CRREL REPORT 89-20

US Army Corps of Engineers
Cold Regions Research & Engineering Laboratory

Ice conditions along the Illinois Waterway as observed on Landsat images, 1972–1985

Cover: *Ice covers the Illinois River (A) and most of the Mississippi River (B) shown on this Landsat MSS image (ID 30325-16062) taken on 24 January 1979. The Missouri River (C) is ice free here. The St. Louis metropolitan area (D) is between the Missouri and Mississippi Rivers at the bottom right of the picture.*

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December 1989

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RIM

RIVER ICE MANAGEMENT

Prepared for
OFFICE OF THE CHIEF OF ENGINEERS

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These conversion factors include all the significant digits given in the conversion tables in the ASTM Metric Practice Guide (E 380), which has been approved for use by the Department of Defense. Converted values should be rounded to have the same precision as the original (see E 380).

Multiply	*By*	*To obtain*
foot	0.3048	meter
$foot^3$/second	0.02831685	$meter^3$/second
mile (U.S. survey)	1609.347	meter
degrees Fahrenheit	$t_{°C} = (t_{°F} - 32)/1.8$	degrees Celsius

EXECUTIVE SUMMARY

Landsat Multispectral Scanner, Thematic Mapper and Return Beam Vidicon images were used to map ice distributions along the navigable river portions of the Illinois Waterway from the Mississippi River to Lake Michigan, and air temperature and discharge data were used to characterize the conditions under which the observed ice formed and changed. The presence or absence of ice on adjacent lakes, channels and sloughs is also discussed.

Ice was observed on the waterway during 10 of the 13 winters from 1972 to 1985 and on adjacent water bodies every winter. Ice conditions changed frequently on the navigation channel of the waterway, which is not surprising since large variations in freezing degree-days (FDD), melting degree-days (MDD) and river flows were typical during and between the winters.

Extensive and long-lasting ice covers formed on the waterway during 1976–77, 1977–78, 1978–79 and 1981–82. The most extensive ice occurred during 1984-85 when 83% of the waterway was covered. This winter had one of the low FDD/MDD ratios for the November–March period, 1.11, but the highest FDD/MDD ratio and rate of freezing during the freezing period, and the fourth highest total flow volume, 5.52×10^6 ft^3/s days. However, most of the flow occurred in March, which is at the end of the normal ice season.

Of the winters with 700 or more accumulated FDD, most saw more than 60% of the waterway ice covered when the cover was at its observed maximum. Exceptions were 1973–74 and 1979–80. The FDD/MDD ratio was extremely variable and thus not a particularly good indicator of early ice conditions, but it was greater than 1 most of the time when maximum ice was observed, and it was always greater than 1 when last ice was observed.

I first observed ice on the waterway usually in early to mid-December, and it was gone by middle to late February, although these times are quite variable. Ice on lakes, channels and sloughs adjacent to the navigation channel was observed earlier and usually lasted well into March.

Total flow volume for the entire winter had no apparent influence on the amount of ice covering the waterway when the ice was at its maximum and on the length of time ice stayed on the waterway and adjacent areas; however, timing and intensity of the changes in discharge were very important. When first ice was observed, discharge was falling or in a trough for most (80%) of the winters. At maximum ice, discharge was falling or in a trough 60% of the winters and was less than 20,000 ft^3/s 70% of the time. When last ice was observed, discharge was rising or peaked for 60% of the winters; it was falling or stable for 40%.

Landsat image analysis provides data on general ice conditions and distribution, especially during winters when ice is extensive and long-lasting. During winters when ice is not so, Landsat images are less useful because of the time gaps between usable images caused by cloud cover and the satellite repeat cycle. Although image resolution is too coarse to determine detailed characteristics of ice cover and to discern thin ice or frazil ice that frequently exists at freezeup, the images provide a view of large reaches of a river on each scene and, for many rivers in cold regions, they commonly are the only source of data on ice conditions.

Air temperature and discharge determine ice conditions and distribution, but the results of this study indicate that temperature is usually the more important factor. When used in conjunction with air temperature and discharge data, Landsat images provide a good and reasonably reliable method to study river ice conditions and changes. The images show ice distributions while the air temperatures and discharge show conditions that produce the observed ice cover and changes in it. This method is especially useful when other data sources on ice conditions are limited or unavailable.

Ice Conditions Along the Illinois Waterway as Observed on Landsat Images, 1972–1985

LAWRENCE W. GATTO

INTRODUCTION

In the northern United States, ice can delay or stop winter navigation and cause unexpected emergencies. Because of its responsibility for providing safe and reliable navigation routes, the Corps of Engineers analyzed river ice and investigated structural and operational solutions to ice problems on rivers as part of its River Ice Management (RIM) program.

Previous reports give the results of the collection of data on past ice conditions along the Ohio, Allegheny and Monongahela Rivers and the Illinois Waterway from ground observations (Bilello et al. in press, 1988a, b), aerial photographs and video tapes (Gatto and Daly 1986, Gatto et al. 1986, 1987a) and Landsat images (Gatto et al. 1987a, Gatto 1988a, b).

The ice data were required for developing an ice forecasting model, for evaluating remote sensing systems, and for other projects in the RIM program. The purpose of this report is to describe ice conditions on the Illinois Waterway during the winters of 1972–73 through 1984–85 as determined from Landsat images. Previous reports (Gatto 1988a, b) detail Landsat image characteristics and the approach and techniques used when analyzing the images, so these topics will only be summarized here.

The area of study is the 327 miles of the Illinois Waterway from Lake Michigan to the Mississippi River (Fig. 1). The Illinois River portion of the

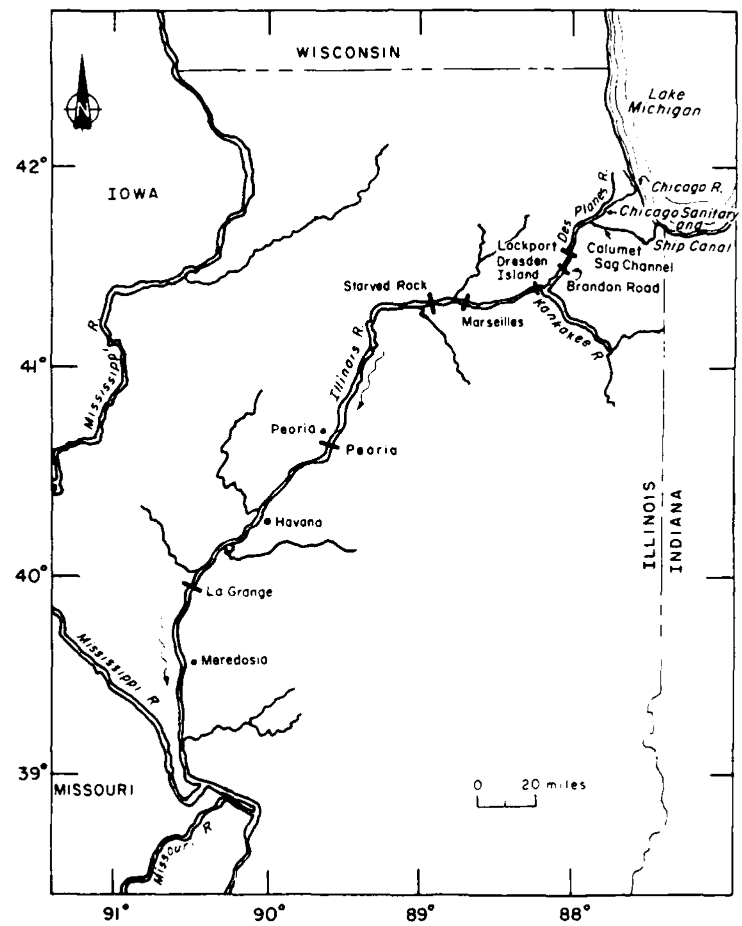


Figure 1. Location map with Corps of Engineers lock and dam sites.

Table 1. Pools along the Illinois Waterway.

Landsat imagery (path-row)		*Pool*		*Pool start and stop points*
Landsats 1–3	*Landsat 4,5*	*No.*	*Length (mi)*	*(river miles)*
24–31, 25–31	22–31, 23–31	1	36.2	Lake Michigan (327.2) to *Lockport** L&D (291)
24–31, 25–31	23–31	2	5.0	Lockport L&D to *Brandon Road* L&D (286)
24–31, 25–31	23–31	3	14.7	Brandon Road L&D to *Dresden Island* L&D (271.3)
24–31, 25–31	23–31	4	27.0	Dresden Island L&D to *Marseilles* L&D (244.3)
24–31, 25–31	23–31, 24–31	5	13.2	Marseilles L&D to *Starved Rock* L&D (231.1)
25–31, 26–31, 25–32, 26–32	23–31, 24–31 23–32, 24–32	6	73.5	Starved Rock L&D to *Peoria* L&D (157.6)
25–32, 26–32	23–32, 24–32	7	77.5	Peoria L&D to *LaGrange* L&D (80.1)
25–32, 26–32, 25–33, 26–33	24–32, 24–33	8	80.1	LaGrange L&D to Mississippi R. *Confluence* (0)

* Italicized names are used in the text of this report to refer to pools that divide the waterway into sections shown here.

waterway extends from the Kankakee River (Fig. A7) to the Mississippi River, is about 273 miles long and has five dams and locks (Table 1). Its navigation depth is at least 9 ft, and it requires periodic dredging. Above the Kankakee River to Lake Michigan (about 54 miles) the waterway includes portions of the DesPlaines River, the Chicago Sanitary and Ship Canal, the Chicago River and the Calumet Sag Channel. The Calumet Sag Channel is not part of this study. On only eight dates was the waterway above Lockport Lock and Dam (L&D) analyzed with the Landsat images. The width of the waterway in this reach varies from approximately 170 to 350 ft, which is too narrow for its ice cover to show distinctly on other than Return Beam Vidicon (RBV) and Thematic Mapper (TM) Landsat images. These two image types are not as numerous as those from the Multispectral Scanner (MSS).

APPROACH

Landsat images

Five Landsat satellites have acquired images since 1972, each with two imaging sensors. Landsat 1, 2 and 3 had an MSS, with an Instantaneous Field of View (IFOV) of approximately 260 by 260 ft. These three satellites also carried an RBV, which had an IFOV of 262 by 262 ft on Landsat 1 and 2, and 131 by 131 ft on Landsat 3. Landsat 4 and 5 have an MSS (same IFOV) and a TM, with an IFOV of 98 by 98 ft. Previous studies (Gatto 1988a, Skorve and Vincent 1987) demonstrated that the 0.6- to 0.7-µm images showed more gray tones in river ice than the other spectral bands, so I analyzed images from the 0.6- to 0.7-µm MSS, the 0.580- to 0.680-µm RBV (Landsat 1 and 2), 0.505- to 0.750-µm RBV (Landsat 3), and 0.63- to 0.69-µm TM (Landsat 4 and 5). Seven images from Landsat 1, 2 and 3 and six images from Landsat 4 and 5 were required to completely cover the waterway (Table 2). Appendix B lists the dates of all Landsat images analyzed during this study.

Using Landsat images for analyzing river ice distributions along the waterway has several drawbacks. First, the number of usable images is limited because repeat coverage of a given Landsat groundtrack occurs only every 8 or 9 days, and cloud cover can obscure the river during some of these passes. A particular ground location along the waterway was imaged on successive days with Landsat 1 through 3, but cloud cover frequently obscured the ground on one or more of the days (App. C). An image of the same location would not be taken again by the same Landsat for 9 more days. The Landsat 4 and 5 satellites take images of the same location every 8 days because of their orbital configurations, but the same cloud cover problems exist.

Second, neither river ice nor all its types and conditions are always apparent on a Landsat image because the IFOV (i.e., footprint) of the sensors is sometimes too large. Each pixel brightness value

Table 2. Nominal coverage of each Landsat image of the Illinois Waterway.

Landsat 1–3		*Landsat 4,5*	
*Path-row**	*Approx. river miles*	*Path-row*	*Approx. river miles*
25–31	Lake Michigan to 195–180	22–31	Lake Michigan to 299
24–31	Lake Michigan to 245–250	23–31	Lake Michigan to 198
26–31	220–230 to 160–170	23–32	202 to 133
25–32	200–190 to 50–70	24–31	235 to 180
26–32	160–180 to 30–50	24–32	183 to 53
25–33	50–70 to 0	24–33	59 to 0
26–33	35–55 to 0		

* Images with the same path number were taken on the same day.

on an image results from the reflected light integrated over the entire footprint, and small ice features and details within a footprint are not differentiated. Sometimes a river channel itself is too narrow to be clearly visible. The MSS IFOV is approximately 260 by 260 ft and the width of the channel between Brandon Road and Lockport L&D varies from about 300 to 450 ft, so the channel appears in only 1 to 1.5 pixels on an MSS image. Upstream of Lockport L&D, the channel width varies from about 170 to 350 ft, which is only 0.5 to 1.5 MSS pixels. This resolution is too coarse for the channel, no less the ice on it, to show distinctly on MSS images. Beginning in the 1979–80 winter, TM images with a smaller IFOV became available and these channels were more apparent because they made up from 1.7 to 4.3 pixels on a TM image. However, more Landsat MSS images have been acquired since 1972 than images from the other sensors with smaller IFOVs and were the most frequently analyzed.

Third, the images do not show all the detail that is detected by the Landsat sensors and, consequently, it is not possible to differentiate as many ice types and characteristics as may have been detected. To get full use of the spectral and spatial resolutions of the imagery data, computer analysis of the data would be necessary. Limited funds and time made this approach impractical, since hundreds of images were analyzed during this study.

The three drawbacks above caused the following difficulties during Landsat image interpretation. First, along reaches with narrow channels bordered by linear islands, it was difficult to determine if gray ice was present or if the observed gray tones resulted from shore effects. Second, numerous adjacent lakes, channels and sloughs complicated the patterns apparent along the waterway, and snow cover frequently obscured the transition from bank to ice, both of which made it difficult to locate the main channel and to determine if ice was present or not. However, early in the winter, snow occasionally enhanced the difference between land and open, ice-free water, so the absence of ice was more evident. Third, gray ice was frequently difficult to see when haze, thin clouds or partly cloudy conditions existed.

Image interpretation and mapping

The IFOV and spectral resolution of Landsat sensors are insufficient to show the differences among ice conditions visible from low-altitude aircraft (Gatto and Daly 1986, Gatto et al. 1986, 1987a,b), but show enough detail to differentiate open water, gray ice that completely or partially covers a water reach, and white ice. Textures and patterns within the tones were also apparent sometimes.

The primary characteristics that influence gray tones for river ice observed on Landsat images are ice thickness, snow cover and mixtures of river conditions, i.e., different ice types, open water areas and various combinations of these, some of which are smaller in area than the IFOV of Landsat sensors. This is important because the principal source of error in this study arises from the erroneous inferences one could make regarding the ice conditions that Landsat gray tones represent. For example, thin ice in one scene may be transparent, appear black, and be classified as open water. This same ice cover viewed after a light snowfall would appear white.

To determine which types of river ice produced the different tones, textures and patterns, I compared ice conditions shown on low-altitude aerial photographs to those visible on Landsat images. From my comparisons, I found that when the river appeared black on an image and had no discernible textures and patterns, the river was ice free (Fig. 2, A1, A2, A9, A15). It is possible, however, that thin

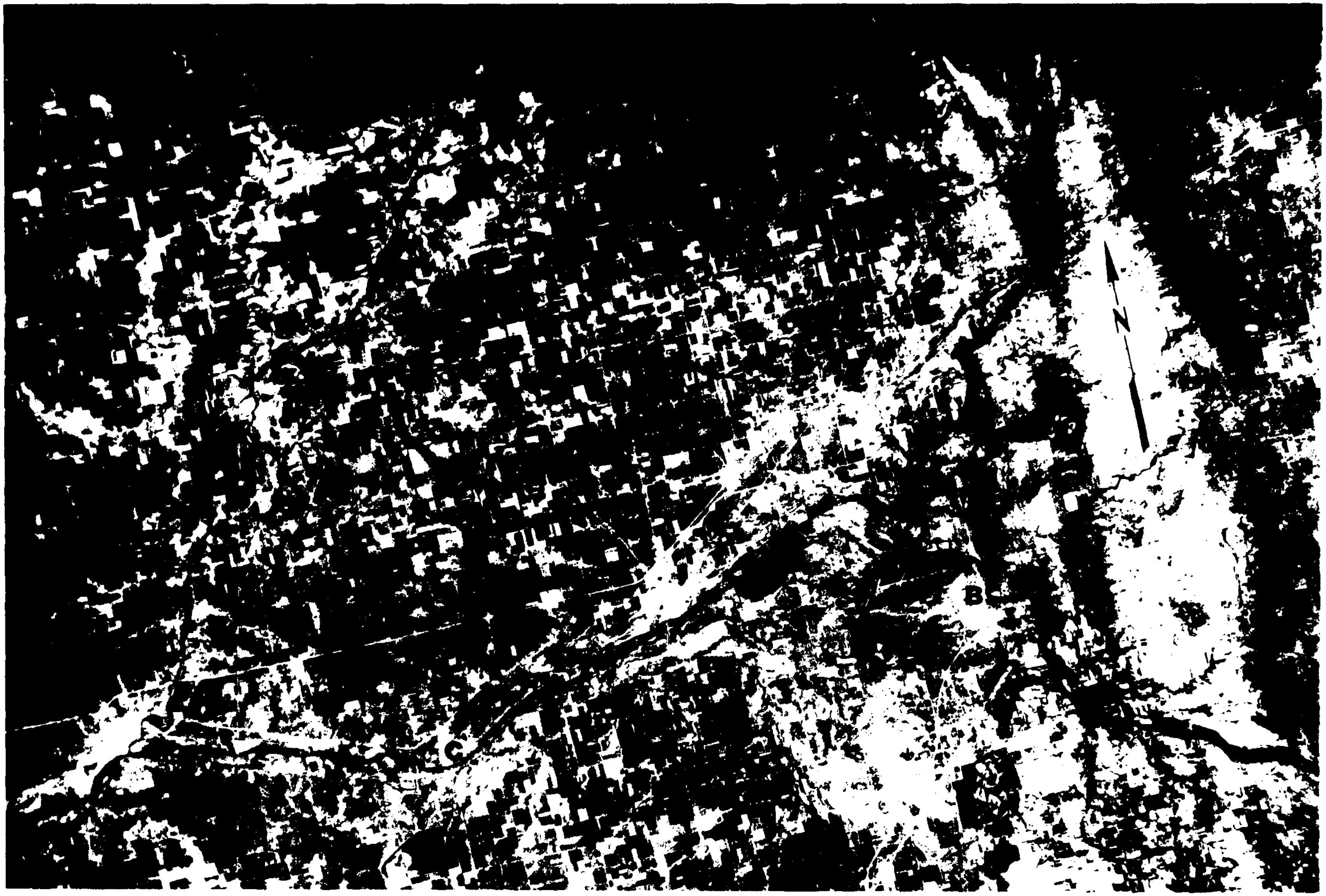
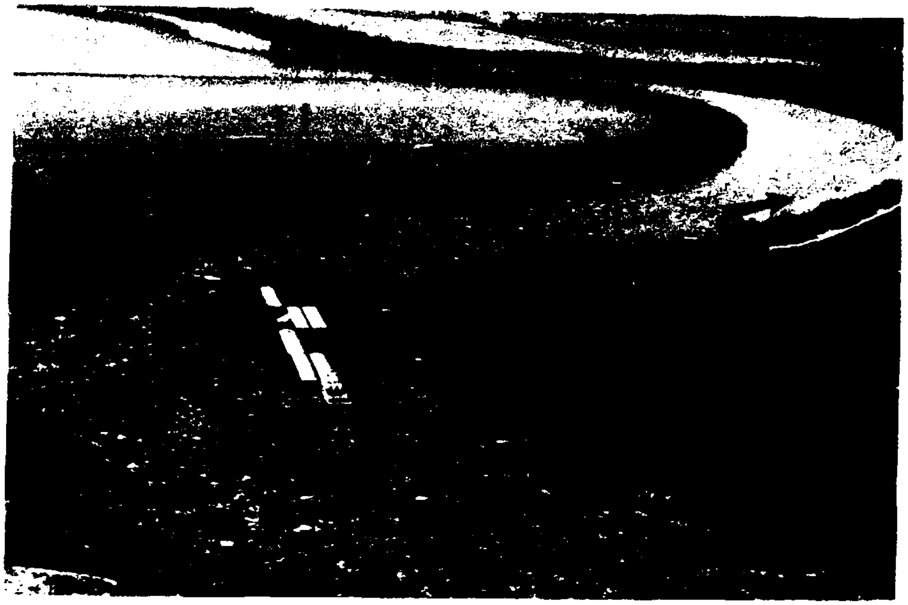


Figure 2. Even-toned, dark appearance of the Des Plaines (A), Kankakee (B) and Illinois (C) Rivers was because they were ice-free; RBV image 31098-15504D, 7 March 1981.



a. 7 miles below Peoria.

b. 5 miles below Peoria.

Figure 3. Low-altitude aerial photographs showing ice conditions that would appear as gray ice, on Landsat images, 14 February 1984.

transparent ice that appears black from above covered part or all of the river in some instances. As mentioned before, thin ice such as this usually cannot be distinguished from open water in Landsat images.

Ice conditions that appear gray on Landsat images vary from fragmented ice (usually thin) with large open areas to ice floes, pans or slush mixed with open areas (Fig. 3). The gray Landsat tone often had a patchy or mottled appearance or showed textures or patterns (Fig. 4).* In some instances, it was also possible to determine where the gray ice completely or partially covered a river reach from bank to bank (Fig. 5, A4, A10, A12, A13). This distribution was mapped when it could be observed.

When the river appeared white, or nearly white (Fig. 6, A5, A6, A14), sometimes with discernible

* Some subtle detail apparent on the original Landsat images may not be obvious on these report reproductions.

a. MSS image 40572-16093 taken 8 February: Peoria Dam (A), open areas (B), gray ice with textures and patterns (C).

Figure 4. A Landsat image and aerial photographs (1, 2) of the same area in 1984.

1.

2.

b. Low-altitude aerial photographs taken 14 February.

Figure 4 (cont'd).

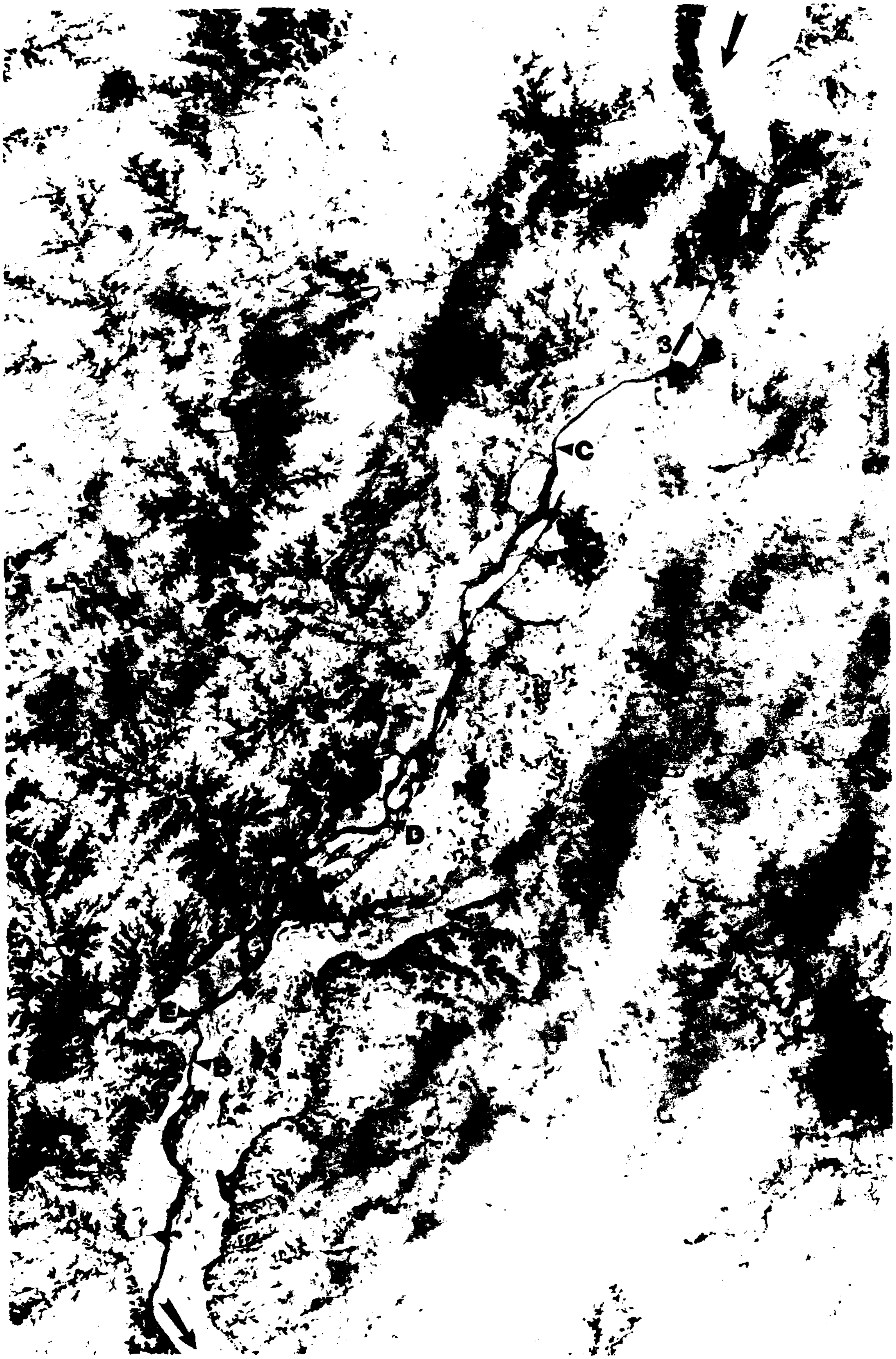
textures or patterns, ice conditions varied from solid or fragmented ice (usually thicker than gray ice) with no open water to ice with scattered open water areas that are smaller than sensor IFOV's. These openings are fewer than those that occur where a gray tone is observed. A white tone could also mean that the river ice was snow-covered. A navigation track in white ice can appear black if the track is ice-free. More commonly, the track appears gray because it is filled with slush ice, brash ice or ice floes.

When I viewed Landsat images (9- by 9-in. black and white film positives) of the waterway on a light table with 7–10 power magnifier, I transferred the upstream and downstream extent of gray ice and white ice to base maps (App. D). The lengths of river with open water, gray ice and white ice within each pool were measured and converted to percentages (App. C). The maps and percentages are for ice conditions in the navigable river portions of the waterway only.

Although ice on adjacent lakes, channels and

Figure 5. Complete (A) and partial gray (B) ice cover and navigation track (C); RBV image 31423-16064B, 26 January 1982.

sloughs was obvious (Fig. 7), it was not included on the maps (App. D). Notations of the presence or absence of ice on these adjacent areas are included in the remarks column of Appendix C. It is possible that some ice observed in the navigable portions of the waterway may have formed in these adjacent areas and been transported into the river portions. This is especially likely along the Illinois River, from the confluence with the Mississippi River to Starved Rock L&D, where adjacent lakes, channels



a. MSS image 50338-16120 taken 2 February: Peoria Dam (A), LaGrange Dam (B), partial gray ice (C), complete gray ice (D), white ice (E), navigation track (F).

Figure 6. A Landsat image and aerial photographs (1, 2, 3) of the same area in 1985.

1.

2.

3.

b. Low-altitude photographs taken 14 February.

Figure 6 (cont'd). A Landsat image and aerial photographs (1, 2, 3) of the same area in 1985.

Figure 7. Ice on adjacent lakes, channels and sloughs (A) while the navigation channel (B) appears open; MSS image 22173-15575, 3 January 1981.

and sloughs are numerous. Discussions of ice observations on the waterway and adjacent areas are included in the next section.

RESULTS

I observed ice on the Illinois Waterway with Landsat images during 10 of the 13 winters from 1972 to 1985 and each winter on the adjacent lakes, channels and sloughs. The dates cited in this report are the dates when ice was observed on Landsat images. Built-in biases regarding the ice distributions reported here are present because the entire waterway is seldom covered on Landsat images in one day, because clouds often covered portions of the waterway on the same day, and because there are large time gaps between sequential images. Consequently, some of the percentages of areal distribution and timing of certain ice conditions stated here are strictly dependent on image availability. Actual ice conditions could have been different, i.e., the dates of Landsat observations do not necessarily coincide with the dates when ice on the waterway may actually have first formed, was at its maximum extent or was last observed. However, previous results of Landsat imagery analysis (Gatto et al. 1987a) show that when Landsat images are available, they show ice 80% of the time when the river water surface temperature is 0°C and it can be conservatively assumed that river ice is present.

This section describes the amount of ice observed and air temperature (measured at Peoria, Illinois) and river discharge (measured at Meredosia, Illinois) conditions from 1 October to 31 March each winter. The temperature and discharge conditions prior to each Landsat observation are given so the reader can develop a sense for the relationship between regional air temperature, discharge and the amount of ice observed.

Note that in selecting the air temperature data to be discussed (see Appendix E), I compared the average daily air temperatures for Peru (National Weather Service station 6753), Peoria (6711) and Griggsville (3717), Illinois, from 1 October 1972 to 31 March 1973 (Fig. 8). It was clear that there was very little difference in the average daily air temperatures at these stations, and that the Peoria temperatures were frequently the lowest on any given day, so I simply used the air temperatures for Peoria to determine regional air temperatures and for calculating the Freezing Degree Days (FDD) and Melting Degree Days (MDD).

The ice cover percentages cited for a particular pool throughout this section are given in Appendix C and are different from those given in Table 3 and shown in Figure 9, which apply to the entire waterway, not individual pools.

1972–73

Ice was observed on 6 days this winter, but only 4 days on the waterway (Fig. 9a). I first observed it on 13 December, and it covered adjacent lakes and 38% of the waterway (Table 3) on the pools downstream of Starved Rock L&D (Fig. D1). Gray ice covered 29% of Peoria, 23% of LaGrange and 85% of the confluence pools on this date (App. C). The average daily air temperatures had been mostly below freezing since 15 November (Fig. E1) and nearly 204 FDD had accumulated since 5 November (Table 4, Fig. 10a), so a substantial ice cover was in place by 13 December. Mean daily discharge in October was 28,460 ft^3/s (Fig. E1).

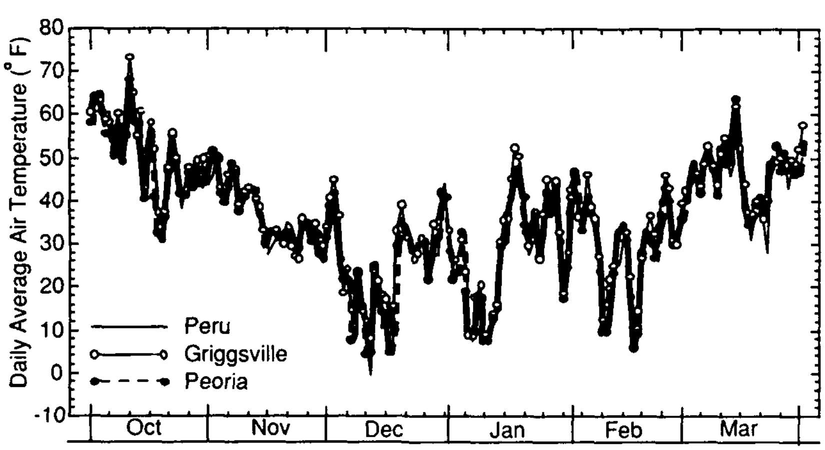
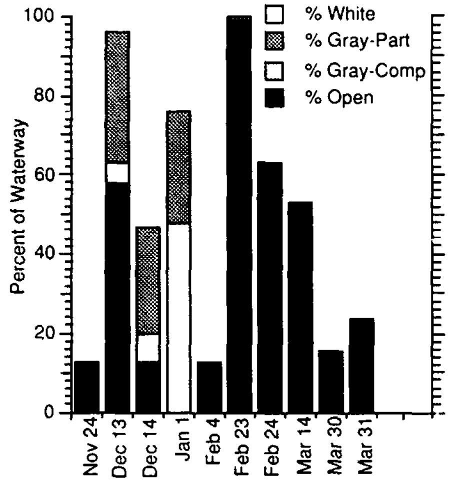


Figure 8. Example comparative graph of air temperatures for the winter of 1972–73.

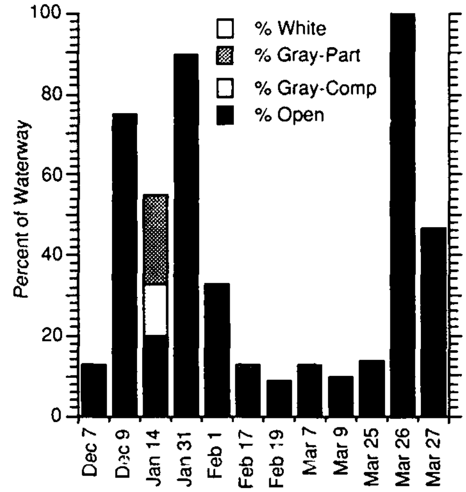
Table 3. Summary of ice distributions in the waterway (%) as observed on Landsat images (percentages rounded to nearest whole percent).

	Date	*Amount of river visible*	*Black (ice free)*	*Gray ice* Partial	*Gray ice* Complete	*White ice*
1972–73						
First ice	13 December	96	58	33	5	0
Maximum extent of ice	1 January	76	0	28	48	0
Last ice	23 February	100	99	1	0	0
1973–1974						
First ice and Maximum extent of ice	14 January	55	20	22	13	0
Last ice	17 February	13	12	1	0	0
1975–1976						
First ice	4 January	72	60	5	7	0
Maximum extent of ice	22 January	51	0	27	24	0
Last ice	9 February	21	2	0	19	0
1976–1977						
First ice	1 December	72	67	1	4	0
Maximum extent of ice	11 February	100	32	4	21	43
Last ice	18 February	42	6	6	19	11
1977–1978						
First ice	26 November	84	82	2	0	0
Maximum extent of ice	7 February	78	2	6	5	65
Last ice	25 February	36	0	2	4	30
1978–1979						
First ice	9 December	79	52	19	7	1
Maximum extent of ice	14 January	78	10	3	0	65
Last ice	10 March	77	58	7	12	0
1980–1981						
First ice	3 January	60	42	15	3	0
Maximum extent of ice	8 February	87	16	31	40	0
Last ice	18 February	3	0	1	2	0
1981–1982						
First ice	20 December	42*	25	13	4	0
Maximum extent of ice	4 February	79	0	9	2	68
Last ice	3 March	42	39	0	0	3
1983–1984						
First ice and Maximum extent of ice	22 December	81	1	51	10	19
Last ice	8 February	82	60	6	16	0
1984–1985						
First ice	25 December	50	41	9	0	0
Maximum extent of ice	2 February	83	0	15	30	38
Last ice	18 February	41	0	2	37	2

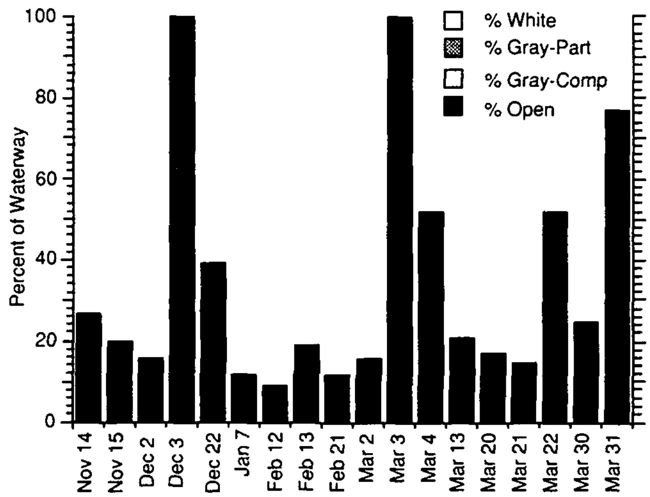
* Percentage of entire waterway (327.2 river miles). The rest of the values are percentages of the waterway downstream of Brandon Road L&D (286 river miles).



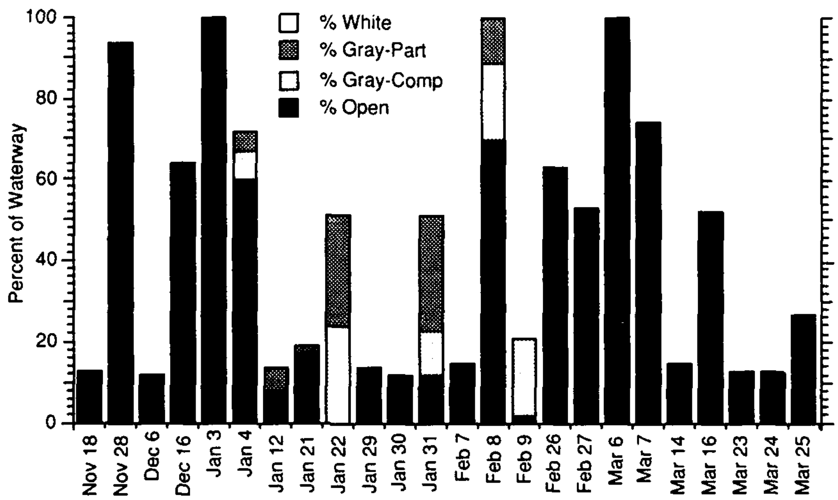
a. 1972–73.



b. 1973–74.

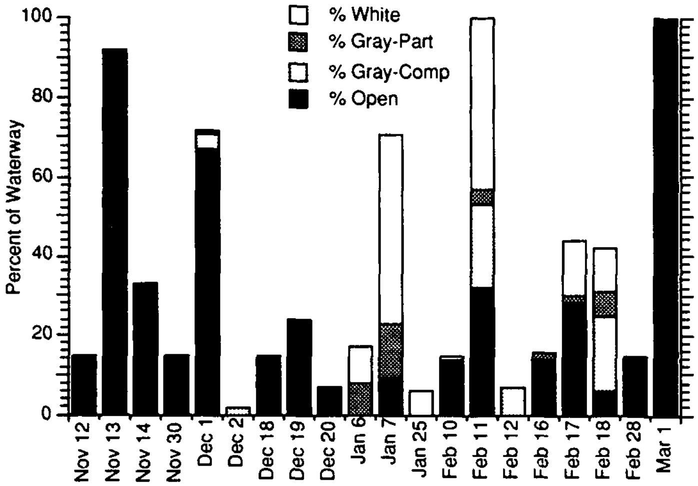


c. 1974–75.

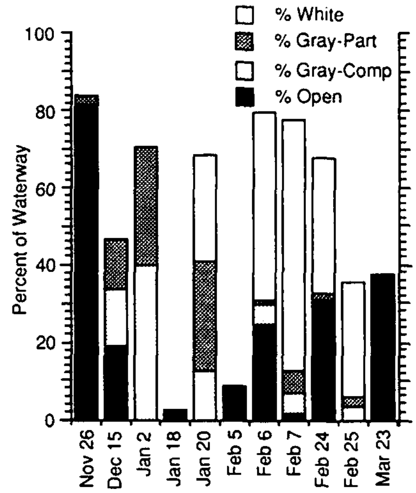


d. 1975–76.

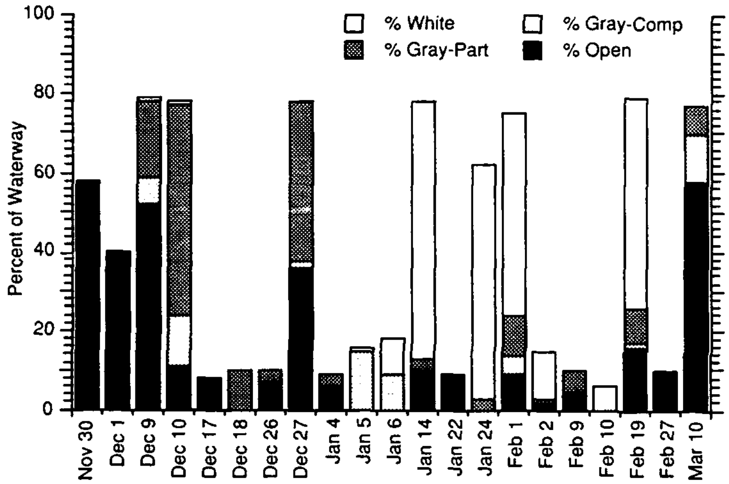
Figure 9. Extent of ice observed on the waterway with Landsat images from 1972 to 1985 (part is partial and comp is complete).



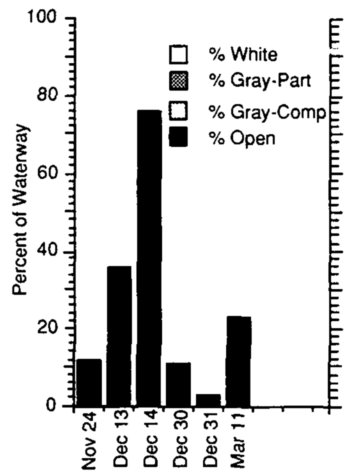
e. 1976–77.



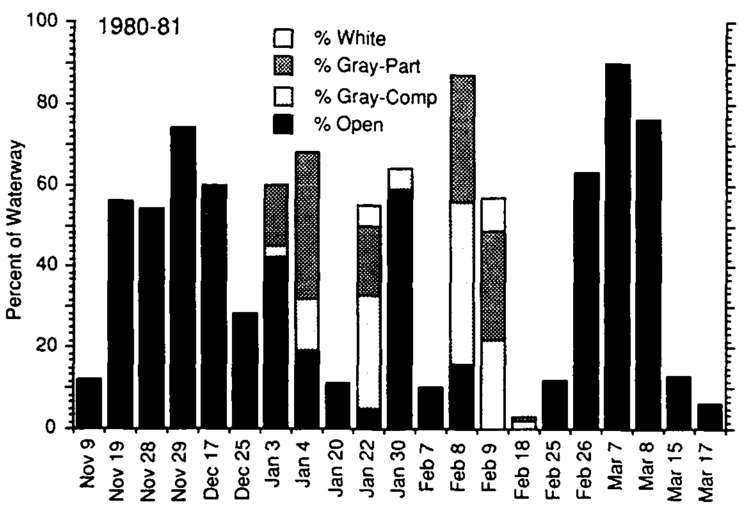
f. 1977–78.



g. 1978–79.

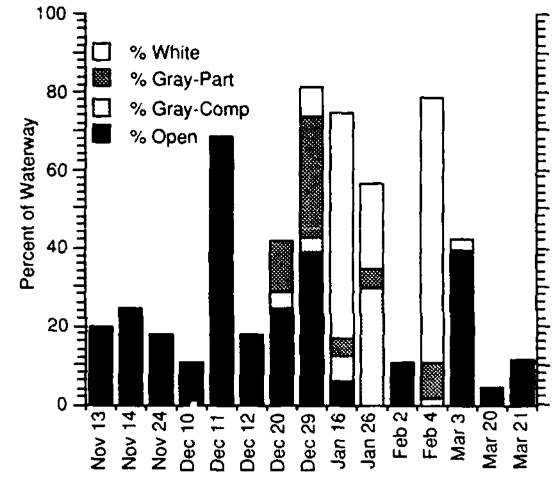


h. 1979–80.

