Isabella ELC .45, Isabella RS .45.

7) Intermediate R, 27 March. Storm center passing Region 27-30 March. Heavier totals Isabella ELC 1.15, Island Lake 1.12, Minnimax 1.05, Wales 1.00. Lighter totals Hibbing Airport .10, Winton .29, Meadowlands .54, Hoyt Lakes .39, Tofte .50, Tower .63.

April 1977

Precipiation was fairly uniform over the Region this month as no single precipitation event dominated the month's totals.

1) Minor R, 1-2 April. Rain, drizzle on night of 1-2 April with passage of occlusion. Heavier totals Tower .29, Tofte .10, Ely, USFSC .06.

2) Minor S, 6-7 April. Very light precipitation associated with passage of cold front from the north-northeast on night of April 6-7. Total of .02 at Minnimax, Isabella SLC, and Crane Lake, lesser amounts elsewhere, except possibly at Kawishiwi where gage tripped .10 increment.

3) Minor R/S, 11-12 April. Rain showers before, behind Pacific cold front on 12 April. Heavier totals Crane Lake .32, Brimson .23, Isabella RS .17, Only a trace at Gunflint Lake, Winton, and Babbitt.

4) Minor R/S, 14-15 April. Showers in southeasterly flow 14-15 April. Heavier totals Tower .21, Isabella RS .10, Cotton .08. Only a trace at Grand Marais, .01 at Winton.

5) Intermediate T, 17 April. Nightime thunderstorms broke out on wee hours of 17 April--the first of the season. Heavier amounts Gunflint Lake .33, Eagles Nest .32. Lesser amounts trace at Grand Marais, .08 at Ely USFSC.

6) Major R/T, 18 April. Morning and afternoon thundershowers 18 april in conncection with Pacific cold front. Four days of rain and east wind 18-21 April as the Pacific cold front stalled over Lake Superior. Total amounts over region fairly uniform, with most locations recording between .90 and 1.10 inches. heavier totals Gunflint Lake 1.54, Finland 1.16. Lesser totals Grand Marais .56, Winton .65, Crane Lake .67, Kawishiwi .80.

7) Minor S, 23 April. Sprinkles on 23 April from passing cloud system. Only traces at some stations.

8) Minor T, 29 April. Light, widely scattered thunderstorms on afternoon of 29 April. Heavier totals Island Lake .17, Gunflint Lake .10, Whiteface .10, Meadowlands .06, Hoyt .03. None or a trace elsewhere. Radar echoes show shower

cells forming just east of St. Louis River,moving from WNW to ESE, disssipating upon reaching Lake Superior. First echoes at 1517 CST 29 April; last echo 2010 CST.

May 1977

Three heavy rainstorms conspired to bring expecially heavy totals to the area between Burntside and Birch Lakes. Precipitation was only about one-third as much along the Lake Superior shore.

1) Minor S, 1 may. Light showers with frontal passage during wee hours of 1 May. Maximum precipitation Crane Lake .06, none or a trace at many stations.

2) Intermediate R/S 4-5 May. Showers in southeasterly flow 5 May. Heavier totals Babbitt .75, Grand Marais .67, Minnimax .65, Kawishiwi .60, Wales .60. Lighter amounts Island Lake .22, Cotton .26.

3) Intermediate S, 10-11 May. Showers in warm air on 10 May. heavier amounts Babbitt .39, Minnimax .35, Ely WFSC .34. But only a trace at Hibbing Airport, .05 at Hibbing and Gunflint Lake.

4) Minor S, 13 May. Convective showers detected on radar evening of 10 May moving from near Northshore Junction to near Split Rock Point. Did not pass over any rain gage stations.

5) Major T, 15 May. Heavy nocturnal thunderstorms wee hours of 15th, more on afternoon of May 15. According to radar, precipitation cells moved from south-southwest while systems moved from west in wee hours and afternoon alike. heavier totals Ely USFSC 1.96, Eagles Nest 1.74, Vermilion College 1.59, Olson Bay 1.45, Hoyt Lakes 1.10, Cotton .96. Lighter amounts Snowbank Lake trace, Gunflint Lake Trace, isabella ELC .02 Hibbing Airport .09.

6) Minor T, 17 May. Convective showers afternoon of 17 May. Heavier amounts Wales .70, Kawishiwi .60, Winton .45, Brimson .41. None at Virginia, Gunflint Lake, only a trace at Hibbing Airport.

7) Minor T, 18-19 May. Convective showers afternoon of 19 May. Hevier amounts .28 at Crane Lake, Cotton .12. None at some stations.

Nocturnal convective showers cells moving from the southwest appeared on radar a few minutes before the end of the day on 18 May, lasting through the night. None as part of organized systems.

8) Major T/R/S 20-24 May. Storm passinf ocwe on 20 May followed by showers off and on at all times of the day from 20 May to 24 May. Heavier totals Embarrass 2.18, Tower 1.81, Hoyt Lakes 1.73, Ely USFSC 1.51, Kawishiw 1.50, Hoyt Lakes 1.73, Meadowlands 1.36, Winton 1.36 Eagles nest 1.31. Lighter amounts Gunflint Lake .45, Isabella RS .49, Grand Marais .72, Wales .80.

9) Minor T, 27 May. Showers in warm air 27 May. Heavier amounts Eagles Nest .26, Embarrass .23, Tower and North Shagawa .15. None at many stations.

10) Minor T, 20 May. Showers cell moving from south-southeat detected on radar just after sunrise 29 May near Beaver Bay. In warm air mass. Moved to east of Brimson, died. Other cells brought scattered showers elsewhere. heavier totals Brimson .81, Meadowlands .41, Hibbing Airport .21, Skibo .08. Many stations none or a trace.

11) Major R, 30-31 May. Warm front passage brought very heavy rains over all of Region except Grand Marais. Heavier totals Tower RS 2.66, Stony River 2.50, Isabella RS 2.34, Isabella ELC 2.22, Crane Lake 2.14, Eagles Nest 2.12, Embarrass 2.08, Hoyt Lakes 2.07, Skibo 2.06, Vermilion College 1.95, North

Shagawa 1.92, Ely USFSC 1.88, Water Hen 1.85, Virginia 1.75, Cotton 1.75, Olson Bay 1.74, Snowbank Lake 1.70, Kawishiwi 1.70. Less amounts Grand Marais .73, Fairbanks .77, Finland .85, Babbitt .92, Hibbing Airport .93, Wales 1.21, Winton 1.37, Gunflint Lake 1.61, Island Lake 1.67, Meadowlands 1.69.

June 1977

1) Minor S, 3-4 June. 3-4 June showers arrived ahead and behind Pacific warm front. Radar indicates cells and systems both moved from west. Heavier totals Meadowlands .47, Cotton .45, Water Hen .31, Island Lake .28, Hibbing Airport .27, Whiteface .25; amounts least at Gunflint Lake, Crane Lake, Snowbirch Lake trace, North Shagawa trace, Olson Bay .02, Embarrass .03, Eagles Nest .03, Tower .03, Grand Marais .03.

2) Intermediate T, 5-6 June. Thunderstorms with continental cold front passage on afternoon of 5 June, lasting to a bit past midnight. Heavier storm totals were done .90, Gunflint Lake .85, Kawishiwi .80, Stony River .70, Snowbank Lake .59, North Shagawa .57, Olsen Bay .52, lighter amounts Fairbanks .02, Meadowlands .02, Cotton .08.

3) Intermediate T/R, 7-8 June. On June 7-8, rainclouds with imbedded thunderstorms north of low center brought appreciable rains to most of the Region, imbedded thunderstorm cells radar-detected as far north as Lake Vermilion moved from north to south. Heavier totals Brimson .92, Olsen Bay .55, Ely USFS .50, lighter amounts .02 Isabella RS .02, Isabella ELC .10.

4) Minor S., 10 June. Slight storms on 10 June from overcast skies, in southeasterly flow. Heavier totals brimson .41, Meadowlands and Island lake .17. None or a trace at some stations.

5) Minor R/S, 13-14 June. Cold front brought light showers on 13-14 June. Heavier amounts Gunflint lake .32, Water Hen .17, Crane Lake .12, Grand Marais .09, Fairbanks .08, Eagles Nest .08.

6) Major T, 15-16 June. Nocturnal thunderstorms June 15-16 ahead of Pacific front brought appreciable amounts of rains over most of region. Cells on radar moved from west to east. Heavier amounts Crane Lake 1.73, Winton 1.44, Hibbing Airport 1.26, Snowbank Lake 1.13. Lighter amounts Water Hen .04, Cotton .09.

7) Major T/S, 18-20 June. Showers, thunderstorms ahead of advancing warm front 18-20 June. Heavier totals Brimson 2.57, Olson Bay 1.89, Crane Lake 1.80, Isabella ELC 1.77, Babbitt 1.62, Isabella RS 1.59, Eagles Nest 1.58, Whiteface 1.53, Water Hen 1.50, Stony River 1.35, Snowbank Lake 1.20, Tower 1.16, Gunflint lake .99. Lesser amounts Grand Marias .26, Island Lake .38, Winton .37, Meadowlands .40.

8) Major T/R, 22-23 June. Thunderstorms and general rains ahead of warm front on night of 22-23 June. Radar cells moved from southwest, with one moving directly over Fairbanks. Heavier totals Fairbanks 1.54, Stony River 1.33, Whiteface 1.14, Hibbing Airport 1.13, Cotton 1.10, Hoyt Lakes 1.09. Lesser amounts Isabella ELC, Crane Lake .28, Gunflint Lake .28, Log Cabin .32.

9) Minor S, 24 June. A few cells, seen on radar morning from northwest, around dawn on 24 June. Most stations recorded northing, and only .02 at Fairbanks and Island Lake.

10) Minor T, 26 June. some nocturnal thunderstorms on wee hours of 26 June. Cells on radar seen moving from west-northwest, detected even in far north of region. But few heavy amounts. Heaviest Snowbank Lake .44, Embarrass .15, Crane Lake .09.

11) Major T, 27-28 June. Afternoon thunderstorms 27 June, nocturnal thunderstorms 27-28 June. Cells, according to radar, moved from WSW. Many detected on radar, some into Ontario. Heavier amounts Isabella ELC 1.69, Skibo 1.42, Island Lake 1.00. Only .02 at Grand Marais, .16 at Snowbank Lake and Virginia.

12) Intermediate, 29-30 June. Nocturnal thunderstorms on night of 29-30 June. Heavier amounts Stony River 1.15, Island Lake .72, Fairbanks .69, Kawishiwi .60, Only .09 at Water Hen, Grand Marais .14, Gunflint Lake .15.

13) Intermediate T, 30 June. Rain and thunderstorms on 30 June, following passage of cold occlusion. Radar indicated cells moved from west-northwest. heavier totals Snowbank Lake .84, Isabella RS .73, Embarrass .65. Cotton reported only .09.

July 1977

Heavy totals south shore Lake Vermilion, Greenwood Lake areas. Dry around Snowbank Lake and along Lake Superior shore north of Beaver Bay. Also, dry trough from Snowbank Lake, along Kawishiwi River through Hoyt Lakes to Hibbing Airport.

1) major T, 2-3 July. Nocturnal thunderstorms on night of 2-3 July ahead of Pacific cold front. Radar-detected cells moved from southwest. Thunderstorms continued on afternoon of 3 July following arrival of Pacific front around noon 3 July. Heavier totals Isabella RS 1.22, Babbitt 1.06, Embarrass 1.00. Only .26 at Meadowlands.

2) Major T, 4-5 July. Daytime thunderstorms on 4 July into 5 July. Heavier totals Tower 1.31, Crane Lake 1.30, Eagles Nest 1.14, Kawishiwi 1.10. Only .02 at Fairbanks, .20 Island Lake.

3) Minor T, 7 July. Afternoon and evening showers 7 July. Heavier amounts Skibo .14, Whiteface .14, Fairbanks .13. None or a trace at many places.

4) Intermediate T/S, 11-13 July. Scattered shower activity ahead of continental cold front on 11 July. Cells moved from the SSW. More showers fell behind front on 11 July into morning of 12 July, with afternoon thunderstorms on 13 July. Heavier totals .37 at Isabella RS, Skibo, Grand Marais and Cotton. Lesser amounts Meadowlands .07, Hibbing Airport .07, Isabella ELC .07, Tower .09.

5) Major T, 16 July. Thunderstorms ahead of cold front on morning and afternoon 16 July. Cells as seen on radar moved from west; systems moved from west-northwest. Cells large on radar, observed as far north as Lake vermilion. Heavier totals Brimson 2.08, Skibo 1.73, Water Hen 1.70, Wales 1.60, Embarrass 1.52, Tower 1.43. Only .01 at Crane Lake, .23 at Gunflint Lake, .28 Olson Bay, .28 at North Shagwa, .30 at Winton, .31 at Ely USFSC, .34 Babbitt, .35 Stony River.

6) Minor S, 20 July. Sprinkles with cold front passage 20 July. Most precipitation .08 at Isabella RS; .02 at Eagles Nest, North Shagwa, Tower.

7) Minor S, 23 July. Showers on 23 July. Most .60 Island Lake, .40 at Stony River. None at many stations.

8) Minor T, 24 July. Evening thunderstorms on 24 July after cold front passage. Heavier totals Stony River .40, Crane Lake .22, Cotton .21, Olson Bay .18. Many stations reported no rain.

10) Intermediate S, 28 July. Evening showers on 28 July in Pacific air. Heavier totals Gunflint Lake .58, Finland .44. None at some stations.

11) Intermediate R/S, 30-31 July. Showers from low overcast associated with advancing occlusion during day of 30 July. More showers, following front, to wee hours of 31 July. Heavier totals Meadowlands .85, Wales .80, Finland .74, Water Hen .69, Cotton .62, Tower .59. Least .21 at Crane Lake; only .29 at McKinley, .30 at Kawishiwi and Hoyt Lakes.

