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Ice observations on the Allegheny and Monongahela Rivers

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RIM

RIVER ICE MANAGEMENT

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Corps of Engineers and National Weather Service records of ice conditions on the Allegheny and Monongahela Rivers in Pennsylvania and West Virginia were analyzed for seven recent winters. The on-ground observations recorded daily at a number of lock and dam locations were issued in the form of alphanumeric ice codes that included the coverage, type, thickness, structure and extent of river ice. These codes were used to graph ice conditions throughout the rivers to allow easier analysis of historical ice conditions. In addition, comparisons were made between these observations and aerial videotapes and satellite images of the ice. Results of these comparisons illustrate that ice data from these three sources are complementary and should be used together whenever possible.

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PREFACE

This report was prepared by Michael A. Bilello, Meteorologist, Science and Technology Corporation, Hampton, Virginia; Lawrence W. Gatto, Geologist, Geological Sciences Branch, Steven F. Daly, Research Hydraulic Engineer, Ice Engineering Research Branch, and John J. Gagnon, Civil Engineering Technician, Ice Engineering Research Branch, U.S. Army Cold Regions Research and Engineering Laboratory. The work was funded by the Office of the Chief of Engineers, Directorate of Civil Works, under the River Ice Management (RIM) Program, CWIS 32228, *Remote Ice Monitoring System*, and CWIS 32227, *Forecasting Ice Conditions on Inland Rivers*.

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CONVERSION FACTORS: U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

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*
inch	25.4	millimeter
foot	0.3048	meter
$foot^3$/second	0.02831685	$meter^3$/second
mile	1609.347	meter
degrees Fahrenheit	T°C = (T°F–32)/1.8	degrees Celsius

Ice Observations on the Allegheny and Monongahela Rivers

MICHAEL A. BILELLO, LAWRENCE W. GATTO, STEVEN F. DALY AND JOHN J. GAGNON

INTRODUCTION

Detailed information on daily ice conditions along entire lengths of navigable rivers is often nonexistent or difficult to recover from data archives. In this report ground observations of ice conditions recorded at a series of U.S. Army Corps of Engineers Lock and Dam sites along the Allegheny River in Pennsylvania and the Monongahela River in Pennsylvania and West Virginia were compiled from archives, graphed, analyzed and compared to ice data obtained from aerial videotapes and Landsat images.

The objectives of this study were 1) to determine the annual variability in river ice conditions for selected winters as observed from the ground, 2) to compare ice data acquired from the ground, videotapes and Landsat images, and 3) to develop a computer program to graphically portray the ground data so that these data, when collected in the future, could be quickly displayed and disseminated as an aid for navigation during the winter. This study was a part of the CRREL River Ice Management (RIM) program, a program that examined several rivers in the United States where ice causes winter navigation problems.

DATA SOURCES, COMPILATION AND ANALYSIS

Ground observations

Ground observations of river ice conditions were routinely obtained from eight U.S. Army Corps of Engineers Lock and Dam (L&D) sites on the Allegheny River and nine L&D sites on the Monongahela River, and occasionally from three National Weather Service (NWS) sites located above L&D 9 on the Allegheny River. These Corps and NWS sites cover the rivers from Pittsburgh to West Hickory, Pennsylvania, about 158 miles upstream on the Allegheny River, and from Pittsburgh to Opekiska, West Virginia, about 115 miles upstream on the Monongahela River (Fig. 1).

The Corps ground observers use a five-element alphanumeric code (Table 1) to describe ice conditions each day and send the codes to Corps and NWS central offices located around Pitts-