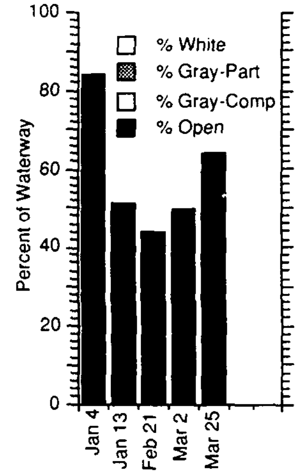


i. 1980–81.

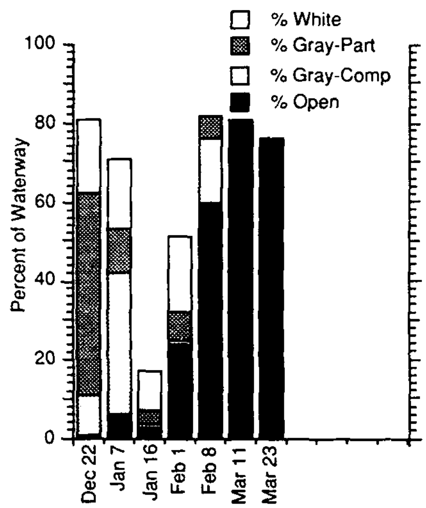
Figure 9 (cont'd).



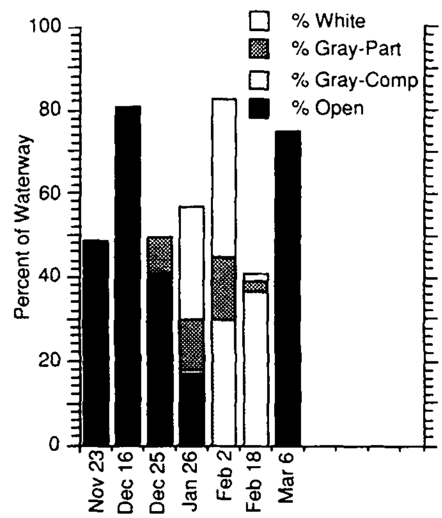
j. 1981–82.



k. 1982–83.



l. 1983–84.



m. 1984–85.

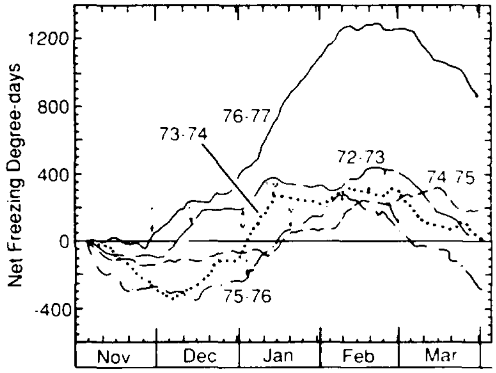
Figure 9 (cont'd). Extent of ice observed on the waterway with Landsat images from 1972 to 1985 (part is partial and comp is complete).

Discharge in November rose from 27,700 ft^3/s on 1 November to 42,400 ft^3/s on 25 November (588 ft^3/s per day). Discharge fell to 31,800 ft^3/s on 12 December and averaged 34,400 ft^3/s for the month. These relatively low and stable discharges allowed an ice cover to form and grow.

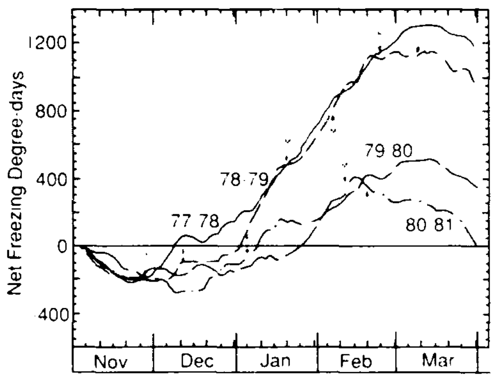
Maximum ice extent on the waterway was observed on 1 January (Fig. 9a) when 76% of the waterway had a gray ice cover. This ice covered 82% of the Peoria pool and 100% of the LaGrange and the confluence pools. Nearly 330 FDD had accumulated by 1 January (Table 4) and discharge was stable at around 32,000 ft^3/s until 28 December (31,300 ft^3/s), when discharge began a rise that peaked at 63,700 ft^3/s on 9 January. This 13-day rise in discharge (average 2700 ft^3/s per day) appears to have flushed much of the ice through the waterway, because on 4 February (only 14% of the waterway being visible) I observed no ice except in adjacent lakes, even though 216 additional FDD had accumulated (Table 4).

Last ice on the waterway was seen on 23 February when gray ice covered only 1%, all on Starved Rock L&D pool. An additional 367 FDD had accumulated since 1 January, but most of the ice on the waterway was likely flushed through during the high discharge in January, even though discharge was falling at 993 ft^3/s per day from 37,800 ft^3/s on 17 February to 22,900 ft^3/s on 4 March (Fig. E1). The last ice in the adjacent areas was seen on 24 February.

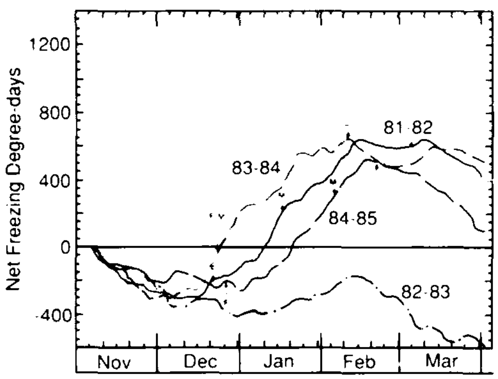
Beginning in late February, air temperatures



a. Winters 1972–73 through 1976–77.



b. Winters 1977–78 through 1980–81.



c. Winters 1981–82 through 1984–84.

Figure 10. Net freezing degree-days each winter (F, L and M indicate first, last and maximum ice, respectively).

rose steadily and MDD increased rapidly through March (Table 4, Fig. 10a). Discharge rose at 3557 ft^3/s per day from 4 March to 18 March (72,700 ft^3/s) and I saw no ice in March.

1973–74

Clouds frequently obscured the waterway on days when Landsat images were acquired in December, resulting in few usable images, although I first observed ice on the adjacent lakes on 9 December (Table 4). On 5 December a 40-day period of below freezing average air temperatures began (Fig. E2) and 46.5 FDD had accumulated by 9 December. River discharge in October fluctuated during the first half of the month, fell during the second half and averaged 18,930 ft^3/s. Discharge during November was stable and averaged 11,460 ft^3/s. On 3 December discharge (14,900 ft^3/s) began a 5-day rise to 29,100 ft^3/s on 8 December, averaging 2480 ft^3/s per day. This increase could have kept ice moving through the waterway, while it was able to form and be in place on the lakes by 9 December.

I observed ice on the waterway on two days (Fig. 9b), for the first time on 14 January; this was also when the observed ice cover was at its maximum extent. The ice was gray and covered 35% of the waterway (Table 3): 100% of the confluence pool and 23% of the LaGrange pool (Fig. D2, App. C). An additional 586.5 FDD had accumulated by 14 January (Table 4) and discharge (20,000 ft^3/s) was in a trough between peaks (Fig. E2), all of which promoted ice growth. On 19 January discharge (24,100 ft^3/s) began a 15-day rise (4647 ft^3/s per day), which peaked on 3 February (93,800 ft^3/s). Air temperatures were high, only 6.5 FDD had accumulated since 14 January (Table 4), and with the high flows there was no ice to be observed on the waterway or lakes on 1 February; flooding was apparent on the images.

Discharge dropped from 3 to 22 February (44,800 ft^3/s) and air temperatures were low, with 93 FDD accumulating from 1 to 17 February. I saw ice on the waterway for the last time on 17 February that covered 14% of the Dresden Island pool (App. C), which amounted to 1% of the waterway (Table 3). Ice persisted until 26 March on the adjacent lakes, but the 23-day discharge rise (926 ft^3/s per day) from 22 February to 17 March (66,100 ft^3/s), with only 85.5 additional FDD after 19 February, probably kept any substantial ice from reforming.

1974–75

Ice formed on adjacent lakes, sloughs and channels by 2 December after 26 FDD had accumulated (Table 4). These areas are generally shallower, have slower water currents and lower discharge through them, so ice forms here earlier and lasts longer. Ice commonly forms here when it does not form in the main river channels. This ice was last observed on 30 March.

This winter was the seventh coldest based on

Table 4. Accumulated degree-days on dates when Landsat observations were made.

Date	Freezing degree-days†	Melting degree-days†
1972–73		
24 Nov	14.0	96.5
13 Dec*	203.5	114.5
14 Dec*	221.5	114.5
1 Jan*	329.5	135.5
4 Feb*	545.5	246.0
23 Feb*	696.5	261.5
24 Feb*	696.5	272.5
14 Mar	700.0	518.0
30 Mar	700.0	666.5
31 Mar (Total)	700.0	666.5
1973–74		
7 Dec	35.5	343.5
9 Dec*	46.5	343.5
14 Jan*	633.0	352.5
31 Jan*	634.5	408.0
1 Feb	639.5	408.0
17 Feb*	732.5	436.0
19 Feb	732.5	446.5
7 Mar*	778.0	624.0
9 Mar	778.0	655.5
25 Mar*	818.0	713.5
26 Mar*	818.0	732.0
27 Mar	818.0	753.5
Total	818.0	788.0
1974–75		
14 Nov	7.5	81.5
15 Nov	7.5	81.5
2 Dec*	26.0	158.5
3 Dec*	38.5	158.5
22 Dec*	103.0	191.0
7 Jan*	147.5	212.0
12 Feb*	466.0	260.5
13 Feb*	482.5	260.5
21 Feb*	498.0	274.5
2 Mar*	536.5	279.5
3 Mar*	549.5	279.5
4 Mar*	561.5	279.5
13 Mar*	599.0	285.0
20 Mar*	601.5	350.0
21 Mar*	601.5	379.0
22 Mar	601.5	395.5
30 Mar*	620.0	430.0
31 Mar (Total)	620.0	443.0
1975–76		
18 Nov	4.5	252.0
28 Nov*	27.0	284.5
6 Dec*	39.0	341.5
16 Dec	69.5	386.0
3 Jan*	186.5	387.5
4 Jan*	213.0	387.5
12 Jan*	341.5	387.5
21 Jan*	475.0	387.5
22 Jan*	483.0	387.5
29 Jan*	546.0	389.5
30 Jan*	548.0	389.5
31 Jan*	554.0	389.5
7 Feb*	677.5	389.5
8 Feb*	679.0	389.5
9 Feb*	679.0	392.0
26 Feb*	684.0	552.0
27 Feb	684.0	573.0
6 Mar	684.0	682.0
7 Mar	685.0	682.0
14 Mar	685.0	723.5
16 Mar	685.0	734.5
23 Mar	691.0	813.5
24 Mar	691.0	827.5
25 Mar	691.0	851.0
Total	691.0	976.0
1976–77		
12 Nov	26.0	24.0
13 Nov	34.5	24.0
14 Nov	42.5	24.0
30 Nov	124.0	87.5
1 Dec*	134.0	87.5
2 Dec*	154.5	87.5
18 Dec*	322.0	98.5
19 Dec*	322.0	108.0
20 Dec	333.5	108.0
6 Jan*	581.5	111.5
7 Jan*	611.0	111.5
25 Jan*	1070.0	111.5
10 Feb*	1381.5	118.0
11 Feb*	1381.5	124.0
12 Feb*	1381.5	131.5
16 Feb*	1413.0	136.5
17 Feb*	1419.0	136.5
18 Feb*	1419.0	141.5
28 Feb*	1443.0	193.0
1 Mar*	1447.0	193.0
Total	1448.5	590.0
1977–78		
26 Nov*	44.0	221.5
15 Dec*	282.5	232.5
2 Jan*	459.5	263.5
18 Jan*	726.5	268.5
20 Jan*	755.0	268.5
5 Feb*	1092.5	268.5
6 Feb*	1119.5	268.5
7 Feb*	1145.0	268.5
24 Feb*	1420.5	268.5
25 Feb*	1428.5	268.5
23 Mar*	1593.5	335.0
Total	1596.0	414.5
1978–79		
30 Nov	22.0	202.0
1 Dec	22.0	208.0
9 Dec*	99.0	210.0
10 Dec*	122.5	210.0
17 Dec*	136.0	213.5
18 Dec*	136.0	218.0
26 Dec*	169.5	221.5
27 Dec*	182.0	221.5
4 Jan*	340.0	223.0
5 Jan*	374.5	223.0
6 Jan*	408.5	223.0
14 Jan*	621.0	223.0
22 Jan*	737.0	223.0
24 Jan*	762.0	223.0
1 Feb*	939.5	223.0
2 Feb*	959.0	223.0
9 Feb*	1161.0	223.0
10 Feb*	1186.0	223.0
19 Feb*	1348.5	223.0
27 Feb*	1391.0	224.5
10 Mar*	1413.0	253.5
Total	1451.0	467.0
1979–80		
24 Nov	[illegible]	175.0
13 Dec	88.5	241.0
14 Dec	95.0	241.0
30 Dec	155.0	301.5
31 Dec	155.0	303.5
11 Mar*	867.0	303.5
Total	882.0	528.0
1980–81		
9 Nov	0	92.0
19 Nov	0	158.5
28 Nov*	9.0	188.5
29 Nov*	9.0	194.0
17 Dec*	48.5	295.0
25 Dec*	168.5	295.0
3 Jan*	221.0	298.5
4 Jan*	247.5	298.5
20 Jan	466.5	315.0
22 Jan*	471.0	317.0
30 Jan*	500.5	345.5
7 Feb*	630.5	345.5
8 Feb*	650.5	345.5
9 Feb*	661.0	345.5
18 Feb*	761.5	385.0
25 Feb	761.5	452.0
26 Feb*	761.5	459.0
7 Mar*	772.5	488.5
8 Mar*	772.5	488.5
15 Mar	772.5	546.0
17 Mar	772.5	553.5
Total	773.0	764.0
1981–82		
13 Nov	0	130.5
14 Nov	0	144.5
24 Nov	10.5	270.0
10 Dec	19.5	328.5
11 Dec*	20.0	328.5
12 Dec	23.0	328.5
20 Dec*	131.0	333.0
29 Dec*	198.0	335.0
16 Jan*	537.0	337.5
26 Jan*	688.5	337.5
2 Feb*	750.0	337.5
4 Feb*	781.5	337.5
3 Mar*	989.0	413.0
20 Mar	1060.5	536.0
21 Mar	1060.5	540.5
Total	1061.0	653.0
1982–83		
4 Jan	138.5	515.0
13 Jan	161.0	530.5
21 Feb	361.5	629.5
2 Mar*	363.5	710.0
25 Mar	405.5	933.5
Total	405.5	974.5
1983–84		
22 Dec*	269.5	329.0
7 Jan*	579.5	332.0
16 Jan*	700.0	332.0
1 Feb*	917.5	339.0
8 Feb*	999.5	352.0
11 Mar*	1094.0	536.5
23 Mar	1128.0	560.6
Total	1128.0	630.0
1984–85		
23 Nov	12.5	140.0
16 Dec*	76.0	294.0
25 Dec*	122.0	320.5
26 Jan*	511.5	385.0
2 Feb*	661.0	385.0
18 Feb*	908.0	386.0
6 Mar	926.5	491.5
Total	926.5	831.5

* Dates when ice was observed on the waterway or adjacent areas, or both.
†Accumulation starts on 5 November and total shown is on 31 March each winter.

the FDD/MDD ratio. Air temperatures fluctuated around freezing until 7 January when 147.5 FDD had accumulated (Table 4). The rest of January to 13 March was cold and FDD were around 600 on 13 March when MDD began to accumulate more rapidly (Fig. 10a). However, I never observed ice on the waterway.

Two rises in discharge, 2467 ft^3/s per day from 10 (19,200 ft^3/s) to 19 January (41,400 ft^3/s) and 2107 ft^3/s per day from 16 February (23,100 ft^3/s) to 3 March (54,700 ft^3/s), may have retarded ice growth enough so that an ice cover significant enough to be visible on Landsat images was never formed, or whatever ice that may have formed was moved through the system. Also, the images acquired from late December to early March usually showed less than 20% of the waterway (Fig. 9c) and may not have shown the reaches that had ice.

1975–76

I first observed ice on adjacent lakes on 28 November (Table 4) but I first spotted ice on the waterway on 4 January (Fig. 9d). The FDD accumulated by those dates were 27 and 213 respectively. Gray ice covered 12% of the waterway (Table 3), but was apparent only on 45% of the Peoria pool (App. C). Discharge rose twice in December—2328 ft^3/s per day from 7930 (28 November) to 21,900 ft^3/s (4 December) and 1300 ft^3/s per day from 15,600 to 27,300ft^3/s (14 to 23 December) (Fig. E4)—but was back to a mean of 13,500 ft^3/s for January, which, along with low temperatures (Fig. 10a, Table 4), promoted ice growth.

Maximum ice cover was observed on 22 January when gray ice covered 51% of the waterway, all below Starved Rock L&D (Fig. D3). The ice covered 8% of Peoria pool, 85% of LaGrange pool and 92% of the confluence pool (App. C). Freezing degree-days were at 483, 270 more than on 4 January, and continued to accumulate rapidly until 7 February (Table 4). Last ice was observed on 9 February when gray ice covered 19% of the waterway, which included 20% of Peoria pool and 51% of the confluence pool (App. C).

After 9 February, air temperatures were generally above freezing and MDD accumulated rapidly (Fig. 10a), melting ice, and discharge rose from 6 February (10,900 ft^3/s) to 1 March (47,500 ft^3/s) at a rate of 1525 ft^3/s per day, flushing ice. By 26 February ice was apparent only on adjacent lakes. Discharge rose again for 9 days from 4 March (47,000 ft^3/s) to 13 March (80,300 ft^3/s) at a rate of 3700 ft^3/s per day, after which ice was no longer apparent on the lakes.

1976–77

Ice had formed on the waterway and adjacent lakes by 1 December (Table 4, Fig. 9e). Gray ice covered 5% of the waterway (Table 3), with all of it on Peoria pool (Fig. D4, App. C). Discharge from 1 October through December was low (Fig. E5) with a mean of 6177 ft^3/s. October and November temperatures were generally near freezing (Fig. E5) and 134 FDD had accumulated by 1 December (Table 4). These conditions promoted the early ice growth.

Temperatures were generally below freezing through December and by 6 January an additional 447.5 FDD had accumulated and white ice was apparent in the waterway (Fig. 9e). January temperatures continued below freezing and by 25 January 488.5 FDD had accumulated. The two 5-day rises in discharge, 1378 ft^3/s per day (8110 ft^3/s on 4 January to 15,000 ft^3/s on 9 January) and 760 ft^3/s per day (11,200 ft^3/s on 14 January to 15,000 ft^3/s on 19 January) apparently did not break the ice cover and move ice through the system.

The low temperatures (1381.5 FDD) and low discharges (about 8000 ft^3/s) continued into February, and I observed the maximum ice extent on the waterway on 11 February. White ice covered 43% of the waterway and gray ice 25%. All the ice was below Dresden Island Dam (Fig. A1, A2, D4). The 5-day increase in discharge, 1080 ft^3/s per day (7000 ft^3/s on 10 February to 12,400 ft^3/s on 15 February), did not break up the ice.

Gray (25%) and white (11%) ice were present when I last observed ice on 18 February. Only the downstream pools were shown on the image, and white ice covered 30% of LaGrange pool and 11% of the confluence pool; gray ice covered 89% of the confluence pool (App. C). On 18 February, discharge (8740 ft^3/s) began a 4-day rise, 3115ft^3/s per day, to 22 February (21,200 ft^3/s), and the MDD began to accumulate faster than the FDD (Table 4). On 1 March (Fig. 9e) when all the waterway was visible, no ice was apparent except on adjacent lakes.

1977–78

Landsat showed ice on the waterway and adjacent lakes first on 26 November (Fig. 9f); 44 FDD had accumulated by then (Table 4) and discharge was falling (385 ft^3/s per day) from 19,100 ft^3/s on 19 November (Fig. E6), so this early ice is not too surprising. The gray ice (Fig. A3) covered only 2% of the waterway (Table 3) and was present only on the Peoria pool (Fig. A3, D5, App. C). By 15 December at least 28% of the waterway was ice-covered and nearly 70% was covered on 20 January (Fig. 9f). Air temperatures averaged well below freezing for most of January (Fig. E6) and 472.5 FDD had accumulated since 15 December (Table 4). Discharge rose twice in December, 1180 ft^3/s per day from 2 December (14,100 ft^3/s) to 7 December (20,000 ft^3/s), and 3700 ft^3/s per day from 13 December (15,000 ft^3/s) to 18 December (33,500 ft^3/s), but had no apparent effect on the ice cover. Discharge was stable at 11,000 ft^3/s by 20 January.

I observed the maximum ice extent on 7 February when 11% of the waterway had gray ice and 65% had white (Table 3). All of this ice was observed below Starved Rock L&D (App. C). Between 20 January and 7 February, 390 FDD had accumulated and discharge remained stable (Fig. E6) so ice growth was widespread (Fig. A4 and A5).

Discharge remained stable for the rest of February and the mean for the month was 9457 ft^3/s. Air temperature averaged well below freezing for the last half of February and 283.5 more FDD accumulated since 7 February. The last ice observed on the waterway on 25 February was gray and white, and covered 6% and 30% of the waterway respectively. By 23 March FDD were 165 higher but discharge increased for 18 days at 3022 ft^3/s per day from 13 March (11,000 ft^3/s) to 31 March (65,400 ft^3/s), so that by 23 March I observed no ice on the 38% of the waterway above Peoria L&D shown on the Landsat image (Fig. 9f, App. C). Ice was still on the adjacent lakes on 23 March, however.

1978–79

Discharge fluctuated by 6500 ft^3/s in December but was generally stable up to 19 February. Mean monthly discharges were: 7348 ft^3/s in October, 7112 ft^3/s in November, 8244 ft^3/s in December and 8751 ft^3/s in January. Air temperatures were generally below freezing during the last week of November and during early December (Fig. E7) and by 9 December 99 FDD had accumulated (Table 4). On 9 December, 79% of the waterway was visible on an image and 27% was covered with ice—26% gray and 1% white (Fig. 9g, Table 3). Most of the waterway below Brandon Road L&D had some ice cover.

On about 1 January, FDD began to accumulate at a rate of about 25 per day. By 14 January, 522 FDD had been added since 9 December and the maximum observed extent of ice cover was measured: gray ice covered 3% and white ice 65% of the waterway (Fig. A6). Ice was present on all pools downstream of Brandon Road L&D (Fig. D6). The rest of January and February continued with subfreezing average temperatures (Fig. E7, 10b) and by 27 February 1391 FDD had accumulated (Table 4). White ice was observed on many days (Fig. 9g) and was last seen on 19 February.

The last usable Landsat image taken on 10 March showed gray ice on 19% of the waterway, only on the LaGrange pool. Temperatures had risen to near freezing after 1 March, there were only 22 FDD and 29 MDD between 27 February and 10 March (Table 4), and the amount of ice cover clearly decreased from 19 February to 10 March (Fig. 9g). Discharge also began to rise in three steps on 19 February (Fig. E7): 3175ft^3/s per day from 6600 (19 February) to 32,000 ft^3/s (27 February), 4654ft^3/s per day from 27,100 (1 March) to 87,600 ft^3/s (14 March), and 1340 ft^3/s per day from 87,600 (14 March) to 101,000 ft^3/s (24 March). This large increase in discharge flushed ice through the waterway, contributing to the small amount of ice observed on 10 March.

1979–80

The only Landsat images cloud-free enough to be usable were taken in December and March (Fig. 9h). I did not see ice on the waterway on any of these, but I did see it on adjacent lakes on the 11 March image (Table 6). It is likely that ice was present on the waterway and the lakes in January and February because this winter was colder than six other winters, during four of which ice was observed, and discharge was low, varying between 11,900 and 6200 ft^3/s during most of January and February (Fig. E8).

Air temperature remained above freezing for most of November and much of December (Fig. E8). On 31 December there were 155 FDD and 303.5 MDD, so it's not surprising that ice was not apparent on the December images. Also, coupled with the generally warm weather, discharge fluctuated frequently in December and rose at 3280 ft^3/s per day from 24 to 29 December, which may have kept an ice cover that could be visible on Landsat images from forming.

Although by 11 March 867 FDD had accumulated, discharge rose sharply at 2740 ft^3/s per day from 19 February (6200 ft^3/s) to 24 February (19,900 ft^3/s) and at 5150 ft^3/s per day from 10 March (14,900 ft^3/s) to 12 March (25,200 ft^3/s). These discharges could have flushed ice from the waterway, leaving only adjacent lakes with an ice cover.

That I did not observe ice on the waterway this winter with Landsat is a result of inadequate Landsat image coverage, which leads to misleading conclusions regarding ice conditions. The FDD total during this winter was the seventh highest, the MDD was the fourth lowest and discharge was low most of the winter. It is very likely that ice formed on the waterway this winter, but the images were too few (six), were acquired at the wrong time (1 in November, 4 December, 1 March) and did not cover enough of the waterway (four images covered less than 25% each) to observe the ice.

1980–81

Daily air temperatures in November and early December averaged above freezing such that net FDD did not begin to increase significantly until mid-December (Fig. E9, 10b, Table 4) and discharge rose at 3550 ft^3/s per day from 7 December (10,200 ft^3/s) to 11 December (24,400 ft^3/s). These conditions are not conducive to ice formation on the waterway, although ice was observed on lakes and backwater areas as early as 28 November. Landsat first showed ice on the waterway on 3 January (Fig. 9i), after 221 FDD had accumulated. This first ice covered 18% of the waterway (Table 3) mostly on the middle pools (Fig. D7).

By 22 January there were 250 more FDD and I observed white ice on parts of the waterway (Fig. D7). After a 2-day rise of 2280 ft^3/s per day, ending on 1 January, discharge remained at about 6000 ft^3/s until 20 January, low enough to allow a substantial ice cover to form. Discharge increased again at 1380 ft^3/s per day from 20 January (6000 ft^3/s) to 25 January (12,900ft^3/s), while 29.5 FDD and 28.5 MDD accumulated from 22 to 30 January (Table 4). The increased discharge during a time when air temperatures were not too low could account for the reduced amount of ice cover observed from 22 January (50%) to 30 January (5%) (Fig. 9i, A8, D7). However, some of this observed reduction may simply be attributable to less of the waterway being visible on images because of clouds and some ice that may have existed not being observed.

By 8 February when the observed ice cover was at its maximum extent, gray ice covered 71% of the visible waterway. There were 179.5 more FDD than on 22 January (Table 4) and discharge was 5000 ft^3/s and had been in a stable trough for 4 days.

I observed no ice on the waterway after 18 February, although ice was on the lakes on 8 March. Only 11 FDD accumulated from 18 February to 7 March (Fig. A9) and a rise in discharge from 15 February (4570 ft^3/s) to 20 February (22,500 ft^3/s) averaged 3586 ft^3/s per day. Little, if any, additional ice would have formed, and it would have moved through the waterway leaving only the lake ice apparent.

1981–82

Daily average air temperatures were generally above freezing in November and early December (Fig. E10) and on 12 December only 23 FDD had accumulated (Table 4). The 12-day rise in discharge from 21 November (10,000 ft^3/s) to 3 December (24,500 ft^3/s) averaged 1208 ft^3/s per day and may have contributed to retarding ice cover growth. On 20 December (Fig. 9j, Table 3) ice was first observed on the waterway and 131 FDD had accumulated. Gray ice (Fig. A10) covered 17% of the waterway that was visible, but was seen only above Peoria Dam (Fig. D8, App. C). Discharge remained below 15,000 ft^3/s for the rest of December (Fig. E10) and below 22,000 ft^3/s in January. Temperatures continued below freezing through December (Fig. E10) and January.

By 29 December white ice was apparent and I measured the maximum ice cover on 4 February when 79% of the waterway had ice, 68% white and 11% gray. Ice was present on Peoria, LaGrange and Confluence pools. There were 781.5 FDD accumulated by 4 February and they continued to accumulate rapidly to 20 March (1060.5 FDD). Discharge was relatively stable and remained less than 20,000 ft^3/s from 1 February to 15 February.

On 16 February, discharge (16,000 ft^3/s) rose sharply (5600 ft^3/s per day) until 27 February (77,600 ft^3/s). Temperatures rose to above freezing in mid-February and remained near freezing until early March (Fig. E10). Last ice on the waterway, covering 3% of it, was observed on 3 March on the Peoria pool. Discharge rose 3525 ft^3/s per day from 60,700 ft^3/s on 13 March to 103,000 ft^3/s on 25 March, while temperatures rose above freezing and MDD accumulated rapidly (Table 4).

1982–83

This was the warmest winter of the 13. Only 405.5 FDD accumulated, while 974.5 MDD accumulated. I did not observe ice on the waterway (Fig. 9k), but I did see it on adjacent lakes on 2 March (Table 5). Discharge rose from 6100 ft^3/s on 1 November to 32,600 ft^3/s on 2 December (855 ft^3/s per day) and from 30,100 ft^3/s on 4 December to 112,000 ft^3/s on 12 December (10,238 ft^3/s per day), fell from 12 December to 1 February (19,500 ft^3/s), fluctuated between 27,700 ft^3/s and 19,500 ft^3/s through February to mid-March, and rose from 21,200 ft^3/s on 19 March to 36,300 ft^3/s on 29 March (1510 ft^3/s per day). This peak discharge (the highest that occurred during the 13 winters) and the other high discharges and the high temperatures this winter kept ice from forming on the waterway.

1983–84

This was the fourth coldest winter of the 13. Air temperatures in December were generally at or below freezing (Fig. E12) and Landsat showed extensive ice on the waterway and lakes on 22 December when 269.5 FDD had accumulated (Fig. 9l, Table 4). Gray ice covered 61% of the waterway, white ice 19% (Fig. A12, A13, Table 3). This was also the maximum extent of ice observed on Landsat images during the 1983–84 winter. The ice was seen only below Marseilles L&D (Fig. D9); the image did not cover upstream of the Starved Rock Dam pool (App. C). Discharge rose 3325 ft^3/s per day from 10,200 ft^3/s (22 November) to 23,500 ft^3/s (26 November), 300 ft^3/s per day to 10 December (27,700 ft^3/s), and 1133 ft^3/s per day to 19 December (37,900 ft^3/s) (Fig. E12). On 22 December, discharge was 33,600 ft^3/s and falling at 995 ft^3/s per day.

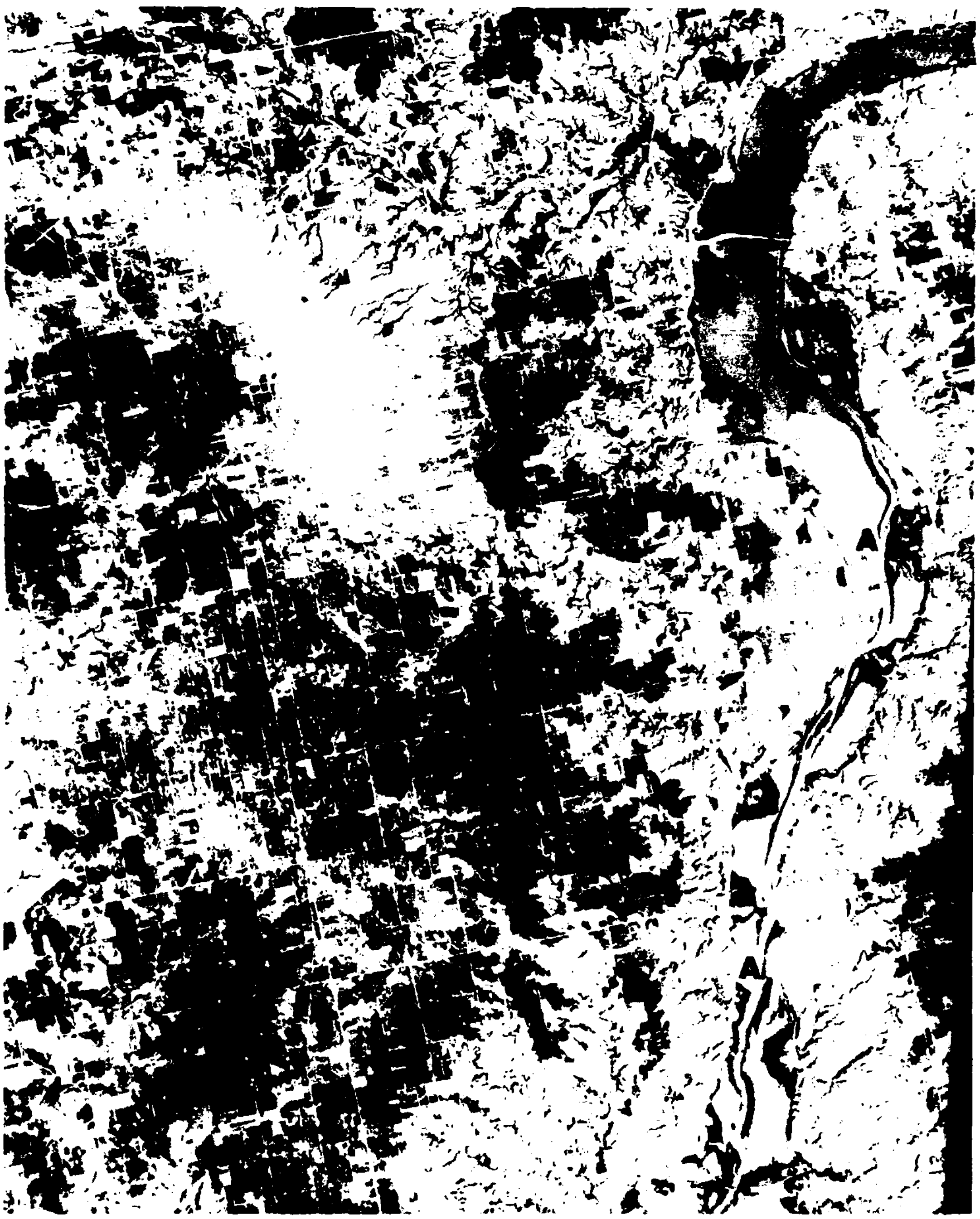


Figure 11. High water (A) along the Illinois River between Peoria and Starved Rock Dams—ice is gone or flooded and not visible; TM image 50022-16091, 23 March 1984.

Temperatures in January were primarily below freezing and 917.5 FDD had accumulated by 1 February (Table 4). White ice was observed twice in January (Fig. 9l) and once in February (Fig. A14). One would expect maximum ice to be apparent in mid-January or early February, but the images acquired then covered only 17 and 51% of the waterway (Fig. 9l), so I could not observe much of the cover that would likely be present.

The last ice I observed on 8 February (999.5 FDD) was gray and covered 22% of the waterway; all of this ice was downstream of the Starved Rock L&D (Fig. D9). Discharge fell 995 ft^3/s per day from 37,900 ft^3/s (19 December) to 17,000 ft^3/s (9 January) and 208 ft^3/s per day from 9 January to 3 February (12,000 ft^3/s), and rose 789 ft^3/s per day from 3 to 12 February (19,100 ft^3/s). From mid-February to early March, an additional 94.5 FDD

Figure 12. Extensive ice cover on 26 January 1985; white ice (A), open areas (B), partial gray ice (C) and Peoria Dam (D); TM image 50331-16055.

accumulated but 184.5 MDD were also added (Table 4), causing erosion of the ice cover. Discharge rose 3683 ft^3/s per day from 12 to 24 February (63,300 ft^3/s) then fell to 30,500 ft^3/s by 15 March (Fig. E12). These high discharges and high temperatures would nearly ensure that most ice visible on the waterway on a Landsat image would be gone by 11 March, and, indeed, I observed ice only on adjacent lakes on that date. By 23 March no ice was apparent on the lakes and the image (Fig. 11) showed high water. Discharge was at 58,200 ft^3/s on 23 March and was rising at 3742 ft^3/s per day from 16 March (30,800 ft^3/s).

1984–85

Daily air temperatures in November generally averaged above freezing (Fig. E13). In December more days averaged below freezing, although by 25 December only 122 FDD had accrued while 320.5 MDD had accumulated. Discharge fluctuated between 25,500 ft^3/s (1 November) and 10,900 ft^3/s (15 November) the first half of November, remained stable with fluctuations of less than 4500 ft^3/s until 14 December (12,100 ft^3/s), and fluctuated to 23,000 ft^3/s (23 December) until 29 December. I saw ice on the lakes on 16 December but didn't observed any on the waterway until 25 December (23,000 ft^3/s) when gray ice covered 9% of it (Fig. 9m, Table 3), only on the Peoria pool (Fig. D10, App. C).

January and the first half of February were cold and an additional 786 FDD days accumulated by 18 February (Table 4). Discharge rose 4400 ft^3/s per day from 29 December (16,000 ft^3/s) to 2 January (33,600 ft^3/s) and 400 ft^3/s per day from 2 to 11 January (37,200 ft^3/s), and fell to 10,000 ft^3/s by 6 February where it remained until 15 February (Fig. E13). Extensive white ice was apparent on the waterway on 26 January (Fig. 12, A15). By 2 February, 83% of the waterway was ice covered, 45% gray, 38% white (Fig. A16). All pools downstream of Starved Rock L&D had ice at this time.

I last observed ice on the waterway and adjacent lakes on 18 February, when gray ice covered 39% and white ice 2% of the waterway (Fig. 9m, A17). Only the two downstream pools were visible on this image. Discharge rose 8900 ft^3/s between 15 February (10,000 ft^3/s) and 16 February (18,900 ft^3/s) then rose 4823 ft^3/s per day from 13,900 ft^3/s (19 February) to 120,000 ft^3/s (13 March) (Fig. E13). Also, from 18 February to 6 March, only 19.5 FDD but 105.5 MDD accumulated (Table 4), so that, by 6 March, no ice was apparent on the waterway or the lakes. There were no more FDD and discharge remained above 65,400 ft^3/s through March. It is virtually impossible that any additional ice formed under these conditions.

DISCUSSION

Landsat images showed ice on the Illinois Waterway during 10 of the 13 winters from 1972 to 1985 and during all winters on adjacent lakes, channels and sloughs. Large variations in FDD, MDD and flows were typical during and between these winters (Fig. 13, 14, Table 5). Since it is the sequence and timing of air temperature and river discharge conditions that play the major roles in the formation and breakup of river ice, it was not surprising that I found the variety of ice cover conditions that I did.

Low temperatures usually produce extensive ice covers, although the areal extent of a cover is often tempered by discharge and its rate of change. Low temperatures during periods of low discharge will generally produce the most extensive ice. Cold during high discharge will usually result in a smaller ice extent (could be thicker where it persists) or, if discharge is large enough, no cover at all. Rapid increases in discharge can also break up an established ice cover. Of course the degree of breakup depends on ice thickness and strength, rate and magnitude of an increase in discharge, and air temperatures preceding and at the time of the increase (Ferrick et al. 1988). In addition, many other factors including thermal inputs to the waterway, sewage outfalls, solar radiation and winds and area of open water influence ice formation, growth and breakup on the waterway.

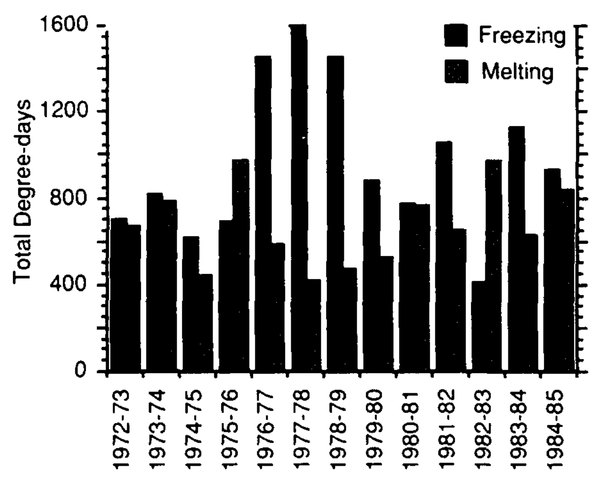
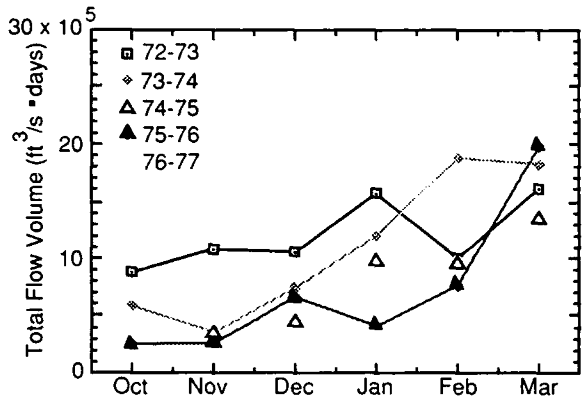
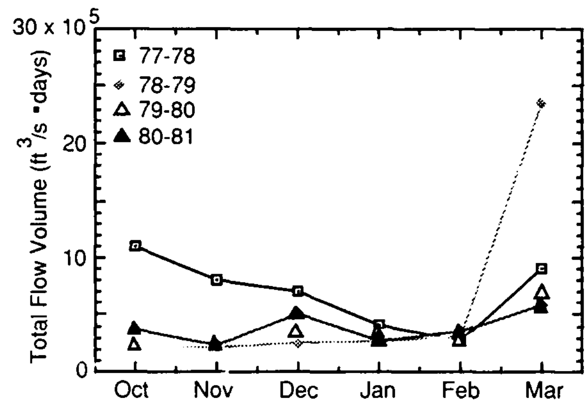


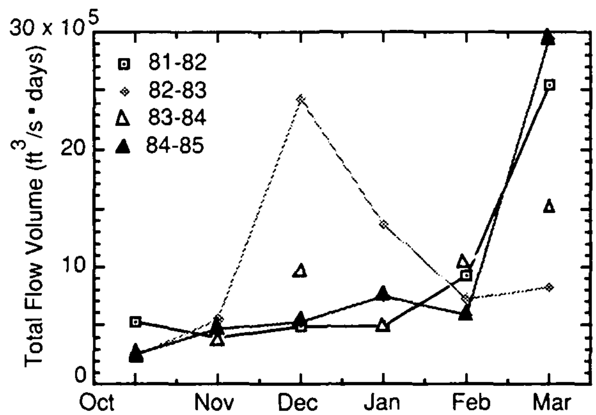
Figure 13. Freezing (FDD) and melting (MDD) degree-days, 5 November to 31 March each winter.



a. Winters 1972–73 through 1976–77.



b. Winters 1977–78 through 1980–81.



c. Winters 1981–82 through 1984–84.

Figure 14. Monthly flow volumes ($ft^3/s \cdot days$) each year.