August 1977

Very heavy totals along axis from Hibbing Airport to Basswood Lake. Dry axis along eastern slope of high ground ridge. Much of wet excess due to outbreak of enormous, stationary system of cells passing over wet axis 26 to 28 August.

1) Minor S/T, 1-5 August. Rain during early hours of 1 August in association with vry cold air behind continental cold front. Several small vorticity maxima brought showers off and on through 3 August. Heavier storm series totals Brimson 1.17, mcKinley .91, Whiteface .68. During some period none at Snowbank Lake, only trace at Log Cabin and Babbitt, .02 at Finland, .06 at Ely USFSC and Grand Marais, .10 at Winton and Kawishiwi.

2) Minor S, 5-8 August. New surge of cold air behind front arriving at 0330 5 August brought more days of a small-shower regime from minor systems. Heaviest totals 5-8 August Gunflint Lake .56, Snowbank Lake .48, North Shagwa .37. Only .07 at Ely USFSC, .08 at McKinley and Meadowlands.

3) Minor S, 10-14 August. A third cold blast of continental air on wee hours of 10 August, followed by afternoon 12 August, continued a regime of very light scattered showers to 14 August. Heavier totals Embarrass .17, Tower .15. No rain reported at Skibo and Lob Cabin.

4) Minor T/S, 15-16 August. Showers on 15 August as wave moved eastward, south of the Region, followed by thundershowers on afternoon of 16 August. heavier totals Tower .48, Crane Lake .45, Island Lake .42, Skibo .38. Only .06 at McKinley, .09 at Finland.

5) Major T, 20 August. Nocturnal thunderstorms began 20 August ahead of cold front arriving about noon that date. Heavier amounts Skibo 2.49, Hoyt Lakes 1.25, Finland .93, Tower .84, Embarass .73, Babbitt .62, Fairbanks .61, Wales .60. Only .05 at Meadowlands and Crane Lake, .15 at Cotton.

6) Minor T, .22 August. Thunderstorms broke at around start of day 22 August. Heaviest totals Winton .22, North Shagawa .21. None at some stations.

7) Very Major T, 26-28 August. Spectacular outbreak of enormous series of scores of thunderstorms in system extending from Region to South Dakota. New storms seen on radar generating from 26-28 August. Thunderstorms cells moved from southwest to northeast while massive system remained almost stationary. 100-year-plus rains at many places. Precipitation totals from systems in order to totals.

Log Cabin	7.72	Kawishiwi	4.10
Snowbank Lake	5.53	Gunflint Lake	3.84
Ely USFSC	5.08	Grand Marais	2.93
Winton	5.01	Skibo	2.63
Tower	4.96	Crane Lake	2.38
Olson Bay	4.80	Isabella ELC	2.34
Eagles Nest	4.73	Isabella RS	1.76
Hoyt Lakes	4.73	Meadowlands	1.59
Hibbing Airport	4.62	Whiteface Res.	1.59

Babbitt	4.60	Finland	1.39
N. Shagawa	4.53	Cotton	1.13
McKinley	4.35	Brimson	1.07
Embarrass	4.12	Fairbanks	1.01
Wales	1.00		

8) Major T, 30-31 August. More heavy rains over mush of region 30 August, extending into 31 August. Heaviest totals Grand marais 3.65, Embarrass 2.23, Isabella RS 2.12, Brimson 1.61. Least at Island Lake .41; McKinley .43, Olson Bay .44, Meadowlands .59, Gunflint .62, Eagles Nest .63, Cabbitt .71.

September 1977

Very wet regime continued. Two cold occlusions responsible for most of totals. Wet axes along high ground ridge and from western Lake Vermilion to Lac La Croix; minimum axis from Hibbing through Birch Lake to Brule lake.

1) Intermediate S, 1 September. Showers on 1 September following cold front passage on afternoon of 31 August. Heavier totals Olson Bay .93, Eagles Nest .67, Tower .53. None at Gunflint Lake, only a trace at Log Cabin.

2) Major T, 3-4 September. Thunderstorms broke out on evening of 3 September ahead of cold occlusion passing of morning of 4 September. heavier totals McKinley 1.73, Hibbing Airport 1.61, Hoyt Lakes 1.56, Skibo 1.45, Virginia 1.30, Embarrass 1.22, Wales 1.20, Cotton 1.20, Whiteface 1.07. Lesser amounts Gunfling Lake .35, Meadowlands .74.

3) Intermediate S/T 4-7 September. Showers, some thunderstorms to rear of cold occlusions 4-7 September. Heavier totals over period were Cotton .88, Meadowlands .81, Island Lake .80. Lesser totals Whiteface .10, McKinley .10, Embarrass .14.

4) Very major T/R 9 September. Heavy showers ahead and behind another cold occlusion forming early on 9 September. Radar recorded cells to Ontario border, moving west and west-southwest. Heavier totals 8-10 September Gunflint Lake 6.40 Crane Lake 2.66, Kawishiwi 2.00. Lesser amounts Meadowlands .19, Island Lake .20, Wales .30.

5) Intermediate R, 11-13 September. Shower activity to rear of cold occlusion from 11 September to 13 September. heavier series totals Skibo .61, Hoyt Lakes .59, Virginia .58. Lesser totals Olsen Bay .04, Winton .05, North Shagawa 10, Eagles Nest .14, Ely USFS .15, Log Cabin .15.

6) Major T/S/R, 18-19 September. Thunderstorm activity on 18 September. Radar indicated cells moving from the west. Followed by showers and drizzle and in northeasterly winds on 19 September. Heavier totals Grand Marias 1.41, Gunflint Lake 1.27, Crane Lake 1.19, Babbitt 1.08. Lesser amounts Skibo .21, Tower .24, McKinley .25, Cotton .27.

Very Major R, 21-29 September. Slow-moving cold occlusion brought eight straight days of rain to nearly every location in the Region. A real soaker. Totals:

Wales	4.90	Tower	2.63	Embarrass	2.13
Brimson	2.99	Vermilion College	2.59	Virginia	2.05
Isabella	3.88	Isabella ELC	2.57	Meadowlands	2.05
Grand Marais	3.70	Ely USFS	2.56	Hibbing City	2.00
Skibo	3.05	Olson Bay	2.54	Eagle Nest	1.84
Island Lake	2.99	Hoyt Lakes	2.44	McKinley	1.77
N. Shagawa	2.98	Winton	2.42	Hibbing Airport	1.67
Whiteface	2.83	Babbitt	2.24	Log Cabin	1.38

Fairbanks	3.19	Crane Lake	2.20	Gunflint Lake	1.24
		Cotton	2.20		

October 1977

Wet axis along high ground ridge and from Isabella to Burntside Lake. Dry from Cotton to Birch Lake. Bulk precipitation from two major storms in first part of month.

1) Minor S, 4 October. Showers behind cold front crossing on afternoon of 4 October. Heavier totals Tower .31, Island Lake .26, Meadowlands .26, Whiteface .18, Crane Lake .17. Only .03 at Virginia, .05 at McKinley, .06 at Babbitt.

2) Major R, 7-8 October. Rain and snow in connection with devloping low pressure system to the south. Heavier totals Finland 2.08, Island Lake 1.55, Isabella RS 1.01, Meadowlands .90. Lesser totals Crane Lake .25, Gunflint Lake .29, Skibo .34, Whiteface .34.

3) Major R, 10-11 October. Cold low pressure area intensified over Lake Superior, bringing northerly gale and heavy snow to the region, causing much damage and destruction to the forest. Heavier totals Isabella RS 3.09, Isabella ELC 2.67, Ely USFSC 2.41, North Shagawa 2.07, Gunflint Lake 2.05, Olson Bay 1.45. Lesser totals Island Lake .41, Hibbing City .61, Meadowlands .72, Skibo .85.

4) Minor S, 17-18 october. Rain in flow behind cold front. Heavier totals Hibbing Airport .43, Meadowlands .36, Hibbing City .30. A trace or more at some stations.

5) Minor S, 25-27 October. Some light rain ahead of and behind Pacific cold front crossing on wee hours of 26 October. Heavier totals Babbitt .09, Skibo

.07, Cotton .05. None or a trace reported most stations.

6) Intermediate R, 31 October. Rain ahead of Pacific cold front on 31 October. Heavier totals Grand Marias .82, Island Lake .52, Isabella Ranger Station .51. But only .04 at Virginia, .12 at Isabella ELC.

November 1977

Wet axis along high ground ridge and from Birch Lake to Burntside Lake. Dry axis from Cotton through Skibo to Saganaga Lake.

1) Minor R, 7-8 November. Drizzle and fog ahead of sharp cold front on 7-8 November. Heavier totals, Hoyt Lakes .15, Embarrass .12. Only a trace at Hibbing.

2) Major R/S, 9-10 November. Drizzle and rain on 9 November ahead of sharp cold front changed to snow behind the front. Heavier totals Babbitt 2.98, Olson Bay 1.66, Hoyt Lakes 1.58, Embarrass 1.57, Eagles Nest 1.54. Only .20 reported at Grand Marais, isabella RS .39.

3) Major R, 15-17 November. Frontal system brought heavy precipitation occurring ahead and behind it on 15-17 November. Heavier totals Olson Bay 1.90, Brimson 1.87. Only .14 at Finland, .23 at Grand Marais.

4) Major R, 19-20 November. Warm passage 19-20 November brought snow to all of region. Heavier totals Finland 1.65, Isabella RS 1.55, Grand Marais 1.48, Island Lake 1.24, Hibbing Airport 1.22, Brimson 1.14. Lesser amounts Babbitt .44, Cotton .46.

5) Minor S, 22 November. Sprinkling of snow on 22 November as low moved to the south of the region. Heavier totals Whiteface .07, Island Lake .06. None or a trace at many stations.

6) Minor R, 27-28 November. a dash of snow 27-28 November as wave moved south of Region. Heavier totals Meadowlands .12, Brimson .10, Tower .07. None or a trace at some stations.

December 1977

Wet axis along high ground, dry along axis from Hibbing airport to Saganaga Lake and along north shore of Lake Superior.

1) Minor S, 1-3 December. Snow showers 1-3 December behind continental cold front. Heavier totals Brimson .13, Tower .08, Hoyt Lakes .06. None or a trace at some stations.

2) Intermediate R, 5-10 December. Six straight days of snow over nearly all of Region as general low cloudiness prevailed. Heavier totals Isabella RS 1.45, Finland 1.13. lesser amounts Island Lake .32, Hibbing City .24, Meadowlands .25.

3) Minor R, 11-15 December. Low pressure to the south 11-15 December brought freezing drizzle, snow to region. Heavier totals Gunflint Lake .51, Embarrass .38, Hoyt Lakes .32. Only a trace at Meadowlands, .01 at Cotton and Island Lake, .02 at Whiteface.

4) Major R, 16-21 December. Approach and passage of Pacific cold front brought rain, freezing precipitation fand snow 16-21 December. Heavier totals Island Lake 1.53, Finland 1.44, Brimson 1.28. Lesser totals Babbitt .27, Eagles Nest .40, Hoyt Lakes .47, Embarrass .53.

5) Minor S, 23-25 December. Dash of snow 23-25 December from occasional cloudiness in northwesterly flow. Heaviest totals .01 at Embarrass, Eagles Nest, island Lake. None reported or a trace elsewhere.

6) Minor S, 27-28 December. Small frontless disturbance brought small amounts of snow 27-28 December; .06 at Eagles Nest and Meadowlands, .05 at Babbitt, .04 at Tower. None reported or a trace at several stations.

4.3 DAILY RAINFALL TOTALS

This section, on tables 5a to 5x gives daily rainfall totals for the raingage station in the Copper-Nickel Region from April 1, 1976 to April 30, 1978. Values are in hundredths of inches, the letter "t" indicates trace, i.e., less than .01 inches. The numbers at the top of each chart are the observation time of the station. All stations except the Hibbing airport operate on local legal time. The Hibbing airport data are based on Central Standard Time year round. Figure 6 gives raingage locations.

Figures and tables

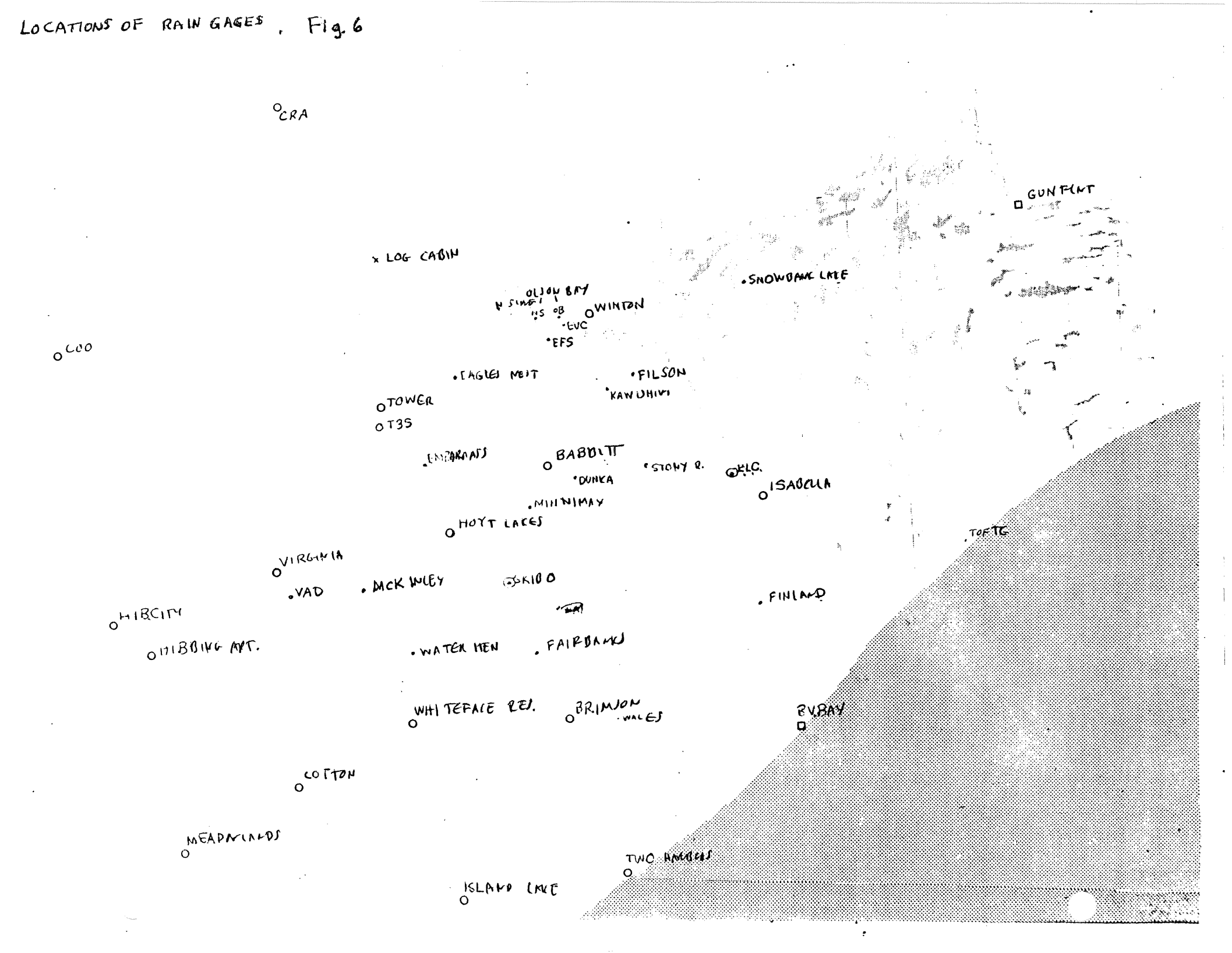
4.4 MONTHLY PRECIPITATION CHARTS (Figures 3a-3x)

This section contains monthly precipitation charts. Values plotted on the charts are in hundreths of inches with isopleths of equal precipitation drawn for every 10 millimeters increment.