For this study, possible relationships between these other factors and ice conditions were not analyzed because the ice data collected by Landsat image interpretations are not sufficiently complete and accurate for such a detailed analysis. However, I reasoned that the percentages of first ice, maximum ice and last ice cover and the number of days between first and last ice observed would be dependent on accumulated FDD, the FDD/MDD ratio or the total flow volume. Scattergrams of combinations of these variables show that there is generally no linear relationship between most of them, yet weak relationships are suggested on some of the scattergrams (App. F).

One of the reasons why these data show such poor relationships is that the sequence and timing of air temperature and discharge determine ice conditions and changes in them, but the data used for the independent variable in the regressions were averaged over a large portion of the winter, which included periods when freezing temperatures were not persistent or discharge was variable. Another reason is the quality of the Landsat-derived ice data. It is not possible for Landsat to acquire images of the entire waterway frequently enough to develop a more complete picture of ice conditions and changes, and, therefore, to determine a detailed ice regime for the waterway. Cloud cover and the time gaps between successive images of the entire waterway are the main impediments to accomplishing this.

To see if correlations were better for periods when freezing temperatures prevailed, I used the total number of days between the dates of first and last ice observed on the waterway as the dependent variable, y, and the freezing period (P_f), which is the length of time in days during which FDD accumulated, as the independent variable, x. When data from all winters are used (n = 13) the r^2 was 0.069 (Fig. 15a). However, the ice data for 1974–75 and 1979–80 acquired through interpretation of Landsat images are likely inaccurate for reasons previously discussed, so by dropping data for these two years (n = 11) the r^2 becomes 0.676 (Fig. 15b).

This is clearly an improvement over the results

Table 5. Summarized air temperature, discharge and ice conditions.

Annual ice conditions	*5 Nov–31 Mar accumulated degree-days* Freezing*	Melting*	*Date*	*Percentage of waterway ice-covered*	*Discharge conditions (1 Oct–31 Mar)*	*Days between first and last ice* Waterway	Lakes
1972–73	700.0	666.5			7,214,800 ft³/s · days	72	73
First–lakes	203.5	114.5	13 Dec	—	32,100 ft³/s; stable trough		
First–waterway	203.5	114.5	13 Dec	38	32,100 ft³/s; stable trough		
Maximum–waterway	329.5	135.5	1 Jan	76	40,400 ft³/s; rising at 2494 ft³/s per day		
Last–waterway	696.5	216.5	23 Feb	1	30,800 ft³/s; falling at 993 ft³/s per day		
Last–lakes	696.5	272.5	24 Feb	—	29,800 ft³/s; falling at 993 ft³/s per day		
1973–74	818.0	788.0			6,575,060 ft³/s · days	34	107
First–lakes	46.5	343.5	9 Dec	—	28,800 ft³/s; peak		
First–waterway	633.0	352.5	14 Jan	35	20,000 ft³/s; trough		
Maximum–waterway	633.0	352.5	14 Jan	35	20,000 ft³/s; trough		
Last–waterway	732.5	436.0	17 Feb	1	54,900 ft³/s; falling at 2579 ft³/s per day		
Last–lakes	818.0	732.0	26 Mar	—	54,400 ft³/s; falling at 1336 ft³/s per day		
1974–75	620.0	433.0			4,231,770 ft³/s · days	0	91
First–lakes	26.0	158.5	2 Dec	—	10,500 ft³/s; rising at 226 ft³/s per day		
First–waterway	No ice observed on waterway						
Maximum–waterway	No ice observed on waterway						
Last–waterway	No ice observed on waterway						
Last–lakes	620.0	430.0	30 Mar	—	37,700 ft³/s; rising at 2067 ft³/s per day		
1975–76	691.0	976.0			4,336,790 ft³/s · day	36	90
First–lakes	27.0	284.5	28 Nov	—	7930 ft³/s; stable		
First–waterway	213.0	387.5	4 Jan	12	13,100 ft³/s; stable trough		
Maximum–waterway	483.0	387.5	22 Jan	51	15,500 ft³/s; falling at 2160 ft³/s per day		
Last–waterway	679.0	392.0	9 Feb	19	14,000 ft³/s; rising at 1525 ft³/s per day		
Last–lakes	684.0	552.0	26 Feb	—	44,800 ft³/s; rising at 1525 ft³/s per day		
1976–77	1448.5	590.0			1,728,540 ft³/s · days	80	91
First–lakes	134.0	87.5	1 Dec	—	7000 ft³/s; stable		
First–waterway	134.0	87.5	1 Dec	5	7000 ft³/s; stable		
Maximum–waterway	1381.5	124.0	11 Feb	68	9350 ft³/s; rising at 1080 ft³/s per day		
Last–waterway	1419.0	141.5	18 Feb	36	8740 ft³/s; rising at 3115 ft³/s per day		
Last–lakes	1447.0	193.0	1 Mar	—	17,000 ft³/s; falling at 519 ft³/s per day		
1977–78	1596.0	414.5			4,181,000 ft³/s · days	91	117
First–lakes	44.0	221.5	26 Nov	—	16,200 ft³/s; falling at 385 ft³/s per day		
First–waterway	44.0	221.5	26 Nov	2	16,200 ft³/s; falling at 385 ft³/s per day		
Maximum–waterway	1145.0	268.5	7 Feb	76	8600 ft³/s; stable		
Last–waterway	1428.5	268.5	25 Feb	36	9800 ft³/s; stable		
Last–lakes	1593.5	335.0	23 Mar	—	44,500 ft³/s; rising at 3022 ft³/s per day		

* FDD/MDD ratio = freezing degree-days/melting degree-days.

† From Figure 10.

Table 5 (cont'd).

1 Oct–31 Mar degree-days				Freezing†			Melting†		
Freezing			Total	Intensity	Period	Rate	Intensity	Period	Rate
First	Last	Total	melting	(net FDD)	(days)	(net FDD/day)	(net MDD)	(days)	(net MDD/day)
19 Oct	27 Feb	701.0	1279	529	81	6.53	407	37	11
6 Nov	21 Mar	818.0	1623	652	84	7.76	290.5	32	9.08
13 Nov	30 Mar	620.0	1197	458	104	4.43	139.5	17	8.21
13 Nov	18 Mar	691.0	1807.5	621	56	11.09	574.5	52	11.05
7 Nov	2 Mar	1448.5	1098.5	1323.5	87	15.21	433	38	11.39
12 Nov	25 Mar	1596.0	1128.0	1532.5	114	13.44	135	13	10.38

Table 5 (cont'd). Summarized air temperature, discharge and ice conditions.

Annual ice conditions	5 Nov–31 Mar accumulated degree-days Freezing*	Melting*	Date	Percentage of waterway ice-covered	Discharge conditions (1 Oct–31 Mar)	Days between first and last ice Waterway	Lakes
1978–79	1451.0	467.0			3,637,120 $ft^3/s \cdot$ days	91	91
First–lakes	99.0	210.0	9 Dec	—	8180 ft^3/s; falling at 1292 ft^3/s per day		
First–waterway	99.0	210.0	9 Dec	27	8180 ft^3/s; falling at 1292 ft^3/s per day		
Maximum–waterway	621.0	223.0	14 Jan	68	11,000 ft^3/s; peak		
Last–waterway	1413.0	253.5	10 Mar	19	69,900 ft^3/s; rising at 4654 ft^3/s per day		
Last–lakes	1413.0	253.5	10 Mar	—	69,900 ft^3/s; rising at 4654 ft^3/s per day		
1979–80	882.0	528.0			2,165,410 $ft^3/s \cdot$ days	0	1
First–lakes	867.0	303.5	11 Mar	—	18,200 ft^3/s; rising at 5150 ft^3/s per day		
First–waterway	No ice observed on waterway						
Maximum–waterway	No ice observed on waterway						
Last–waterway	No ice observed on waterway						
Last–lakes	867.0	303.5	11 Mar	—	18,200 ft^3/s; rising at 5150 ft^3/s per day		
1980–81	773.0	764.0			2,327,270 $ft^3/s \cdot$ days	46	100
First–lakes	9.0	188.5	28 Nov	—	7800 ft^3/s; stable		
First–waterway	221.0	298.5	3 Jan	18	13,000 ft^3/s; falling at 1171 ft^3/s per day		
Maximum–waterway	650.5	345.5	8 Feb	71	5000 ft^3/s; stable trough		
Last–waterway	761.5	385.0	18 Feb	3	11,300 ft^3/s; rising at 3586 ft^3/s per day		
Last–lakes	772.5	488.0	8 Mar	—	26,700 ft^3/s; falling at 267 ft^3/s per day		
1981–82	1061.0	653.0			5,352,840 $ft^3/s \cdot$ days	73	82
First–lakes	20.0	328.5	11 Dec	—	16,800 ft^3/s; falling at 520 ft^3/s per day		
First–waterway	131.0	333.0	20 Dec	17	10,200 ft^3/s; falling at 789 ft^3/s per day		
Maximum–waterway	781.5	337.5	4 Feb	79	19,000 ft^3/s; falling at 444 ft^3/s per day		
Last–waterway	989.0	413.0	3 Mar	3	77,500 ft^3/s; peak		
Last–lakes	989.0	413.0	3 Mar	—	77,500 ft^3/s; peak		
1982–83	405.5	974.5			6,140,300 $ft^3/s \cdot$ days	0	1
First–lakes	363.5	710.0	2 Mar	—	25,900 ft^3/s; falling at 443 ft^3/s per day		
First–waterway	No ice observed on waterway						
Maximum–waterway	No ice observed on waterway						
Last–waterway	No ice observed on waterway						
Last–lakes	363.5	710.0	2 Mar	—	25,900 ft^3/s; falling at 443 ft^3/s per day		
1983–84	1128.0	630.0			4,655,960 $ft^3/s \cdot$ days	48	80
First–lakes	269.5	329.0	22 Dec	—	33,600 ft^3/s; falling at 995 ft^3/s per day		
First–waterway	269.5	329.0	22 Dec	80	33,600 ft^3/s; falling at 995 ft^3/s per day		
Maximum–waterway	269.5	329.0	22 Dec	80	33,600 ft^3/s; falling at 995 ft^3/s per day		
Last–waterway	999.5	352.0	8 Feb	22	15,800 ft^3/s; rising at 789 ft^3/s per day		
Last–lakes	1094.0	536.5	11 Mar	—	35,600 ft^3/s; falling at 1621 ft^3/s per day		

* FDD/MDD ratio = freezing degree days/melting degree days.

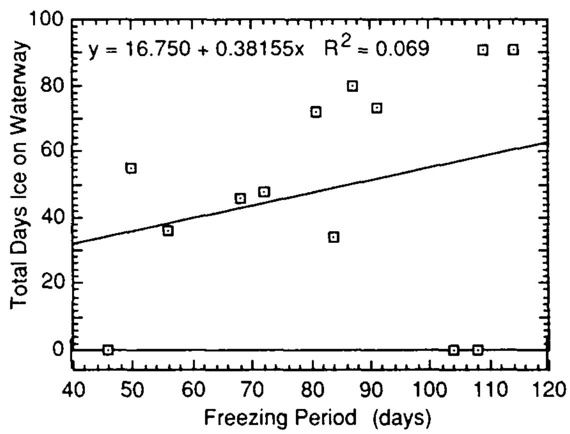
Table 5 (cont'd).

1 Oct–31 Mar degree-days				*Freezing*[†]			*Melting*[†]		
Freezing			*Total*	*Intensity*	*Period*	*Rate*	*Intensity*	*Period*	*Rate*
First	*Last*	*Total*	*melting*	*(net FDD)*	*(days)*	*(net FDD/day)*	*(net MDD)*	*(days)*	*(net MDD/day)*
20 Nov	25 Mar	1451.0	1189.5	1369	109	12.56	190.5	16	11.91
10 Nov	15 Mar	882.0	1188.5	696.5	108	6.45	166	17	9.76
24 Nov	18 Mar	773.0	1373.5	675	68	9.93	407	45	904
23 Oct	27 Mar	1062.0	1437.5	965	91	10.60	239.5	22	10.89
5 Nov	25 Mar	405.5	1748.0	236	46	5.13	394.5	47	8.39
12 Nov	19 Mar	1128.0	1435.5	956	72	13.28	149.5	52	2.88

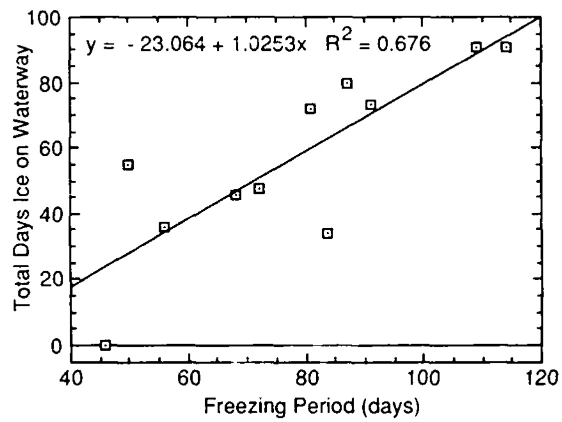
Table 5 (cont'd). Summarized air temperature, discharge and ice conditions.

Annual ice conditions	*5 Nov–31 Mar accumulated degree-days* Freezing*	Melting*	*Date*	*Percentage of waterway ice-covered*	*Discharge conditions (1 Oct–31 Mar)*	*Days between first and last ice* Waterway	Lakes
1984–85	926.5	831.5			5,519,520 $ft^3/s \cdot$ days	55	64
First-lakes	76.0	294.0	16 Dec	—	16,500 ft^3/s; trough		
First-waterway	122.0	320.5	25 Dec	9	23,000 ft^3/s; peak		
Maximum-waterway	661.0	385.0	2 Feb	83	12,000 ft^3/s; trough		
Last-waterway	908.0	386.0	18 Feb	41	16,600 ft^3/s; falling at 1667 ft^3/s per day		
Last-lakes	908.0	386.0	18 Feb		16,600 ft^3/s; falling at 1667 ft^3/s per day		

* FDD/MDD ratio = freezing degree days/melting degree days.
† From Figure 10.



a. Data from all winters (n = 13).



b. Data from 1974–75 and 79–80 excluded (n = 11).

Figure 15. Correlation between freezing period and number of days between first and last observed ice on the waterway.

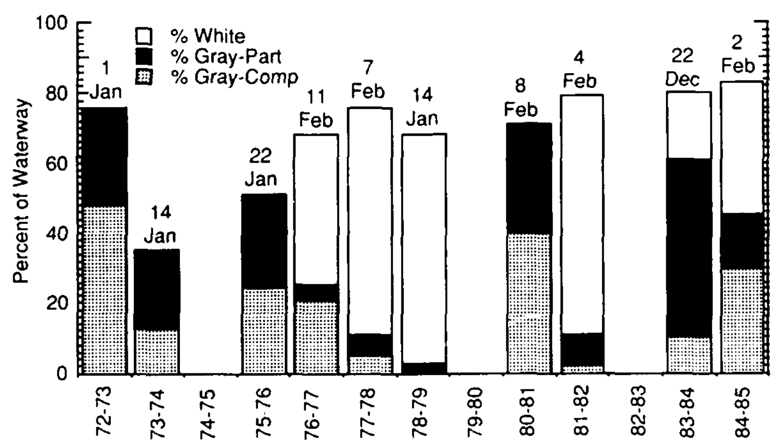


Figure 16. Maximum extent of ice cover each winter as observed on Landsat images.

Table 5 (cont'd).

1 Oct–31 Mar degree-days				*Freezing†*			*Melting†*		
Freezing			*Total*	*Intensity*	*Period*	*Rate*	*Intensity*	*Period*	*Rate*
First	*Last*	*Total*	*melting*	*(net FDD)*	*(days)*	*(net FDD/day)*	*(net MDD)*	*(days)*	*(net MDD/day)*
11 Nov	6 Mar	926.5	1673.0	784.5	50	15.69	432	40	10.8

of the previous correlations (App. F), but not as strong as I expected because the relationship is not that simple. Intuitively, I would reason that the length of time that ice would remain on a river is a direct function of the length of a freezing period in that more ice would form during longer freezing periods and remain longer. However, the severity of the freezing during that period would also influence the amount of ice formed and, therefore, how long an ice cover would stay on a river. So I would expect correlations without multiple independent variables to be weak because they don't "model" the physical world.

In this light, I did a multiple linear regression using the total number of days between the dates of first and last ice observed on the waterway as the dependent variable, z, and two independent variables P_f as x and the average rate of freezing during P_f as y. The r^2 for this correlation is 0.821 ($z = -48.653 + 0.906x + 2.166y$; $n = 11$). This multiple regression did not include a discharge factor. Discharge at the time of interest for a particular ice condition is usually secondary to temperature except when discharge is extremely high, and the average discharge during P_f would not be specific enough.

I present the following observations in an attempt to characterize the ice regime on the Illinois Waterway as determined from Landsat images, air temperatures and discharge.

1. Extensive (Fig. 16) and long-lasting (Fig. 17) ice covers formed on the waterway during 1976–77, 1977–78, 1978–79 and 1981–82, when the maximum extent of observed white ice was 43, 65, 65 and 68% of the waterway respectively. Gray ice covered 25, 11, 3 and 11% of the waterway at the same time. Maximum observed ice covered more than 50% of the waterway 69% of the remaining winters, and less than 50% for 31% of the winters (Fig. 16).

2. I observed the most extensive ice during

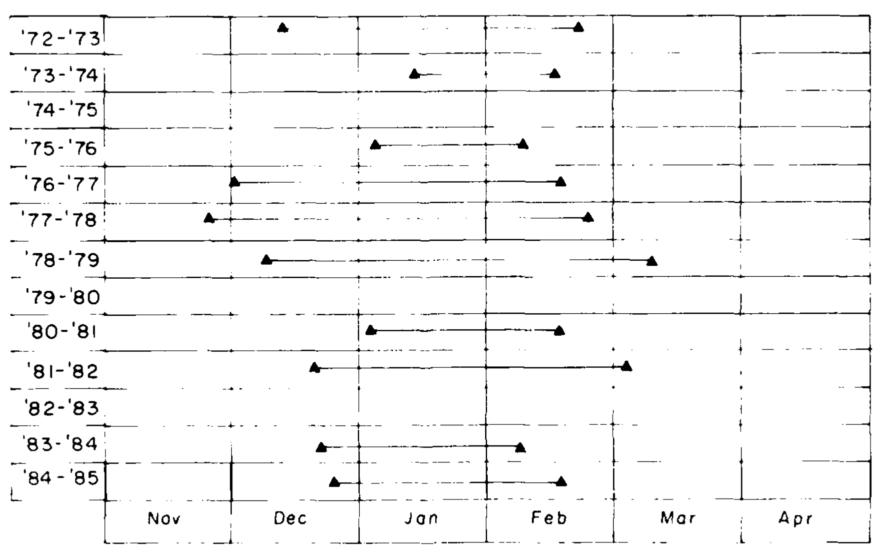
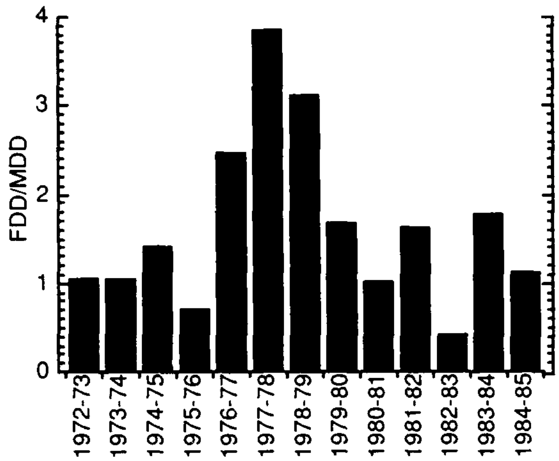
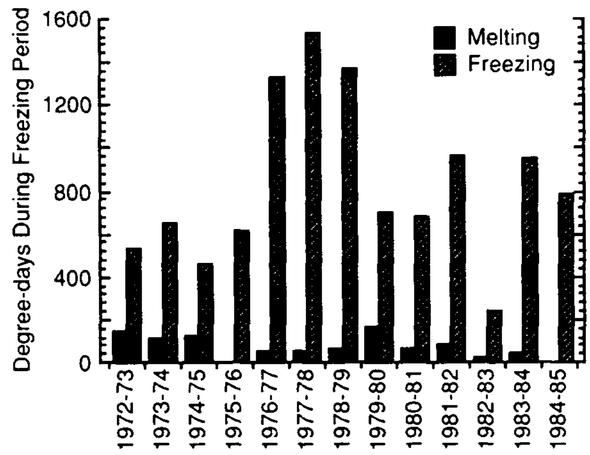


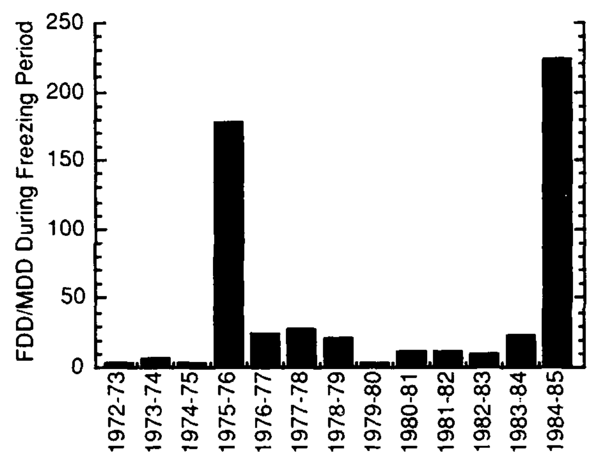
Figure 17. Period between first and last ice observed on the waterway with Landsat images.



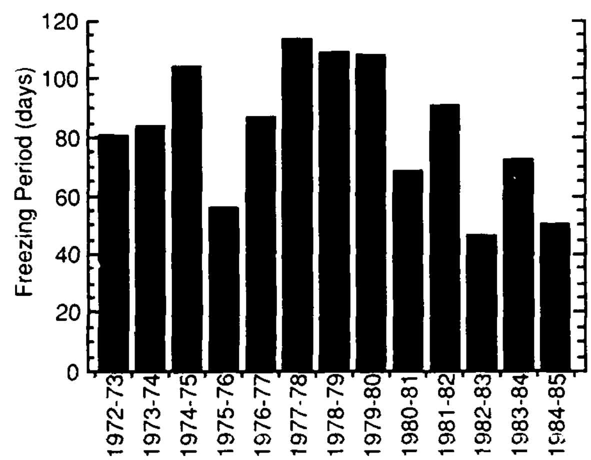
a. FDD/MDD ratios, 5 November to 31 March each winter.



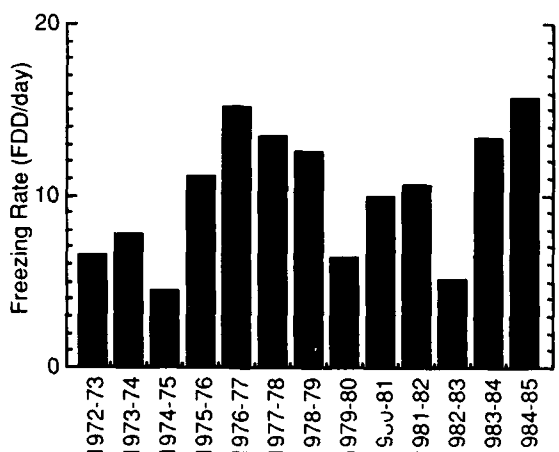
b. FDD and MDD during freezing periods.



c. FDD/MDD ratios, freezing periods.



d. Number of days during the freezing periods.



e. Freezing rate during freezing periods.

Figure 18. FDD and MDD comparisons (most data in Table 5).

1984–85 when 83% of the waterway was covered with 38% white ice. This winter had one of the low FDD/MDD ratios for the November–March period, 1.11 (Fig. 18a), but the highest FDD/MDD ratio and rate of freezing during the freezing period (Fig. 18c, 18e), and the fourth highest total flow volume, 5.52×10^6 $ft^3/s \cdot day$ (Fig. 19). However, most of the flow occurred in March, which is at the end of the normal ice season (Fig 14c).

3. Of the winters with 700 or more accumulated FDD, 80% saw more than 60% of the waterway ice covered when the cover was at its observed maximum. Exceptions were 1973–74 and 1979–80.

4. The FDD/MDD ratio on the date of first ice was greater than 1 for 30% of the winters, between 0.5 to 1 for 30%, and less than 0.5 for 40%, suggesting no relationship (Fig. F4). Once FDD start accumulating, first ice was observed before 30% of the total net FDD had accumulated during 80% of the winters. The FDD/MDD ratio was greater than 1 when maximum ice was observed 90% of the time, but was extremely variable (Fig. F5). In 70% of the winters, the maximum ice observed by Landsat was detected before 75% of the total net FDD had accumulated for the winter. The FDD/MDD ratio was always greater than 1 when last ice was observed. Last ice was observed during 70% of the winter after 90% of the total net FDD had accumulated.

5. I first observed ice on the waterway usually in early to mid-December, and it was gone by middle to late February, although these times are quite variable. The earliest first ice was on 26 November 1977, the latest was on 14 January 1974; the earliest last ice was on 8 February 1984, the latest was on 10 March 1979 (Fig. 17). The number of days between first and last ice observed on the waterway was 50 or more for 6 of the 13 winters and less than 50 days for 7 of the winters (Fig. 20).

6. First ice on the waterway was observed on the Peoria pool for 90% of the winters, the LaGrange pool for 50%, the Starved Rock and confluence pools for 40%, and Dresden Island pool for 20%. Last ice was on the confluence pool for 60% of the winters, the LaGrange pool for 40%, Peoria pool for 30%, and the Starved Rock and Dresden Island pools for 10% each (App. D).

7. Ice on the lakes, channels and sloughs adjacent to the main river channel was observed earlier and usually lasted well into March (Table 6; App. C). Ice was in these areas for 50 or more days for 11 of the 13 winters and for less than 50 days for 2 of the winters (Fig. 20).

8. Total flow volume for the entire winter (Fig. 19) has no apparent influence on the amount of ice covering the waterway when the ice is at its maximum and on the length of time ice stays on the waterway and adjacent areas (Fig. F11, F12, F15); however, timing and intensity of the changes in discharge are very important. When first ice was observed, discharge was falling or in a trough 80% of the winters and was less than 20,000 ft^3/s for 60% of the winters. At maximum ice, discharge was falling or in a trough 60% of the winters and was less than 20,000 ft^3/s 70% of the time. When last ice was observed, discharge had peaked or was rising for 60% of the winters; it was falling or stable for 40% of the winters. The discharge was

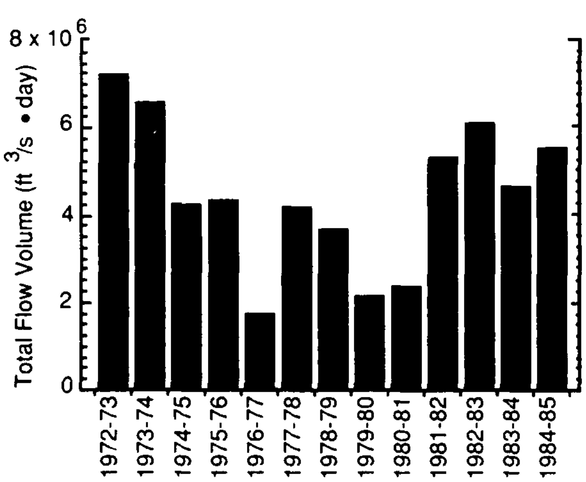


Figure 19. Total flow volume ($ft^3/s \cdot days$), 1 October to 31 March each winter (see Table 5).

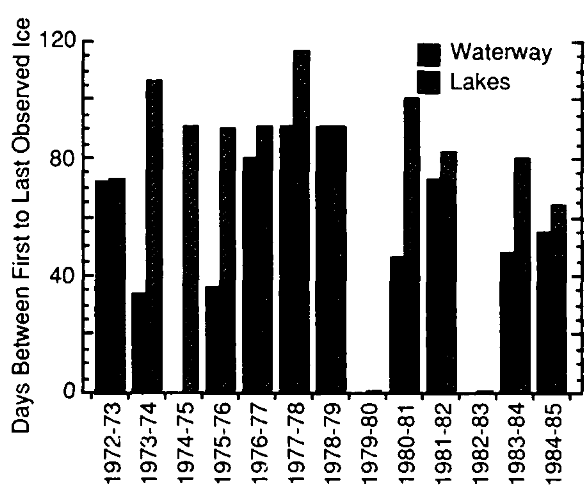


Figure 20. Number of days between the first and last observed ice (see Table 5).

Table 6. Periods when ice was observed on the adjacent channels, lakes and sloughs with Landsat images.

	Lockport	*Brandon Road*	*Dresden Island*	*Marseilles*	*Starved Rock*	*Peoria*	*LaGrange*	*Illinois–Mississippi confluence*
1972–73	—	—	13 Dec–23 Feb	13 Dec–23 Feb	13 Dec–23 Feb	13 Dec–24 Feb	13 Dec–24 Feb	13 Dec–1 Jan
1973–74	—	—	31 Jan–26 Mar	31 Jan–26 Mar	31 Jan–26 Mar	9 Dec–31 Jan	9 Dec–14 Jan	9 Dec–14 Jan
1974–75	—	—	2 Dec–21 Mar	2 Dec–30 Mar	2 Dec–30 Mar	3 Dec–13 Mar	3 Dec–4 Mar	22 Dec–4 Mar
1975–76	—	—	6 Dec–8 Feb	6 Dec–8 Feb	3 Jan–8 Feb	28 Nov–26 Feb	3 Jan–8 Feb	28 Nov–9 Feb
1976–77	—	—	1 Dec–1 Mar	1 Dec–1 Mar	1 Dec–1 Mar	1 Dec–1 Mar	1 Dec–1 Mar	7 Jan–1 Mar
1977–78	—	—	5 Feb–23 Mar	18 Jan–23 Mar	26 Nov–23 Mar	26 Nov–23 Mar	26 Nov–25 Feb	26 Nov–25 Feb
1978–79	—	—	9 Dec–27 Feb	9 Dec–27 Feb	9 Dec–19 Feb	9 Dec–10 Mar	9 Dec–10 Mar	9 Dec–10 Mar
1979–80	—	11 Mar	11 Mar'	11 Mar	No ice observed	No ice observed	No ice observed	No ice observed
1980–81	25 Dec	25 Dec	25 Dec–8 Feb	25 Dec–8 Feb	25 Dec–8 Feb	28 Nov–7 Mar	28 Nov–8 Mar	22 Jan–18 Feb
1981–82	20 Dec	20 Dec	20 Dec–2 Feb	20 Dec–2 Feb	20 Dec–16 Jan	11 Dec–3 Mar	29 Dec–3 Mar	29 Dec–4 Feb
1982–83	—	—	2 Mar	2 Mar	2 Mar	2 Mar	No ice observed	No ice observed
1983–84	—	—	1 Feb	1 Feb	22 Dec–8 Feb	22 Dec–11 Mar	22 Dec–11 Mar	22 Dec–11 Mar
1984–85	26 Jan	26 Jan	25 Dec–26 Jan	25 Dec–26 Jan	26 Jan–2 Feb	16 Dec–2 Feb	16 Dec–18 Feb	2 Feb–18 Feb

* A dash means insufficient spatial resolution or cloud covered.

Table 7. Rates of rise in discharge (ft³/s per day) after which either no ice or less ice was observed on lakes, lakes and the waterway or the waterway.

	Lakes				*Lakes and waterway*				*Waterway*			
Year	*Rate (ft^3/s per day)*	*Dates*	*No. of days*	*Beginning and ending Q* (ft^3/s)*	*Rate (ft^3/s per day)*	*Dates*	*No. of days*	*Beginning ending Q* (ft^3/s)*	*Rate (ft^3/s per day)*	*Dates*	*No. of days*	*Beginning and ending Q* (ft^3/s)*
1972–73					3557	4–18 Mar	14	22,900–72,700	2700	28 Dec–9 Jan	12	31,300–63,700
1973–74					4647	9 Jan–3 Feb	15	24,100–93,800				
1974–75		Discharge did not clear out ice							No ice on waterway			
1975–76	3700	4–13 Mar	9	47,000–80,300					1525	6 Feb–1 Mar	24	10,900–47,500
1976–77									3115	18–22 Feb	5	8,740–21,200
1977–78									3022	13–31 Mar	18	11,000–65,400
1978–79									4654	1–14 Mar	13	27,100–87,600
1979–80									No ice on waterway			
1980–81									3586	5–20 Feb	5	4,570–22,500
1981–82					3525	13–25 Mar	12	60,700–103,000	5600	16–27 Feb	11	16,000–77,600
1982–83									No ice on waterway			
1983–84	3914	16–23 Mar	7	30,800–58,200					3683	12–24 Feb	12	19,100–63,300
1984–85					5807	19 Feb–6 Mar	15	13,900–101,000				

*Q = discharge.

equal to or greater than 20,000 ft^3/s for 40% of the winters, and less than 20,000 ft^3/s for 60% of the winters.

9. Discharge increases of 1525 ft^3/s per day for 24 days to 5600 ft/^{3} per day for 11 days removed ~! and 78% of the existing ice cover on the waterway (Table 7); increases of 3525 (12 days) to 5807 (15 days) ft^3/s per day removed 3 and 41% of the waterway ice and the lake ice. Lake ice was removed in March 1976 and 1984 by discharge increases of 3700 ft^3/s per day for 9 days and 3914 ft^3/s per day for 7 days, respectively.

CONCLUSIONS

Landsat image analysis provides data on general ice conditions and distribution, especially during winters when ice is extensive and long-lasting. During winters when ice is not so, Landsat images are less useful because of the time gaps between usable images caused by cloud cover and satellite repeat cycle. Although image resolution is too coarse to determine detailed characteristics of ice cover and to discern thin ice or frazil ice that frequently exists at freezeup, the images provide a view of large reaches of a river on each scene and, for many rivers in cold regions, they commonly are the only source of data on ice conditions.

Ice conditions on the waterway change frequently during each winter and can be quite different between winters. Ice discernible on Landsat images was observed first and lasted the longest on the lakes, channels and sloughs adjacent to the main channel of the waterway. It lasted an average of 100 days during a period from early to mid-December to mid-March. Ice on the main channel lasted an average of 63 days during a period from middle to late December to middle to late February. Gray ice was observed most frequently, but white ice formed during seven winters. Air temperature and discharge determine ice conditions and distribution, but the results of this study indicate that temperature is usually the more important factor.

When used in conjunction with air temperature and discharge data, Landsat images provide a good and reasonably reliable method to study river ice conditions and changes. The images show ice distributions while the air temperatures and discharge show conditions that produce the observed ice cover and changes in it. This method is especially useful when other data sources on ice conditions are limited or unavailable.

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APPENDIX A: SELECTED LANDSAT IMAGES

The Landsat images reproduced as figures here are not at the same scale. The reason for this is that some of the figures show enlarged portions of whole images and the portions of images shown are not the same size.

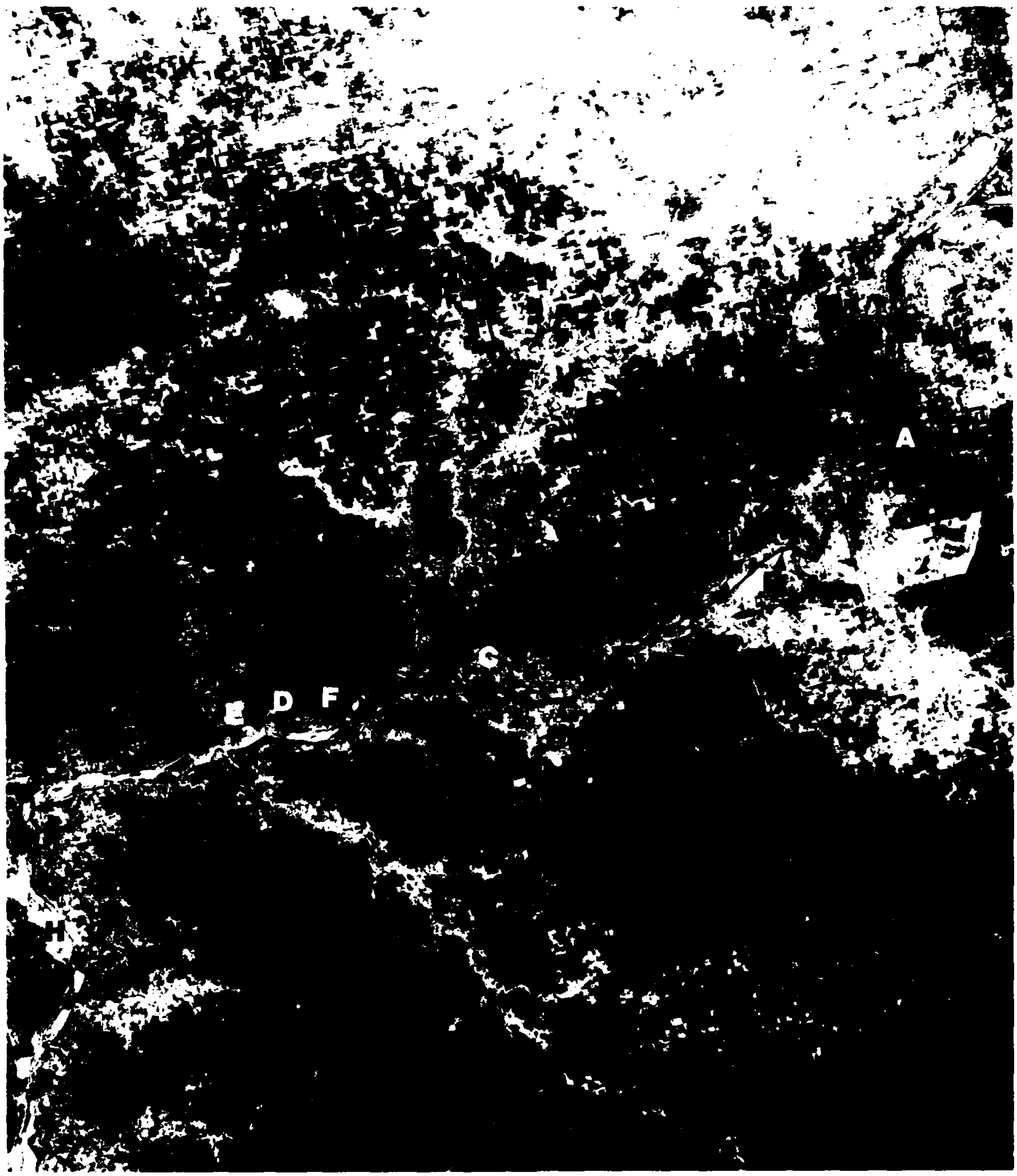


Figure A1. MSS image 2751-15441, 11 February 1977; Brandon Road Dam (A), Dresden Island Dam (B), Marseilles Dam (C), Starved Rock Dam (D), white ice (E), partial gray ice (F), open areas (G), ice on lakes (H).

Figure A2. MSS image 2751-15443, 11 February 1977; Peoria Dam (A), LaGrange Dam (B), partial gray ice (C), complete gray ice (D), white ice (E), open areas (F), ice on lakes (G).

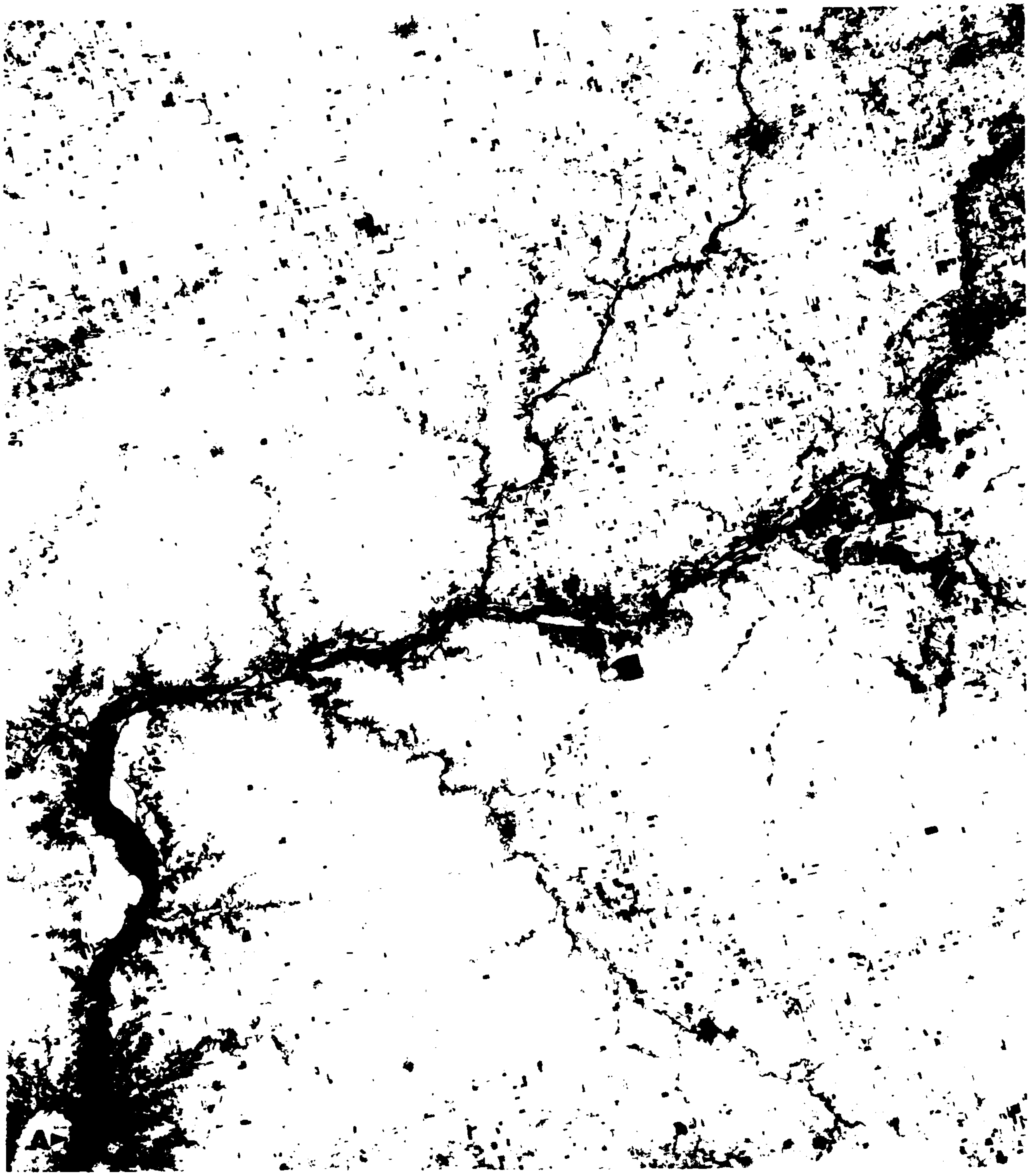


Figure A3. MSS image 6039-15293, 26 November 1977; partial gray ice (A) on the lakes portion of the Peoria Dam pool.

Figure A4. MSS image 21129-15310, 24 February 1978; white ice (A), navigation track (B), partial gray ice (C), Peoria Dam (D).