The monthly totals are true monthly totals, i.e., if the rainfall actually occurred on the last day of the month, but was recorded by the observer on the first day of the next month, the value was incorporated into the month in which it actually fell. This was done by reference to other rainfall data and by reference to the weather radar. The patterns herein are described in the Precipitation Events section.

Figures

LOCATIONS OF RAIN GAGES . Fig. 6



4.5 DAILY WEATHER RADAR PRECIPITATION ECHO LOCATIONS

This section charts, on a daily basis, the locations of precipitation echoes over the Copper-Nickel Region as observed by the Minneapolis-St. Paul weather radar. In some cases, echoes recorded outside of the Region where their continuity is important. Where a sharp, straight cutoff appears, the echo was not charted. On days when no echoes were observed no dates are included. In essence, the shaded patterns on these maps give th elocation of where the larger precipitation-bearing systems appeared on each given day. In order for the Minneapolis-St. Paul radar to pick up the echoes, precipitation cells must be quite high in altitude. Since the earth curves, precipitation cells further from Minneapolis-St. Paul must be higher than those closer. Thus, cells in the southern part of the Region will appear more often than those in the north, which is further from Minneapolis-St. Paul.

The patterns on the charts are discussed in the Events section. On these charts, echoes occurring between midnight (0000) and noon (1200), CST, are shaded green, and those occurring between noon (1200) and midnight 2400) CST are shaded red.

Figures 8a to 8ff

4.6 STORM TRACK COMPOSITS

The following charts give all of the radar precipitation tracks in the Copper-Nickel Region observed each month by the Minneapolis-St. Paul weather radar during 1977. In 1976, there were virtually no tracks observed. In lieu of 1976, therefore, tracks of echos in July, August, and September 1975 are presented so that the reader may compare tracks between two years.

Figures 9a to

Radar Precipitation Echo Locations

Figure 8a

APRIL 29, 1977

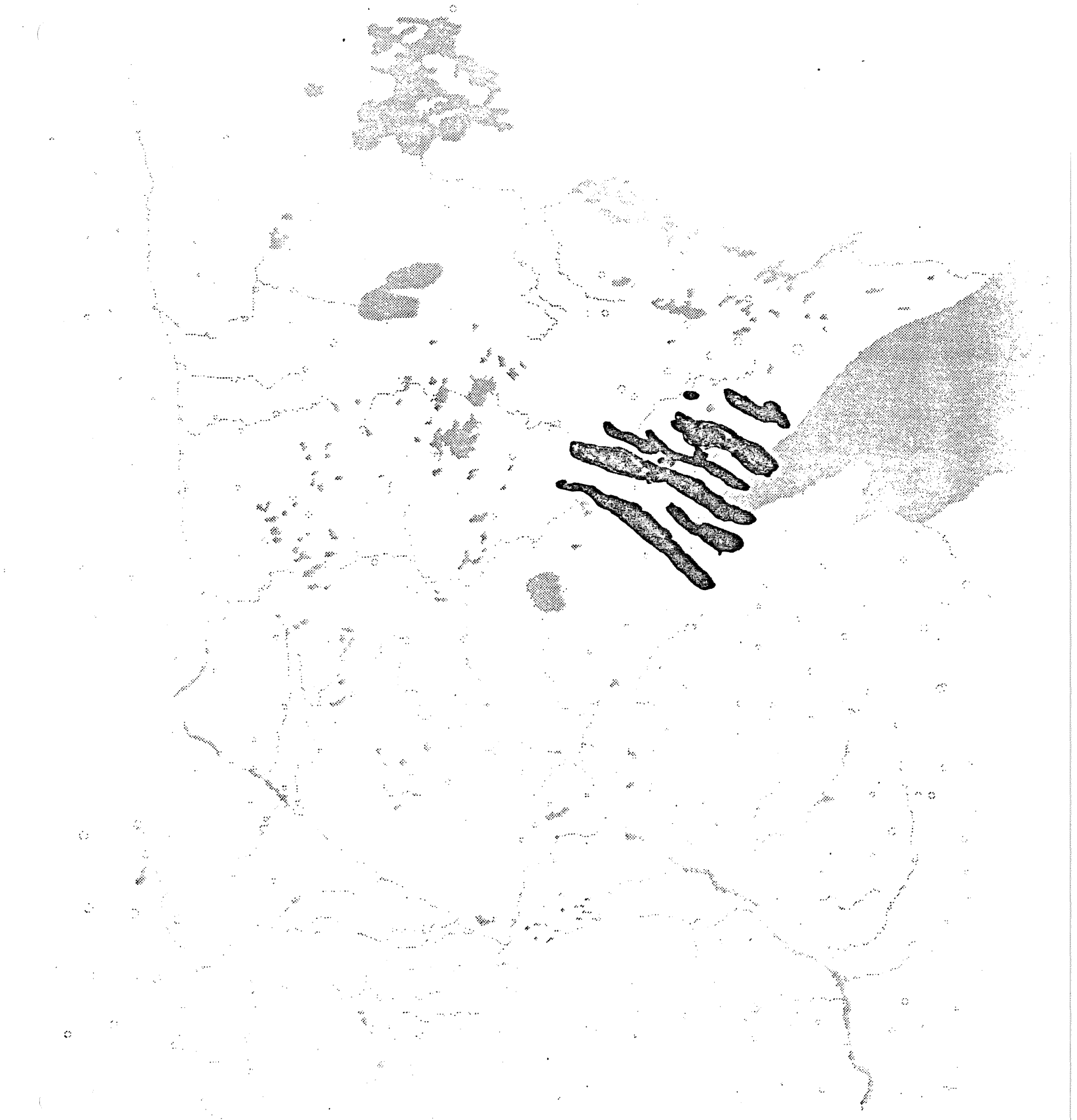


Figure 86

MAY 1, 1977

Figure 8c

MAY 3 1977

Figure 8d

MAY 13, 1977

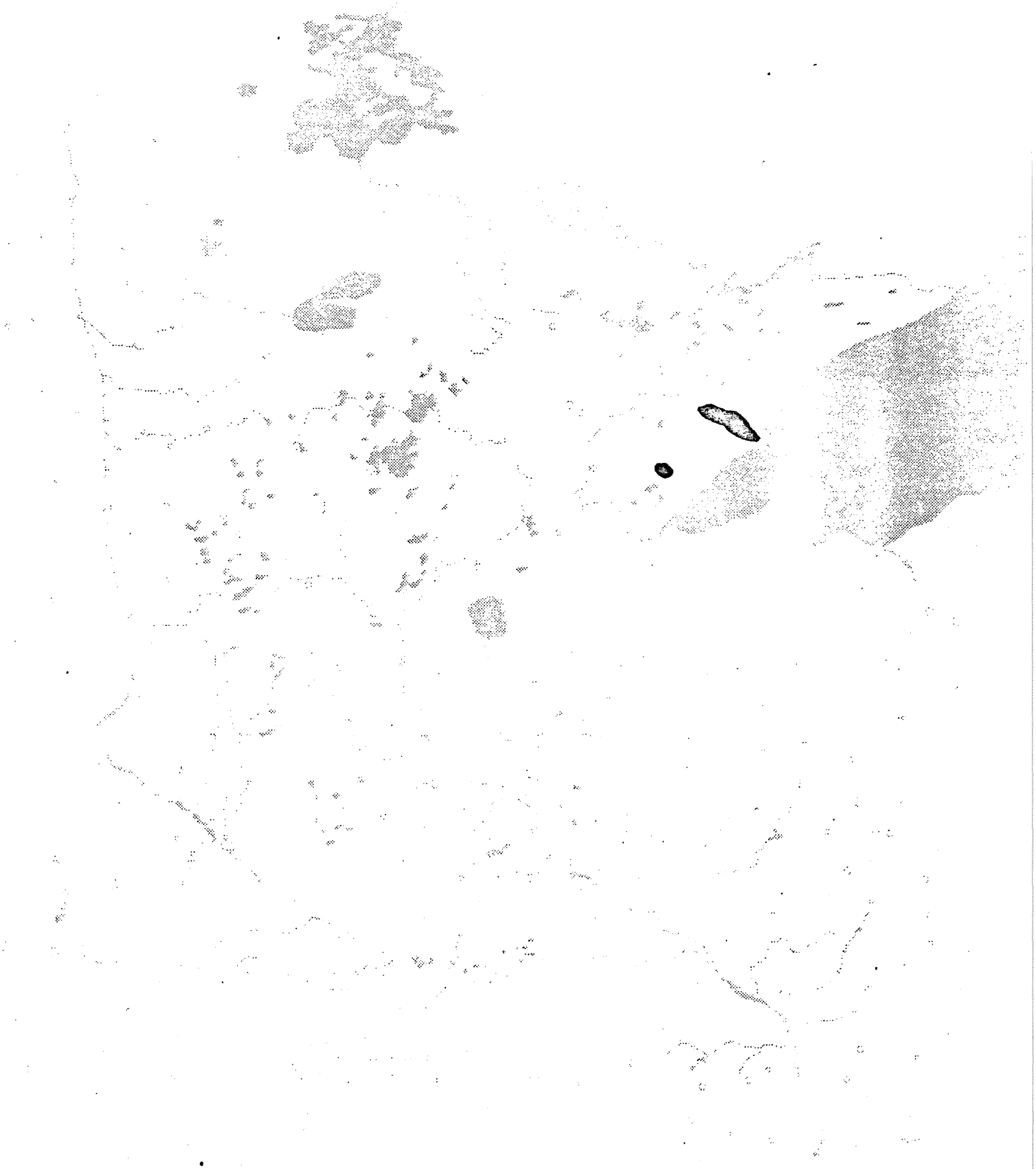


Figure 8e

MAY 15, 1977

Figure 8f

MAY 19, 1977

Figure 8g

MAY 29, 1977

Figure 8h

JUNE 3 1977

Figure 8:

JUNE 7 1977

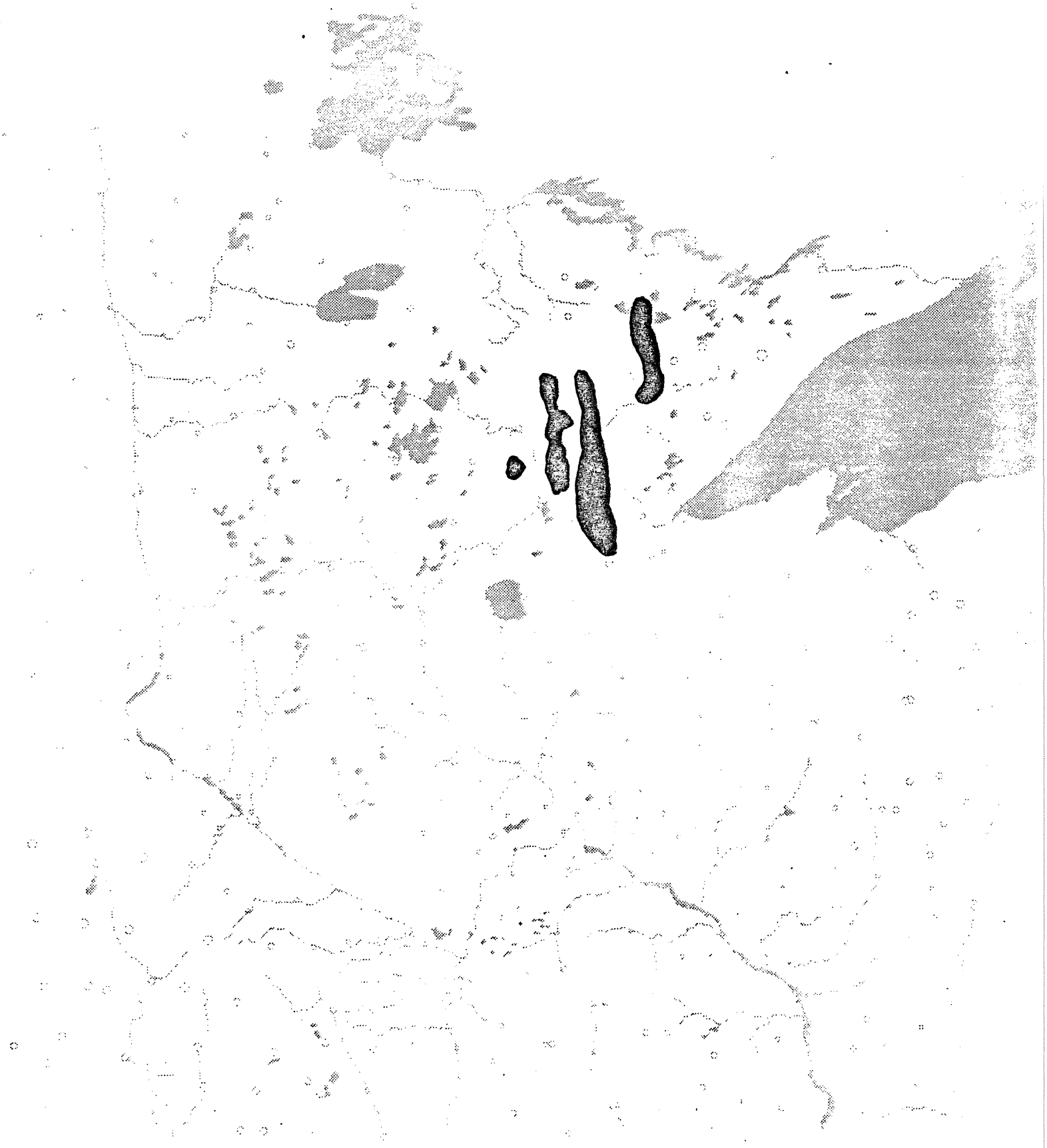


Figure 8j

JUNE 16 1977

Figure 8k

JUNE 22 1977

Figure 8l

JUNE 23, 1977

Figure 8m

JUNE 24, 1977

Figure 8n

JUNE 25, 1970

Figure 80

JUNE 26 1977

Figure 8p

JUNE 27 1977

Figure 8q

JUNE 28 1977

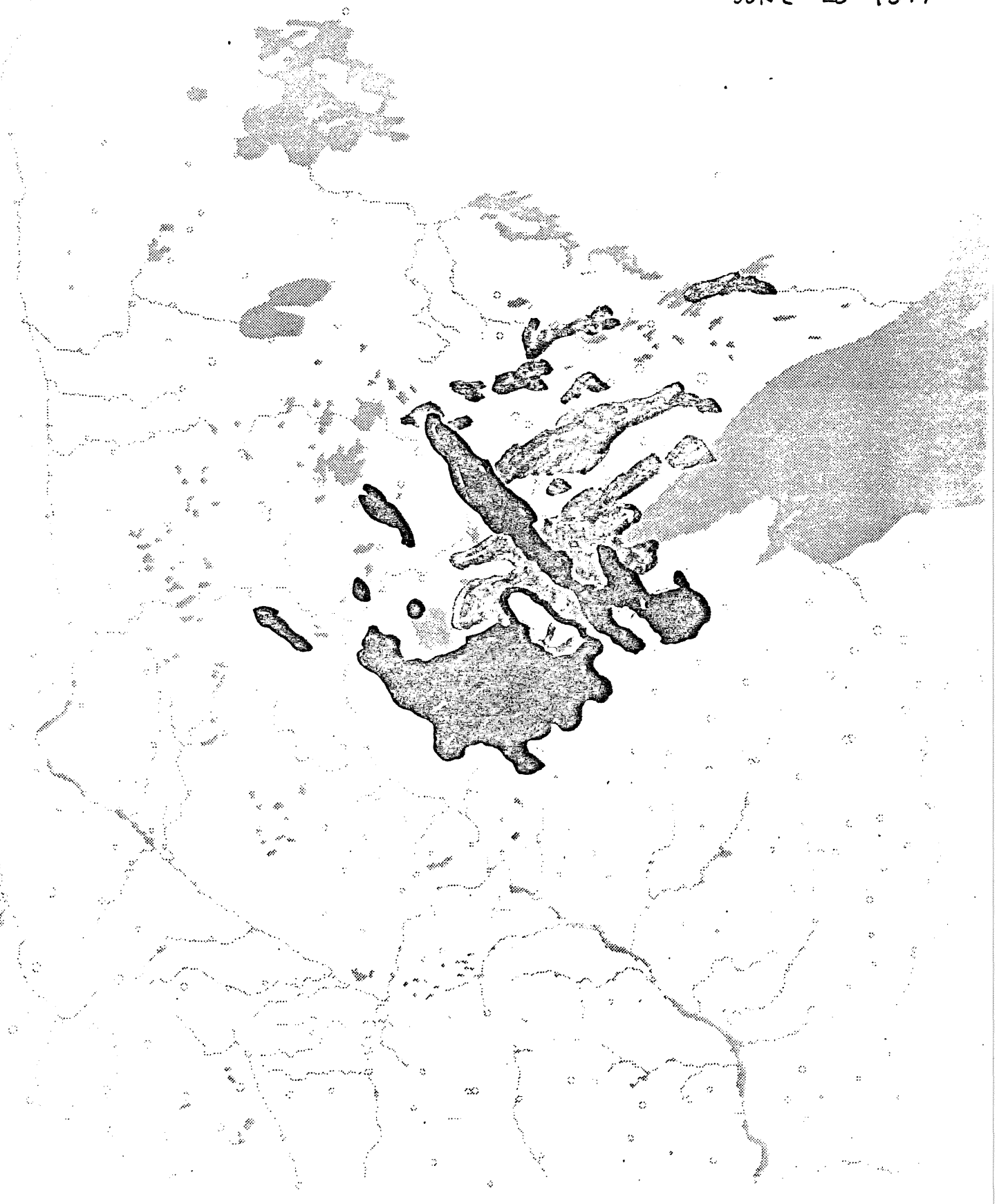


Figure 8r

JUNE 30 1977

Figure 8s

JULY 3 1977

Figure 8t

JULY 4 1977

Figure 8a

JULY 5, 1977

Figure 8v

JULY 7, 1977

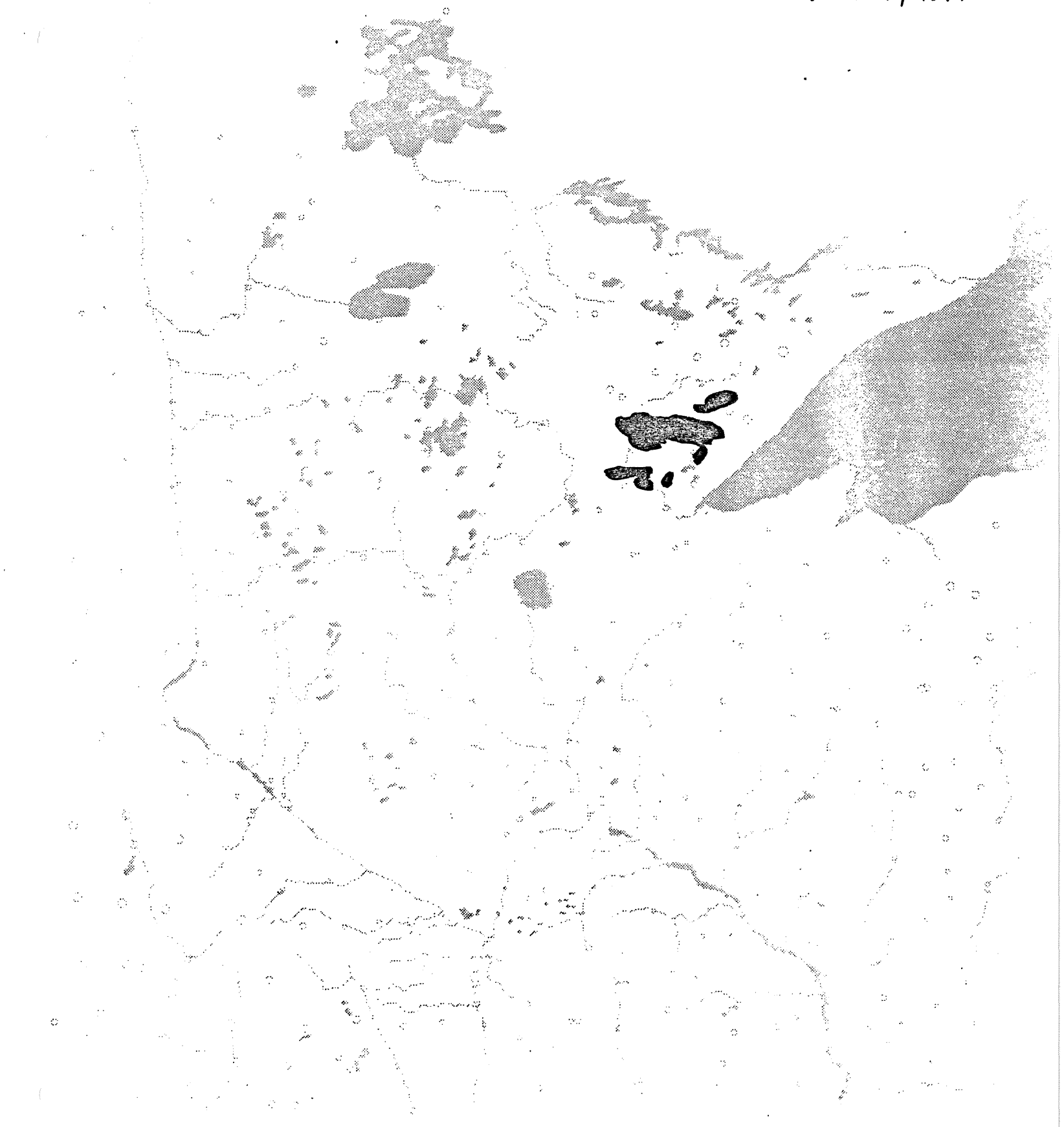


Figure 8w

JULY 11, 1977

Figure 8x

JULY 16, 1977

Figure 8y

JULY 27, 1977

Figure 8z

JULY 30, 1977

Figure 8aa

AUGUST 26, 1977

Figure 86b

AUGUST 27, 1977

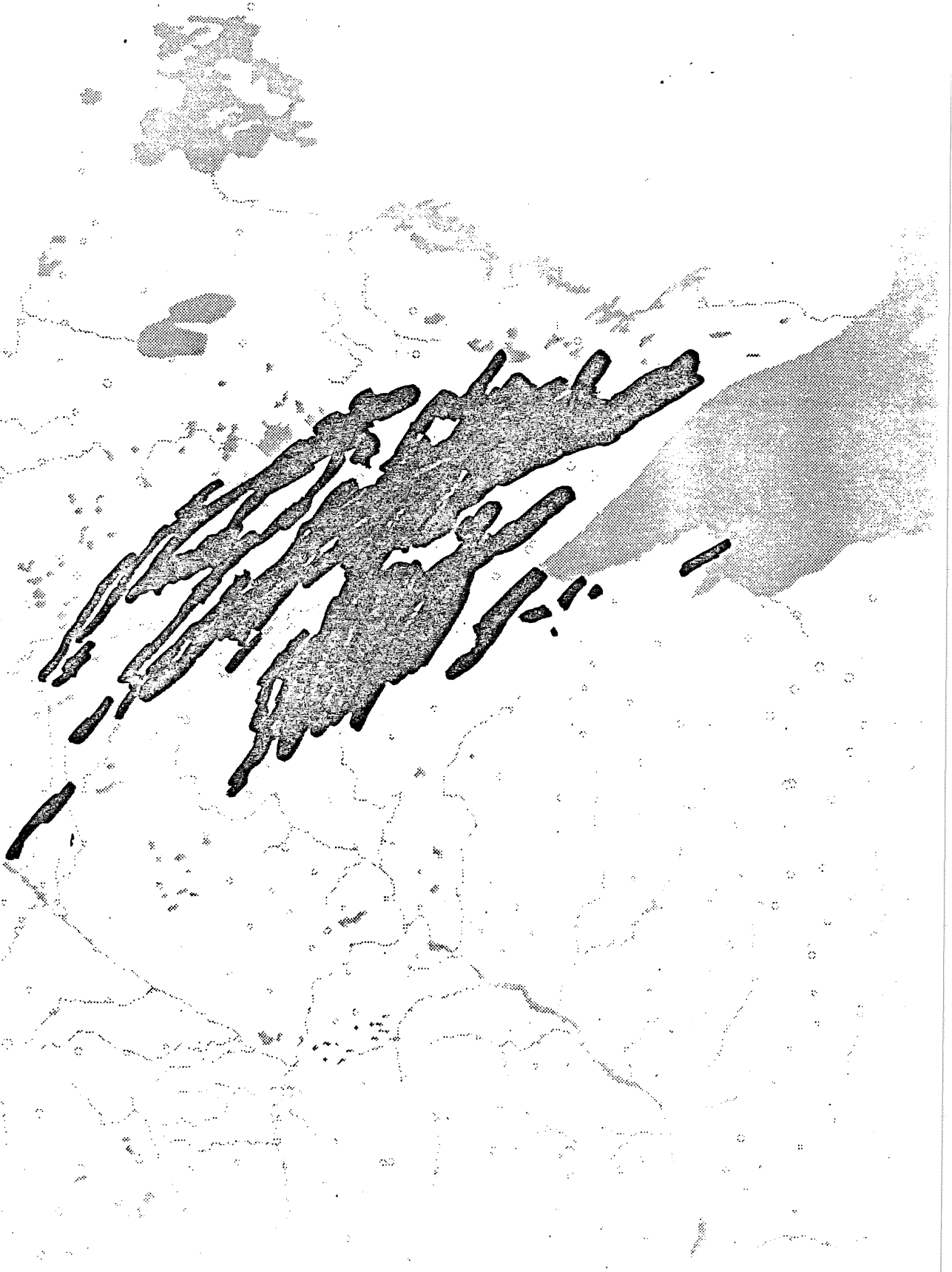