Figure A5. MSS image 21130-15371, 25 February 1978; white ice (A), navigation track (B), Mississippi–Illinois confluence (C).

Figure A6. MSS image 21453-15462, 14 January 1979; Peoria Dam (A), white ice (B).

Figure A7. RBV image 31026-15473D, 25 December 1980; Kankakee River (A) with scattered ice cover and open areas.

Figure A8. RBV image 31062-15491A, 30 January 1981; ice on adjacent lakes, channels and sloughs (A) while the navigation channel (B) appears open.

Figure A9. RBV image 31098-15504C, 7 March 1981; even-toned, dark appearance of the Illinois River due to open, ice-free water.

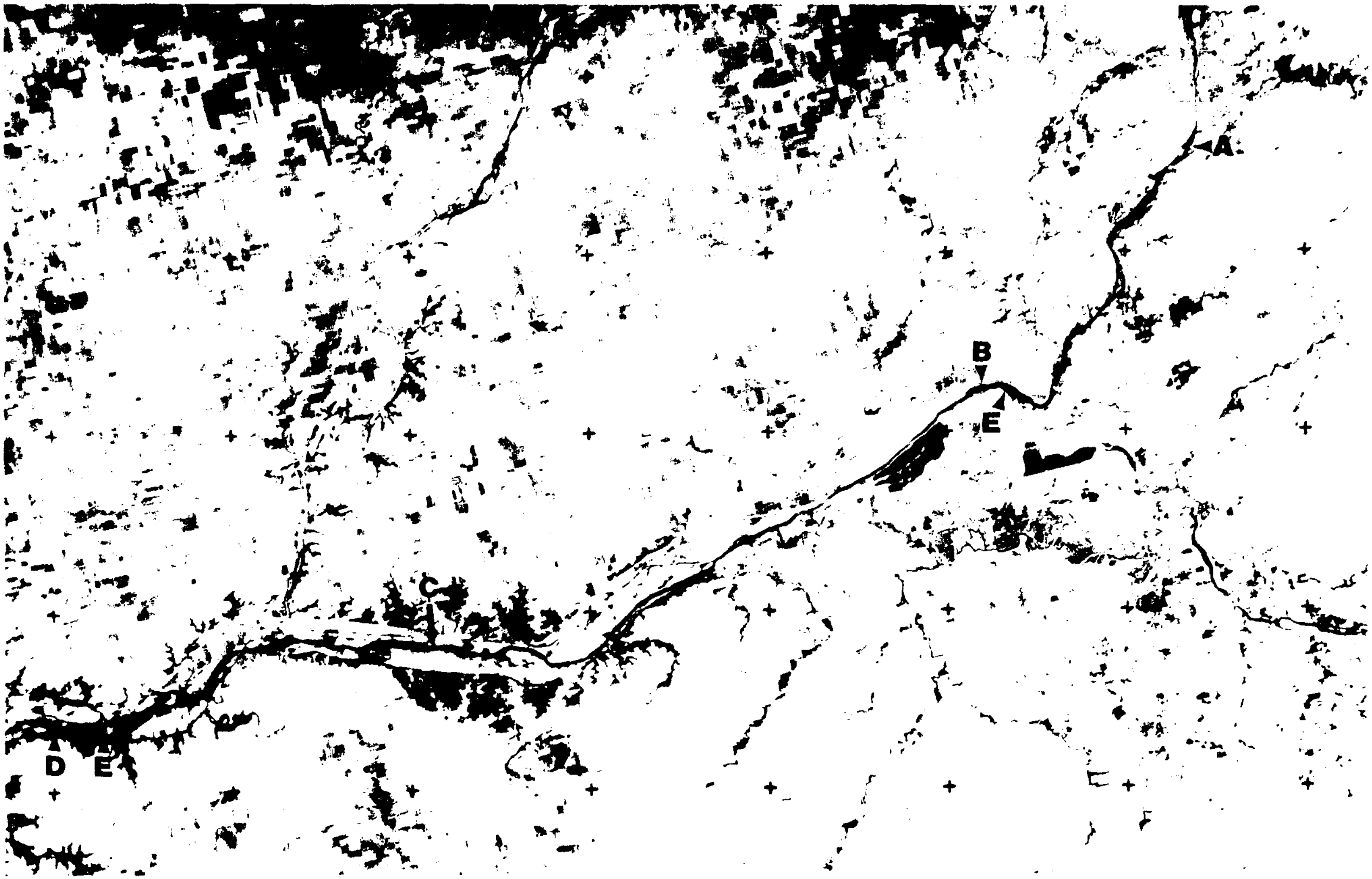


Figure A10. RBV image 31386-15591C,D, 20 December 1981; Brandon Road Dam (A), Dresden Island Dam (B), Marseilles Dam (C), Starved Rock Dam (D), partial gray ice (E), complete gray ice (F).

Figure A10 (cont'd).

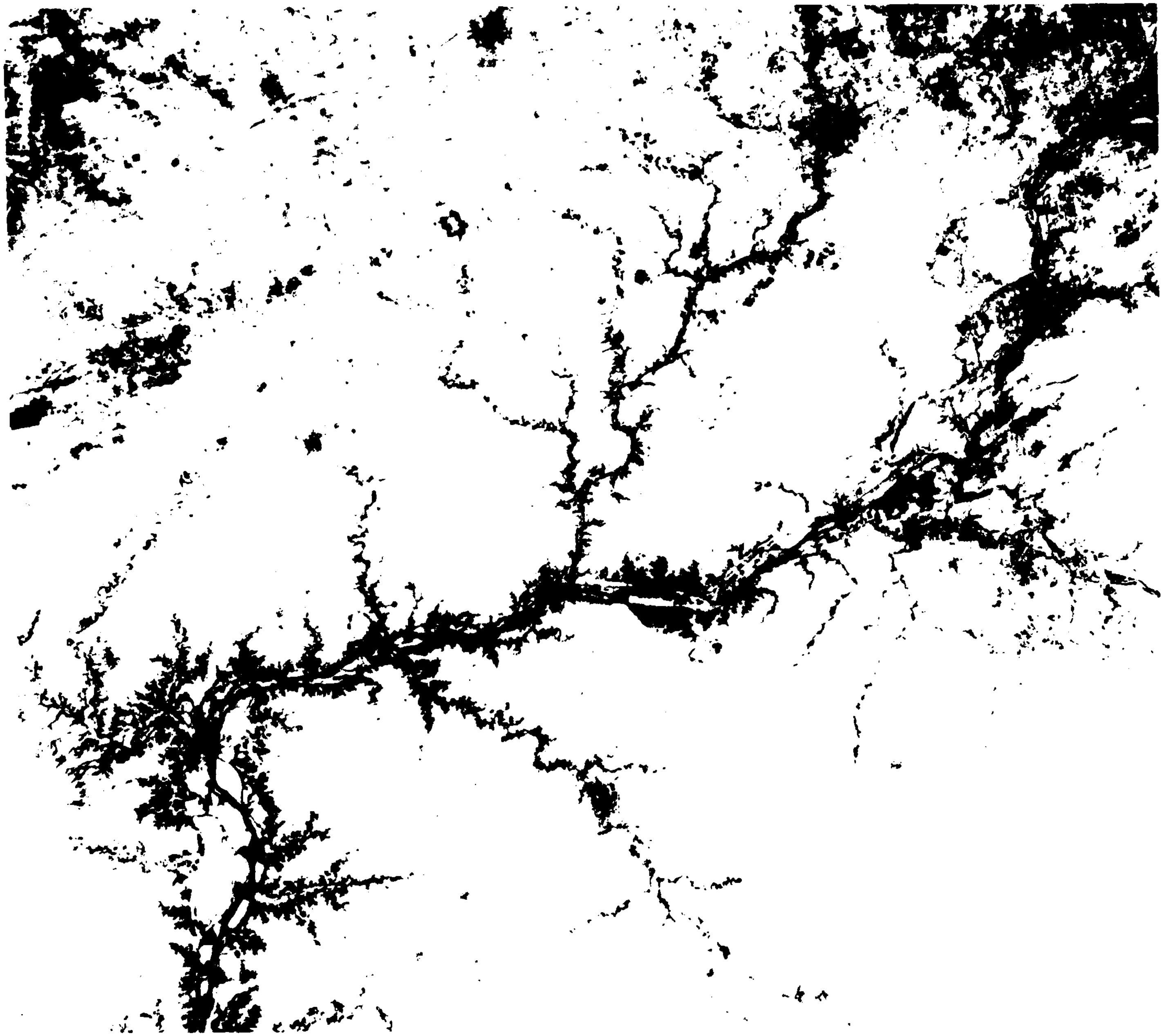


Figure 11. MSS image 22533-15562, 29 December 1981; water vapor (A) coming off of pond near Kankakee–Illinois River confluence.

Figure A12. MSS image 40524-16101, 22 December 1983; Peoria Dam (A), LaGrange Dam (B), partial gray ice (C), white ice (D), navigation track (E), complete gray ice (F).

Figure A13. MSS image 40524-16103, 22 December 1983; Mississippi–Illinois confluence (A), white ice (B), partial gray ice (C), complete gray ice (D).

Figure A14. MSS image 40565-16032, 1 February 1984; Peoria Dam (A), white ice (B), navigation track (C), complete gray ice (D), partial gray ice (E).

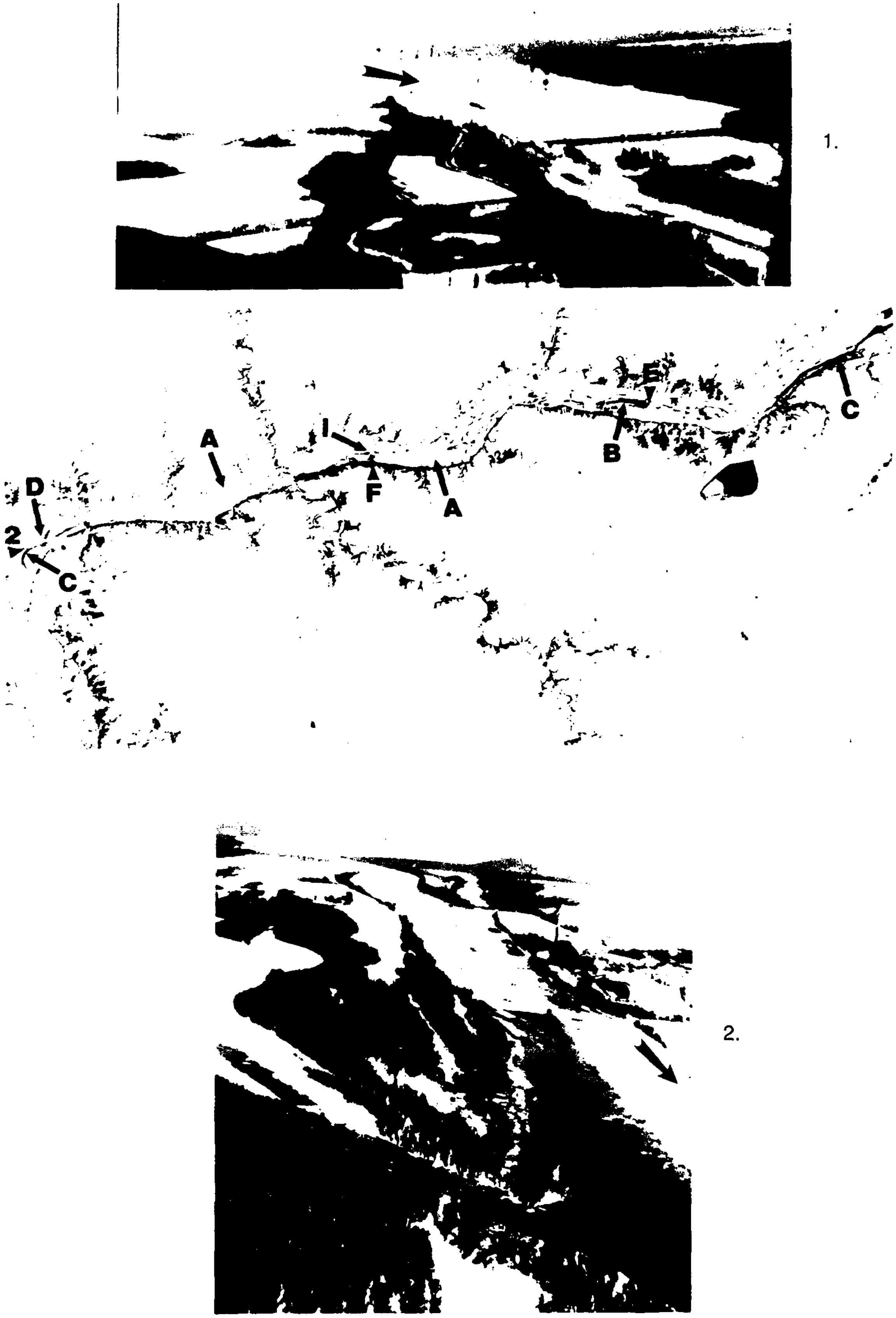
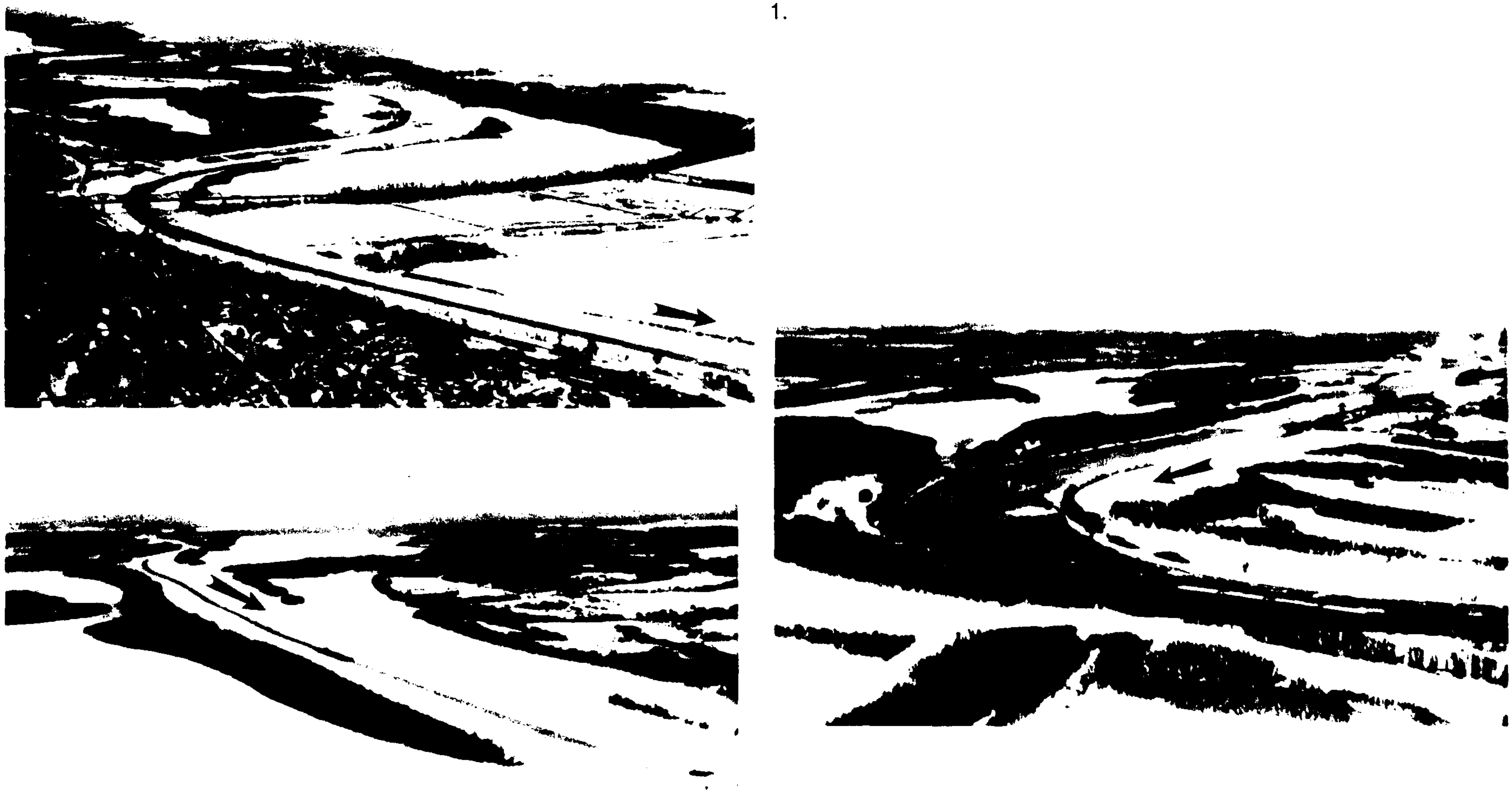


Figure A15. TM image 50331-16052, 26 January 1985; white ice (A), open areas (B), partial gray ice (C), complete gray ice (D), Marseilles Dam (E), Starved Rock Dam (F); aerial photographs (1 and 2) taken 14 February 1985.

Figure A16. MSS image 50338-16114, 2 February 1985; Starved Rock Dam (A), white ice (B), navigation track (C), complete gray ice (D); aerial photographs (1–3) taken 14 February 1985.

1.

2.



3.

Figure A16 (cont'd). Aerial photographs (1–3) taken 14 February 1985.

Figure A17. MSS image 50354-16120, 18 February 1985; LaGrange Dam (A), complete gray ice (B), white ice (C), partial gray ice (D).

APPENDIX B: LANDSAT IMAGES ANALYZED

Dates	Pool No. 1	2	3	4	5	6	7	8
1972-73 (17 dates)								
24 November	X	X	X	X				
26 November						X	X	X
13 December	X	X	X	X	X	X	X	X
14 December						X	X	X
31 Dec								X
1 January						X	X	X
17 January	X	X	X	X				
19 January								X
4 February	X	X	X	X				
5 February						X	X	X
6 February						X	X	
23 February	X	X	X	X	X	X	X	X
24 February						X	X	X
13 March	X	X	X	X	X	X	X	X
14 March							X	X
30 March	X	X	X	X	X			
31 March								X
1973-74 (15 dates)								
19 November	X	X	X	X				
21 November								X
7 December	X	X	X	X				
9 December						X	X	X
14 January						X	X	X
31 January	X	X	X	X	X	X	X	X
1 February						X	X	X
17 February	X	X	X	X				
19 February						X	X	X
7 March	X	X	X	X				
8 March								X
9 March						X	X	X
25 March	X	X	X	X				
26 March	X	X	X	X	X	X	X	X
27 March						X	X	X
1974-75 (20 dates)								
14 November	X	X	X	X	X			
15 November	X	X	X	X	X	X		
2 December	X	X	X	X	X			
3 December	X	X	X	X	X	X	X	X
4 December						X	X	X
22 December						X	X	X
7 January	X	X	X	X	X			
9 January								X
12 February	X	X	X	X	X			
13 February	X	X	X	X	X	X		
21 February	X	X	X	X				
2 March	X	X	X	X	X			
3 March	X	X	X	X	X	X	X	X
4 March							X	X
13 March						X	X	X
20 March	X	X	X	X	X			
21 March	X	X	X	X	X	X	X	X
22 March							X	X
30 March	X	X	X	X	X	X		X
31 March						X	X	X
1975-76 (26 dates)								
18 November	X	X	X	X				
20 November								X
28 November	X	X	X	X	X	X	X	X
6 December	X	X	X	X				
16 December						X	X	X
3 January	X	X	X	X	X	X	X	X
4 January						X	X	X
12 January	X	X	X	X	X	X	X	X
21 January	X	X	X	X	X	X		X
22 January						X	X	X
29 January	X	X	X	X				
30 January	X	X	X	X	X	X		X
31 January						X	X	X
7 February	X	X	X	X	X			
8 February	X	X	X	X	X	X	X	X
9 February						X		X
26 February	X	X	X	X	X	X	X	X
27 February							X	X
6 March	X	X	X	X	X	X	X	X
7 March						X	X	X
14 March	X	X	X	X	X			
15 March	X	X	X	X	X	X	X	X
16 March							X	X
23 March	X	X	X	X				
24 March	X	X	X	X	X	X	X	X
25 March						X	X	X
1976-77 (25 dates)								
12 November	X	X	X	X	X			
13 November	X	X	X	X	X	X	X	X
14 November						X	X	X
30 November	X	X	X	X				
1 December	X	X	X	X	X	X	X	X
2 December						X		
18 December	X	X	X	X				
19 December	X	X	X	X	X	X	X	X
20 December						X	X	X
5 January	X	X	X	X				
6 January	X	X	X	X	X	X	X	X
7 January						X	X	X
24 January								X
25 January						X	X	X
10 February	X	X	X	X	X			
11 February	X	X	X	X	X	X	X	X
12 February						X	X	X
16 February	X	X	X	X	X			
17 February	X	X	X	X	X	X	X	X
18 February							X	X
28 February	X	X	X	X	X	X		
1 March	X	X	X	X	X	X	X	X
2 March						X		X
19 March	X	X	X	X	X	X		X
20 March							X	X
1977-78 (11 dates)								
26 November	X	X	X	X	X	X	X	X
15 December						X	X	X
2 January						X	X	X
18 January	X	X	X	X				
20 January						X	X	X
5 February	X	X	X	X				
6 February	X	X	X	X	X	X	X	X
7 February						X	X	X
24 February	X	X	X	X	X	X	X	X
25 February						X	X	X
23 March	X	X	X	X	X	X	X	
1978-79 (23 dates)								
29 November	X	X	X	X				
30 November	X	X	X	X	X	X	X	X
1 December						X	X	X
9 December	X	X	X	X	X	X	X	X
10 December						X	X	X
17 December	X	X	X	X				
18 December	X	X	X	X	X	X		X
26 December	X	X	X	X				

Dates	Pool No. 1	2	3	4	5	6	7	8
27 December	X	X	X	X	X	X	X	X
4 January	X	X	X	X				
5 January	X	X	X	X	X	X		
6 January						X	X	X
14 January	X	X	X	X	X	X	X	X
22 January	X	X	X	X				
24 January						X	X	X
1 February	X	X	X	X	X	X	X	X
2 February						X		
9 February	X	X	X	X				
10 February								X
19 February	X	X	X	X	X	X	X	X
20 February						X		
27 February	X	X	X	X				
10 March						X	X	X
1979-80 (6 dates)								
24 November	X	X	X	X				
26 November						X		
13 December	X	X	X	X	X	X		
14 December						X	X	X
30 December	X	X	X	X				
31 December	X	X	X	X	X	X		
11 March	X	X	X	X				
1980-81 (22 dates)								
9 November	X	X	X	X				
19 November	X	X	X	X	X	X		X
28 November						X	X	X
29 November						X	X	X
17 December						X	X	X
25 December	X	X	X	X	X			
3 January	X	X	X	X	X	X	X	X
4 January						X	X	X
20 January	X	X	X	X				
22 January						X	X	X
30 January	X	X	X	X	X	X	X	X
7 February	X	X	X	X				
8 February	X	X	X	X	X	X	X	X
9 February						X	X	X
18 February								X
25 February	X	X	X	X				
26 February	X	X	X	X	X	X	X	X
27 February								X
7 March	X	X	X	X	X	X	X	X
8 March						X	X	X
15 March	X	X	X	X				
17 March						X		

Dates	Pool No. 1	2	3	4	5	6	7	8
1981-82 (16 dates)								
13 November	X	X	X	X				
14 November	X	X	X	X	X	X		
24 November						X		
10 December	X	X	X	X				
11 December	X	X	X	X	X	X	X	X
12 December						X		
20 December	X	X	X	X	X	X		X
29 December	X	X	X	X	X	X	X	X
16 January	X	X	X	X	X	X	X	X
26 January						X	X	X
2 February	X	X	X	X				
4 February						X	X	X
11 February	X							
3 March						X	X	
20 March								X
21 March								X
1982-83 (5 dates)								
4 January						X	X	X
13 January	X	X	X	X	X	X	X	X
21 February						X	X	X
2 March	X	X	X	X	X	X	X	
25 March						X	X	X
1983-84 (9 dates)								
20 November								X
22 December					X	X	X	X
7 January					X	X	X	X
16 January	X	X	X	X	X	X		
25 January	X							
1 February	X	X	X	X	X	X	X	
8 February					X	X	X	X
11 March						X	X	X
23 March						X	X	X
1984-85 (12 dates)								
16 November	X							
23 November	X	X	X	X	X	X	X	
16 December					X	X	X	X
25 December	X	X	X	X	X	X	X	
2 January	X							
19 January	X							
26 January	X	X	X	X	X	X	X	
2 February					X	X	X	X
18 February						X	X	X
20 February	X							
27 February	X	X	X	X	X	X		
6 March					X	X	X	X

APPENDIX C: OPEN WATER, GRAY ICE AND WHITE ICE

Abbreviations here are as follows:

SIOL:	Scattered ice on adjacent lakes and sloughs	RBV:	Return beam vidicon image
NIOL:	No ice on adjacent lakes and sloughs	TM:	Thematic mapper image
IOL:	Ice covers on adjacent lakes and sloughs	CC:	Cloud-covered
NT:	Navigation track visible	PC:	Partial cloud cover
ISR:	Insufficient spatial resolution	NOI:	Not on image

Pool: Lockport **River: Chicago Sanitary and Ship Canal** **Pool length: 36.2 miles**

	Open		Gray Ice		White Ice		
Date	Length	Percent	Length	Percent	Length	Percent	Remarks
1972-73							
24 Nov							ISR
13 Dec							ISR
17 Jan							CC
4 Feb							ISR; PC
23 Feb							ISR
13 Mar							CC
30 Mar							ISR
1973-74							
19 Nov							CC
7 Dec							CC
31 Jan							ISR
17 Feb							ISR
7 Mar							ISR
25 Mar							ISR
26 Mar							ISR; PC
1974-75							
14 Nov							ISR; PC
15 Nov							ISR
2 Dec							ISR; hazy
3 Dec							ISR; PC
7 Jan							ISR; hazy
12 Feb							ISR
13 Feb							ISR; hazy
21 Feb							ISR; CC
2 Mar							ISR
3 Mar							ISR
20 Mar							ISR
21 Mar							ISR; PC-hazy
30 Mar							ISR; CC
1975-76							
18 Nov							ISR
28 Nov							ISR; CC
6 Dec							ISR; CC-PC
3 Jan							ISR; PC
12 Jan							ISR; CC
21 Jan							ISR; PC
29 Jan							ISR; PC
30 Jan							ISR; CC
7 Feb							ISR
8 Feb							ISR
26 Feb							ISR
6 Mar							ISR
14 Mar							ISR
15 Mar							ISR; PC
23 Mar							ISR
24 Mar							ISR
1976-77							
12 Nov							ISR
13 Nov							ISR
30 Nov							ISR
1 Dec							ISR
18 Dec							ISR
19 Dec							ISR; PC
5 Jan							CC
6 Jan							CC
10 Feb							ISR
11 Feb							ISR
16 Feb							ISR
17 Feb							CC
28 Feb							ISR; PC

	Open		Gray Ice		White Ice		
Date	Length	Percent	Length	Percent	Length	Percent	Remarks
1 Mar							ISR
19 Mar							ISR; PC
1977-78							
26 Nov							ISR
18 Jan							CC
5 Feb							ISR; PC
6 Feb							ISR; PC
24 Feb							CC
23 Mar							ISR
1978-79							
29 Nov							CC
30 Nov							ISR
9 Dec							ISR
17 Dec							ISR
18 Dec							CC
26 Dec							ISR
27 Dec							ISR
4 Jan							ISR
5 Jan							CC
14 Jan							ISR
22 Jan							CC
1 Feb							ISR
9 Feb							ISR
19 Feb							ISR
27 Feb							ISR
1979-80							
24 Nov							ISR
13 Dec							ISR
30 Dec							ISR
31 Dec							ISR; CC
11 Mar	36.2	100					RBV
1980-81							
9 Nov							ISR
19 Nov	36.2	100					RBV; NIOL
25 Dec	36.2	100					RBV; IOL
3 Jan							ISR
20 Jan							ISR
30 Jan							RBV; CC
7 Feb							ISR; PC
8 Feb							ISR; PC
25 Feb							ISR
26 Feb							CC
7 Mar	36.2	100					RBV; NIOL
15 Mar							ISR
1981-82							
13 Nov	36.2	100					RBV; NIOL
14 Nov	6.2	17					RBV; up. 30 mi-NOI; NIOL
10 Dec							ISR; up. 7 mi-CC
11 Dec							ISR
20 Dec	36.2	100					RBV; up. 5 mi-NOI; IOL
29 Dec							ISR
16 Jan							ISR
2 Feb							ISR; PC-CC
11 Feb							RBV; sensor saturation
1982-83							
21 Dec							CC
13 Jan							ISR
2 Mar							ISR; hazy
1983-84							
16 Jan							ISR; PC
25 Jan							ISR; low. 13 mi-NOI
1 Feb							ISR
1984-85							
16 Nov							ISR

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
23 Nov							ISR
25 Dec							ISR
3 Jan							ISR
19 Jan							ISR
26 Jan	36.2	100					TM; IOL
20 Feb							ISR
27 Feb							ISR

Pool: Brandon Road **River: Des Plaines** **Pool length: 5 miles**

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
1972-73							
24 Nov							ISR
13 Dec							ISR
17 Jan							CC
4 Feb							ISR; PC
23 Feb							ISR
13 Mar							CC
30 Mar							ISR
1973-74							
19 Nov							CC
7 Dec							CC
31 Jan							ISR
17 Feb							ISR
7 Mar							ISR
25 Mar							ISR
26 Mar							ISR; PC
1974-75							
14 Nov							ISR; PC
15 Nov							ISR
2 Dec							ISR; hazy
3 Dec							ISR
7 Jan							ISR, PC
12 Feb							ISR
13 Feb							ISR; hazy
21 Feb							ISR; PC
2 Mar							ISR
3 Mar							ISR
20 Mar							ISR
21 Mar							ISR; PC-hazy
30 Mar							ISR; CC
1975-76							
18 Nov							ISR
28 Nov							ISR; PC
6 Dec							ISR
3 Jan							ISR; PC
12 Jan							ISR; CC
21 Jan							ISR
29 Jan							ISR
30 Jan							ISR; CC
7 Feb							ISR
8 Feb							ISR
26 Feb							ISR
6 Mar							ISR
14 Mar							ISR
15 Mar							ISR; CC
23 Mar							ISR
24 Mar							ISR
1976-77							
12 Nov							ISR
13 Nov							ISR
30 Nov							ISR
1 Dec							ISR
18 Dec							ISR
19 Dec							ISR; PC
5 Jan							CC
6 Jan							CC

	Open		Gray Ice		White Ice		
Date	Length	Percent	Length	Percent	Length	Percent	Remarks
10 Feb							ISR
11 Feb							ISR
16 Feb							ISR
17 Feb							CC
28 Feb							ISR; PC
1 Mar							ISR
19 Mar							CC
1977-78							
26 Nov							ISR
18 Jan							CC
5 Feb							ISR; PC
6 Feb							ISR; PC
24 Feb							CC
23 Mar							ISR
1978-79							
29 Nov							CC
30 Nov							ISR
9 Dec							ISR
17 Dec							ISR
18 Dec							CC
26 Dec							ISR
27 Dec							ISR
4 Jan							ISR
5 Jan							ISR
14 Jan							ISR
22 Jan							ISR
1 Feb							ISR
9 Feb							ISR
19 Feb							ISR
27 Feb							ISR
1979-80							
24 Nov							ISR
13 Dec							ISR
30 Dec							ISR
31 Dec							ISR; CC
11 Mar	5	100					RBV; IOL
1980-81							
9 Nov							ISR
19 Nov	5	100					RBV; NIOL
25 Dec	5	100					RBV; IOL
3 Jan							ISR
20 Jan							ISR
30 Jan							RBV; CC
7 Feb							ISR; PC
8 Feb							ISR; PC
25 Feb							ISR
26 Feb							CC
7 Mar	5	100					RBV; NIOL
15 Mar							ISR
1981-82							
13 Nov	5	100					RBV; NIOL
14 Nov	5	100					RBV; NIOL
10 Dec							ISR
11 Dec							ISR
20 Dec	5	100					RBV; IOL
29 Dec							ISR
16 Jan							ISR
2 Feb							ISR
1982-83							
13 Jan							ISR
2 Mar							ISR; Hazy
1983-84							
16 Jan							ISR; PC
1 Feb							ISR
1984-85							
23 Nov							ISR
25 Dec							ISR
26 Jan	5	100					TM; IOL
27 Feb							ISR

Pool: Dresden Island **River: Illinois/Des Plaines** **Pool length: 14.7 miles**

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
1972-73							
24 Nov	14.7	100					NIOL
13 Dec	14.7	100					SIOL
17 Jan							CC
4 Feb	14.7	100					PC; SIOL
23 Feb	14.7	100					SIOL
13 Mar							CC
30 Mar	14.7	100					Hazy; NIOL
1973-74							
19 Nov							CC
7 Dec	13.7	93					up. 1 mi-CC; NIOL
31 Jan	14.7	100					SIOL-NIOL; flooding
17 Feb	12.7	86	2	14			SIOL-NIOL
7 Mar	14.7	100					SIOL-NIOL
25 Mar	14.7	100					SIOL-NIOL
26 Mar	14.7	100					PC; SIOL-NIOL
1974-75							
14 Nov	14.7	100					PC; NIOL
15 Nov	14.7	100					NIOL
2 Dec	14.7	100					SIOL-NIOL; hazy
3 Dec	14.7	100					SIOL-NIOL
7 Jan	4	27					up. 10.7 mi.-CC; SIOL
12 Feb	14.7	100					SIOL-NIOL
13 Feb	14.7	100					SIOL-NIOL; hazy
21 Feb	14.7	100					SIOL; PC-hazy
2 Mar	14.7	100					SIOL
7 Mar	14.7	100					SIOL
20 Mar	14.7	100					SIOL
21 Mar	14.7	100					PC-hazy; SIOL
30 Mar	14.7	100					CC
1975-76							
18 Nov	14.7	100					NIOL
28 Nov	14.7	100					NIOL
6 Dec	14.7	100					NIOL-SIOL
3 Jan	14.7	100					PC; SIOL
12 Jan							CC-PC; SIOL
21 Jan	14.7	100					SIOL
29 Jan	14.7	100					SIOL
30 Jan							CC
7 Feb	14.7	100					SIOL
8 Feb	14.7	100					SIOL
26 Feb	14.7	100					NIOL
6 Mar	14.7	100					NIOL
14 Mar	14.7	100					NIOL; PC
15 Mar							CC
23 Mar	14.7	100					NIOL
24 Mar	14.7	100					NIOL
1976-77							
12 Nov	14.7	100					NIOL
13 Nov	14.7	100					NIOL
30 Nov	14.7	100					NIOL
1 Dec	14.7	100					SIOL; PC
18 Dec	14.7	100					SIOL
19 Dec	14.7	100					SIOL; PC
5 Jan							CC
6 Jan							CC
10 Feb	14.7	100					SIOL
11 Feb	14.7	100					SIOL
16 Feb	14.7	100					SIOL
17 Feb							CC
28 Feb	14.7	100					PC; SIOL
1 Mar	14.7	100					SIOL-IOL
19 Mar							CC
1977-78							
26 Nov	14.7	100					NIOL
18 Jan							CC
5 Feb	14.7	100					SIOL
6 Feb	14.7	100					SIOL

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
24 Feb							CC
23 Mar	14.7	100					SIOL
1978-79							
29 Nov							CC
30 Nov	14.7	100					NIOL
9 Dec	13.7	93	1	7			SIOL
17 Dec	14.7	100					SIOL
18 Dec							CC
26 Dec	7.7	52	7	48			SIOL
27 Dec	14.7	100					SIOL
4 Jan	6.7	46	8	54			SIOL; PC
5 Jan							CC
14 Jan	10.7	73	3	20	1	7	IOL; NT
22 Jan	13.7	93			1	7	IOL; NT
1 Feb			13.7	93	1	7	IOL; NT
9 Feb			13.7	93	1	7	IOL; NT
19 Feb	12.7	86	1	7	1	7	PC; SIOL; NT
27 Feb	14.7	100					SIOL
1979-80							
24 Nov	14.7	100					NIOL
13 Dec	14.7	100					NIOL
30 Dec	14.7	100					NIOL
31 Dec							CC
11 Mar	14.7	100					RBV; IOL
1980-81							
9 Nov	14.7	100					NIOL
19 Nov	14.7	100					RBV; NIOL
25 Dec	14.7	100					RBV; SIOL-IOL
3 Jan	14.7	100					SIOL
20 Jan	14.7	100					PC
30 Jan	4.7	32					RBV; up. 10 mi.-CC; SIOL
7 Feb	14.7	100					PC; SIOL
8 Feb	14.7	100					PC; SIOL
25 Feb	14.7	100					NIOL
26 Feb							CC
7 Mar	14.7	100					RBV; NIOL
15 Mar	14.7	100					NIOL
1981-82							
13 Nov	14.7	100					RBV; NIOL
14 Nov	14.7	100					RBV; PC; NIOL
10 Dec	14.7	100					NIOL
11 Dec	14.7	100					NIOL; PC
20 Dec	12.7	86	2	14			RBV; IOL
29 Dec	7.7	52	2* 5	14* 34			IOL; NT; hazy
16 Jan	7.7	52	5	34	2	14	IOL; PC; NT; hazy
2 Feb	12.7	86			2	14	IOL; NT
1982-83							
13 Jan	14.7	100					NIOL
2 Mar	14.7	100					SIOL-NIOL
1983-84							
16 Jan							CC
1 Feb	14.7	100					SIOL
1984-85							
23 Nov	14.7	100					NIOL
25 Dec	14.7	100					SIOL
26 Jan	12.7	86	2	14			TM; SIOL
27 Feb							CC

Pool: Marseilles **River: Illinois** **Pool length: 27.0 miles**

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
1972-73							
24 Nov	22	81					low. 5 mi.-NOI; NIOL
13 Dec	27	100					IOL
17 Jan							CC
4 Feb	22	81					low. 5 mi.-NOI; PC; SIOL
23 Feb	27	100					SIOL
13 Mar							CC
30 Mar	27	100					Hazy; NIOL
1973-74							
19 Nov							CC
7 Dec	23.8	88					low. 3.2 mi.-NOI; NIOL
31 Jan	27	100					SIOL-NIOL; flooding
17 Feb	20.7	77					low. 6.3 mi.-NOI; SIOL-NIOL
7 Mar	22.3	83					low. 4.7 mi.-NOI; SIOL-NIOL
25 Mar	24.5	91					low. 2.5 mi.-NOI; SIOL-NIOL
26 Mar	27	100					PC; SIOL-NIOL
1974-75							
14 Nov	14	52					low. 7 & mid. 6 mi.-CC; NIOL
15 Nov	27	100					NIOL
2 Dec	27	100					SIOL-NIOL
3 Dec	27	100					SIOL-NIOL
7 Jan	27	100					SIOL; hazy
12 Feb	11	41					low. 16 mi.-CC; SIOL
13 Feb	27	100					SIOL; PC
21 Feb	20	74					low. 7 mi.-NOI; IOL; hazy
2 Mar	27	100					SIOL
3 Mar	27	100					SIOL
20 Mar	27	100					SIOL
21 Mar	27	100					SIOL; PC-hazy
30 Mar	27	100					PC-hazy; SIOL-NIOL
1975-76							
18 Nov	23.3	86					low. 4.7 mi.-NOI; NIOL
28 Nov	27	100					NIOL
6 Dec	21	78					low. 6 mi.-NOI; NIOL-SIOL
3 Jan	27	100					SIOL
12 Jan	21	78	6	22			SIOL; PC
21 Jan	27	100					SIOL
29 Jan	25.5	94					SIOL; low. 1.5 mi.-NOI
30 Jan							CC
7 Feb	27	100					SIOL
8 Feb	27	100					SIOL
26 Feb	27	100					NIOL
6 Mar	27	100					NIOL
14 Mar	27	100					NIOL
15 Mar							CC
23 Mar	24	89					low. 3 mi.-NOI
24 Mar	24	89					low. 3 mi.-CC
1976-77							
12 Nov	27	100					NIOL
13 Nov	27	100					NIOL
30 Nov	27	100					NIOL
1 Dec	27	100					SIOL
18 Dec	27	100					SIOL
19 Dec	27	100					SIOL; PC-hazy
5 Jan							CC; low. 1 mi.-NOI
6 Jan							CC
10 Feb	24.5	91			2.5	9	IOL
11 Feb	24.5	91			2.5	9	IOL
16 Feb	22	81	5	19			IOL
17 Feb							CC
28 Feb	27	100					PC; SIOL
1 Mar	27	100					SIOL-IOL
19 Mar							CC
1977-78							
26 Nov	27	100					NIOL
18 Jan	9	33					up. 13 mi.-CC; low. 5 mi.-NOI. SIOL

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
5 Feb	11	41					low. 16 mi.-NOI; SIOL
6 Feb	27	100					SIOL
24 Feb							CC
23 Mar	27	100					SIOL
1978-79							
29 Nov							CC
30 Nov	27	100					NIOL
9 Dec	27	100					SIOL
17 Dec	8	30					SIOL; low. 19 mi.-NOI
18 Dec							CC
26 Dec	11	41	1	4			low. 15 mi.-NOI; SIOL
27 Dec	27	100					SIOL
4 Jan	10	37					SIOL; low. 17 mi.-NOI; PC
5 Jan							CC
14 Jan	18	67			9	33	IOL
22 Jan	11	41	1	4			low. 15 mi.-CC; IOL
1 Feb	23	86	2* 2	7* 7			IOL
9 Feb	14	52					low. 13 mi.-NOI
19 Feb	23	85	1	4	3	11	IOL
27 Feb	13	48					low. 14 mi.-NOI; IOL-SIOL
1979-80							
24 Nov	20	74					low. 7 mi.-NOI; NIOL
13 Dec	27	100					NIOL
30 Dec	18	67					low. 9 mi.-NOI; NIOL
31 Dec							CC
11 Mar	20	74					RBV; low. 7 mi.-NOI; IOL
1980-81							
9 Nov	20	74					low. 7 mi.-NOI; NIOL
19 Nov	27	100					RBV; NIOL
25 Dec	27	100					RBV; SIOL-IOL
3 Jan	27	100					SIOL
20 Jan	18	67					low. 9 mi.-NOI; PC
30 Jan	2	7					RBV; low. 25 mi.-CC; SIOL
7 Feb	14	52					low. 13 mi.-CC; PC; SIOL
8 Feb	22	81					low. 5 mi.-CC; PC; SIOL
25 Feb	20.3	75					low. 6.7 mi.-NOI; NIOL
26 Feb							CC
7 Mar	27	100					RBV; NIOL
15 Mar	21.3	79					low. 5.7 mi.-NOI; NIOL
1981-82							
13 Nov	11	41					RBV; NIOL; low. 16 mi.-NOI
14 Nov	14	52					RBV; NIOL; low. 13 mi.-CC
10 Dec	17	63					low. 10 mi.-NOI; NIOL
11 Dec	27	100					NIOL; PC-CC
20 Dec	27	100					RBV; IOL
29 Dec	27	100					IOL
16 Jan	9	33	2	7	16	59	IOL; NT; hazy-PC
2 Feb	15	56					IOL; low. 12 mi.-NOI; hazy-PC
1982-83							
13 Jan	27	100					NIOL
2 Mar	27	100					SIOL-NIOL
1983-84							
16 Jan	8	30					19 mi.-CC
1 Feb	19	70	8	30			SIOL
1984-85							
23 Nov	27	100					NIOL
25 Dec	27	100					SIOL
26 Jan			17	63	10	37	TM; SIOL; NT
27 Feb							CC