Figure 8cc

AUGUST 30, 1977

Figure 8dd

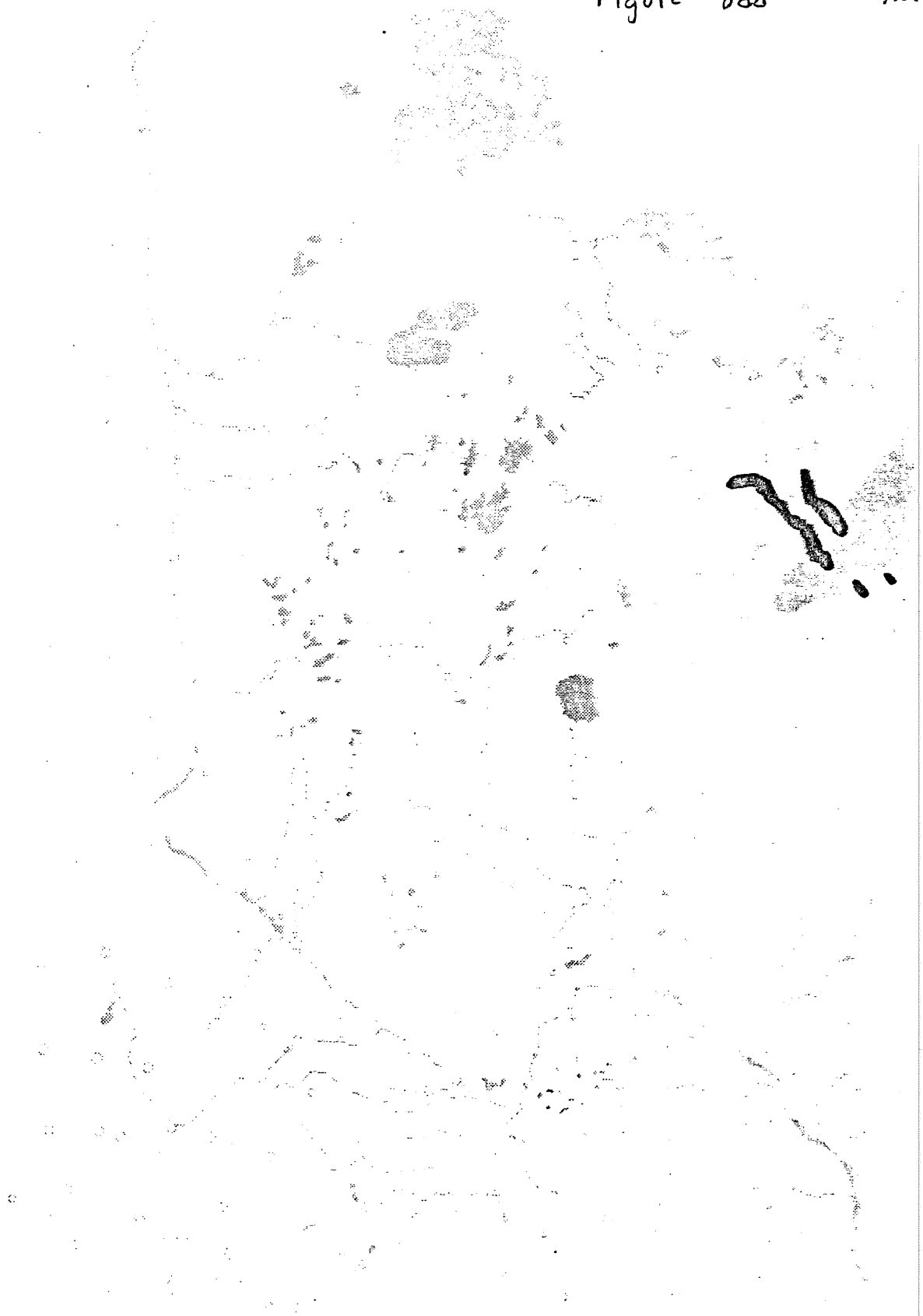


Figure 8ee

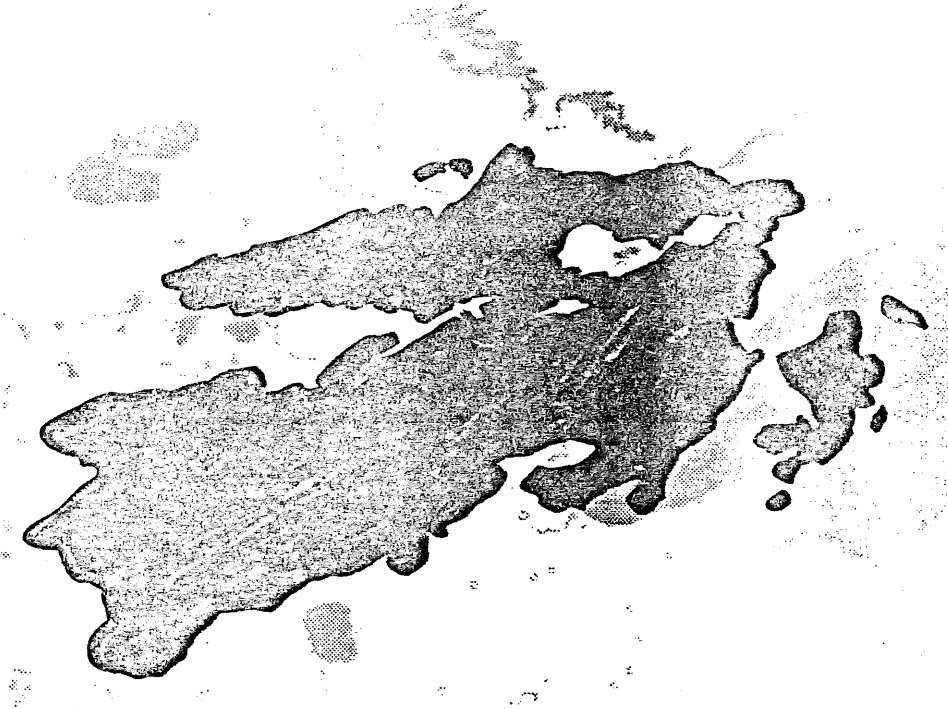
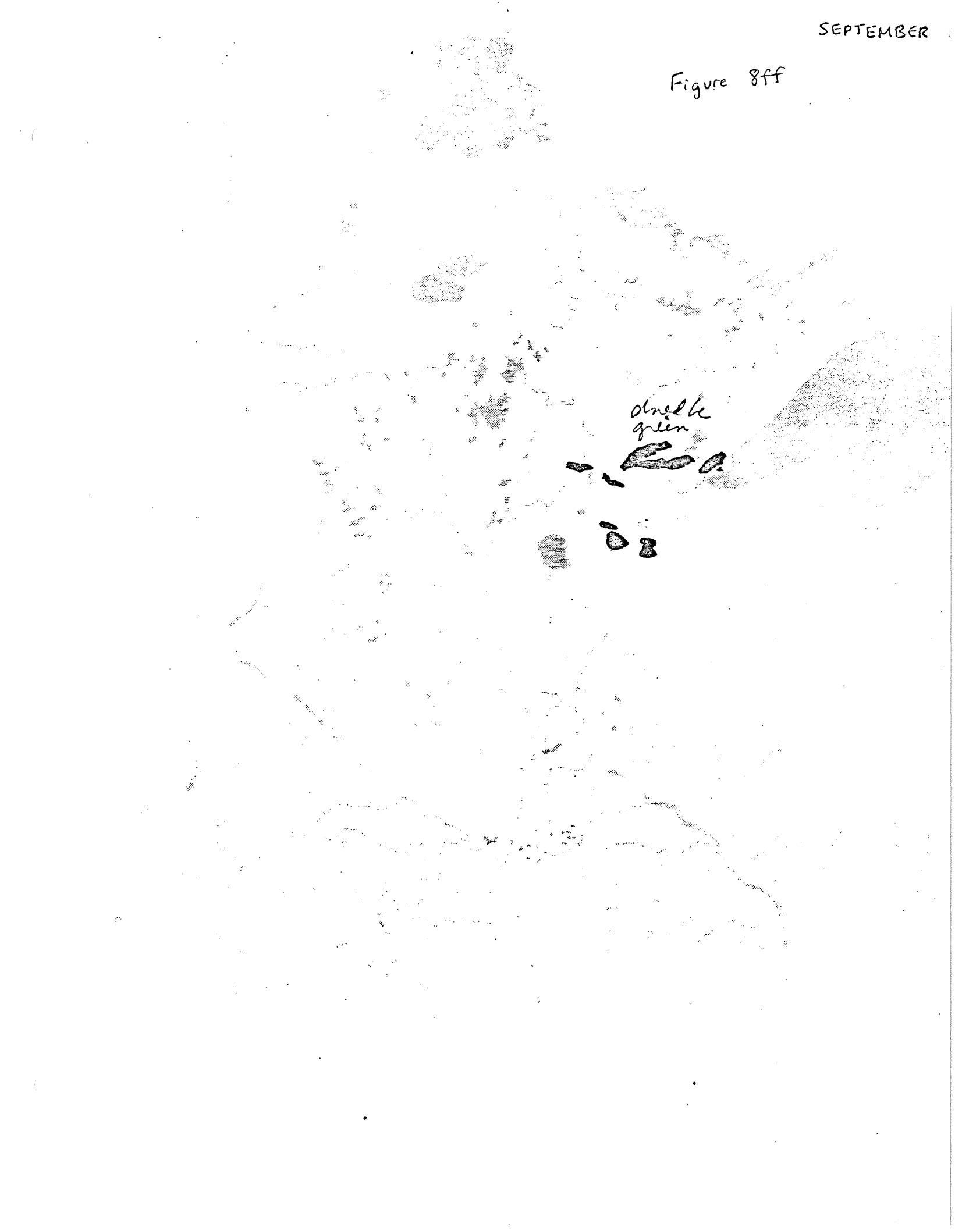


Figure 8ff



Stormtracks Figure 9a

JULY 1975

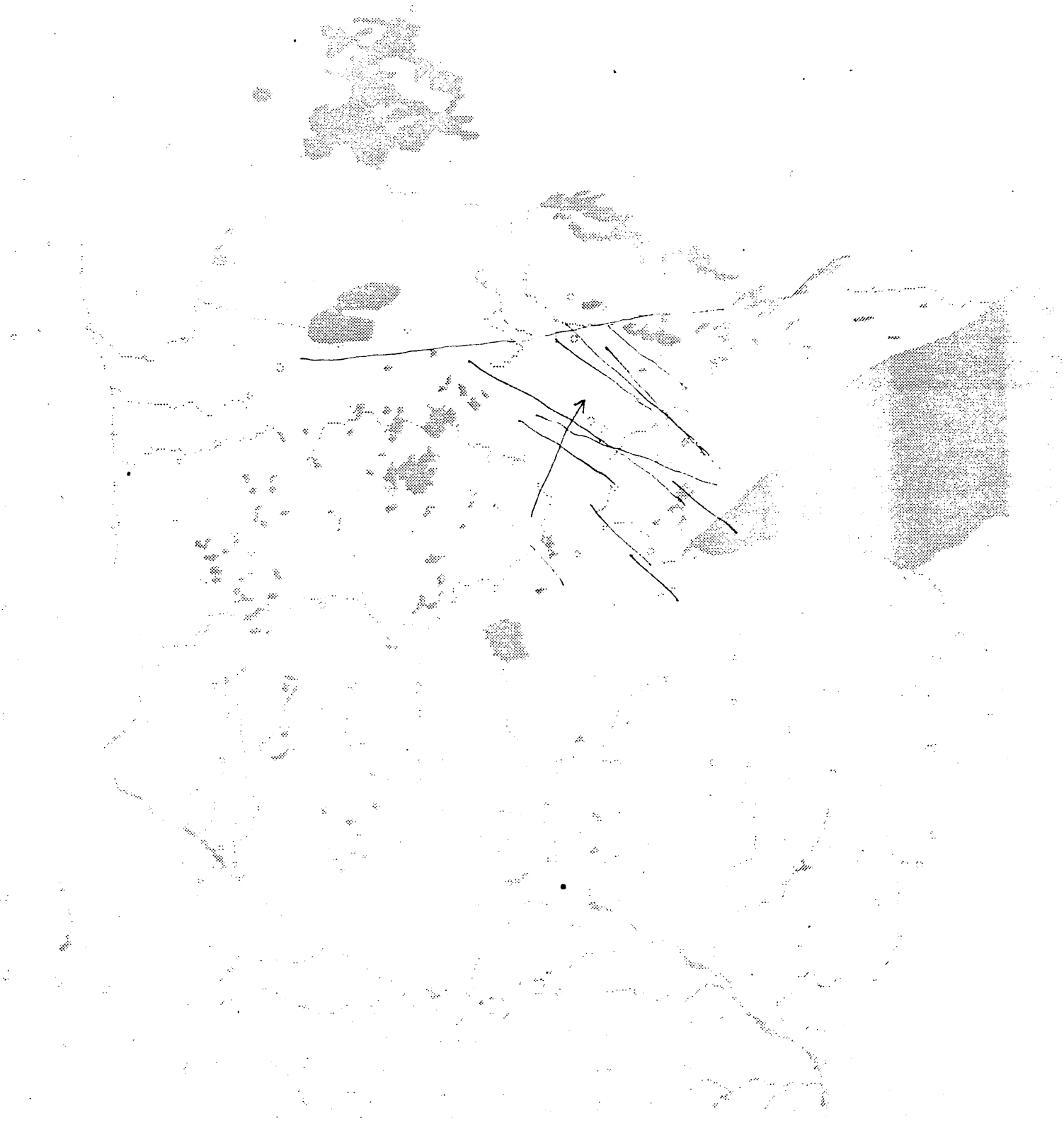


Figure 96

AUGUST 1975

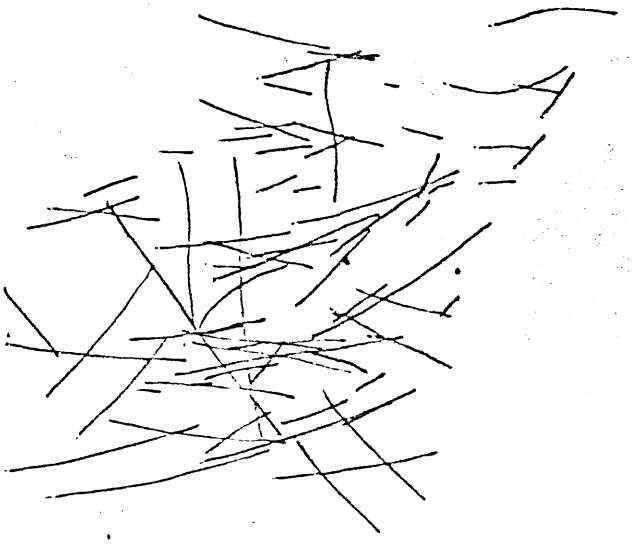
Figure 9c

SEPTEMBER 1975

Figure 9d

APRIL 1977

Figure 9e



SEPTEMBER 1977

Figure 9f

4.7 CONCLUDING REMARKS

This section has presented information on rainfall that occurred during the Copper-Nickel Project. What summary can be made from this information? Let us look at some conslusions that the evidence appears to offer.