Pool: Starved Rock **River: Illinois** **Pool length: 13.2 miles**

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
1972-73							
13 Dec	13.2	100					IOL
23 Feb	9.2	70	4	30			SIOL
13 Mar							CC
30 Mar	5.2	39					low. 8 mi.-NOI, hazy; SIOL
1973-74							
31 Jan	13.2	100					SIOL-NIOL; flooding
26 Mar	13.2	100					SIOL-NIOL
1974-75							
14 Nov							up. 6.2 mi.-CC, low. 7 mi.-NOI
15 Nov	13.2	100					NIOL
2 Dec	3.2	24					low. 10 mi.-NOI; SIOL-NIOL
3 Dec	13.2	100					SIOL-NIOL
7 Jan	2	15					low. 11.2 mi.-NOI, SIOL, hazy
12 Feb							CC
13 Feb	13.2	100					PC; SIOL
2 Mar	5	38					low. 8.2 mi.-NOI; SIOL
3 Mar	13.2	100					SIOL
20 Mar	7	53					low 6.2 mi.-NOI; SIOL-NIOL
21 Mar							CC
30 Mar	13.2	100					SIOL-NIOL; PC-hazy
1975-76							
28 Nov	6	45					mid. 7.2 mi.-CC; NIOL
3 Jan	13.2	100					SIOL
12 Jan	1.2	9	12	91			hazy
21 Jan	6.2	47	7	53			SIOL
30 Jan	13.2	100					PC; SIOL-NIOL
7 Feb	1.2	9					low. 12 mi.-NOI; SIOL-NIOL
8 Feb	13.2	100					SIOL-NIOL
26 Feb	13.2	100					NIOL
6 Mar	13.2	100					NIOL
14 Mar	2	15					low. 11.2 mi.-NOI
15 Mar							CC
24 Mar							CC
1976-77							
12 Nov	1	8					low. 12.2 mi.-NOI; NIOL
13 Nov	13.2	100					NIOL
1 Dec	13.2	100					SIOL
19 Dec	13.2	100					SIOL; PC
6 Jan							CC
10 Feb	1	8					low. 12.2 mi.-NOI
11 Feb	9.2	70	2	15	2	15	IOL; NT
16 Feb	4	30					low. 9.2 mi.-NOI; IOL
17 Feb							CC
28 Feb	2	15					low. 11.2 mi.-NOI; IOL
1 Mar	13.2	100					SIOL-IOL
19 Mar							CC
1977-78							
26 Nov	13.2	100					NIOL-SIOL
6 Feb	8	61			5.2	39	IOL; NT
24 Feb	5	38					up. 8.2 mi.-CC; SIOL
23 Mar	13.2	100					SIOL
1978-79							
30 Nov	7.2	55					low. 6 mi.-CC; NIOL
9 Dec	11.2	85	2	15			SIOL
18 Dec							CC
27 Dec	9.2	70	4	30			SIOL
5 Jan					4	30	PC; up. 9.2 mi.-CC; NT
14 Jan					13.2	100	IOL; NT
1 Feb	4	30	4.2	32	5	38	IOL; NT
19 Feb	5.2	39	1* 3	8* 23	4	30	IOL; NT

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
1979-80							
13 Dec	13.2	100					NIOL
31 Dec	7.2	55					up. 6 mi.-CC; NIOL; PC-hazy
1980-81							
19 Nov	13.2	100					RBV; NIOL
25 Dec	9	68					RBV; low. 4.2 mi.-NOI; SIOL-IOL
3 Jan	10	76	3.2	24			SIOL
30 Jan							RBV; CC
8 Feb	5.7	43	7.5	57			PC; SIOL
26 Feb							CC
7 Mar	13.2	100					RBV; NIOL
1981-82							
14 Nov	10.2	77					RBV; NIOL; up. 3 mi.-CC
11 Dec	13.2	100					NIOL; PC-CC
20 Dec			4	30			RBV; IOL
29 Dec			9	68			IOL
16 Jan			4*	30*	9.2	70	IOL; NT; hazy-PC
1982-83							
4 Jan	8.2	62					TM; up. 5 mi.-NOI; NIOL
13 Jan	13.2	100					NIOL
2 Mar	13.2	100					SIOL-NIOL
1983-84							
22 Dec					2.2	17	IOL; up. 11 mi.-NOI; NT
7 Jan							CC
16 Jan					7	53	IOL; PC; NT. up. 6.2 mi.-CC
1 Feb	12.2	92	1*	8*			IOL
8 Feb	2.4	18					up. 10.8 mi.-NOI; IOL
1984-85							
23 Nov	13.2	100					NIOL
16 Dec							TM; CC
25 Dec	13.2	100					NIOL
26 Jan					13.2	100	TM; IOL; NT
2 Feb					5	38	IOL; NT; PC; up. 8.2 mi.-NOI
27 Feb							CC
6 Mar							CC

Pool: Peoria **River: Illinois** **Pool length: 73.5 miles**

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
1972-73							
26 Nov							CC
13 Dec	52.5	71	8 13*	11 18*			IOL
14 Dec	33	45	19 8*	26 11*			up. 13.5 mi.-NOI; IOL
1 Jan			60*	82*			up. 13.5 mi.-NOI; IOL
5 Feb							CC
6 Feb							CC
23 Feb	73.5	100					SIOL-IOL
24 Feb	22	30					up. 51.5 mi -NOI; SIOL
13 Mar							CC
1973-74							
9 Dec	56	76					up. 17.5 mi.-NOI; NIOL-SIOL
14 Jan							up. 16.5 mi.-NOI; CC
31 Jan	73.5	100					SIOL-NIOL; flooding
1 Feb							CC
19 Feb	25	34					up. 18.5 mi.-NOI; low 27 mi.-CC; NIOL
9 Mar							CC
26 Mar	73.5	100					NIOL; flooding
27 Mar	19	26					up. 54.5 mi.-NOI; NIOL

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
1974-75							
15 Nov	48	65					NIOL; low. 25.5 mi.-NOI
3 Dec	73.5	100					SIOL-NIOL
4 Dec							CC
22 Dec							CC
13 Feb							CC
3 Mar	73.5	100					SIOL-NIOL; high water
13 Mar	59	80					up. 14.5 mi.-NOI; NIOL-SIOL; low. 7 mi.-hazy
21 Mar							CC
30 Mar	32	44					low. 41.5 mi.-NOI; NIOL; high water
31 Mar	63	86					up. 10.5 mi.-NOI; NIOL
1975-76							
28 Nov	63.5	86					mid. 10 mi.-CC; SIOL-NIOL
16 Dec	26	36					up. 32.5 mi.-NOI; mid. 15 mi.-CC; NIOL
3 Jan	73.5	100					SIOL; low. 20 mi.-PC
4 Jan	14	19	20* 13	27* 18			up. 18.5 mi. and mid. 8 mi.-NOI; SIOL
12 Jan							PC-CC; IOL
21 Jan							low. 27.5 mi.-NOI; CC
22 Jan			6	8			up. 67.5 mi.-NOI; IOL
30 Jan	20	27					low. 23.5 mi.-NOI; mid. 30 mi.-CC; IOL
31 Jan	9	12	32* 2	44* 3			up. 18.5 mi. and mid. 12 mi.-NOI; IOL
8 Feb	50.5	68	21* 2	29* 3			IOL
9 Feb	6	8	14.5*	20*			up. 19 mi., mid. 25 mi. and low. 9 mi.-NOI; IOL
26 Feb	73.5	100					NIOL-SIOL
6 Mar	73.5	100					NIOL; high water
7 Mar	54	73					up. 19.5 mi.-NOI; NIOL; high water
15 Mar							PC-CC
24 Mar							PC-CC
25 Mar	10	14					up. and mid. 63.5 mi.-NOI; PC; NIOL
1976-77							
13 Nov	73.5	100					NIOL
14 Nov	17	23					up. 56.5 mi.-NOI; PC; NIOL
1 Dec	59.5	81	11* 3	15* 4			IOL; PC-hazy; NT
2 Dec			7	10			IOL; up. 54 mi. and low. 12.5 mi.-NOI
19 Dec	13	18					low. 60.5 mi-CC; IOL
20 Dec							CC
6 Jan			4	5	26.5	36	up. 43 mi.-CC; IOL; PC; NT
7 Jan			12	16	32	44	up. 19 and mid. 10.5 mi. NOI; IOL; NT
25 Jan					9	12	up. & low. 64.5 mi.-NOI & CC; NT; IOL
11 Feb	11	15			62.5	85	IOL; NT
12 Feb							CC
17 Feb	27	37	5	7	33	45	IOL; up. 8.5 mi.-CC; PC; NT
1 Mar	73.5	100					SIOL
2 Mar							CC
19 Mar							CC
1977-78							
26 Nov	68.5	93	5	7			SIOL
15 Dec							CC
2 Jan	1	1	35 5* 12	48* 16			up. 16 mi. & mid. 9 mi.-NOI; IOL; NT
20 Jan	1	1	32* 7	44* 10			PC; up. 19 mi. & mid.-8 mi.-NOI; IOL; mid. 6.5-CC; NT
6 Feb	3	4	4	5	66.5	90	IOL; NT
7 Feb			7	10	58	79	up. 8.5 mi.-NOI; IOL; NT
24 Feb	32 5	44	6	8	35	48	IOL; up. 11 mi.-PC; NT
25 Feb							CC
23 Mar	53	72					NIOL-SIOL; RBV; low. 20.5 mi.-CC
1978-79							
30 Nov	18.5	25					up. 55 mi.-CC; NIOL
1 Dec							CC
4 Dec	38 5	52	21* 10	29* 14	4	5	IOL; NT
[illegible] Dec	13	18	21* 28 5	29* 39	4	5	up. [illegible] mi.-NOI; IOL; NT

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
18 Dec							CC
27 Dec	51.5	70	5* 17	7* 23			IOL; NT
5 Jan			43.5*	59*			PC; low. 30 mi.-CC
6 Jan							CC
14 Jan			7	10	67.5	92	IOL; NT
24 Jan			4	5	25	34	PC-CC; up. 44.5 mi.-CC; IOL
1 Feb			3* 6	4* 8	64.5	88	IOL; NT
2 Feb	7	10	3	4	35	48	up. 11 mi.-CC; low. 17.5 mi.-NOI; NT; IOL; PC
19 Feb			2.5* 10	3* 14	61	83	NT; IOL
20 Feb							CC
10 Mar	56.5	77					Flooding over ice locally. IOL. up. 17 mi.-NOI, PC
1979-80							
26 Nov							CC
13 Dec	48	65					low. 25.5 mi.-NOI; NIOL
14 Dec	61	83					up. 12.5 mi.-NOI; NIOL; low 23 mi.-RBV
31 Dec							CC
1980-81							
19 Nov	35	48					RBV; NIOL; low. 38.5 mi.-NOI
28 Nov	26	35					up. 47.5 mi.-NOI; PC; NIOL-SIOL
29 Nov	55	75					up. 18.5 mi.-CC; PC; SIOL
17 Dec	14.5	20					up. 59 mi.-NOI; PC; NIOL
3 Jan	31.5	43	10* 31	14* 42			IOL; PC; NT
4 Jan			34* 28	46* 38			up. 11.5 mi.-NOI; IOL
22 Jan	14.5	20	37* 9	50* 12			IOL; up. 13 mi.- NOI; low 28 mi.-PC
30 Jan	46.5	63	13*	18*			RBV; up. 8 mi.-CC; IOL; PC; low. 6 mi.-CC; NT
8 Feb	3	4	66.5* 4	90* 5			IOL; PC; NT
9 Feb			26* 15.5	35* 21	22	30	IOL; NT; up. 10 mi.-NOI
26 Feb	48.5	66					up. 25 mi.-CC; SIOL
7 Mar	73.5	100					RBV; NIOL-SIOL
8 Mar	60.5	82					RBV; up. 13 mi.-NOI; NIOL
17 Mar	18.5	25					up. 46 mi.-CC; NIOL; low. 9 mi.-NOI
1981-82							
14 Nov	30.5	41					RBV; low. 43 mi.-CC; NIOL; PC-hazy
24 Nov	52.5	71					low. 10 mi. and up. 11 mi-NOI; NIOL; PC
11 Dec	73.5	100					PC-CC; NIOL-SIOL
12 Dec	52.5	71					up. 12 mi.-NOI; hazy-PC; NIOL; low. 9 mi.-NOI
20 Dec			37 13.5*	50 18*			RBV; SIOL-IOL; low. 23 mi.-NOI; NT
29 Dec	24	33	4* 24	5* 33	21.5	29	IOL; NT
16 Jan			4*	5*	69.5	95	IOL; NT; PC
26 Jan			5	7			RBV; IOL; up. 68.5 mi.-NOI
4 Feb			5* 7	7* 10	53.5	73	up. 8 mi.-NOI; IOL; NT
3 Mar	65.5	89			8	11	RBV; flooding; SIOL; NT
1982-83							
4 Jan	73.5	100					TN; NIOL
13 Jan	73.5	100					NIOL
21 Feb	25.5	35					up. 48 mi.-NOI; hazy; NIOL
2 Mar	73.5	100					SIOL-NIOL
25 Mar	25.5	35					up. 48 mi.-NOI; NIOL
1983-84							
22 Dec	3.5	5	9* 22	12* 30	39	53	IOL; NT
7 Jan			3	4	39.5	54	IOL; NT; up. & low. 31 mi.-CC
16 Jan			2* 8.5	3* 12	22	30	low. 41 mi.-CC; IOL; NT; PC
1 Feb	7	10	2* 10	3* 14	54.5	74	IOL; NT
8 Feb	26.5	36	37* 10	50* 14			IOL; NT; PC-hazy
11 Mar	73	99					up. 5 mi.-NOI; IOL-SIOL
23 Mar	59.5	81					TM; up. 14 mi.-NOI; high water; NIOL
1984-85							
23 Nov	73.5	100					TM; NIOL
16 Dec	73.5	100					TM; SIOL
25 Dec	47.5	65	26	35			SIOL-IOL

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
26 Jan	2	3	3* 4	4* 5	64.5	88	TM; IOL; NT
2 Feb			7* 3	10* 4	63.5	86	IOL; NT; PC
18 Feb							CC
27 Feb							CC
6 Mar	57.5	78					up. 16 mi.-CC; NIOL; high water

Pool: LaGrange River: Illinois Pool length: 77.5 miles

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
1972-73							
26 Nov							CC
13 Dec	59.5	77	18	23			IOL
14 Dec	5.5	7	59 13*	76 17*			IOL
1 Jan			77.5*	100*			IOL
5 Feb							CC
6 Feb							CC
23 Feb	77.5	100					SIOL-NIOL
24 Feb	77.5	100					SIOL-NIOL
13 Mar							CC
14 Mar	70.5	91					up. 7 mi.-NOI; NIOL
1973-74							
9 Dec	77.5	100					SIOL
14 Jan	57	74	18	23			up. 2.5 m.-CC; IOL
31 Jan	73	94					low. 4.5 mi.-NOI; NIOL; flooding
1 Feb	15	19					up. 62.5-CC; NIOL
19 Feb							CC
9 Mar							PC-CC; NIOL
26 Mar	77.5	100					NIOL; flooding
27 Mar	77.5	100					NIOL; flooding
1974-75							
3 Dec	77.5	100					SIOL-NIOL
4 Dec							73 mi.-PC to CC; up. 4.5 mi.-NOI
22 Dec	72	93					up. 5.5 mi.-NOI; PC; NIOL-SIOL
3 Mar	77.5	100					SIOL-NIOL; high water
4 Mar	70	90					up. 7.5 mi.-NOI; SIOL-NIOL; high water
13 Mar							CC
21 Mar							CC
22 Mar	68	88					up. 9.5-mi.-NOI; NIOL
31 Mar	77.5	100					NIOL
1975-76							
28 Nov	77.5	100					NIOL
16 Dec	77.5	100					NIOL; high water
3 Jan	77.5	100					SIOL; PC
4 Jan	77.5	100					SIOL
12 Jan							PC-CC; IOL
22 Jan			65.5	85			low. 12 mi.-CC; IOL
31 Jan			77.5	100			IOL
8 Feb	65.5	85	12	15			IOL
26 Feb	10	13					low. 67.5 mi.-CC; NIOL
27 Feb	72	93					up. 5.5 mi.-NOI; NIOL
6 Mar	77.5	100					NIOL; high water
7 Mar	77.5	100					NIOL; high water
15 Mar							PC-CC
16 Mar	70	90					up. 7.5 mi.-NOI; NIOL; PC
24 Mar							PC-CC
25 Mar	57	74					low. 20.5 mi.-CC; PC; NIOL
1976-77							
13 Nov	77.5	100					NIOL
14 Nov	77.5	100					NIOL; PC
1 Dec	77.5	100					IOL; PC
19 Dec							CC
20 Dec							CC
6 Jan			20	26			PC; low. 50.5 mi. & up. 7 mi.-CC; IOL
7 Jan	26.5	34	16	21	35	45	IOL; NT

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
25 Jan					10	13	up. & low. 67.5 mi.-CC; IOL; NT
11 Feb	29.5	38			48	62	IOL; NT
12 Feb							CC
17 Feb	52	67			8	10	PC-CC; IOL; low. 17.5 mi.-CC; NT
18 Feb	16	21			23	30	up. 7.5 mi.-NOI; IOL; mid. 21-CC; NT
1 Mar	77.5	100					SIOL
20 Mar							CC
1977-78							
26 Nov	77.5	100					SIOL, PC
15 Dec	53	68					up. 24.5 mi.-CC; SIOL-IOL
2 Jan			77.5	100			IOL
20 Jan			63.5	82	14	18	PC; IOL; NT
6 Feb	18.5	24	13*	17*	28	36	low. 18 mi.-NOI; IOL; NT
7 Feb	5	6	14* 10	18* 13	48.5	63	low. 40 mi.-PC to hazy; IOL; NT
24 Feb	50	65			15	19	low. 12.5 mi.-NOI; IOL; NT
25 Feb			3*	4*	23	30	up. 51.5 mi.-CC; PC; IOL; NT
23 Mar							CC; RBV
1978-79							
30 Nov	58.5	75					low. 19 mi.-NOI; NIOL
1 Dec	34.5	45					up. 43 mi.-CC; NIOL
9 Dec	57	74					low. 20.5 mi.-NOI; IOL
10 Dec	15	19	15* 47.5	19* 61			IOL; NT
27 Dec			58.5	75			low. 19 mi.-NOI; IOL
6 Jan					9	12	RBV; up. 68.5 mi.-CC
14 Jan					59.5	77	low 18 mi.-NOI; NT
24 Jan			9	12	68.5	88	PC; IOL; NT
1 Feb			9* 4	12* 5	42.5	55	low. 22 mi.-NOI; IOL; NT
19 Feb	5.5	7	12	15	43	55	low. 17 mi.-NOI; IOL; NT
10 Mar	23.5	30	35* 19	45* 25			flooding; IOL
1979-80							
14 Dec	77.5	100					RBV; NIOL
1980-81							
28 Nov	73	94					low. 4.5 mi.-NOI; PC; SIOL
29 Nov	77.5	100					SIOL-NIOL
17 Dec	77.5	100					PC; SIOL-NIOL
3 Jan			8	10			IOL; low. 7 mi.-NOI
4 Jan			3* 74.5	4* 96			IOL
22 Jan			12* 9	15* 12	13	17	IOL; up. 43.5 mi.-CC
30 Jan	61	79					RBV; IOL; up. 4.5 mi.-CC; low. 12 mi.-NOI
8 Feb			35* 35.5	45* 46			IOL; low. 7 mi.-NOI; NT
9 Feb			20	26			low. 57 mi.-CC; IOL
26 Feb	74.5	96					SIOL; low. 3 mi.-NOI
7 Mar	68.5	88					RBV; low. 9 mi.-NOI; SIOL-NIOL
8 Mar	77.5	100					RBV; NIOL-SIOL
1981-82							
11 Dec	69.5	90					NIOL; low. 8 mi.-CC; hazy
29 Dec	52.5	68	25	32			low 20 mi.-NOI; IOL
16 Jan			11* 4	14* 5	40.5	52	low. 22 mi.-NOI; IOL; NT
26 Jan			22* 8	30* 10	46.5	60	RBV; IOL; NT
4 Feb			17.5	23	60	77	IOL; NT; PC
3 Mar	45.5	59					RBV; low. 32 mi.-CC; flooding; SIOL
1982-83							
4 Jan	77.5	100					TM; NIOL; high water
13 Jan	17.5	23					NIOL; low. 60 mi.-NOI
21 Feb	77.5	100					PC-CC; NIOL
2 Mar	13.5	17					low. 64 mi.-NOI; NIOL; PC
25 Mar	77.5	100					NIOL
1983-84							
22 Dec			12.5* 65	16* 84			IOL; NT
7 Jan	17	22	42* 18.5	54* 24			IOL; NT; PC
1 Feb	15.5	20	2	3			low. 60 mi.-NOI; IOL
8 Feb	77.5	100					IOL; hazy-PC
11 Mar	77.5	100					SIOL
23 Mar	77.5	100					TM; NIOL; high water

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
1984-85							
23 Nov	12	15					TM; low. 65.5 mi.-NOI; NIOL
16 Dec	77.5	100					TM; SIOL-NIOL
25 Dec	16	21					low. 61.5 mi.-NOI; SIOL-IOL
26 Jan	1	1	15	19			TM; low 61.5 mi.-NOI; IOL; NT
2 Feb			36* 26	46* 34	15.5	20	IOL; NT; PC
18 Feb			40*	52*			up. 37.5 mi.-CC; IOL; NT; PC
6 Mar	77.5	100					NIOL; PC; high water

Pool: Illinois–Mississippi Confluence River: Illinois Pool length: 80.1 miles

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
1972-73							
26 Nov							CC
13 Dec			68.1	85			mile 70 to 58-NOI; PC; IOL
14 Dec			25.1	31			low. 55 mi.-CC; PC; IOL
31 Dec							CC
1 Jan			80.1	100			SIOL
19 Jan							CC
5 Feb							CC
23 Feb	80.1	100					NIOL
24 Feb	80.1	100					NIOL
13 Mar							CC
14 Mar	80.1	100					NIOL
31 Mar	70	87					up. 10.1-mi.-NOI; PC
1973-74							
21 Nov							CC
9 Dec	80.1	100					SIOL-NIOL
14 Jan			36* 44.1	45* 55			IOL
31 Jan	55	69					up. 25.1 mi.-NOI; NIOL
1 Feb	80.1	100					NIOL
19 Feb							CC
8 Mar							CC
9 Mar	30	37					50.1-CC; NIOL
26 Mar	80.1	100					NIOL; flooding
27 Mar	37	46					low. 43.1-NOI; NIOL; flooding
1974-75							
3 Dec	80.1	100					NIOL
4 Dec							CC
22 Dec	40	50					low. 40.1-NOI; PC; NIOL-SIOL
9 Jan							CC
3 Mar	80.1	100					NIOL-SIOL; high water
4 Mar	80.1	100					NIOL-SIOL; high water; PC-hazy
13 Mar							CC
21 Mar							PC-CC
22 Mar	80.1	100					NIOL
30 Mar							CC
31 Mar	80.1	100					NIOL
1975-76							
20 Nov							up. 40.1 mi.-NOI; CC
28 Nov	80.1	100					SIOL-NIOL
16 Dec	80.1	100					NIOL
3 Jan	80.1	100					PC; NIOL
4 Jan	80.1	100					NIOL
12 Jan							PC-CC; low 45.1 mi-CC; SIOL-NIOL
21 Jan			23*	29*			up. 57.1 mi.-CC
22 Jan			69* 5	86* 6			up. 6.1 mi.-CC; SIOL-IOL
30 Jan							CC
31 Jan	24	30					IOL; low 56.1 mi.-CC
8 Feb	30.1	38	32* 17	40* 21			IOL
9 Feb			41*	51*			up. 39.1 mi.-NOI; IOL
26 Feb	41	51					up. 39.1 mi.-CC; NIOL
27 Feb	80.1	100					NIOL; high water
6 Mar	80.1	100					NIOL
7 Mar	80.1	100					NIOL
15 Mar							CC
16 Mar	80.1	100					PC; NIOL
24 Mar							CC
25 Mar	10	12					up. and low. 70.1 mi.-CC

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
1976-77							
13 Nov	58	72					low. 22.1 mi.-CC; NIOL
14 Nov							PC-hazy; NIOL
1 Dec							CC
19 Dec							CC
20 Dec	20	25					up. 60.1 mi.-CC; NIOL
6 Jan							CC
7 Jan			11	11	69.1	86	IOL; NT
24 Jan							CC
25 Jan							CC
11 Feb			61.1* 10	76* 12	9	11	IOL; NT
12 Feb			20*	25*			up. 20.1 mi.-CC; low. 40 mi. -NOI; NT
17 Feb							CC
18 Feb			54.1* 17	68* 21	9	11	IOL; NT
1 Mar	80.1	100					SIOL
2 Mar							CC
19 Mar							CC
20 Mar							CC
1977-78							
26 Nov	35	44					PC; SIOL-NIOL; low. 45.1 mi.-CC
15 Dec			42* 38.1	52* 48			SIOL-IOL
2 Jan			80.1*	100*			IOL; NT
20 Jan			4* 9	5* 11	67.1	84	low 22 mi.-PC; IOL; NT
6 Feb					40	50	up. 40.1 mi.-NOI; IOL; NT
7 Feb					80.1	100	PC-hazy; IOL; NT
24 Feb					51	64	up. 29.1 mi.-NOI; IOL; NT
25 Feb			9* 7	11* 9	64.1	80	IOL; NT
1978-79							
30 Nov	40.1	50					up. 40 mi.-NOI; NIOL
1 Dec	80.1	100					NIOL; PC
9 Dec			33.1	41			up. 47 mi.-NOI; IOL
10 Dec	4.1	5	76	95			IOL
18 Dec			28.1	35			up. 52 mi.-NOI; SIOL
27 Dec			35.1	44			up. 45 mi.-NOI; SIOL
6 Jan			27*	34*	18	22	RBV; PC; low. 35.1 mi.-NOI; IOL; NT
14 Jan					35	44	up. 45.1 mi.-NOI; IOL; NT
24 Jan			5	6.2	75.1	94	IOL; NT
1 Feb					32	40	up. 48.1 mi.-NOI; IOL; NT
10 Feb					16.1	20	up. 64 mi.-CC; IOL; NT; PC
19 Feb					40	50	up. 40.1 mi.-NOI; IOL; NT
10 Mar	80.1	100					SIOL; PC; highwater
1979-80							
14 Dec	80.1	100					RBV; NIOL
1980-81							
19 Nov	50.6	63					RBV; up. 29.5 mi.-NOI; NIOL
28 Nov	55.1	69					up. 25 mi.-NOI; NIOL
29 Nov	80.1	100					NIOL
17 Dec	80.1	100					NIOL
3 Jan	38.1	48					low. 17 mi.-CC; up. 25 mi.-NOI, NIOL
4 Jan	55.1	69					NIOL; low. 25 mi.-CC
22 Jan			30* 32	37* 40			IOL; low. 18.1 mi.-CC
30 Jan	54.1	68					RBV; up. 26 mi.-NOI; NIOL
8 Feb			14.1* 41	18* 51			up. 25 mi.-NOI; IOL; NT
9 Feb			38.1* 42	48* 52			up. 15.1 mi.-PC; IOL; NT
18 Feb			5* 4	6* 5			RBV; IOL; up. 71.1 mi.-CC
26 Feb	57	71					up. 23.1 mi.-NOI, NIOL
27 Feb							CC
7 Mar	55	69					RBV; NIOL; up. 25.1 mi.-NOI
8 Mar	80.1	100					RBV; NIOL
1981-82							
11 Dec							CC
20 Dec							RBV; image not useable
29 Dec			5* 25	6* 31			up. 50.1 mi.-NOI; IOL
16 Jan					29	36	up. 51.1 mi.-NOI; IOL; NT
26 Jan			63*	79*	17.1	21	RBV; IOL; NT
4 Feb					80.1	100	IOL; PC-CC; NT
20 Mar	15	19					RBV; up. 65.1 mi.-NOI; NIOL
21 Mar	34	42					NIOL; up 46.1 mi.-NOI; PC

Date	Open Length	Open Percent	Gray Ice Length	Gray Ice Percent	White Ice Length	White Ice Percent	Remarks
1982-83							
4 Jan	80.1	100					TM; NIOL; high water
21 Feb	24.1	30					low. 56 mi.-NOI· PC; NIOL
25 Mar	80.1	100					NIOL
1983-84							
20 Nov							CC
22 Dec			7* 60.1	9* 75	13	16	IOL; NT
7 Jan			60* 9.1	75* 11	11	14	IOL; NT
8 Feb	64.1	80	8* 8	10* 10			IOL; hazy-PC
11 Mar	80.1	100					SIOL-NIOL; PC
23 Mar	80.1	100					TM; NIOL; high water
1984-85							
16 Dec	80.1	100					TM; NIOL
2 Feb			42* 13	[illegible]2* 16	25.1	31	IOL; NT; PC
18 Feb			67* 6	84* 7	7.1	9	IOL; NT
6 Mar	80.1	100					NIOL; high water; PC

APPENDIX D: ICE DISTRIBUTIONS AS OBSERVED ON LANDSAT IMAGES

These maps show ice conditions on the portions of the waterway visible on Landsat images for a given day. No single image or set of images taken on the same day show all of the waterway. Therefore, some of the maps have CC or NOI at the end of the line showing the areal extent of ice on a pool. The CC means the rest of the pool was cloud-covered (e.g., Fig. D1). The NOI means the rest of the pool was not on the image (e.g., Fig. D1). In all figures a dashed line denotes gray ice. When a superscript asterisk appears next to the date of a dashed line (e.g., Fig. D1), the gray ice fills the channel bank to bank; otherwise, the gray ice partially fills the channel. A solid line denotes white ice.

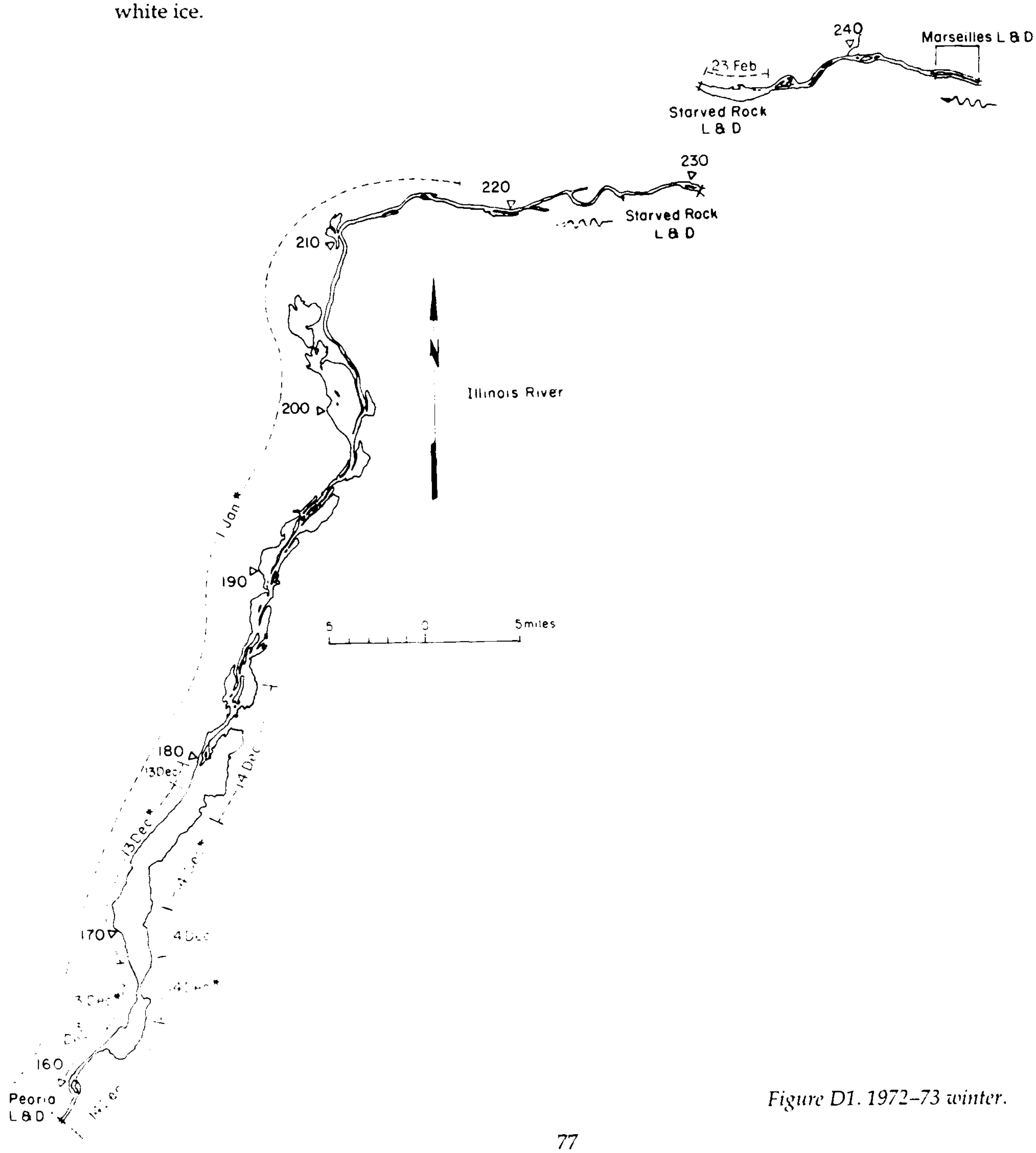


Figure D1. 1972–73 winter.

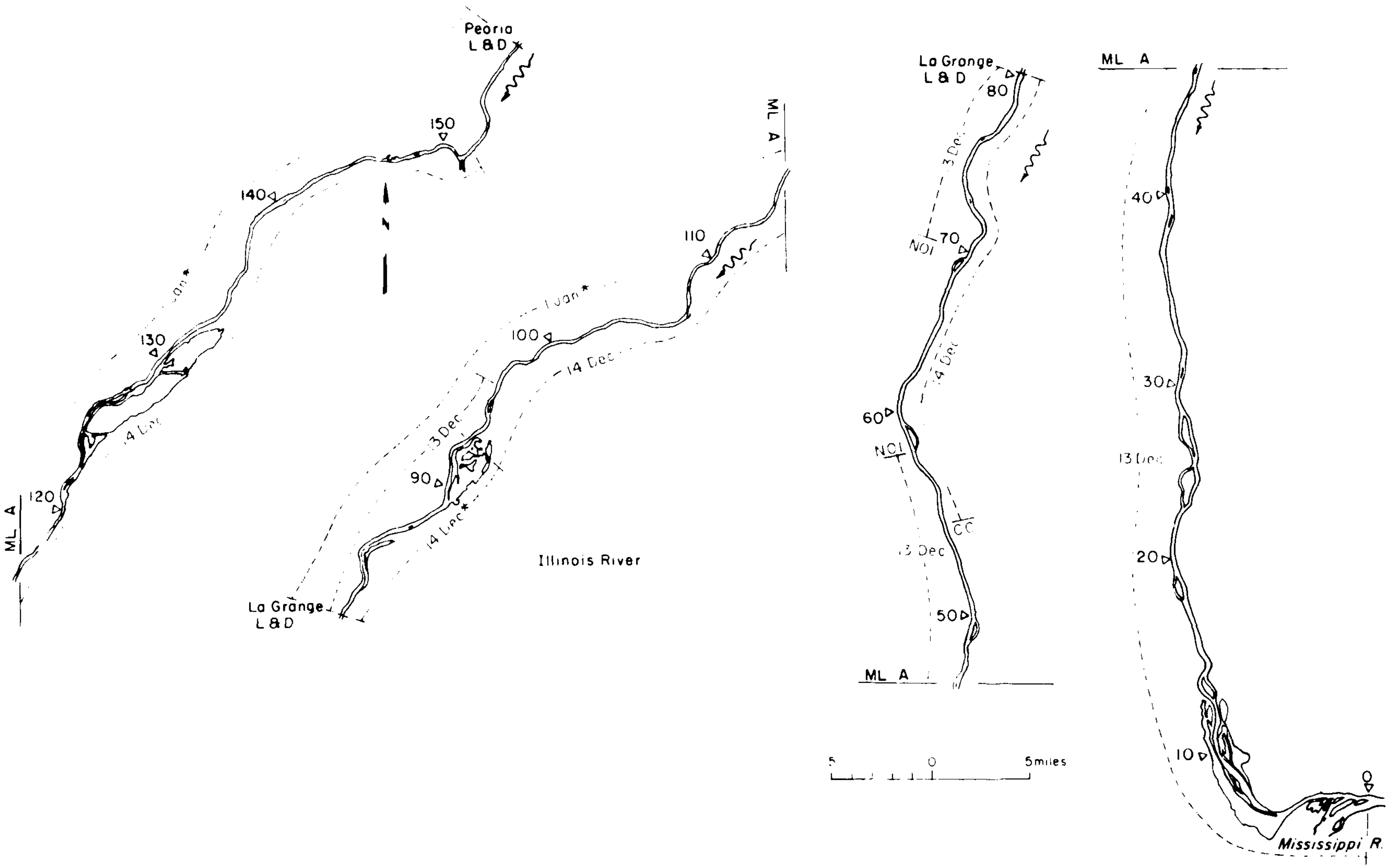


Figure D1 (cont'd). 1972–73 winter.

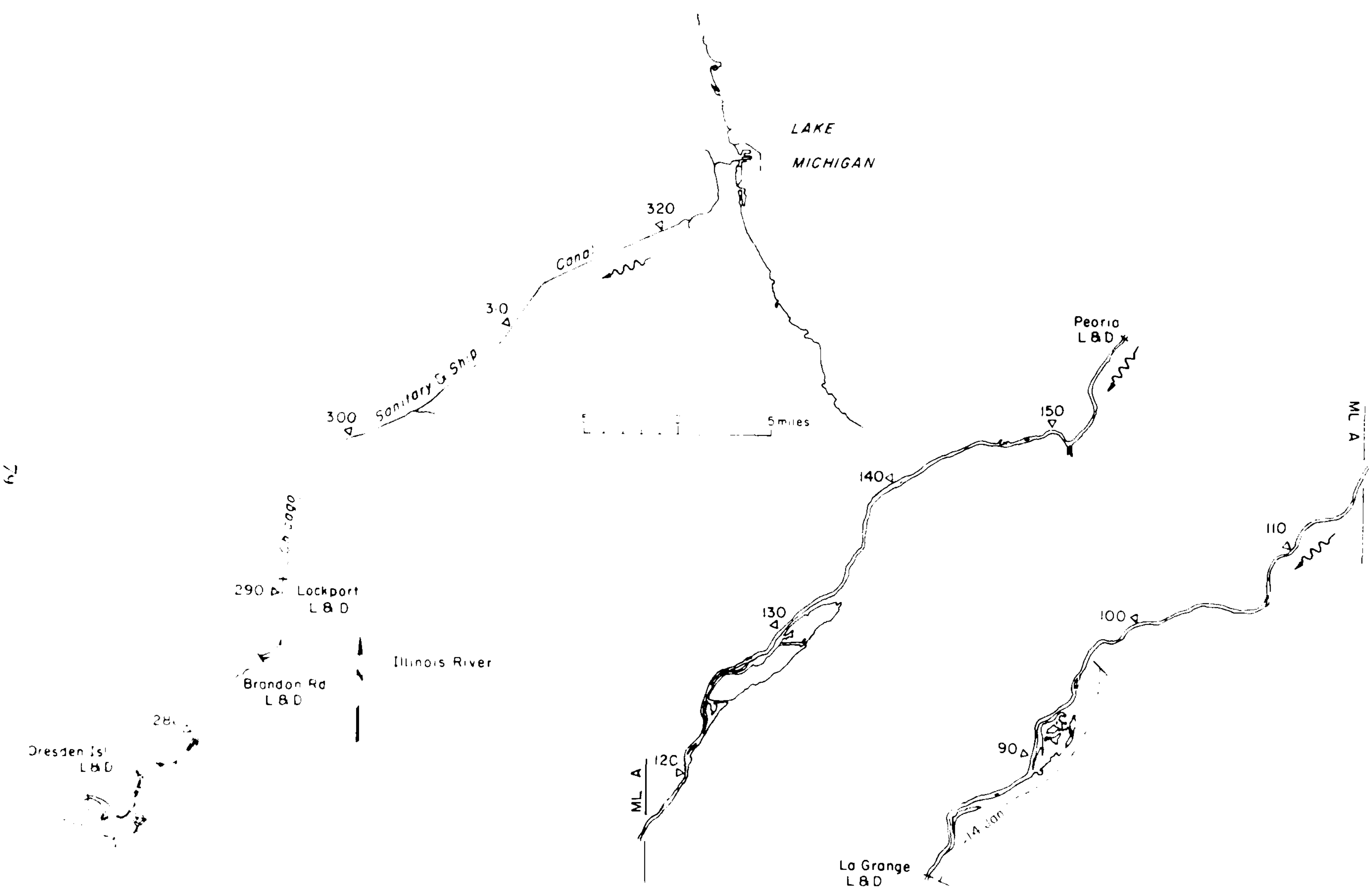


Figure D2. 1973–74 winter.