1) The general rainfall pattern apparent in most months is one of higher precipitation along the high ground from the Island Lake Reservior through Isabella to Eagle Mountain.

2) The monthly (and annual) precipitation pattern is generally directed parallel to lake Superior. This patern breaks up west of Lake Vermilion. This is a dry axis along the shore, and another from Meadowlands through Brich Lake to Basswood Lake.

3) The radar data strongly shows that precipitation echoes moving from the Region into Lake Superior nearly always quickly disappear, indicating sudden death of thunderstorms and convective systems over the lake. Only a few enormous echos were found which survived very far out on the lake. Air over the lake is cold in the warm season--ingestion of this cold air into any free rising updrafts apparently quickly kills the updrafts. The immediate land area along the north shore is likely drier than further inland due not only to subsidence (sinking) of air moving from the west, but also because convective cells from the south and south-southwest cannot generally cross the lake to reach the shore.

4) In a given month, there is about a 3 to 1 ratio in the total precipitation value between the station recording the most precipitation and the station recording the least, the station spacing and number of stations being what they were.

5) Thunderstorms dominate the precipitation events most strongly in May, June and July, while general storms dominate in March, April. General storms and thunderstorms are both important in August and September. From October to February, general storms and shower regimes are both important.

6) As might be anticipated, thunderstorm events are associated with the greatest variations in precipitation over the region, general storms the least, with non-thunderstorm showers being in-between in variation.

7) As might be anticipated, most convective cells observed on radar move from between WSW and WNW. Wetter years and months seem to favor tracks from the WSW, drier times favor tacks from the west and WNW.

Chapter 5 SNOW

5.1 SNOWFALL

Using the Reserve Mining Babbitt station as the reference station for monthly snowfall for the two seasons, we have the following values of total snowfall:

	1976-1977	1977-1978
September	t	0
October	0.8	3.0
November	1.7	10.0
December	9.5	5.5
January	7.3	4.3
February	3.2	4.5
March	2.5	10.0
April	t	t 3.0
Total	25.0	40.3

Both of the cold seasons are well below the normal of 55 inches of snow at the station.

5.2 SNOW DEPTH

Snow on the ground is a meteorological variable which heavily influences other meteorological variables. It has an effect on air temperature, since it acts as a resistor to heat exchange between the soil and the air. For the same reason, it has a profound effect on soil temperature. It affects absorbtion of solar radiation, with the white reflecting far more sunlight than would the natural ground cover. It also affects fog, impeding its formation when the cover is complete, but encouraging it during melt times. During melt, it thus also affects atmospheric humidity.

The 1977-1978 winter had a much more extensive snow cover from the standpoint of duration and depth than that of 1976-1977. During the 1976-1977 cold season, the permanent snow cover lasted from early November to early March, while in 1977-1978 the cover lasted from early November to early April--a full month longer.

Figures 10a to 10b give plots of the depth of snow on the ground from daily observations during both seasons at Babbitt. Maximum depth occurred at the end of January in 1977, and in late March in 1978.

Snow depth observations were made by Copper-Nickel staff at other locations, notably at the air quality stations and at plots operated by the terrestrial biology group. Turning attention first to the depths from the air quality stations, Figures 11a to 11b give depths for Whiteface, the Babbitt Golf Course, Toimi, Dunka River, Bearhead Lake, Isabella Environmental Learning Center (ELC), Kawishiwi, and Fernberg Road. During both cold seasons, not much difference in snow depth was observed, and the length of cover was about the same, except for the Fernberg Road site, which is well within the forest and displayed an expected longer lingering cover in the spring of 1977.

Data taken by the Copper-Nickel staff on plots in remote areas in January and February of 1977 are of special interest in that they, too, reflect very little difference in snow cover between stations.

Care should be taken in interpreting the results of the snow data. First, both years were well below normal in snowfall. In more snowy years, it would be expected that greater variations in snow would occur, since heavy snow would mean big storms. Big storms would likely favor heavier snows in the east, lesser snows in the west of the region. (The long-term climatic data indicate that the

eastern end is snowier than the western parts of the region. However, it can also be considered that the differences are not great.

Chapter 6 WIND

6.1 YEAR-TO-YEAR VARIATIONS

Plots were made of the year-to-year wind variation at Hibbing from 1970 to 1976. These were de-biased, and are shown in Figures 12a to 12f, along with the 10-year average wind rose from 1964-1977 (Figure 13). The yearly roses show that there is not a great deal of difference in wind from one year to the next. Note that in every case the prevailing wind varies only between 310 to 335 degrees. Further, the southeasterly secondary maximum varies between 135 and 180 degrees.

The warm year, 1973, which had an average annual temperature of 39.6°, has a very strong south component, coming close but not equalling the northwesterly maximum. Contrast this with the cold year, 1972, which an average annual temperature of 34.9°, and more northwesterly through northeasterly winds. The south winds were significantly less frequent in 1972 than in 1973.

6.2 MONTHLY WINDS

Monthly wind roses were plotted for Hibbing comparison of monthly wind data with the 10-year averages from the summer of 1976 to the summer of 1977. These are shown in Figures 14a to 14l.

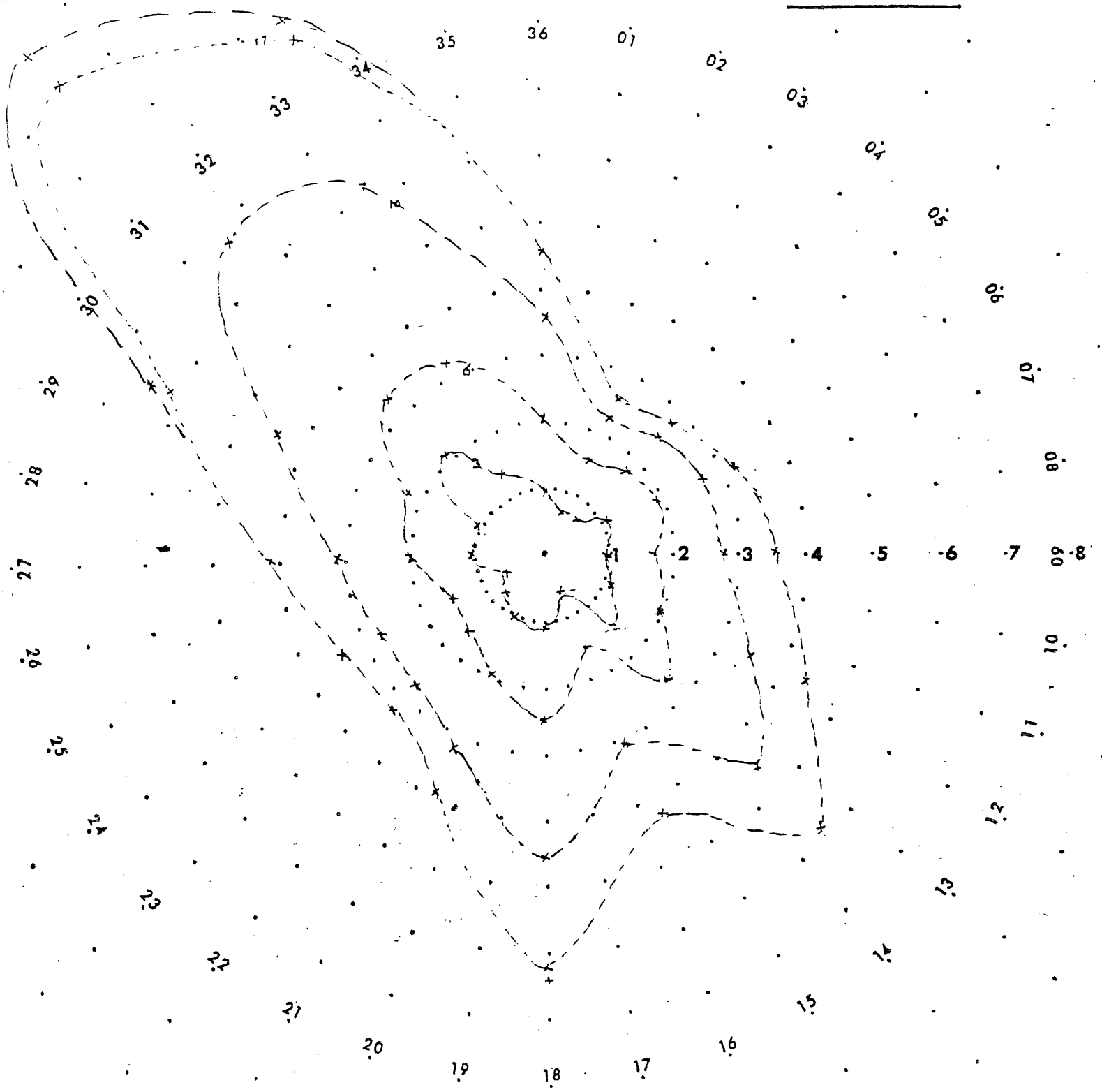
It can be seen from comparison with the 10-year average roses that monthly roses may vary radically from the average. A month-by-month discussion is enlightening, especially in context with the departure of mean temperature from the normal. The temperature average given here is for Babbitt, which has a large period of record in the same location.

FIG. 12a

WIND ROSE 36.7

~~RADAR~~ 19.28

1970



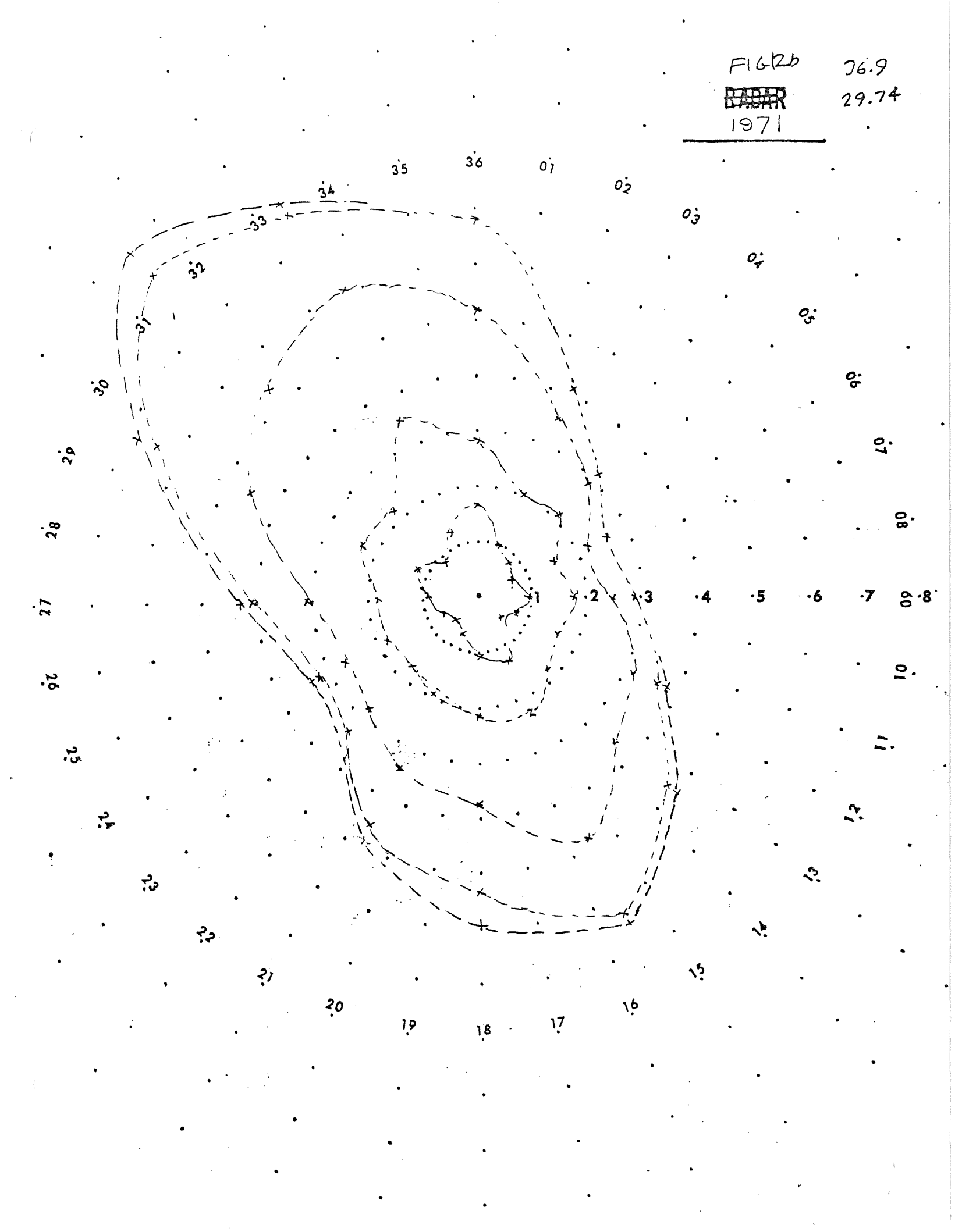


FIG 2b
36.9
RADAR
29.74
1971

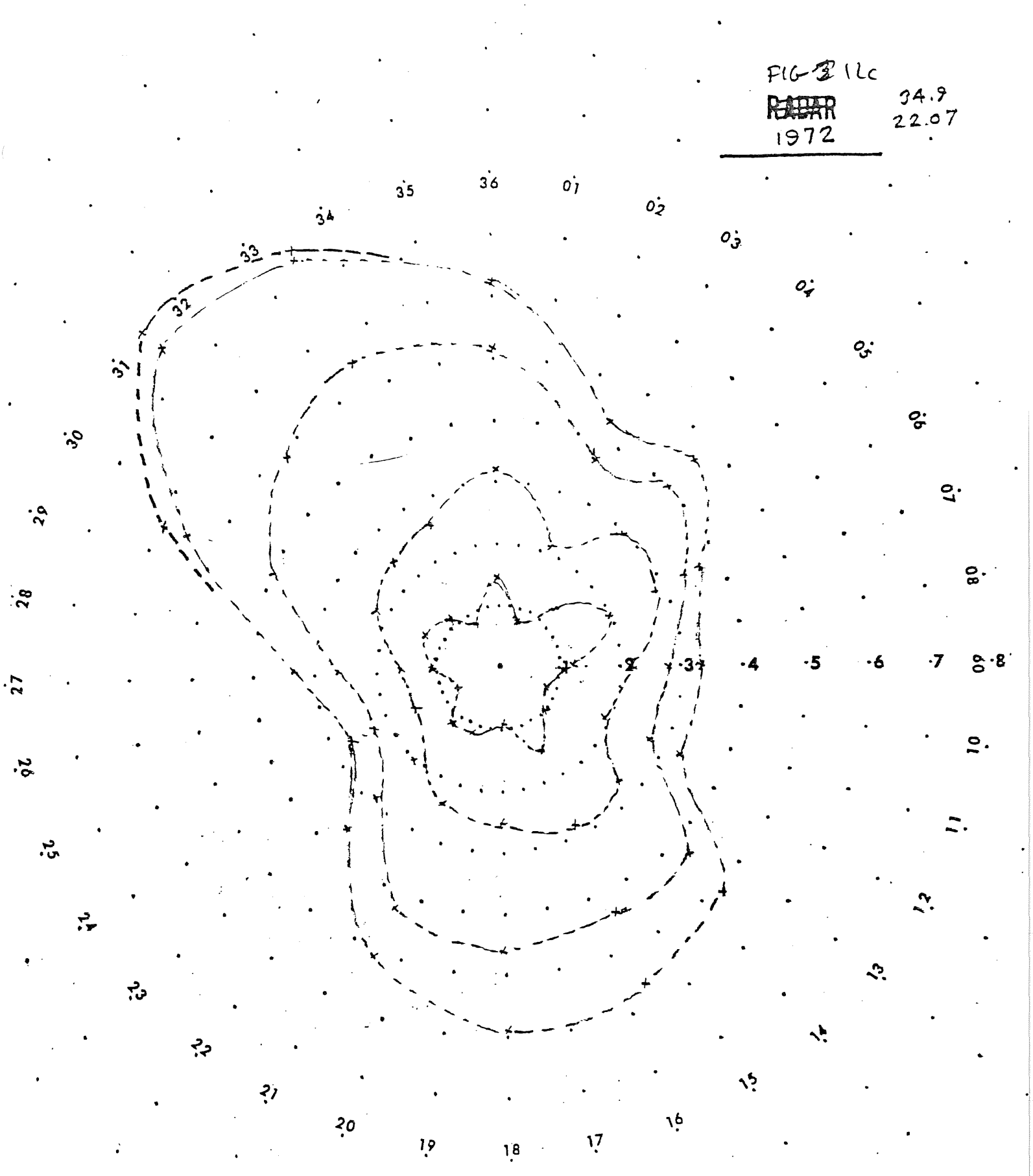


FIG 3 11c
RADAR
1972
34.9
22.07

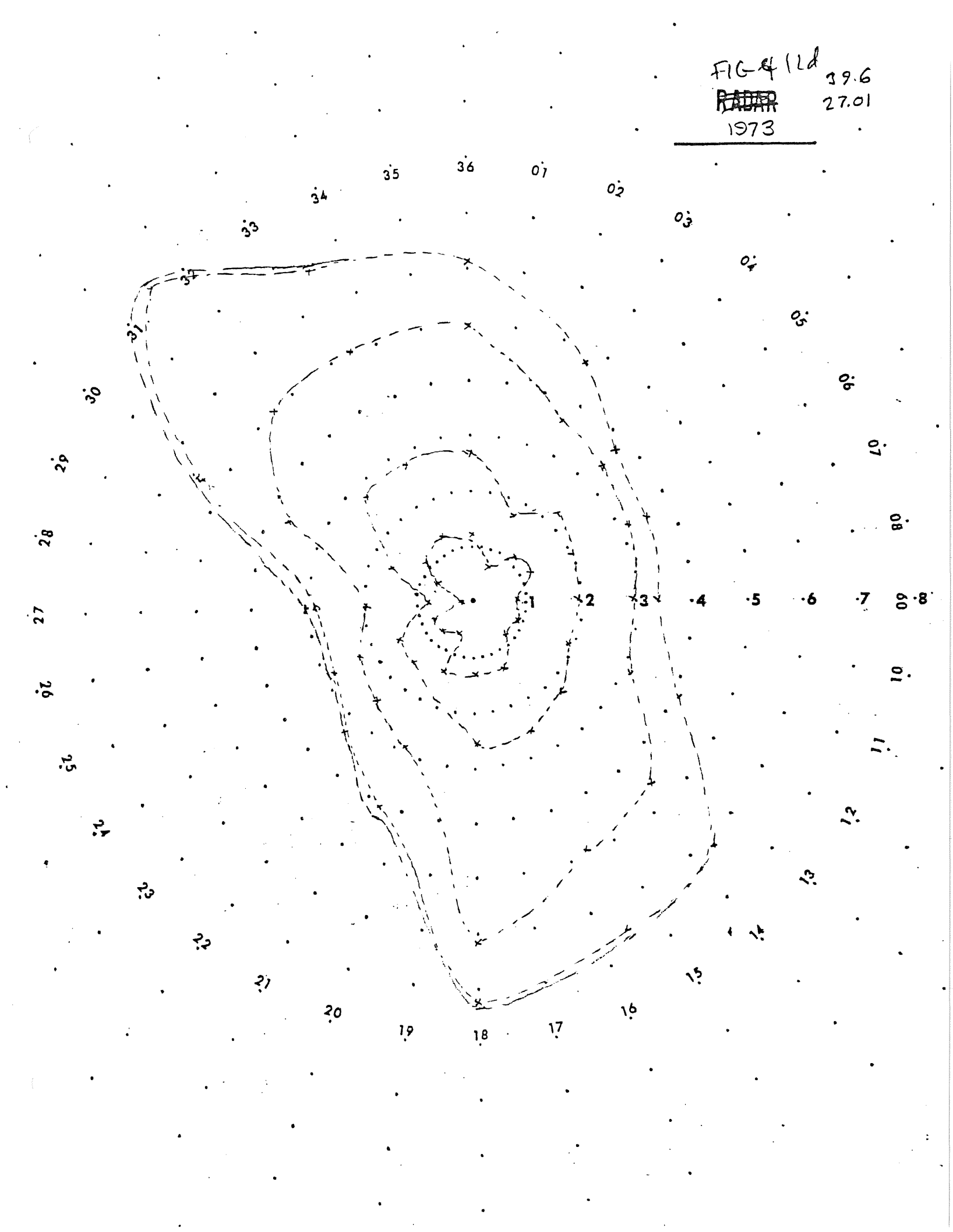


FIG-4 12d
39.6
27.01
1973

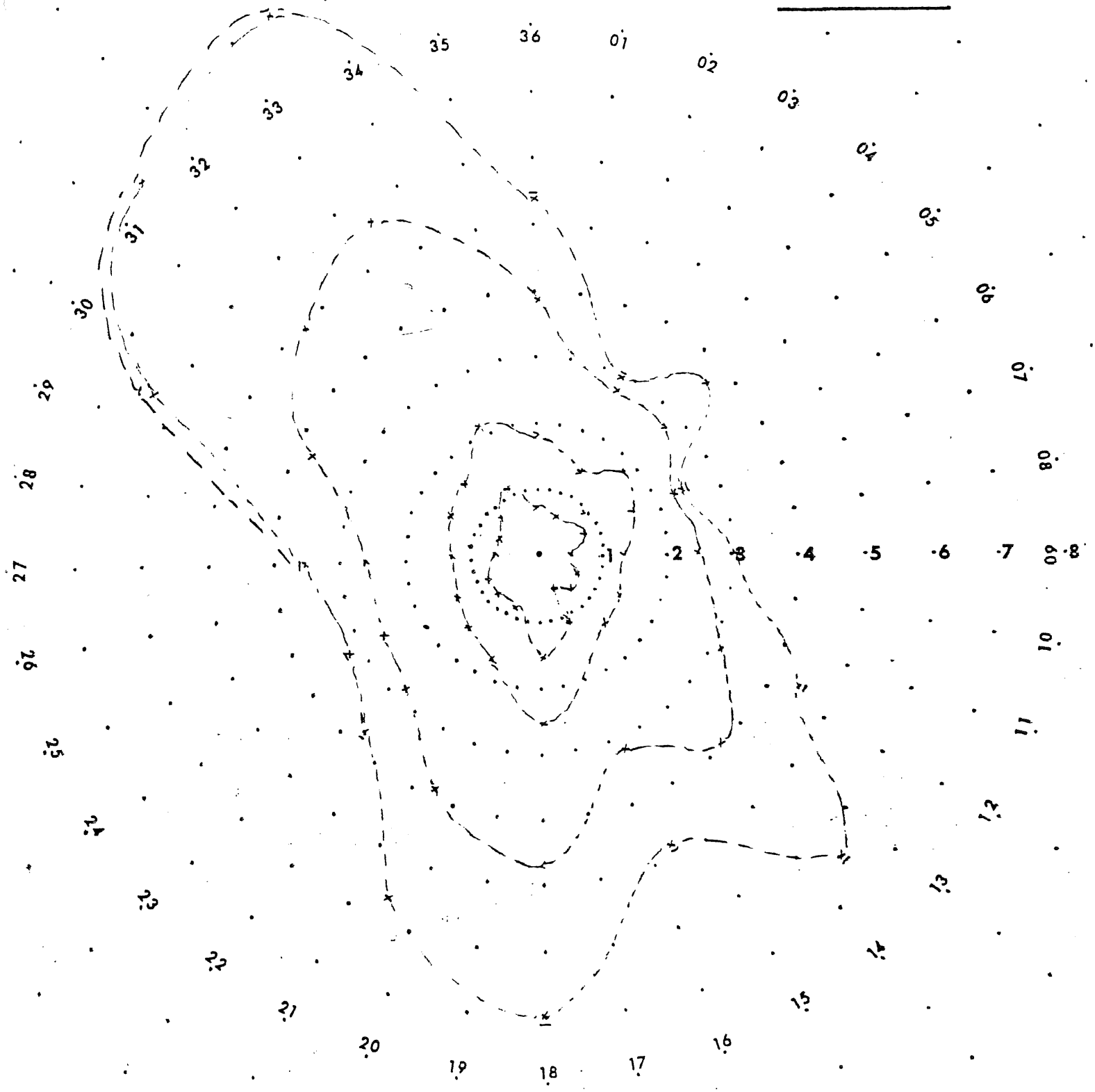
12 k

Fig 3 36.9

32.92

RADAR

1974

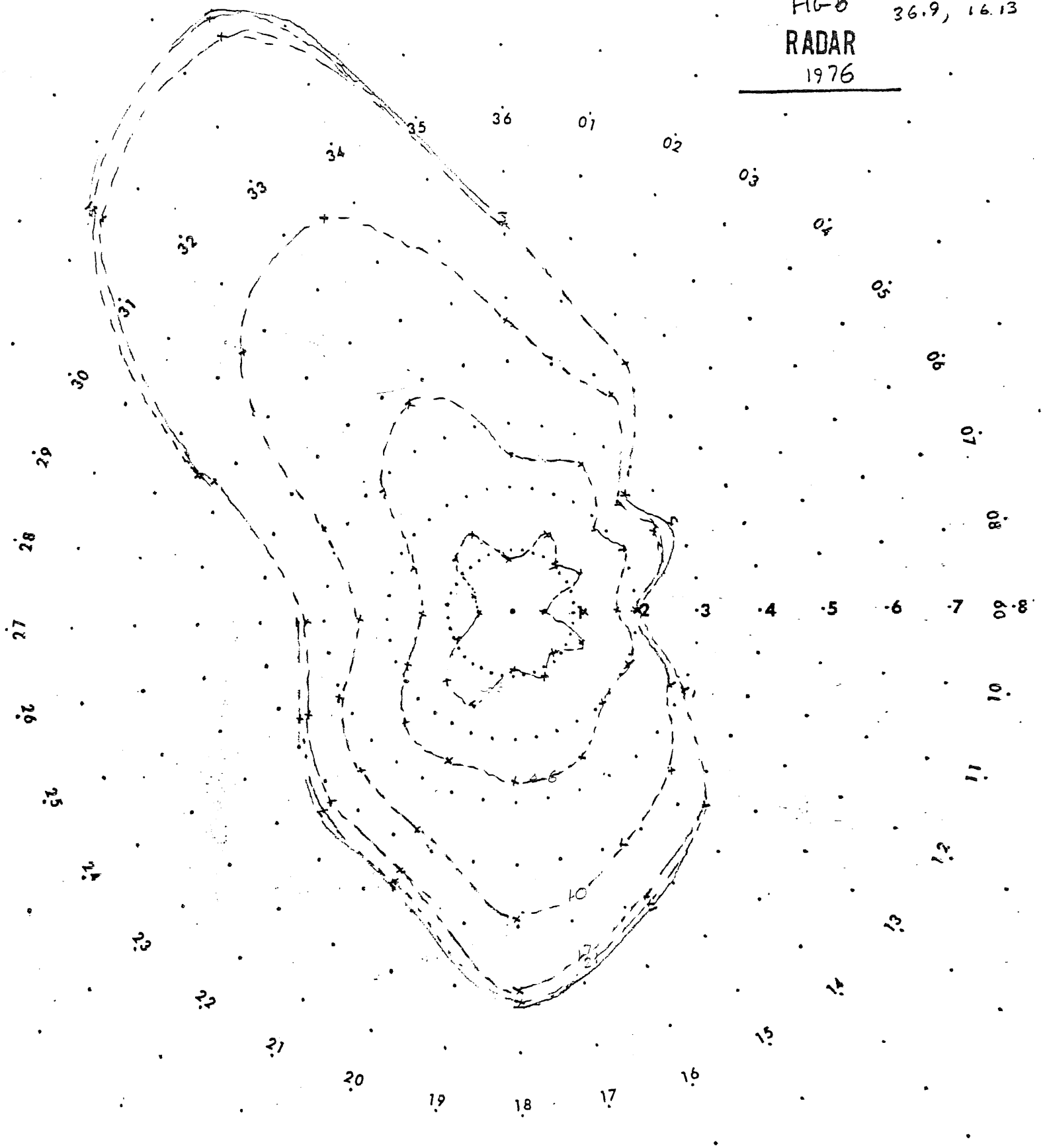


12 f

FIG-B 36.9, 16.13

RADAR

1976



June 1976--An excess of winds between 130° to 220°, a deficit between 280° and 320°. Also, a deficit between 070° and 120°. With the surplus of southerlies and lack of northwesterlies, the mean month's temperature averaged 3.3° above normal.

July 1976--The rose was near the normal. The mean monthly temperature was near normal also, with the temperature 67.3°, 1°F above the average.

August 1976--A very strong southerly surplus, from 135° to 210°. Also strong deficit of northwesterlies, from 240° to 350°. The temperature was 3.3° above normal.

September 1976--The wind rose was near the normal, but with more southwesterlies and fewer southeasterlies than usual. Temperature averaged 1.6° above normal.

October 1976--Southeasterlies and southerlies were far below normal, with a strong surplus northwesterlies. The temperature was 7.3° below normal.

November 1976--Virtually no easterly winds blew during the month. Very strong surplus of winds between 315 to 355°. Temperature 4.7° below normal.

December 1976--Very few easterlies and strong surplus of northerlies as in November. Temperature 9.7° below normal.

January 1977--This month was the third straight of very strong northwesterlies. The wind was from between 280° and 300°, about 90% of the time. The temperature was 8° below normal.

March 1977--The month was marked by a surplus of winds between 40° to 220° and very muted northwesterlies. The temperature was a strong 9.4° above normal.

April 1977--April brought a strong surplus of southeasterlies and winds from due north to north-northeast. Northwesterlies and easterlies in general were less than usual. The temperature was 7.3° above normal.

May 1977--Lopsided bias toward southeasterlies and southerlies with very little northwesterlies, northerlies, or northeasterlies. The temperature averaged an extreme 11.3° above normal, the most above normal of any month of the Study.

June 1977--The wind rose was near normal, but with more southerlies and fewer southeasterlies than usual. Westerlies were enhanced and easterlies muted. Temperature was 1/2° above normal.

6.2.1 Comparison of Winds in the Region

6.2.1.1 Hibbing and Isabella--Comparison of wind roses between Hibbing, at the west end of the Study Area, and Isabella, at the eastern end, is of interest to learn about variations over the region.

March 1977--Isabella was with slightly more westerly components, slightly stronger ESE.

April 1977--Fewer northerlies at Isabella than at Hibbing. Difference made up by more southerlies at Isabella.

May 1977--Wind roses much the same.

June 1977--Wind roses much the same. Northerly peak at Hibbing mostly due to local air drainage and/or local channeling.

July 1-24, 1977--Wind roses much the same.

August 18-31, 1977--More northwesterlies at Hibbing, made up by more southeasterlies at Isabella.

6.2.1.2 Hibbing and Other Locations--Comparison of wind roses is also available for Eveleth from data taken by Interpoll (from Interpoll report to MPCA 1978) from January to September, 1977. The roses, not shown here, are similar to those at Hibbing and Isabella. During April, Eveleth, like Isabella, did not have the high occurrence of winds from 350, 360, and 10° that were found at Hibbing. Possibly, the occasional north wind anomaly that seems to show up at Hibbing is due to a local channeling effect.

During the Study, wind roses for a 7-year period for Atikokan, Ontario, were obtained. The Atikokan roses show directions similar to those at Hibbing, except for much higher frequencies out of the southwest at Atikokan. This difference may be due to local effects.

6.2.2 Similarities and Variations

What can be concluded from the comparison of the wind roses and from general observations made during the Copper-Nickel Study?

First, there are no strong, basic differences in wind regime over the general "mine site" area. The "mine site" area is sufficiently remote from Lake Superior in that the Lake-influenced winds is not important. Isabella is undoubtedly very near the western edge of Lake Superior influence, but since Isabella is east of the "mine site" area, it can be concluded that since Hibbing winds and Isabella winds are similar, the Hibbing wind data can be used to adequately represent winds in the "mine site" area on the broad scale.

However, local topographic effects are important. It must be borne in mind that both the Hibbing and Isabella stations are relatively free of topographic influence, except for a tendency toward an apparent topographic-enhanced north wind at Hibbing. Immediately south and north of the Embarrass Range there must be important local modifications to wind direction and speed. This was observed directly many times in passing through that area--as would be expected from such a high range of hills--or mountains, as they are referred to on some maps.

Locations such as Isabella are largely free of local effects--Isabella was, of course, chosen as a site since topographical consideration was made in selecting it as an observing site. However, it must be remembered that much of the region is quite hilly. Any specific location should be evaluated for local effects as related to specific activities. In general, local effects will be important to airborne materials that have their origin at or near the surface. However, any emission to the atmosphere occurring through a stack well above the local terrain will not be influenced significantly by that terrain.

Depressed locations such as the Embarrass Valley will be subject to a high frequency of light winds and calms. The low nighttime temperatures found at the Embarrass station and on temperature surveys are associated with very light winds. Temperature observations can be a key used to evaluate the susceptibility of a site to light winds. It would be useful to any future evaluation project to install a thermograph in the Reserve Mining weather station, if Reserve is willing, to facilitate easy comparison of a study site (equipped with a thermograph) for susceptibility to light winds. A measure of temperature differences at nighttime between the high-ground Babbitt station and a lower station is an index to wind as well as to variables such as stability.

Chapter 7 UPPER AIR OBSERVATIONS

Observations of the upper atmosphere were made during the Regional Copper-Nickel Study, mainly to support air quality and other work. Data were taken with a Contel upper air sounding station. Some of these data are of interest to review here.

7.1 PROJECT BALLOON-BORNE SONDINGS

Figures 15a - 15c give a series of observations made in July , 1977, in support of "Operation Dust Cloud." The first three days of the observations, July 25-27 were taken between frontal passages 47 and 48 (see section on weather events during the Study). High pressure passed mid-morning on 26 July, as noted in the weather events section.

The transition of winds at all levels to 4,500 meters from northwesterly on the 25th to westerly on the 26th to southwesterly on the 27th as the high passed to the south can be seen. The reader can benefit by reviewing the figures to note how structure of the atmosphere varies from behind a cold front through the high to the southerly flow behind the high and ahead of the next front.