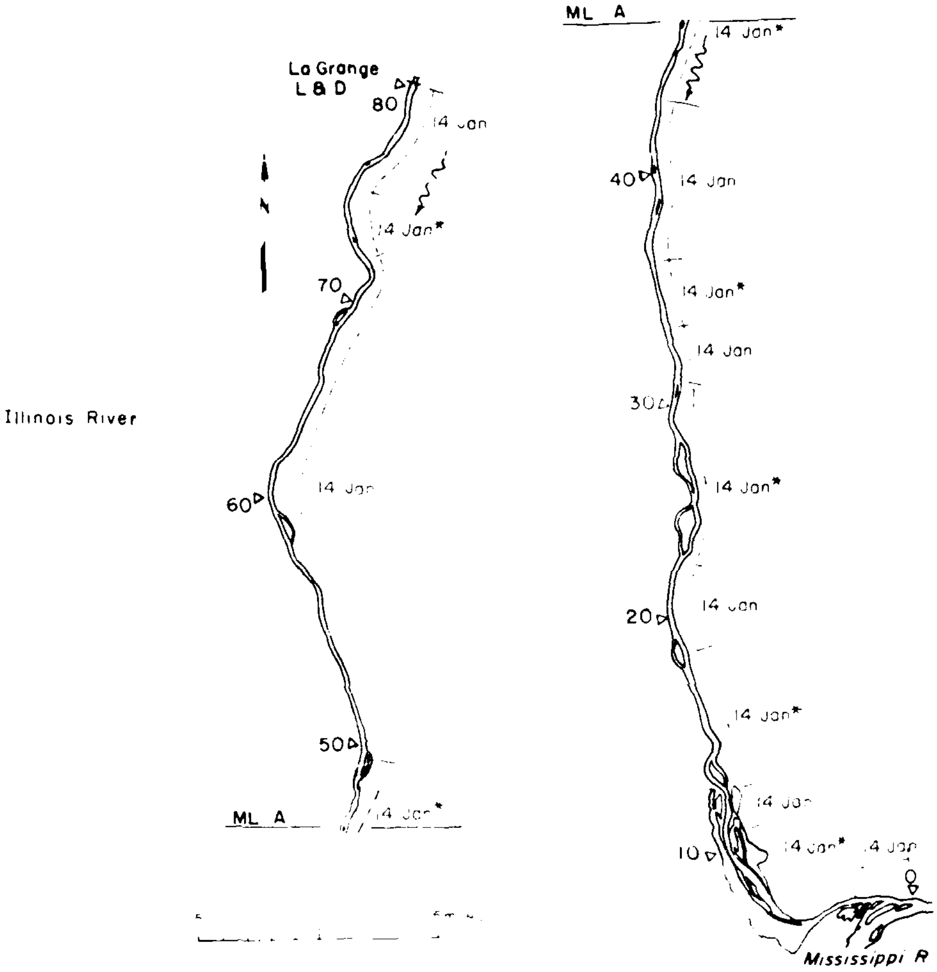


Figure D2 (cont'd). 1973–74 winter.

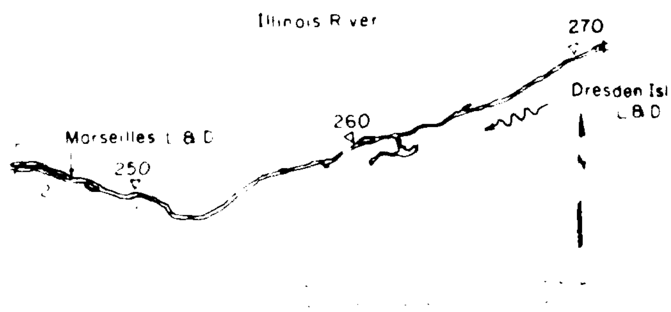
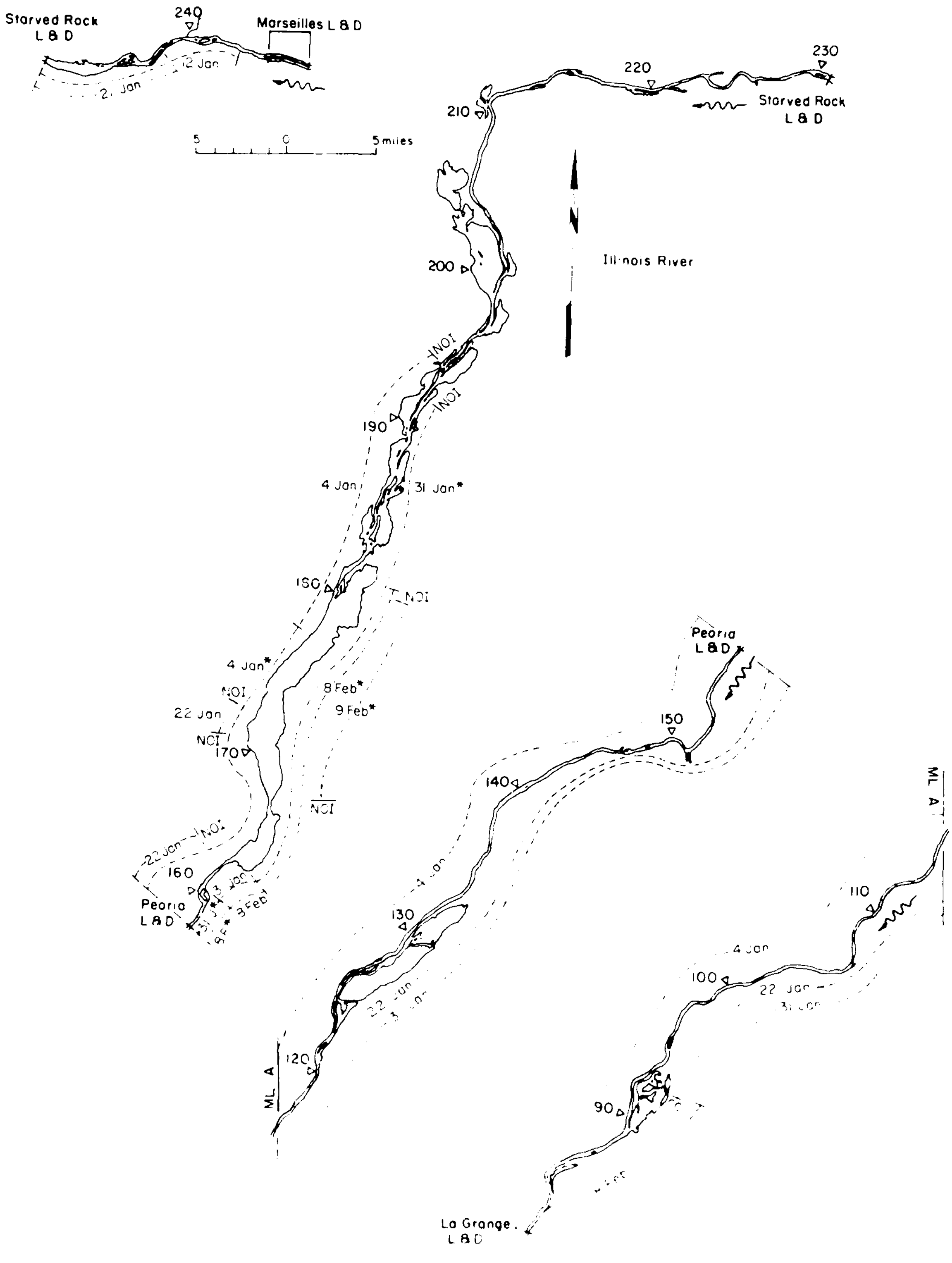


Figure D3. 1975–76 winter



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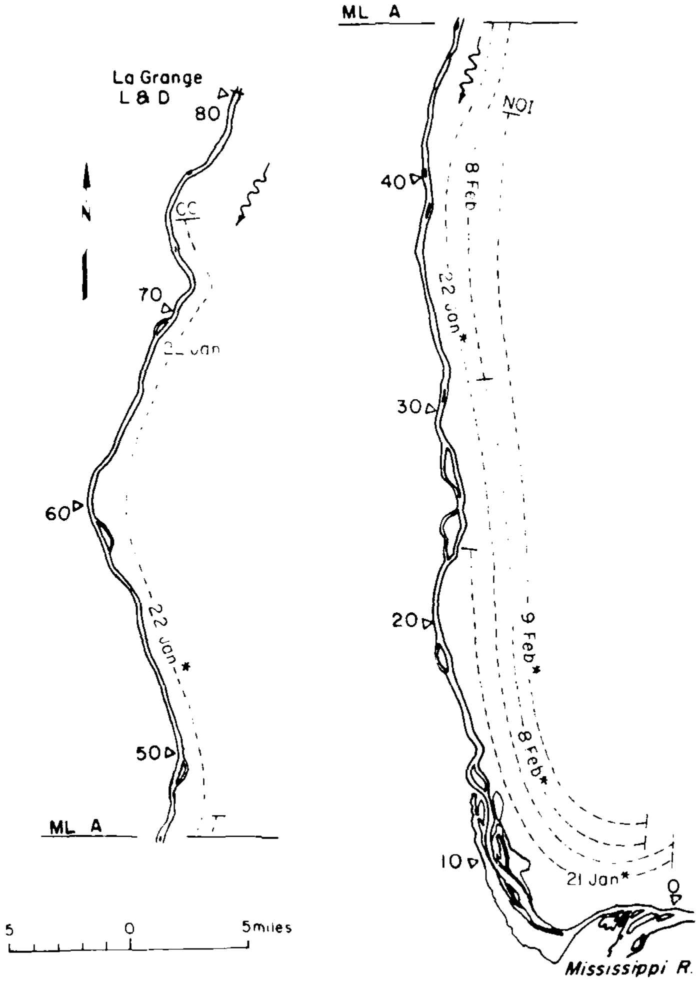


Figure D3 (cont'd). 1975–76 winter.

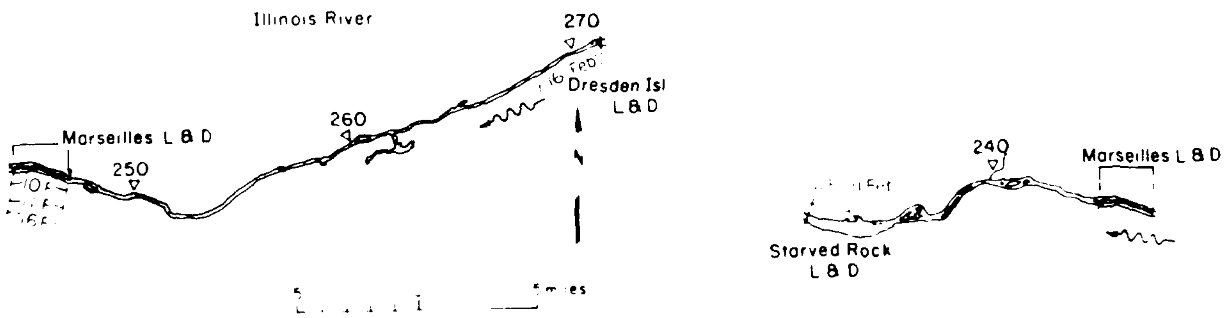


Figure D4. 1976–77 winter.

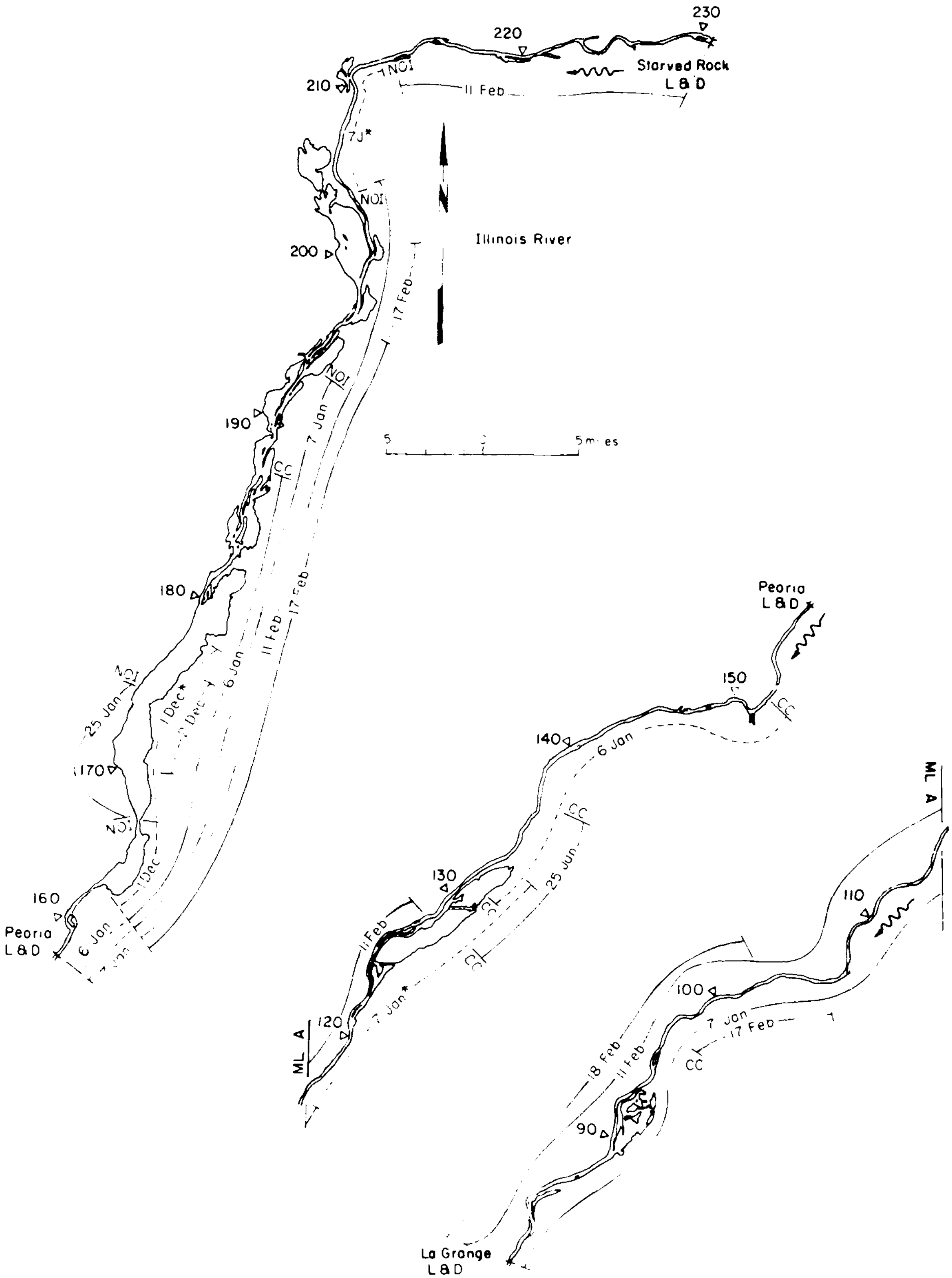


Figure D4 (cont'd).

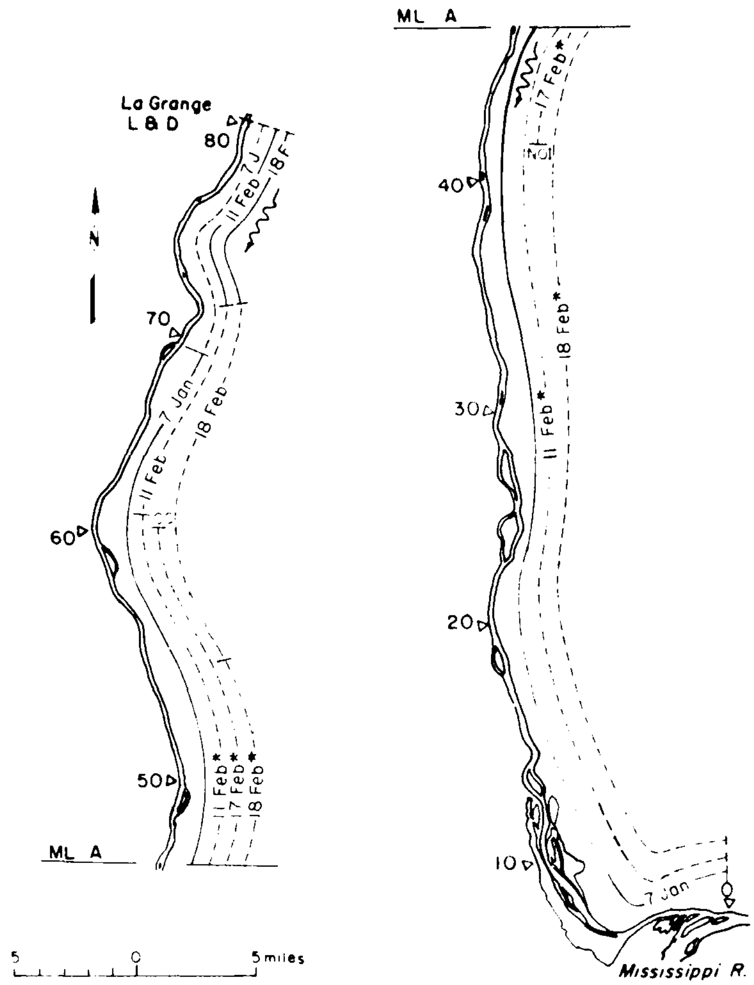


Figure D4 (cont'd). 1976–77 winter.

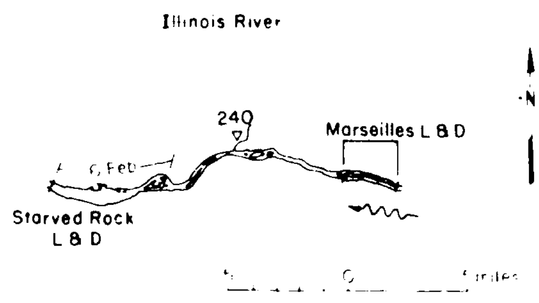


Figure D5. 1977–78 winter.

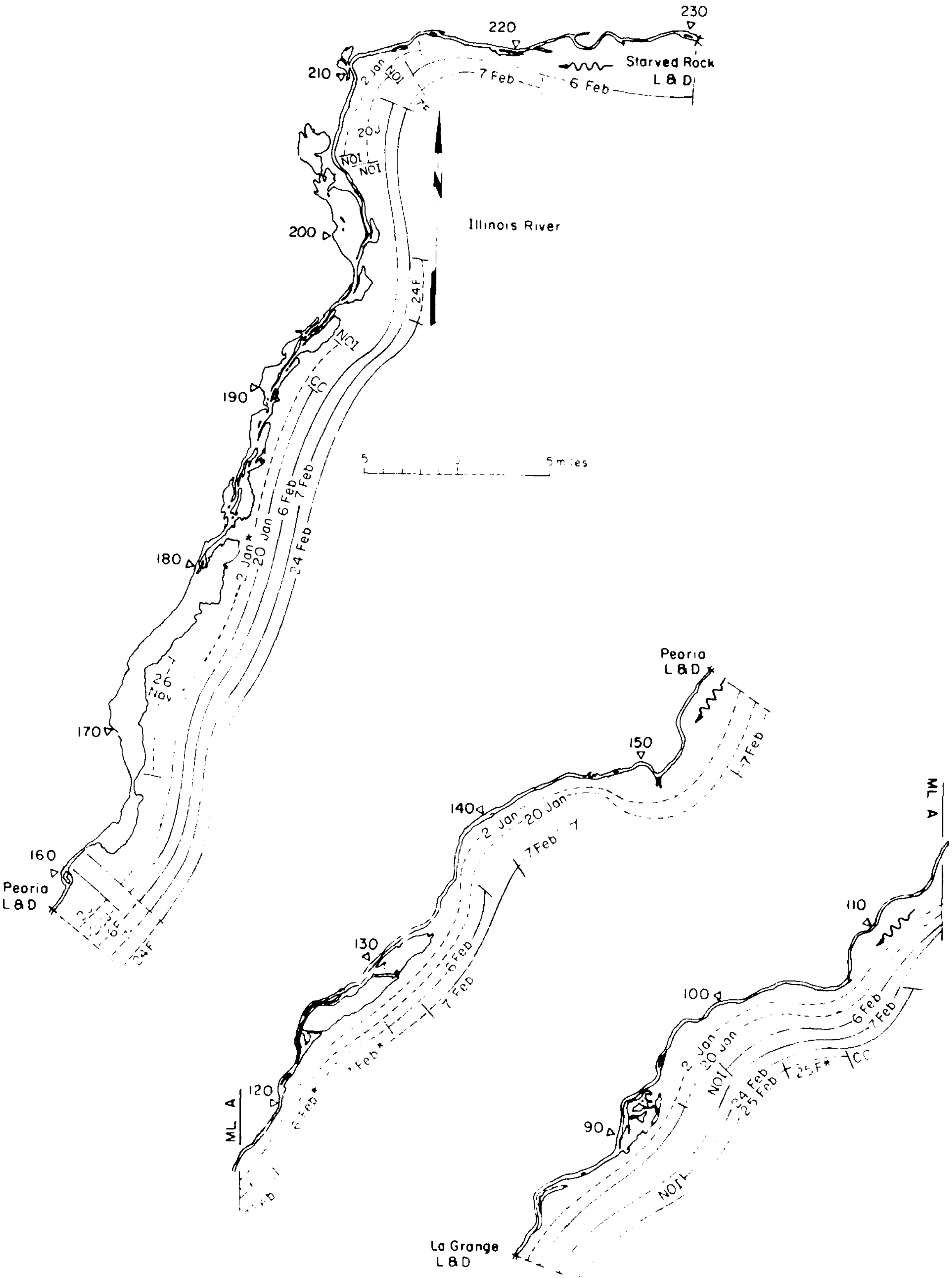


Figure D5 (cont'd).

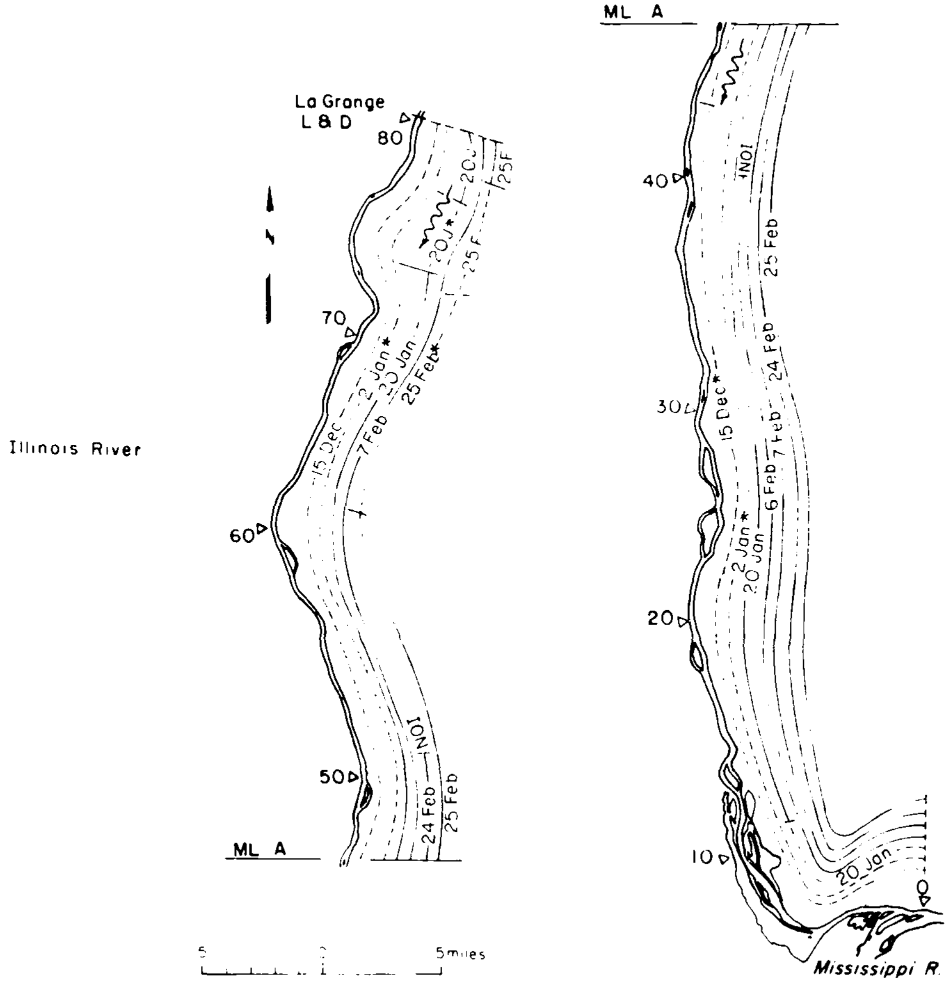


Figure D5 (cont'd). 1977–78 winter.

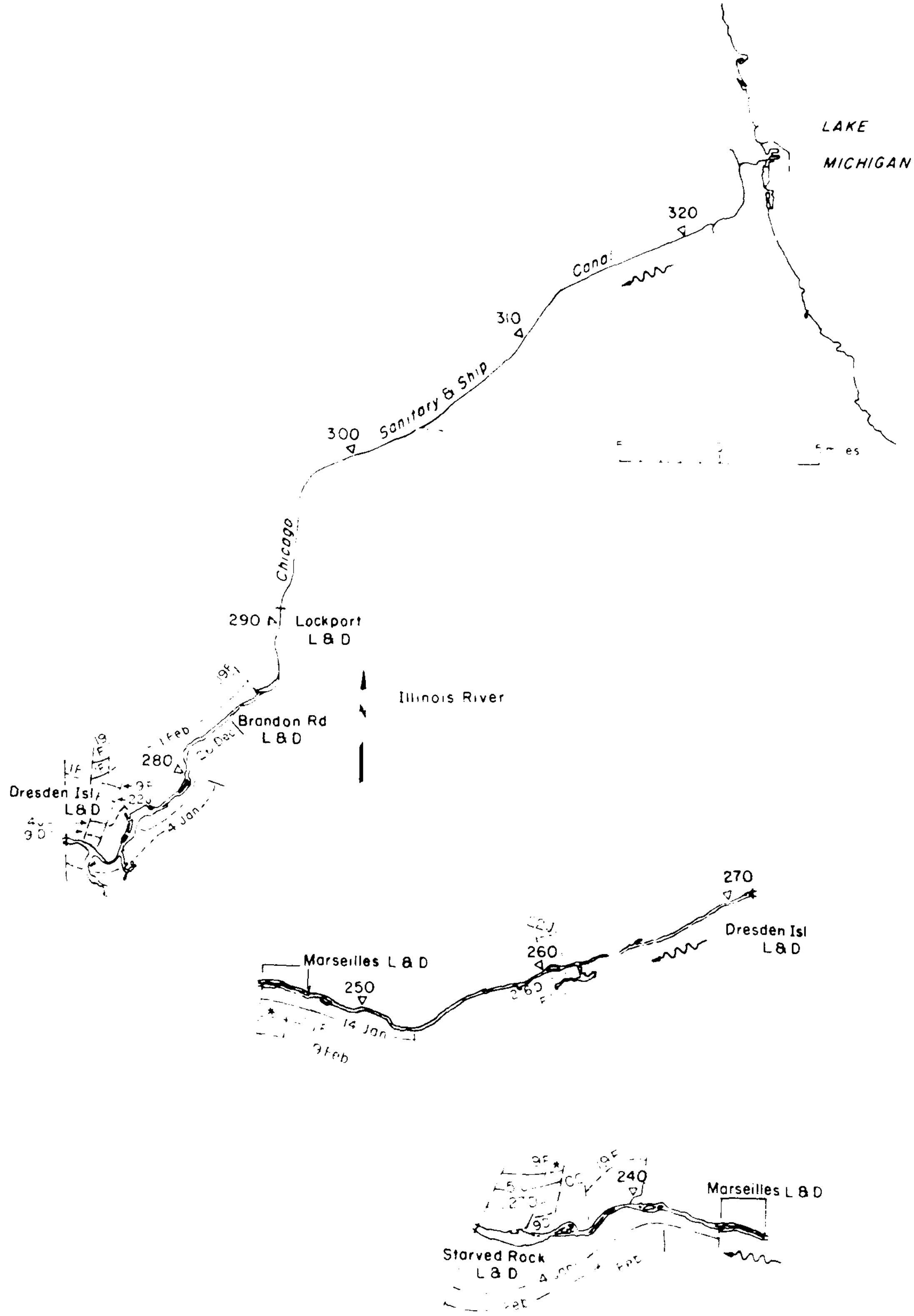


Figure D6. 1978–79 winter.

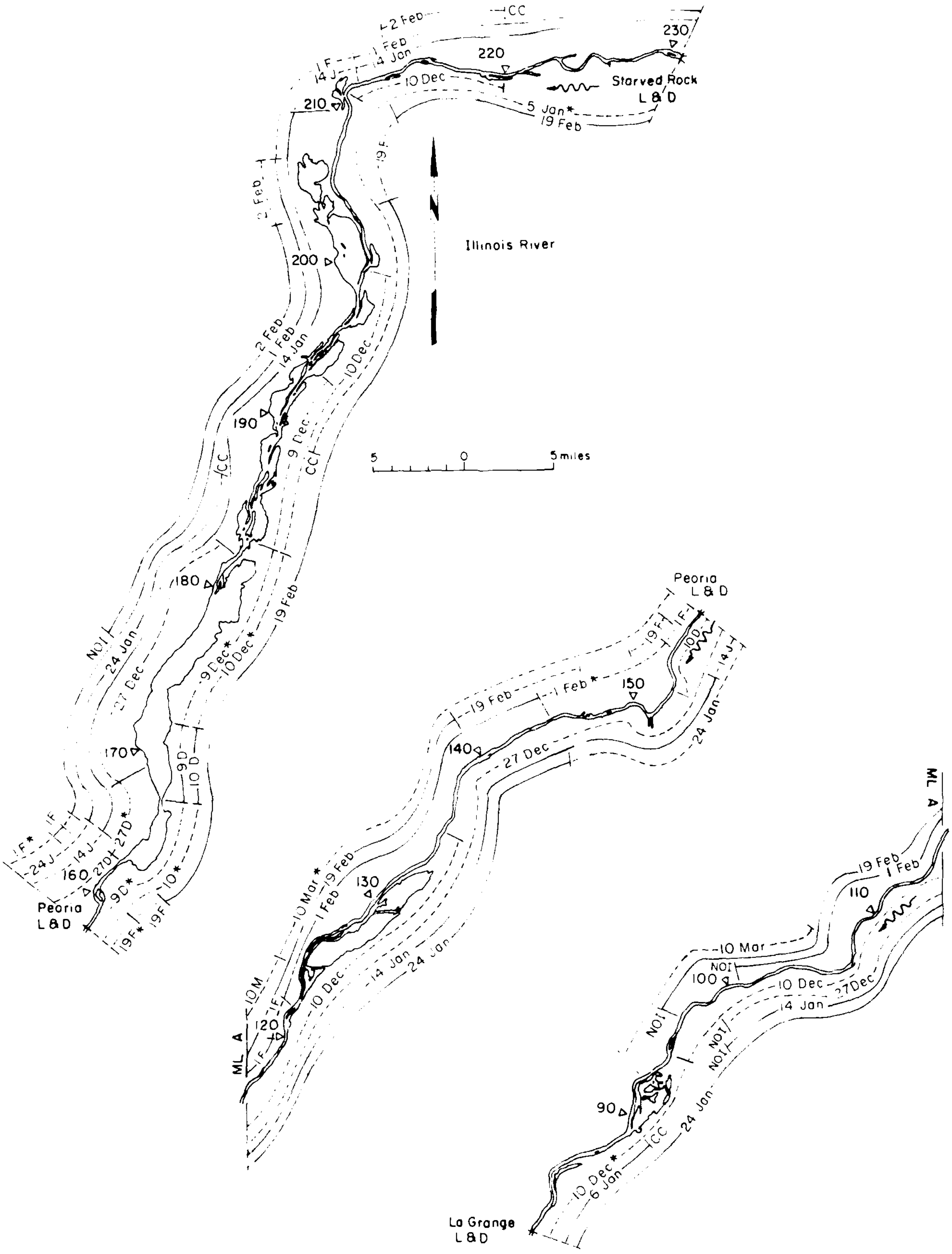


Figure D6 (cont'd). 1978–79 winter.

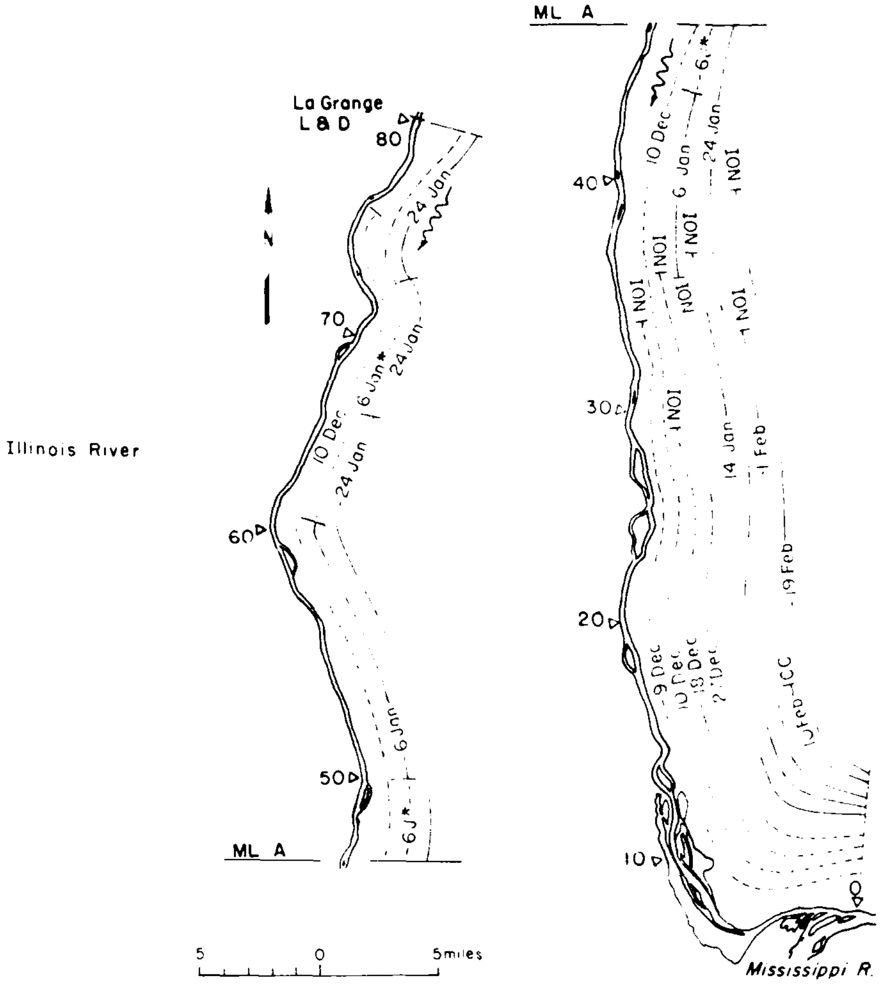


Figure D6 (cont'd).

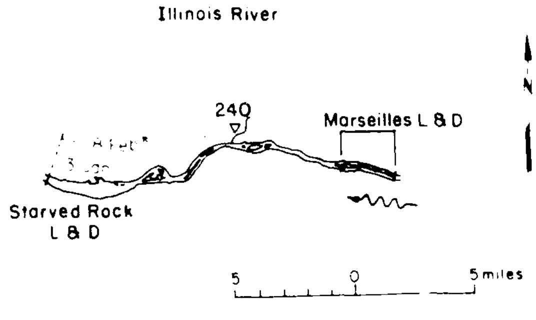


Figure D7. 1980–81 winter.

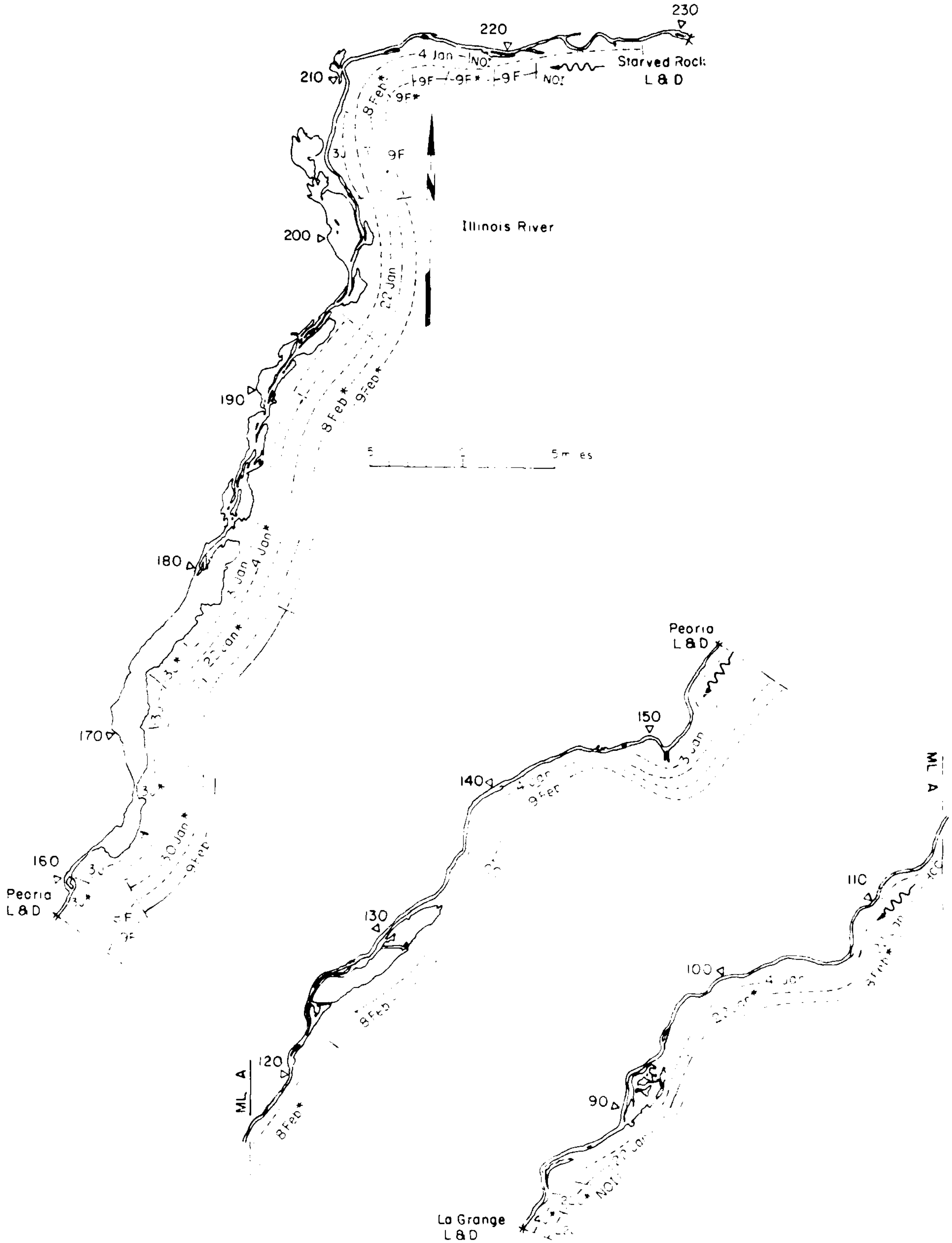


Figure D7 (cont'd). 1980-81 winter.

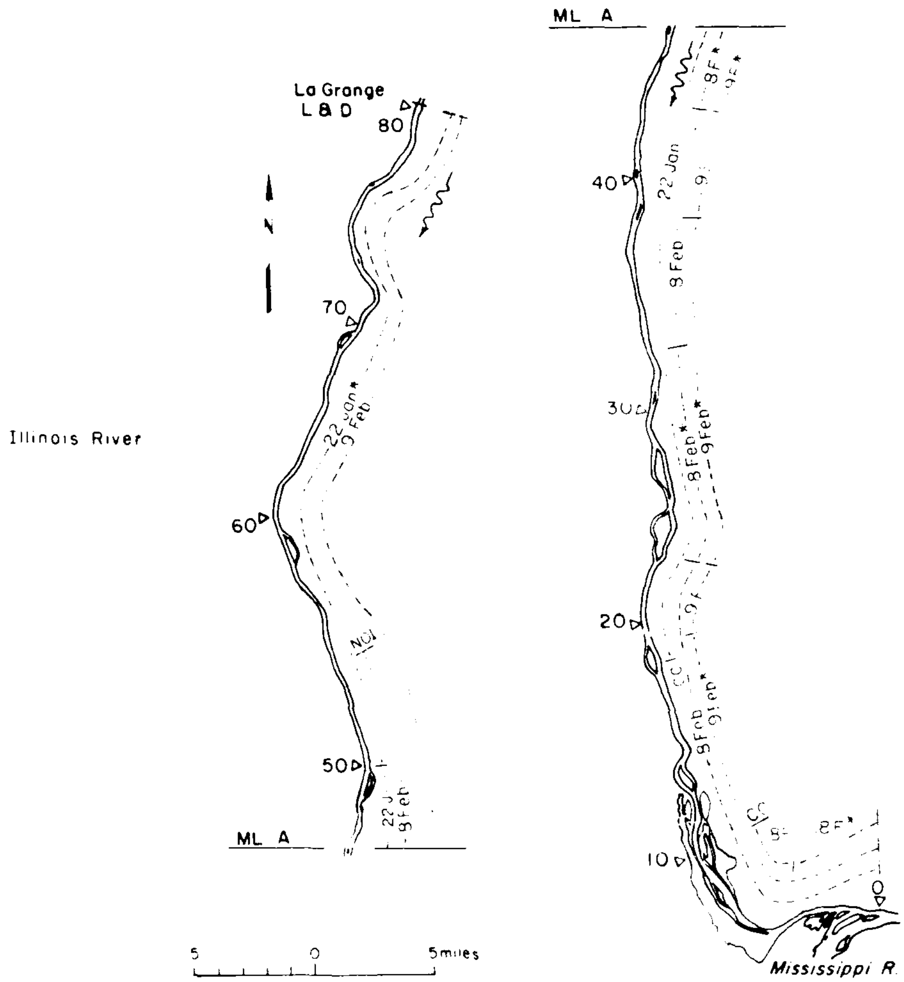


Figure D7 (cont'd).

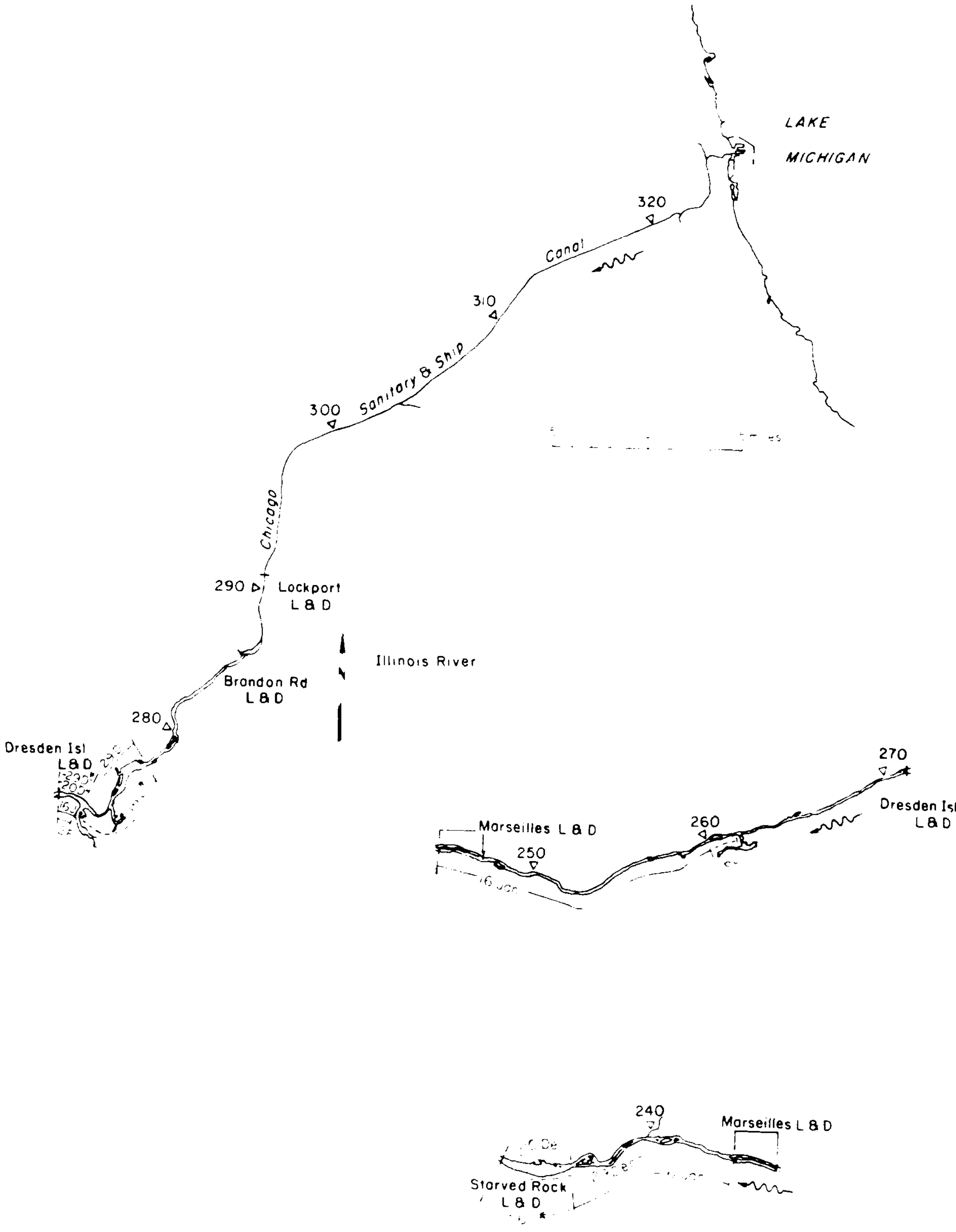


Figure D8. 1981–82 winter.