July 28 was marked by the passage of a Pacific front and showers, with a cold continental front coming in on July 29. Wind observations were limited on July 29 by low clouds that arrived in connection with the unstable polar air from the north.

Further frequent observations were made in August in support of a sound propogation experiment. Upper air data were taken here between fronts 58 and 58W of 1977 on August 23, 24, and 25. Data for the 24th show the northwesterly flow

behind the front on August 3, 1977. The chart for August 24 is especially interesting. It shows the entire sequence from northerly flow ahead of the high pressure in the early morning to the very weak flow during midday to southerly flow in the evening.

Other data were taken about once a month to compare upper air patterns with those at International Falls to see how well that station reflects upper air patterns in the Study Area. Outside of the very lowest altitude, very near to the surface, no important differences were found.

7.2 INTERNATIONAL FALLS CROSS-SECTIONS

Figures 16a-16d give upper air temperature cross-sections at International Falls during four selected months during the Study from 100 to 40 Kilo-Pascals (kPa) (1,000 to 400 millibar).

In Figure 16c, for July, 1976, note the very strong cooling at mid-month. This was in connection with a cold Pacific occlusion followed by a surge of polar air. Note the freezing level (0 degree isotherm) extending below 80 kPa (about 5,000 ft above the surface of the region).

In August, 1976, the cold influx in the 26th followed another Pacific front followed by a continental polar surge. Cold air flow behind the sharp cold fronts can be seen having a deep effect on September 9 and 20, 1976, and on September 10 and 19, 1977.

The reader is invited to review these upper air cross-sections in connection with the review of the weather section to gain further understanding of the meteorology of the Study Area.

Figure 17 is an event graph of inversions at Isabella from the tower. In winter, very long inversions take place when winds are light and skies are clear, but during storms a few days may go by without any inversion. Note from the graph that in summer inversions are short-lived, but they are present on most nights. In summer, inversions are often interrupted for several hours when thunderstorms pass through. No low-level inversions were ever present in the hours around midday, summer and winter alike.

7.3 ISABELLA TOWER OBSERVATIONS

7.3.1 Lapse Rates

The subject of lapse rate, i.e., temperature charge with height above ground, must be addressed with great care, especially in the Copper-Nickel Region. The significance of lapse rate is very much a matter of scale. For reference to lapse rates derived during the Project in connection with air quality applications, the reader is referred to the report on Air Quality. Here we shall discuss lape rates on the various scales as they pertain to the climate of the Copper-Nickel Region.

Over the daily cycle, air is heated by the ground by day and cooled by the ground at night. In addition, cold air drainage brings enhancement to inversions by night. Indeed, in valleys and dells, cold air drainage may be the dominating factor in setting up strong inversions rather than simple radiational cooling of the ground space.

7.3.2. Tower Data

Figure 18 gives the temperature difference on a fine weather day, September 14, 1977 on the Isabella River, with sensors at 5 feet and 50 feet above the sur-

face. From the start of the day to 0700 an inversion is present, i.e., the temperature at 50 feet is warmer than at 5 feet. During most of the day, the 5-foot level is a bit less than 1°C warmer than the 50-foot level, corresponding to a superadiabatic lapse rate in the shallow layer near the surface. With nightfall, the inversion sets is once again. For the same day, the temperatures at Eagles Nest and Embarrass are shown in Figure 19, and the temperature difference between Eagles Nest and Embarrass for the same date and data shown in Figure 20. It is likely that the temperature curve at Eagles Nest would be more the same as that at the Reserve station above Babbitt; in any case, it would be roughly similar as a typical day. Note that it takes until about 0940 before the Embarrass valley station becomes warmed to the point where it is equal to the Eagles Nest station, and presumably the Reserve station. In the evening, the Embarrass station is cooler than the other station after 1730 CST. Visualize the very enormous amount of heat that must be poured into the Embarrass Valley before the inversion therein is broken--as compared to the quick overturning in the shallow layer from 5 to 50 feet at the Isabella tower.

The meteorology of atmospheric dispersion is much different for dust and emissions near the ground than for emissions at heights on the order of a hundred or hundreds of meters. Considering the topography of the Copper-Nickel Region, with low regions such as the Embarrass and Dunka River valleys in proximity to high hills, it is important to take into account the exact problem (design character of emission source) in conjunction with exact location and topographical situation when addressing dispersion problems.

One approach often used to aid in the description of dispersion character of the atmosphere is mixing height. This is the height to which atmospheric mixing is taking place

for the ground upward. These heights were calculated by the author for 1976 from International Falls radiosonde and Hibbing surface data: and from these data plus consideration of the meteorological anomolies for each month, estimates were made for mixing heights to be expected on the average over a normal period.

Table 5 gives calculated mixing heights for 1976, and Table 6 gives normal mixing heights for the Region. Maximum mixing heights are to be expected in May, when temperatures in the lower layers are the warmest with respect to temperatures aloft. The evidence is overwhelming that Holzworth values, which were very crudely arrived at, and which give a greater mixing depth in the Region summer than in spring, are not the best to use.

Chapter 8 CONCLUSIONS

Variability of climate in the Copper-Nickel Region is much more due to topography than it is due to other factors. This should be, perhaps, expected because of the strong topographical variations found in the region, from the high ground of the Embarrass Range to the Valleys of the Dunka and Embarrass Rivers, and from the rough hills and deep-sited lakes of much of the rest of the region.

The difference in winds between Hibbing and Isabella is slight--much less than the difference in winds between Hibbing and International Falls. But the difference in winds that prevail between Hibbing and International Falls is found mostly in the very lowest levels of the atmosphere.

Perhaps the strongest influence of Lake Superior on the Copper-Nickel Region is in precipitation pattern. Month after month, the precipitation patterns tended to be parallel to the lake shore.

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APPENDIX

English-to-Metric Tables

The metrological community had planned to convert to the SI (System Internationale) units just prior to the beginning of the Copper-Nickel Study. Presently, a mixture of English+SI units are used in the meteorological community. In addition, plans were to convert the following year during every year since up to several months ago, when plans were shelved indefinitely. These postponements have been due to political pressure. Units used in this report are those in common use at present. The following tables are presented to enable the reader to make any needed conversions.