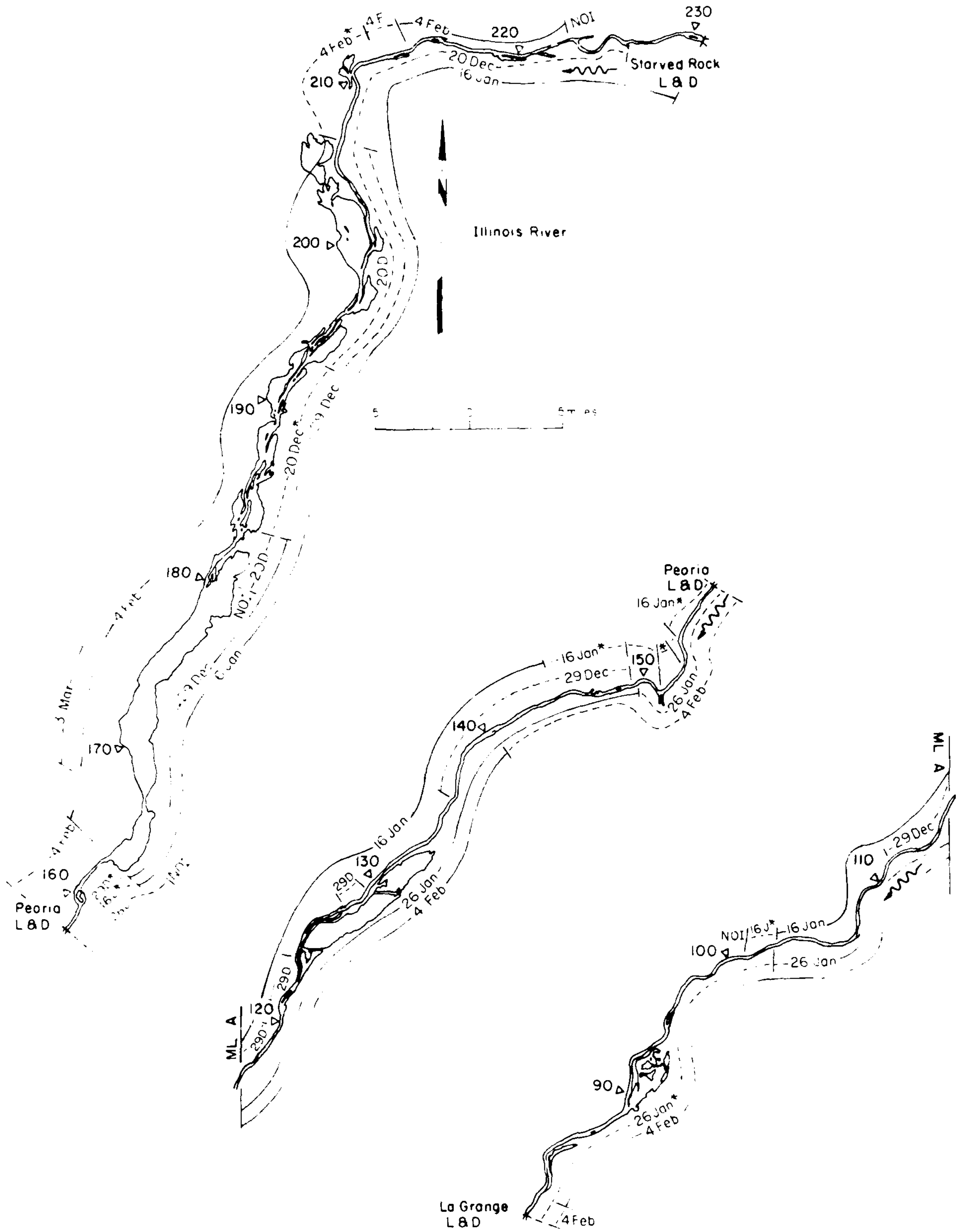


Figure D8 (cont'd).

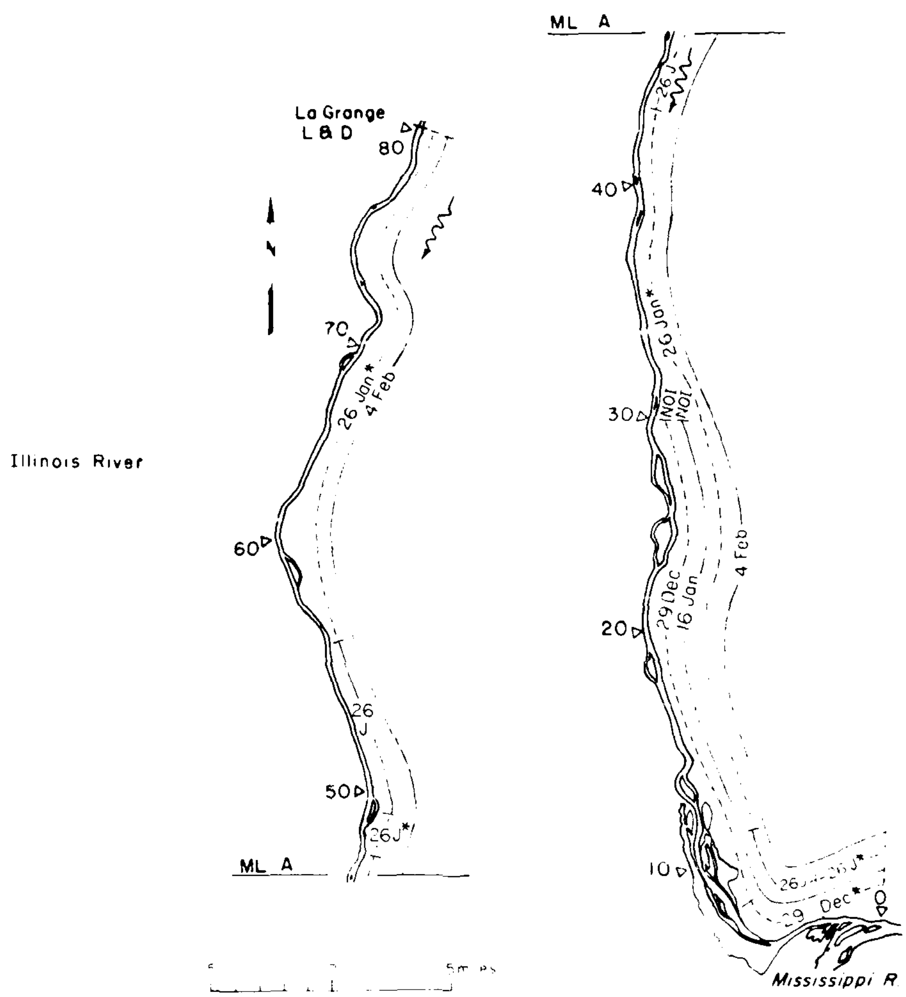


Figure D8 (cont'd). 1981–82 winter.

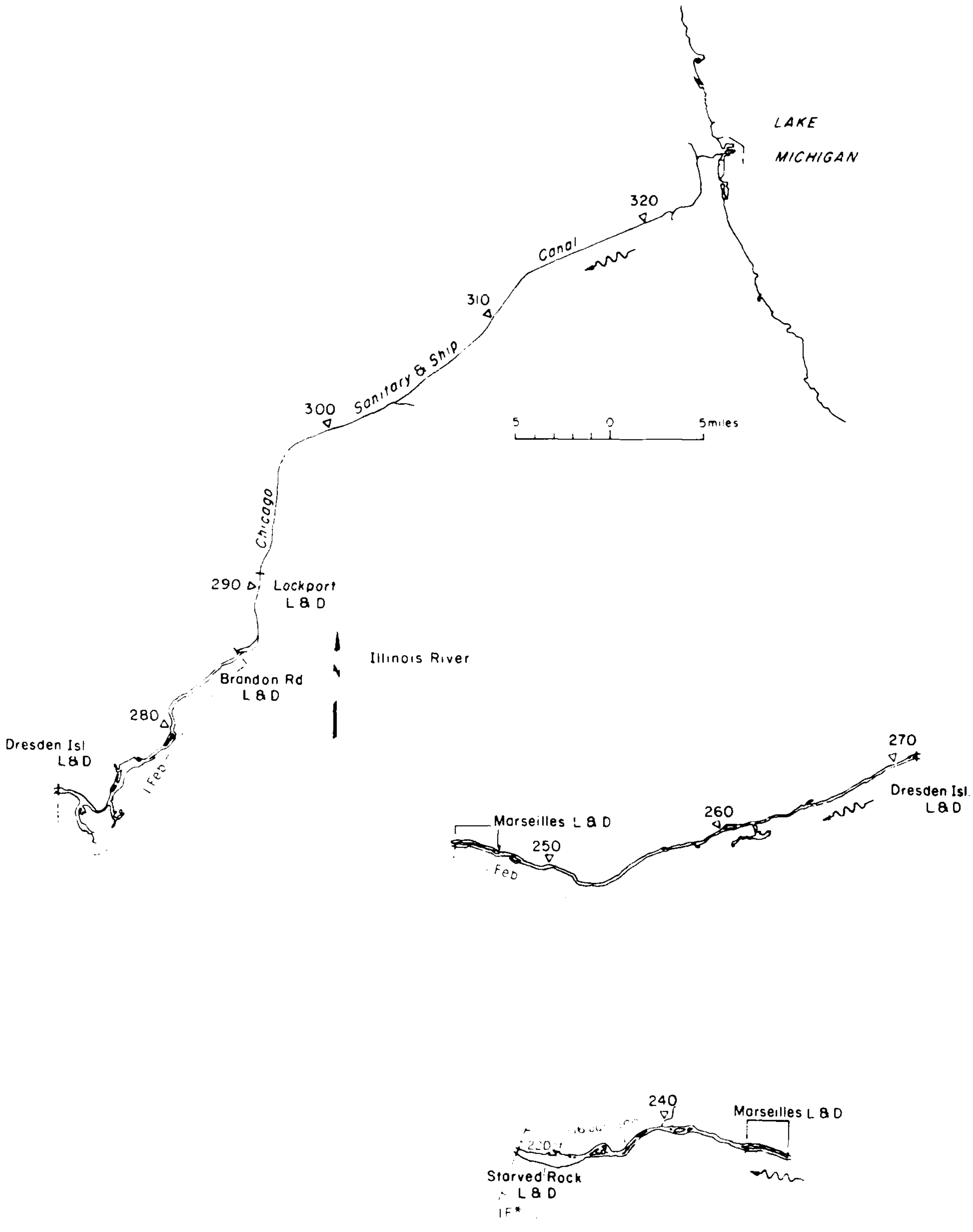


Figure D9. 1983–84 winter.

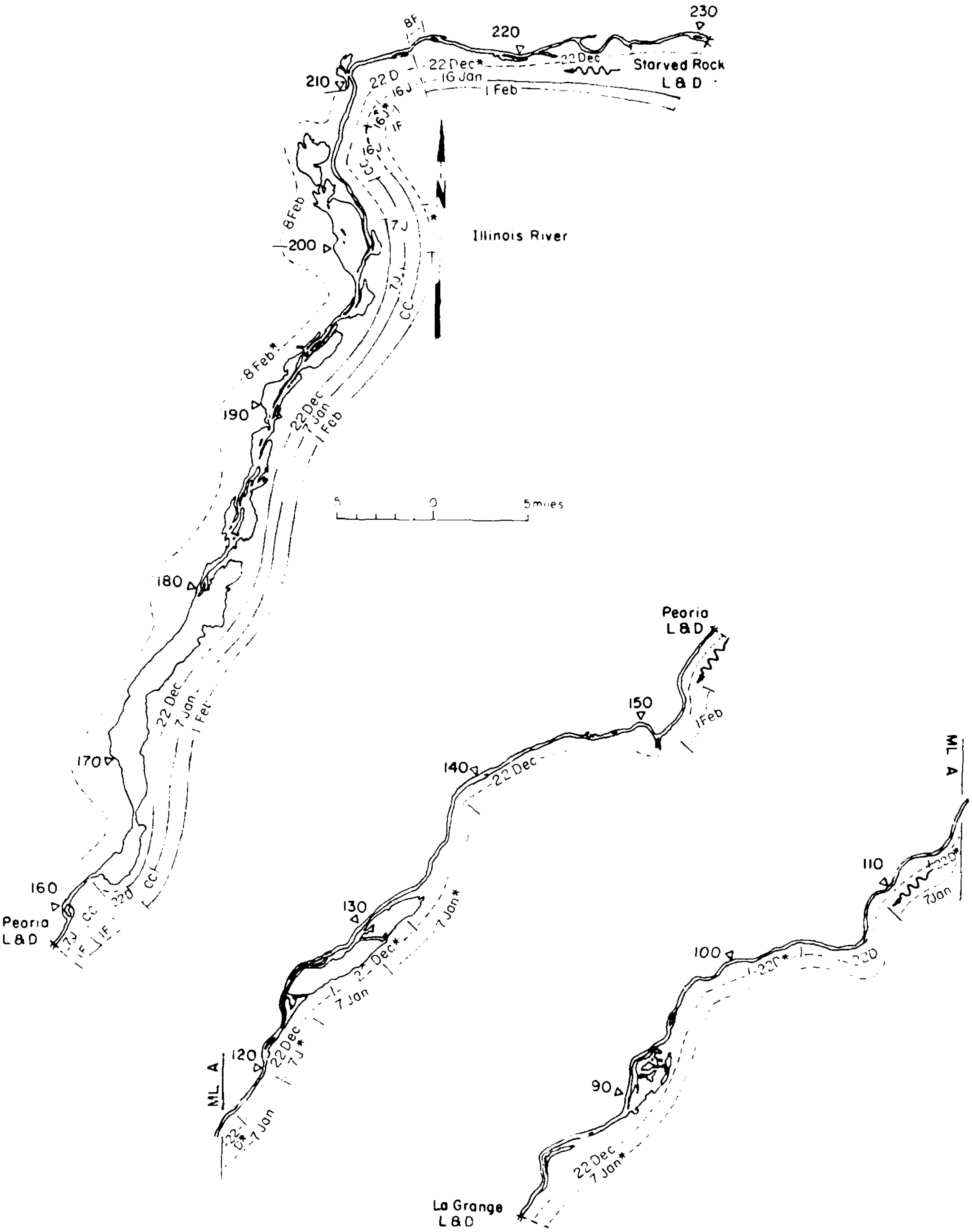


Figure D9 (cont'd). 1983–84 winter.

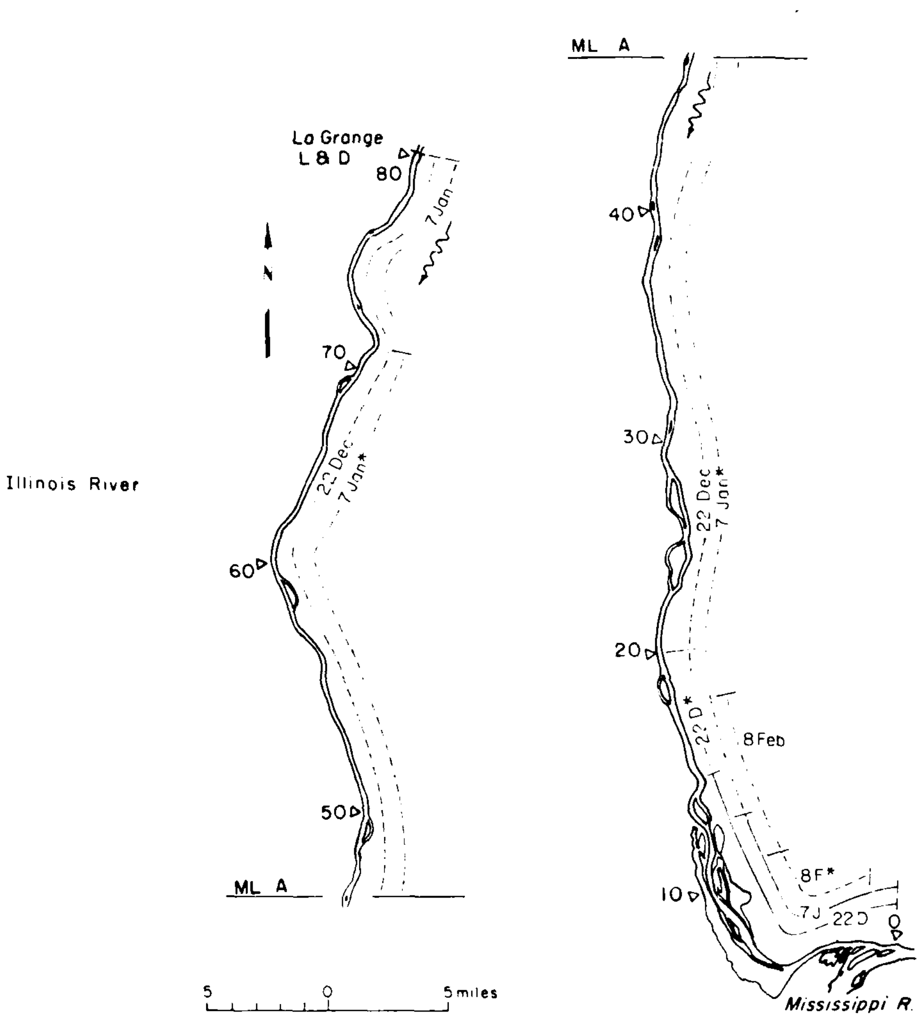


Figure D9 (cont'd).

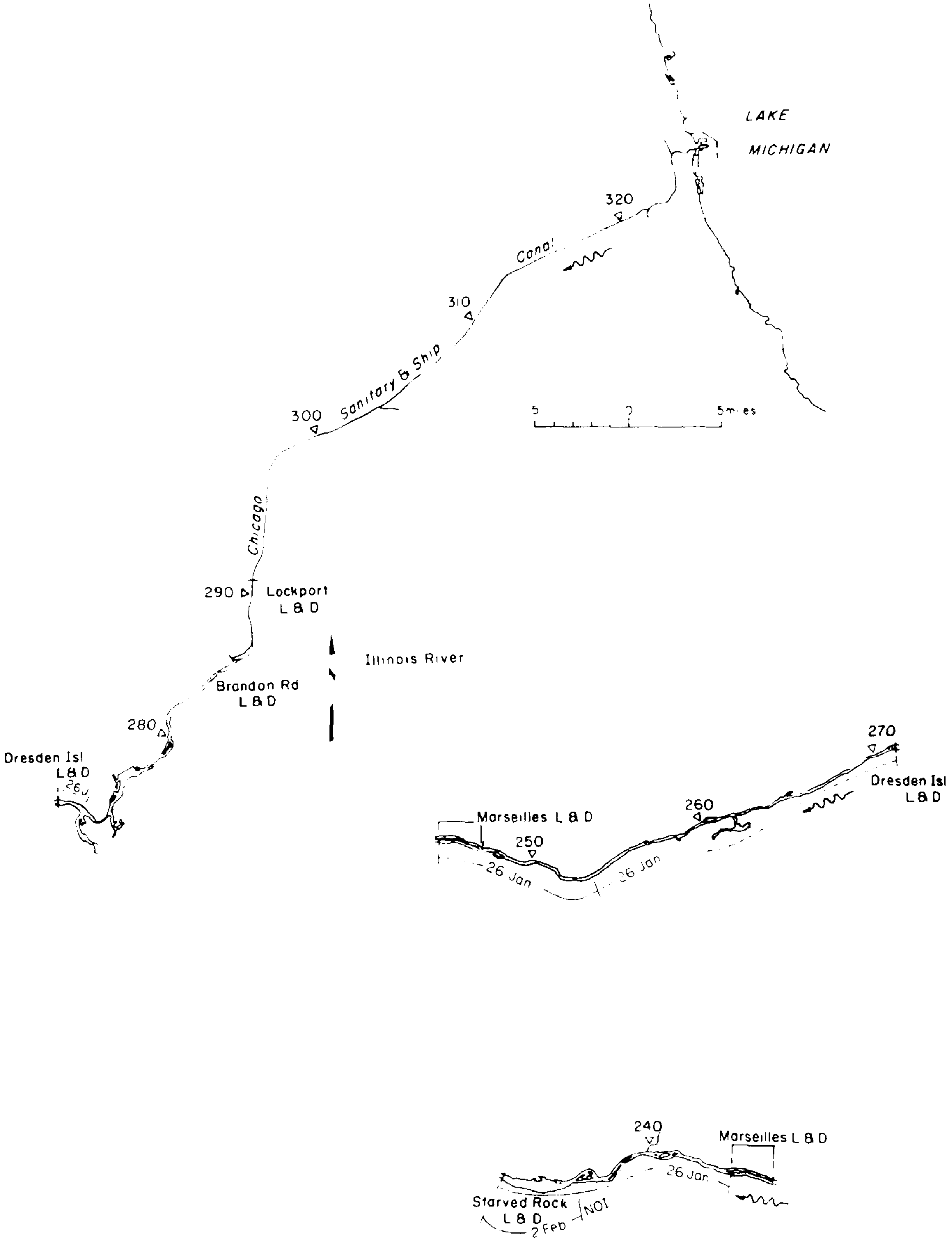


Figure D10. 1984–85 winter.

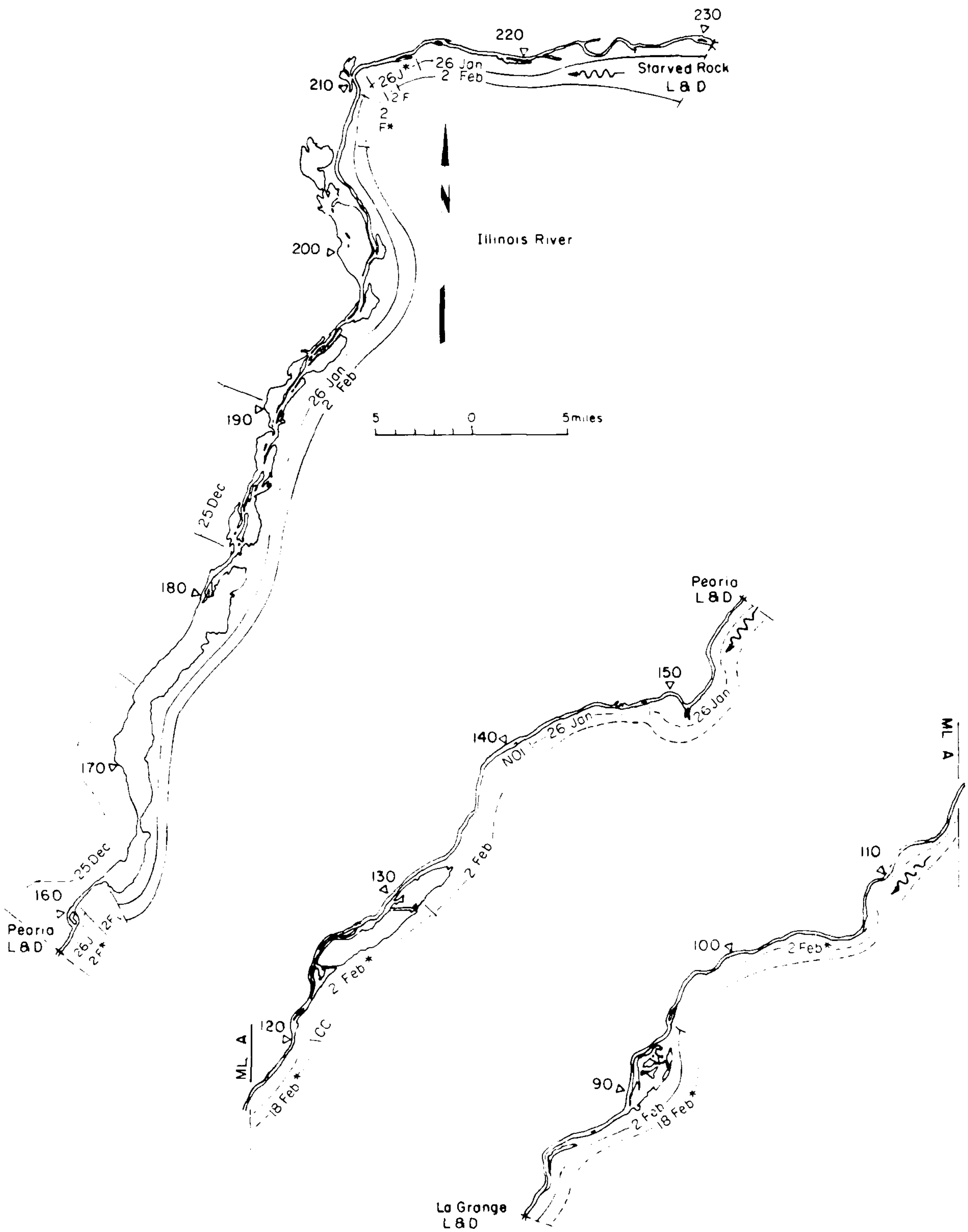


Figure D10 (cont'd).

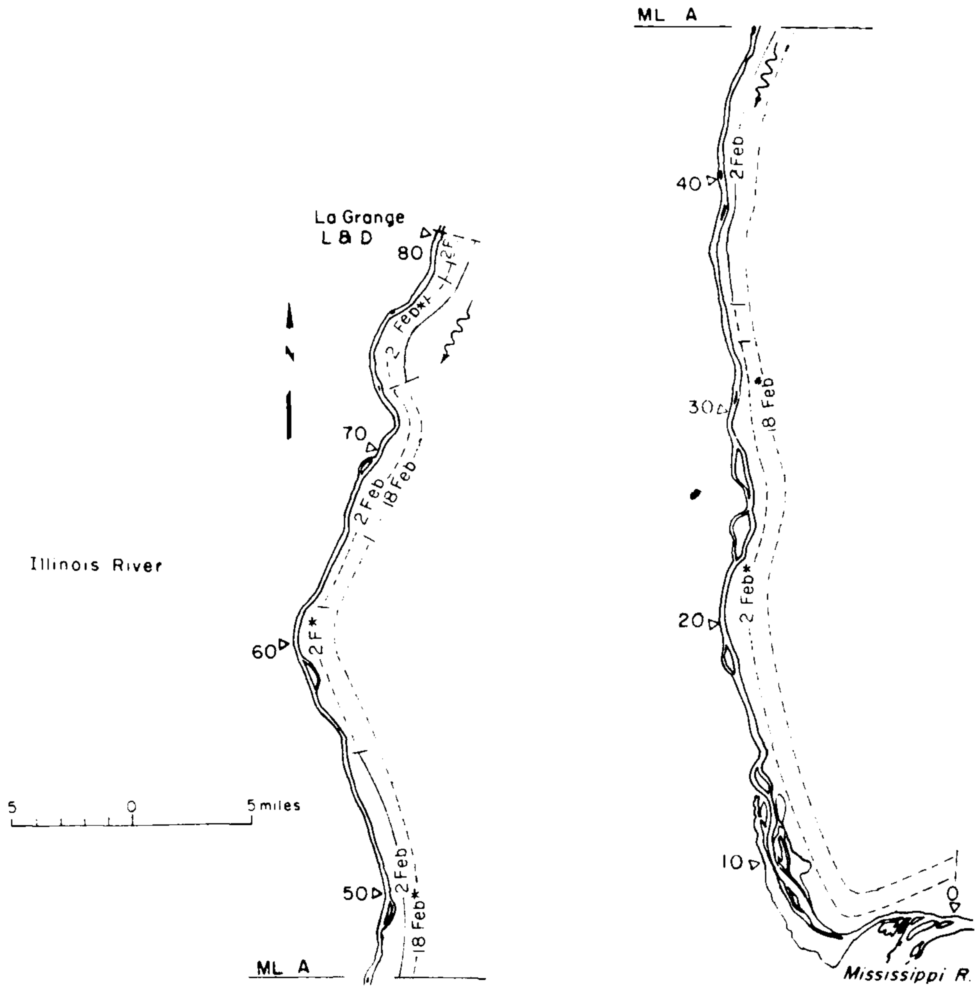
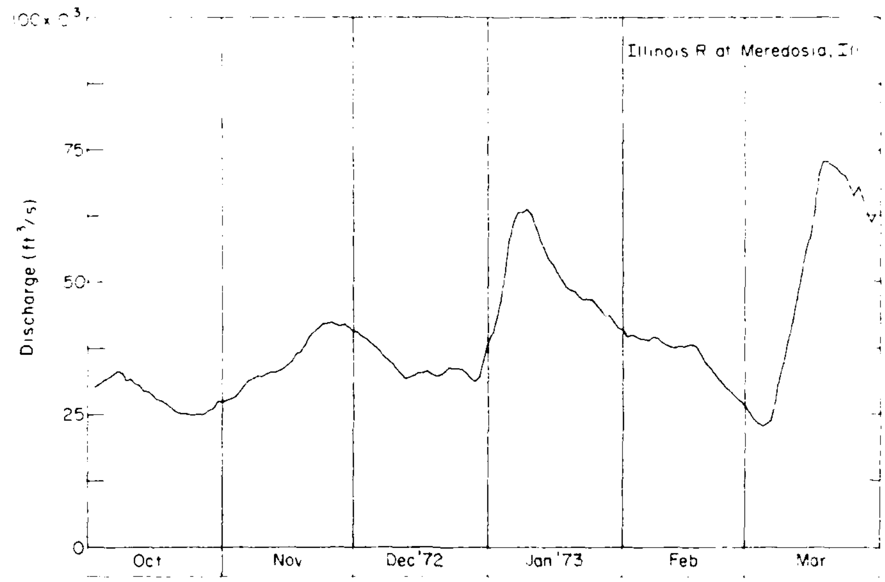


Figure D10 (cont'd). 1984–85 winter.

APPENDIX E: DAILY AVERAGE AIR TEMPERATURE AND MEAN DAILY DISCHARGES



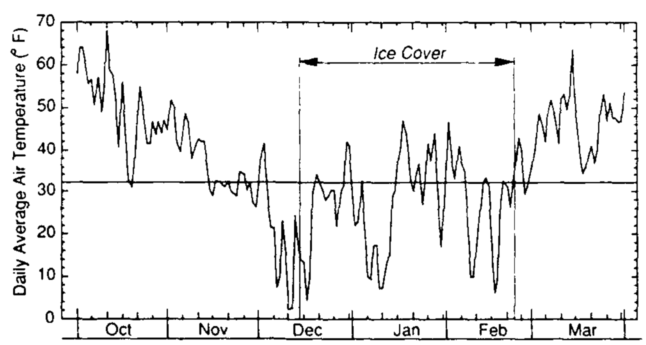


Figure E1. 1972–73.

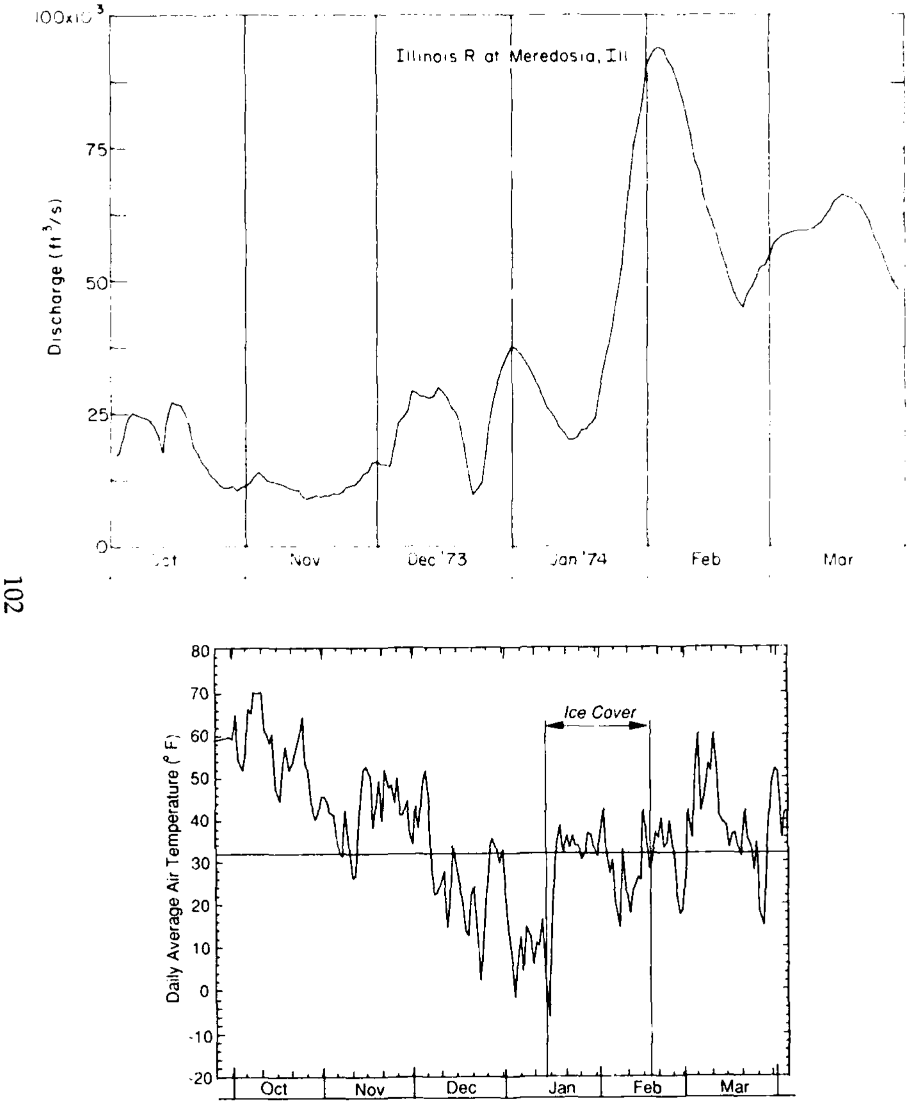


Figure E2. 1973–74.

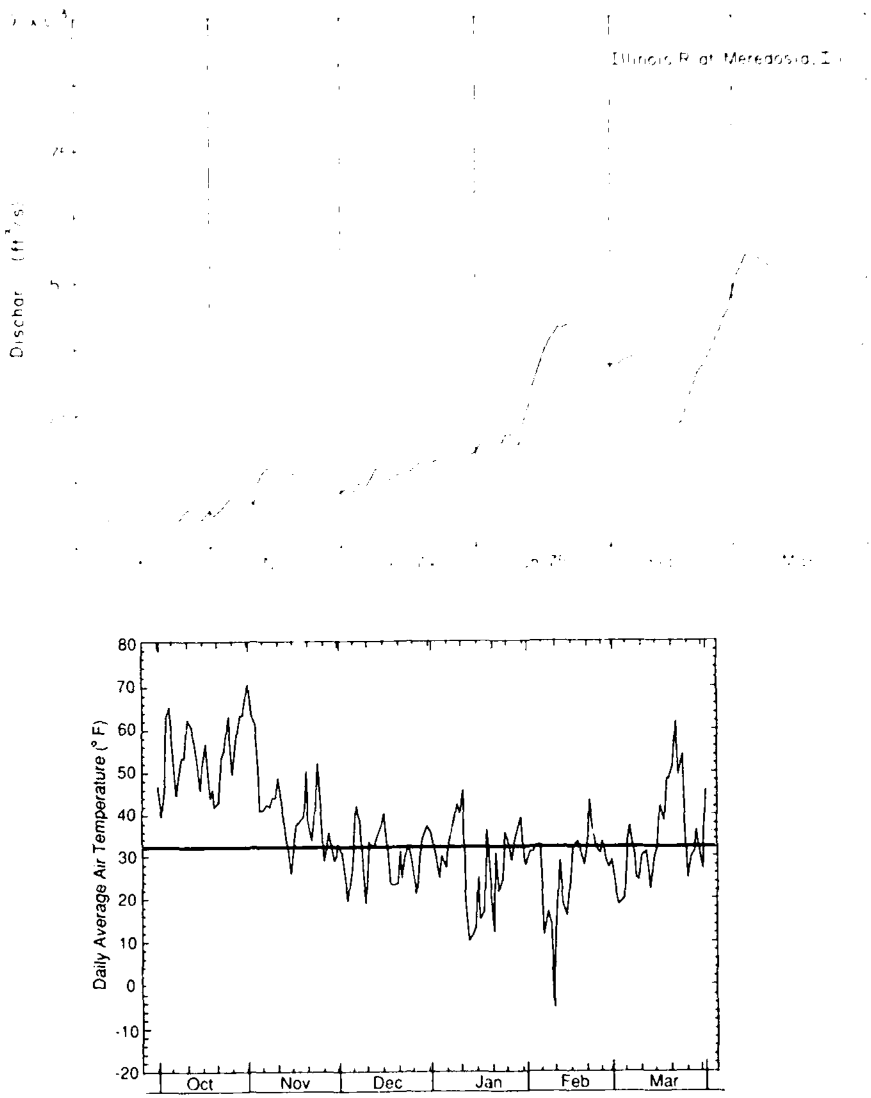


Figure E3. 1974–75.

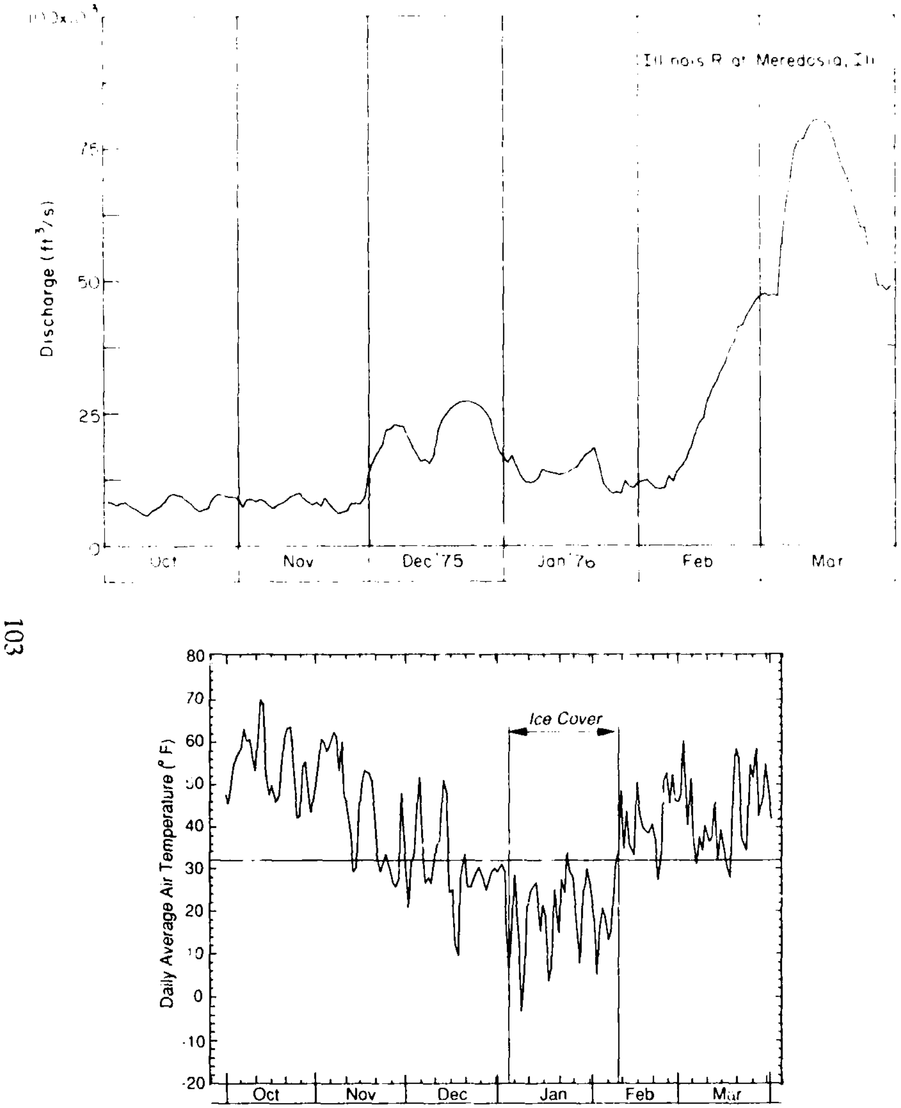


Figure E4. 1975–76.

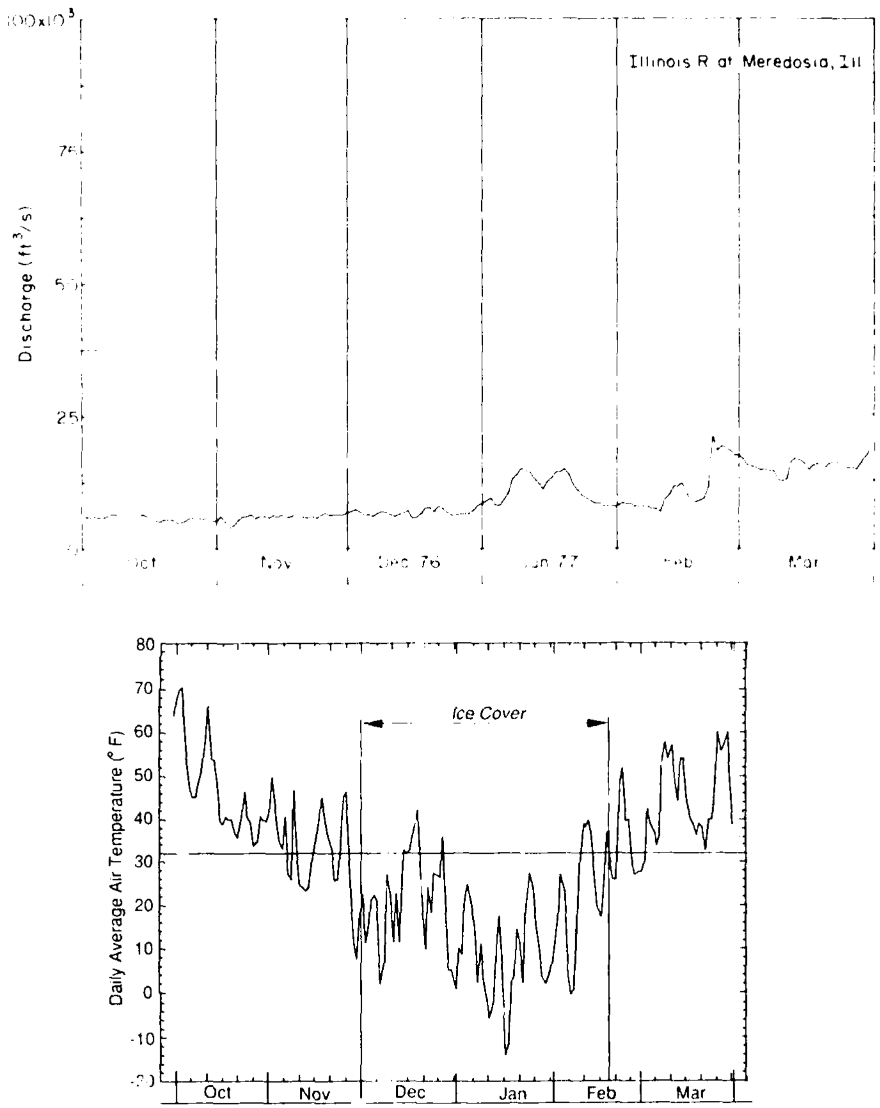


Figure E5. 1976–77.

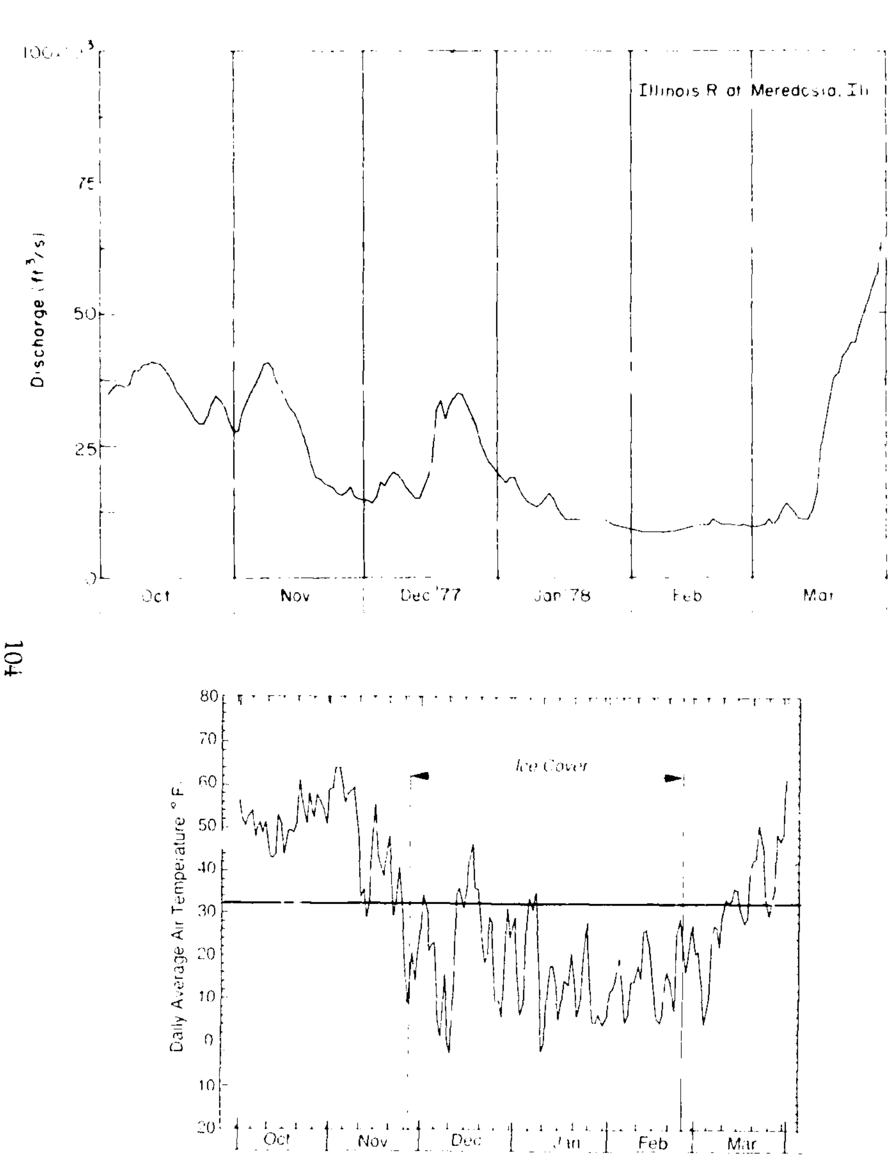


Figure I.6. 1977–78.

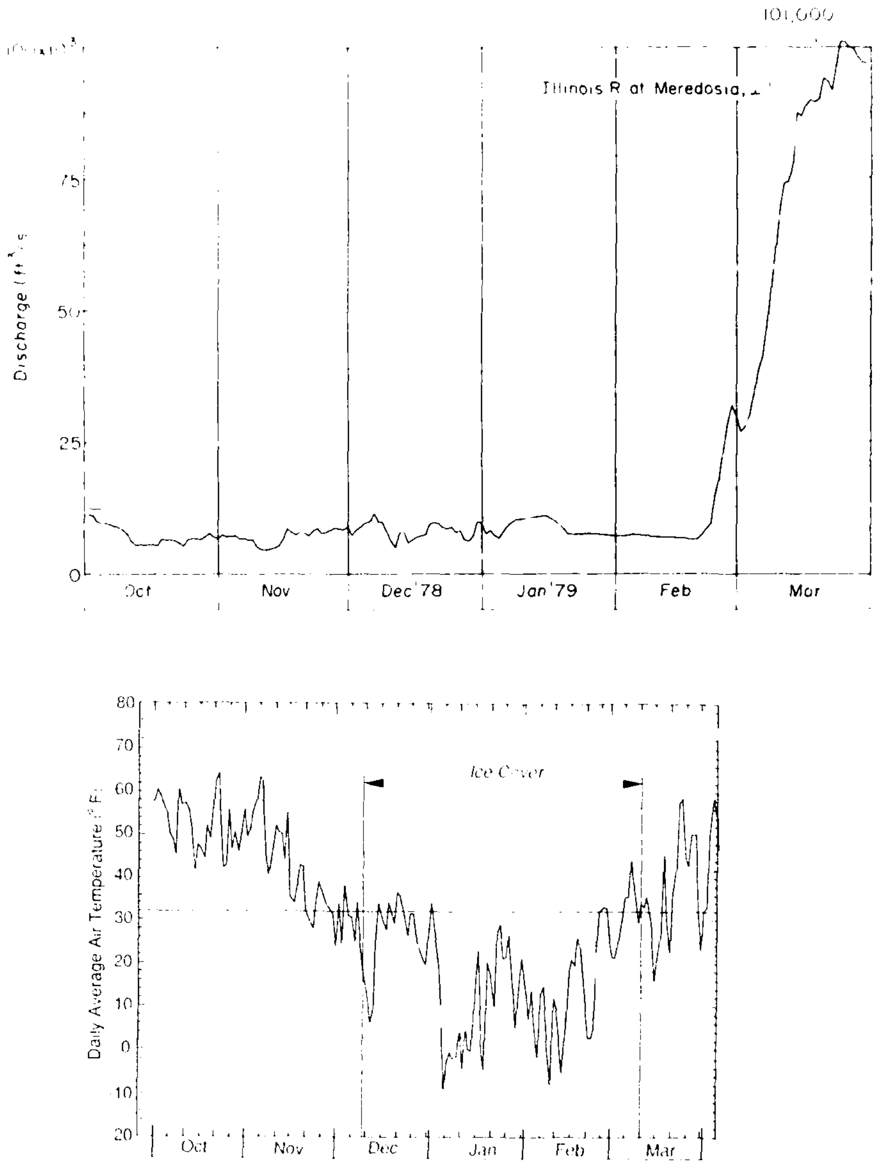


Figure I.7. 1978–79.

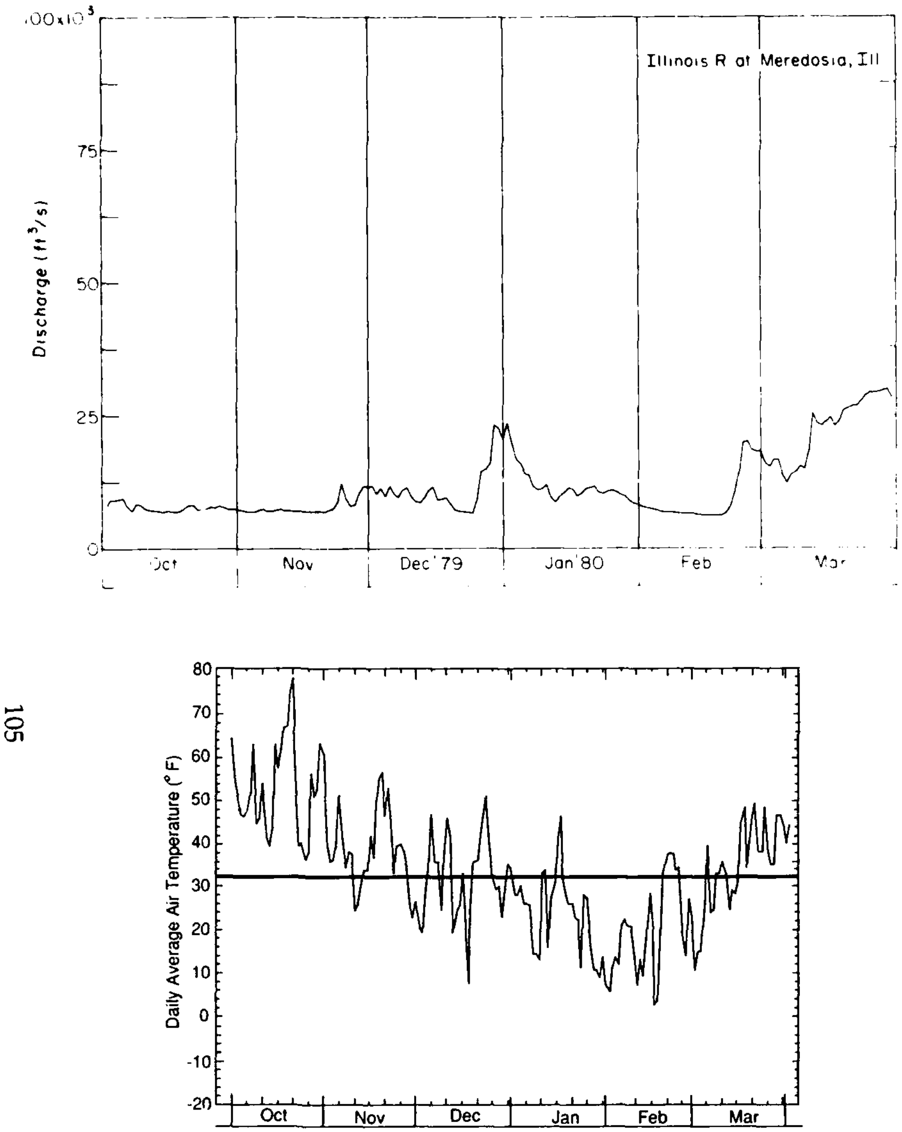


Figure E8. 1979–80.

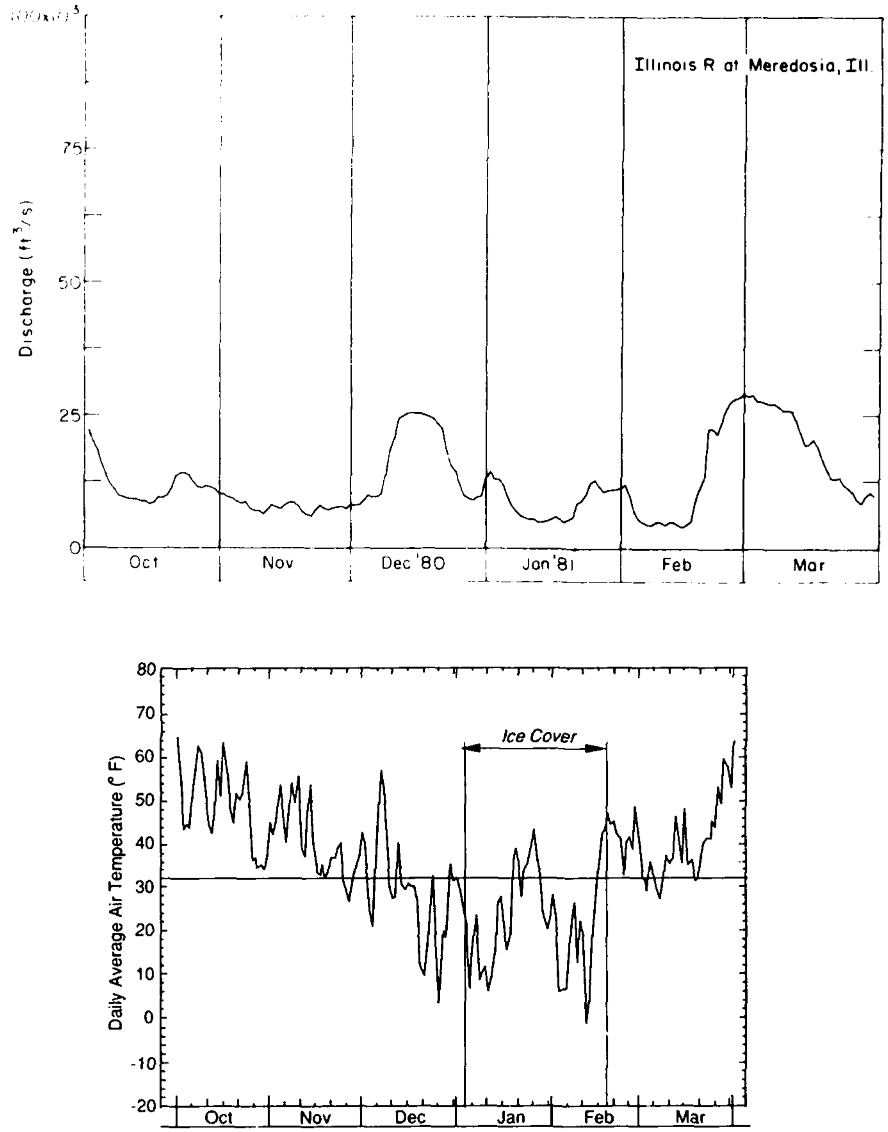


Figure E9. 1980–81.

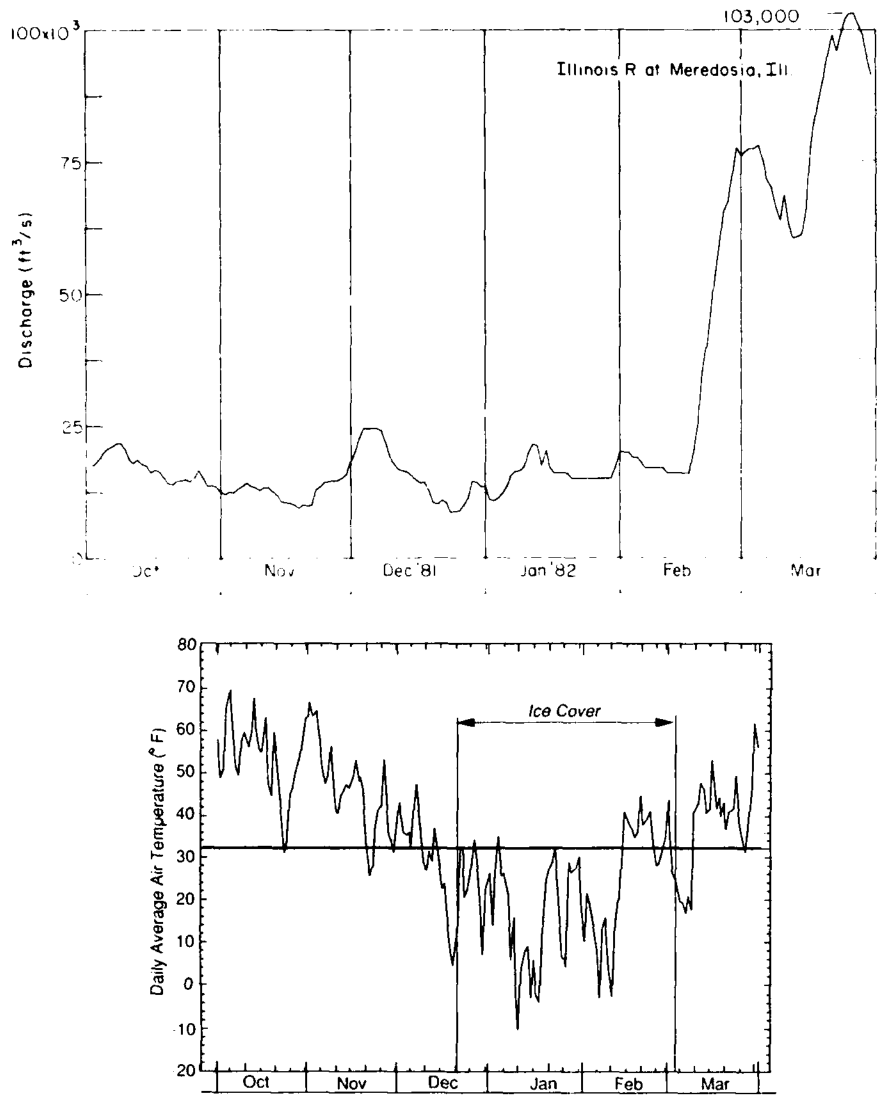


Figure E10. 1981–82.

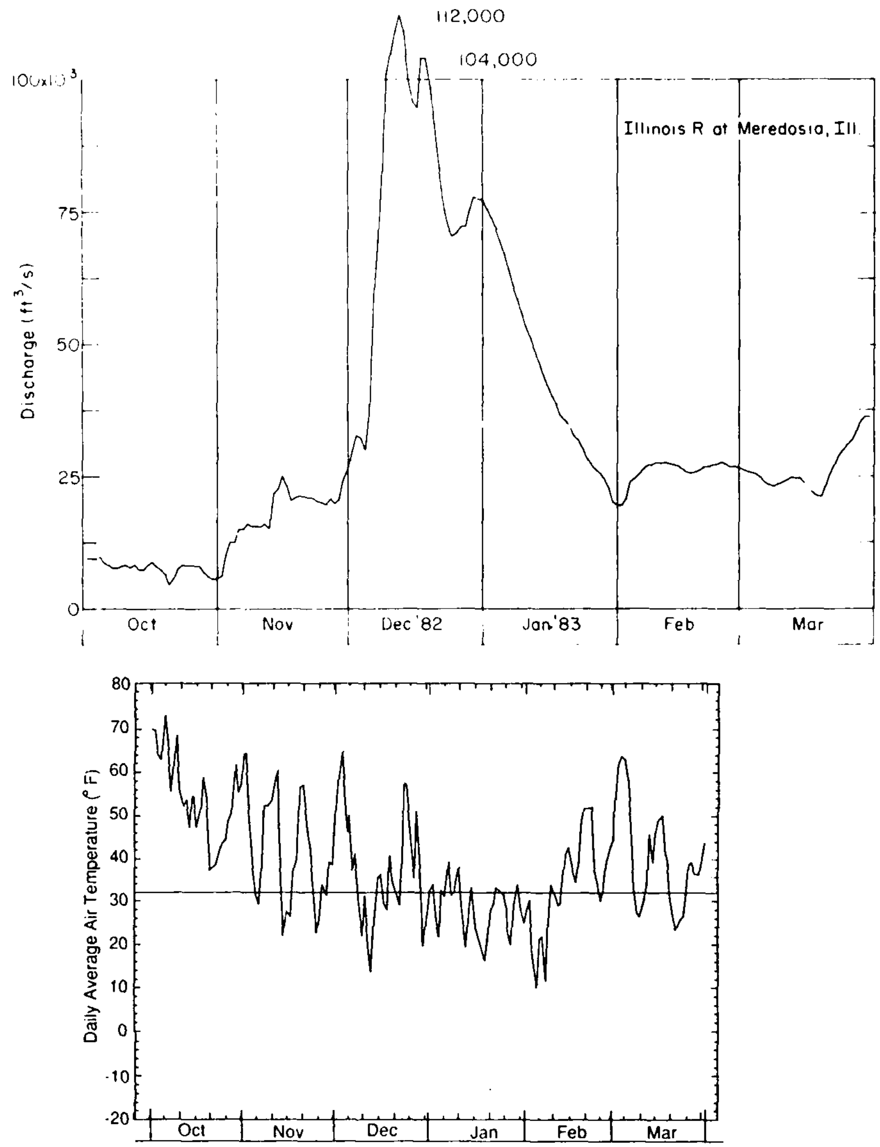


Figure E11. 1982–83.

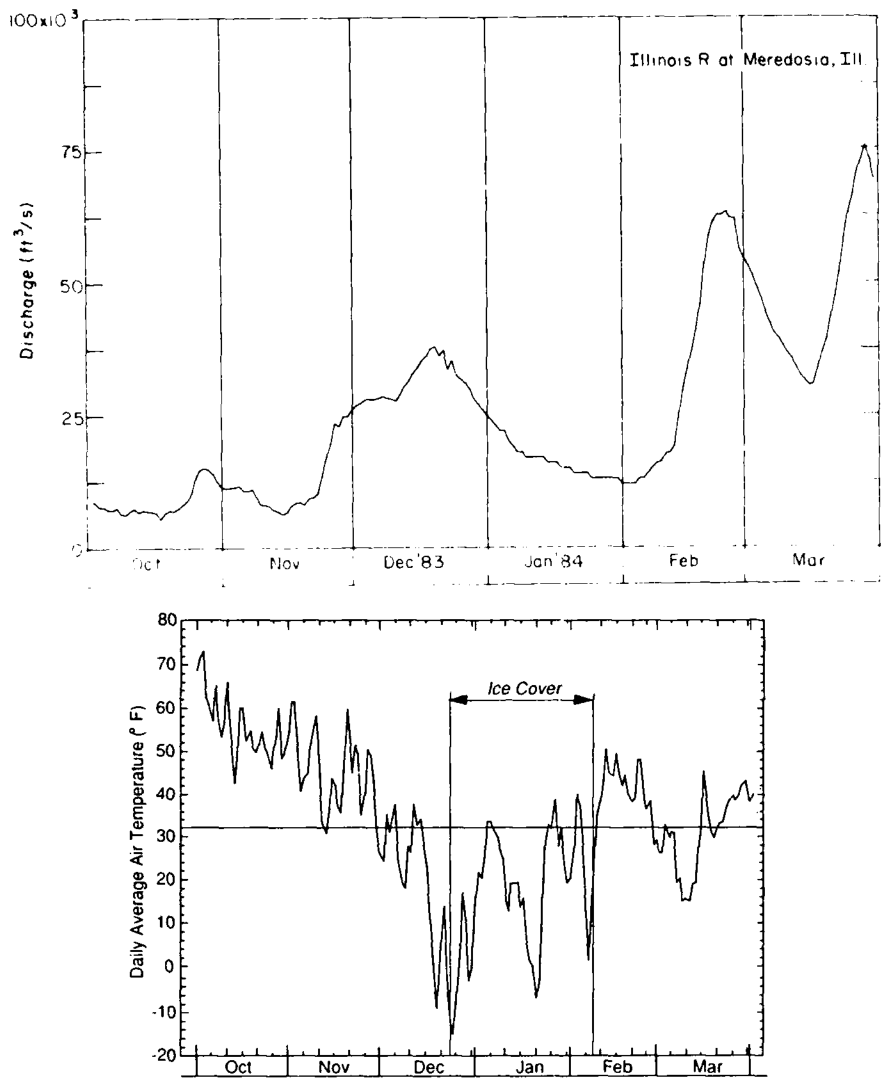


Figure E12. 1983–84.

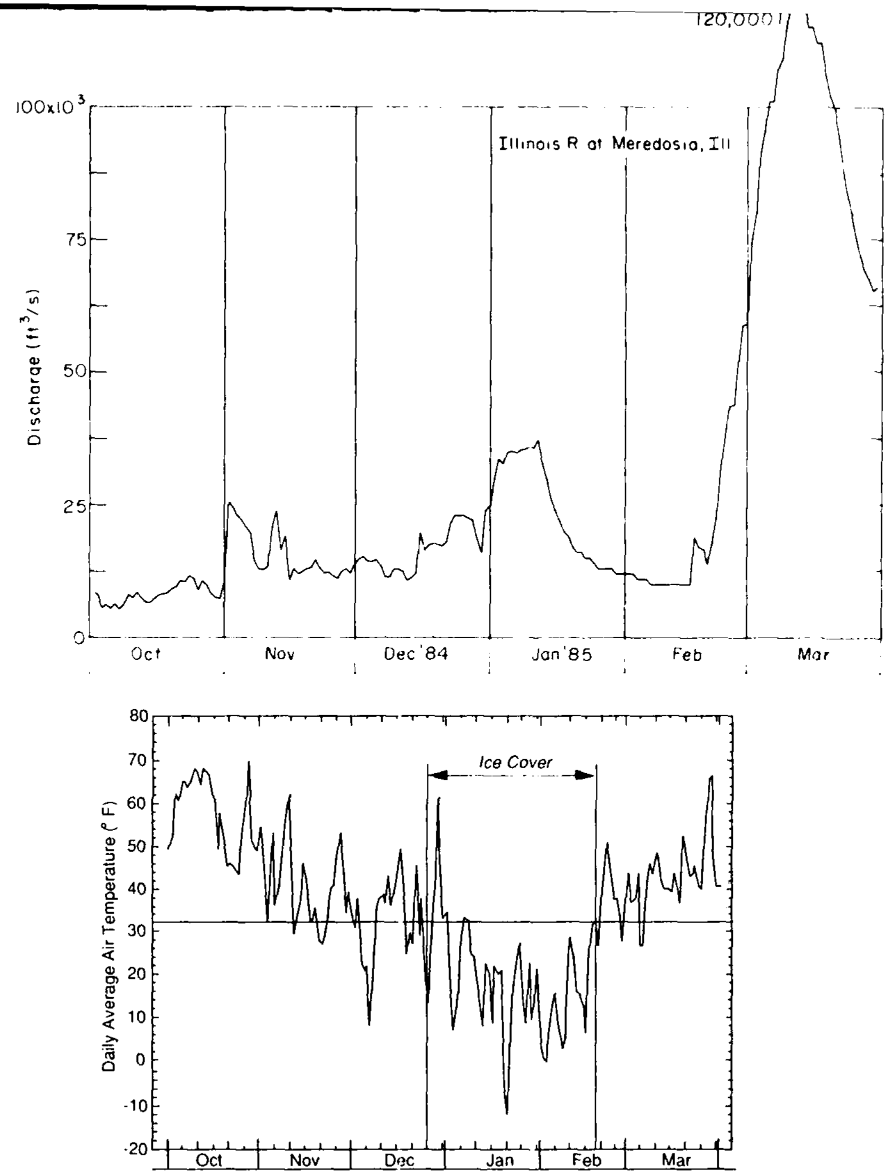


Figure E13. 1984–85.

APPENDIX F: SCATTERGRAMS, EQUATIONS AND CORRELATIONS

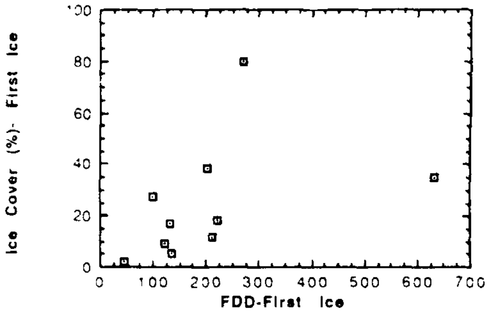


Figure F1. First ice cover (%) and FDD accumulated on the date first ice was observed (n = 10).

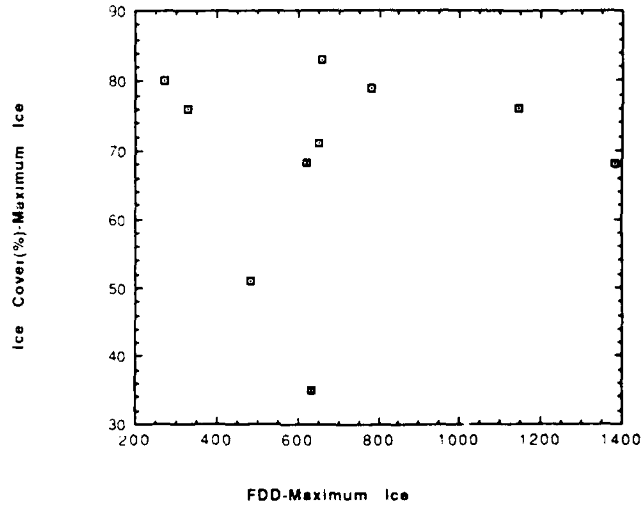


Figure F2. Maximum ice cover (%) and FDD accumulated on the date maximum ice was observed (n = 10).

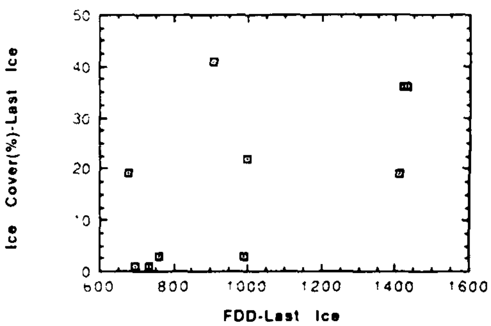


Figure F3. Last ice cover (%) and FDD accumulated on the date last ice was observed (n = 10).

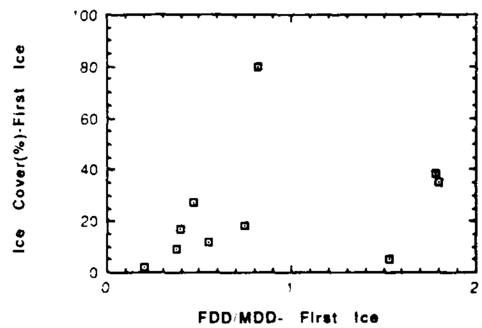


Figure F4. First ice cover (%) and FDD/MDD ratio on the date first ice was observed (n = 10).

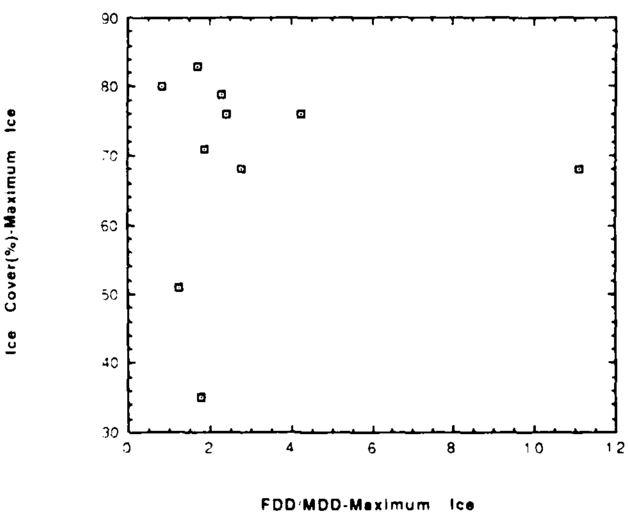


Figure F5. Maximum ice cover (%) and FDD/MDD ratio on the date maximum ice was observed (n = 10).

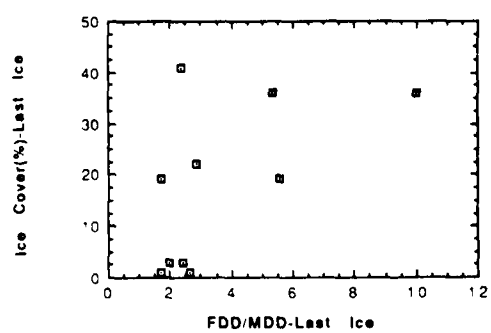


Figure F6. Last ice cover (%) and FDD ratio on the date last ice was observed (n = 10).

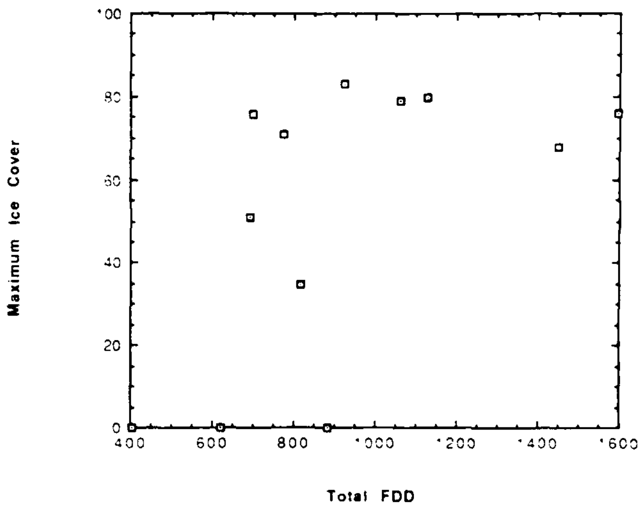


Figure F7. Maximum ice cover (%) and FDD accumulated from 5 November to 31 March (n = 13).

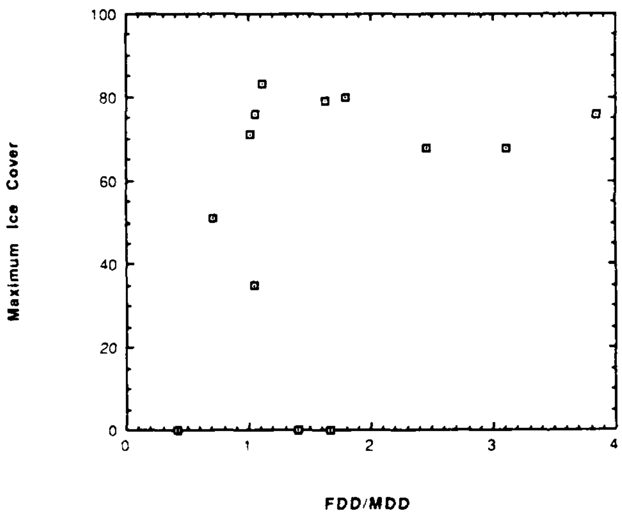


Figure F8. Maximum ice cover (%) and FDD/MDD ratio for the period 5 November to 31 March (n = 13).

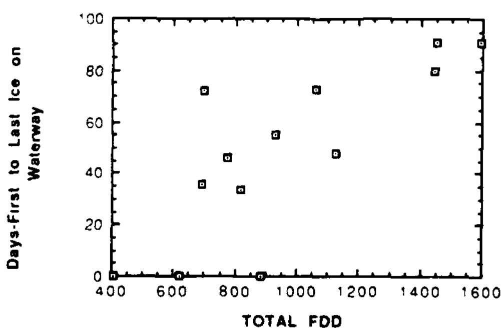


Figure F9. Days from first to last ice and FDD accumulated from 5 November to 31 March (n = 13).

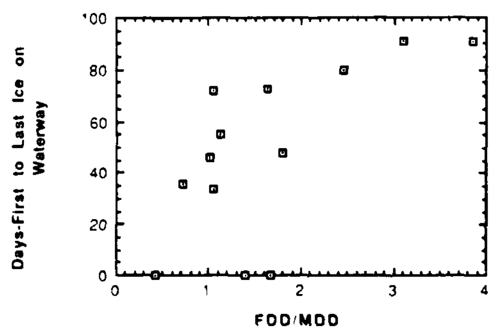


Figure F10. Days from first to last ice and the FDD/MDD ratio for the period 5 November to 31 March (n = 13).

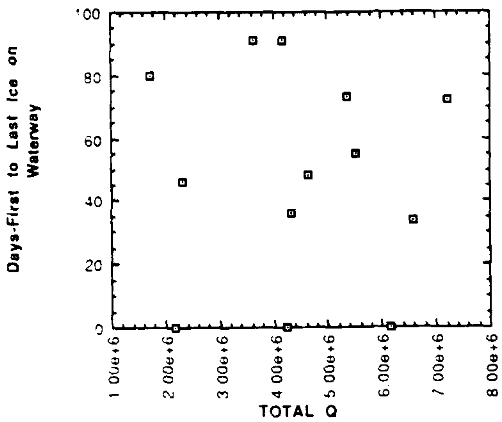


Figure F11. Days from first to last ice and the total flow volume (ft³/s • days, Q) from 1 October to 31 March (n = 13).

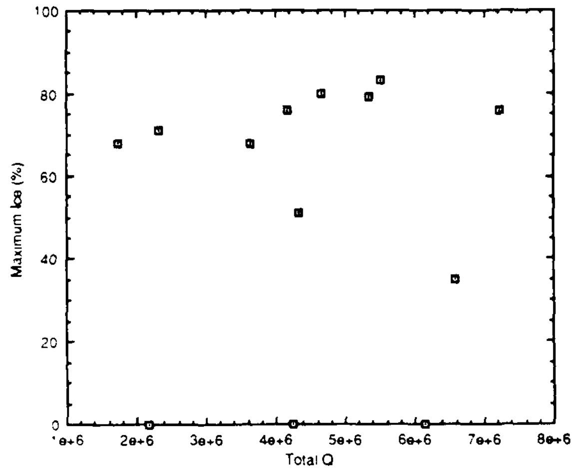


Figure F12. Maximum ice cover (%) and the total flow volume (ft³/s • days, Q) from 1 October to 31 March (n = 13).

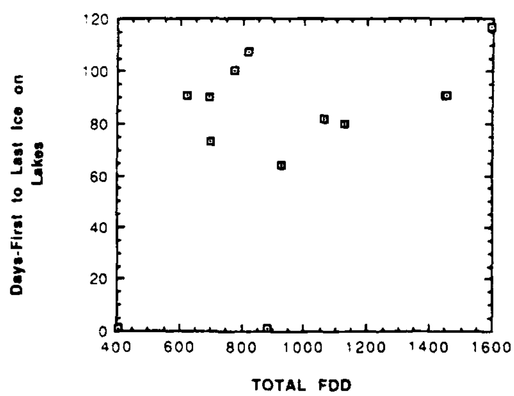


Figure F13. Days from first to last ice on the adjacent lakes and the FDD accumulated from 5 November to 31 March (n = 13).

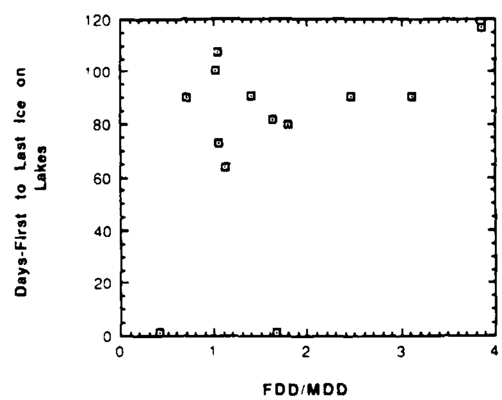


Figure F14. Days from first to last ice on the adjacent lakes and the FDD/MDD ratio for the period 5 November to 31 March (n = 13).

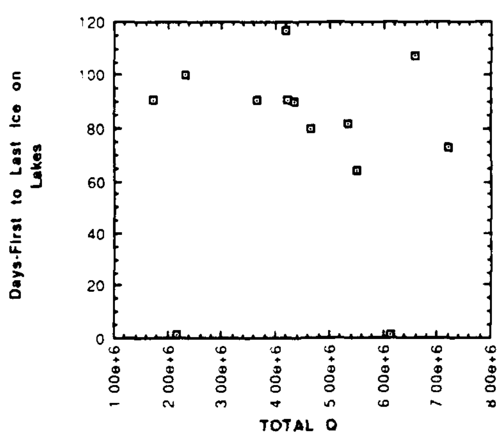


Figure F15. Days from first to last ice on the adjacent lake and the total flow volume (ft³/s • days, Q) from 1 October to 31 March (n = 13).

Table F1. Regression lines fitted to the scattergrams. Cricket Graph 1.2 by Cricket Software on a Macintosh Plus computer was used to fit lines to the scattergrams.

Independent variable	*Dependent variable*	*Slope of the line*	*y Intercept*	*Coefficient of determination,* r^2	n
FDD–First ice (Fig. F1)	% First ice cover	0.0596	11.961	0.181	10
FDD–Maximum ice (Fig. F2)	% Maximum ice cover	0.0014	67.694	0.001	10
FDD–Last ice (Fig. F3)	% Last ice cover	0.0309	−12.934	0.371	10
FDD/MDD–First ice (Fig. F4)	% First ice cover	10.965	14.807	0.084	10
FDD/MDD–Maximum ice (Fig. F5)	% Maximum ice cover	0.2294	68.003	0.002	10
FDD/MDD–Last ice (Fig. F6)	% Last ice cover	3.2996	6.036	0.306	10
Total FDD (Fig. F7)	% Maximum ice cover	0.0522	2.672	0.327	13
FDD/MDD (Fig. F8)	% Maximum ice cover	11.861	33.470	0.126	13
Total FDD (Fig. F9)	Total days ice on waterway	0.0726	−21.674	0.617	13
FDD/MDD (Fig. F10)	Total days ice on waterway	22.175	11.930	0.429	13
Total Q (Fig. F11)	Total days ice on waterway	-0.0640×10^{-5}	51.014	0.001	13
Total Q (Fig. F12)	% Maximum ice cover	0.0926×10^{-5}	48.708	0.002	13
Total FDD (Fig. F13)	Total days ice on lakes	0.0471	30.709	0.221	13
FDD/MDD (Fig. F14)	Total days ice on lakes	14.965	51.554	0.166	13
Total Q (Fig. F15)	Total days ice on lakes	-0.0695×10^{-5}	79.105	0.001	13

A facsimile catalog card in Library of Congress MARC format is reproduced below.

Gatto, Lawrence W.
Ice conditions along the Illinois Waterway as observed on Landsat images, 1972–1985 / by Lawrence W. Gatto. Hanover, N.H.: U.S. Army Cold Regions Research and Engineering Laboratory; Springfield, Va.: available from National Technical Information Service, 1989.
vi, 118 p., illus., 28 cm. (CRREL Report 89-20.)
Bibliography: p. 35.
1. Ice conditions. 2. Illinois Waterway. 3. Landsat images. 4. Remote sensing. 5. River ice. I. United States Army. II. Corps of Engineers. III. Cold Regions Research and Engineering Laboratory. IV. Series: CRREL Report 89-20.