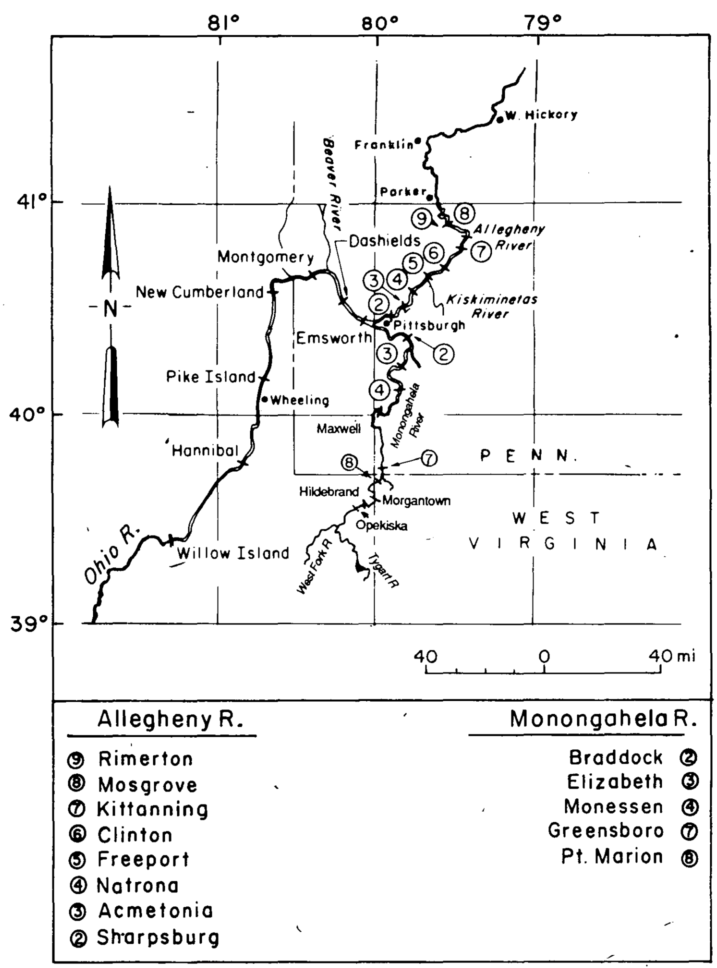


Figure 1. Location map (circled numbers are L&D numbers).

Table 1. Corps of Engineers alphanumeric ice code.

Amount (coverage)	*Type*	*Thickness*	*Structure*	*Extent*
0–None	R–Running (floating)	In inches	B–Breaking	In miles upstream
1–Scattered	A–Stationary		H–Honeycombed	
2–2 tenths	P–Stopped		T–Rotten	
3–3 tenths	J–Jammed		L–Layered	
4–4 tenths	F–Formed locally		C–Clear	
5–5 tenths	S–Shore			
6–6 tenths				
7–7 tenths	Examples:			
8–8 tenths				
9–9 tenths	1 S 1/2 T X means scattered shore ice, 1/2 in. thick, rotten and extending an unknown distance upstream; unknown data in any category are shown as "X"; 3 R 2 H 4 means 3 tenths of the river is covered by running ice, 2 in. thick, honeycombed, and extending 4 miles upstream .			
10–10 tenths, full				

Table 2. Partial record of ice conditions on the Monongahela River, January 1985.

Date	*Braddock*	*Elizabeth*	*Monessen*	*Maxwell*	*Greensboro*	*Pt. Marion*	*Morgantown*	*Hildebrand*	*Opekisa*
19									7F 1/2 CX
20						1F 1/8 CX	1F 1/4 CX		9A 1 CX
21	9A 1/2 CX	2F 1/2 CX	10A 1 CX	10A 2 CX	10F 1 CX	10F 1 CX	10F 2 CK	10F 2 CX	10A 2 CX
22	10A 1 CX	6R 1 CX	10A 2 CX	10A 3 CX	10F 1 CX	10F 4 CX	10F 4 CX	10F 4 CX	10A 3 CX
23	10A 1 CX	5R 2 CX	10A 2 1/2 CX	10A 3 1/2	10R BX	10F 5 CX	10F 5 CX	10F 4 CX	10A 3 CX
24	10A 1 CX	5R 2 C10	10A 3 C18	10A 3 1/2 CX	1R 1 C2	10F 5 C11	10F 4 C6	10F 3 C7	10A 4 C14
25	9A 2 C5	6R 3 C10	10R 3 L18	10A 3 C22	1R 1 B5	10F 5 C10	10F 4 C6	10F 3 C7	10A 3 CX
26	9A 2 C5	6R 2 C10	10R 3 L18	10A 1 C22	10A 1 C1	10F 5 B10	10F 5 B6	10F 3 C7	10A 4 C14
27	9A 2 C4	2R 2 C10	10A 3 L18	10A 3 L22	5A 1 B2	10F 5 C10	10F 5 C6	10F 4 C8	10A 5 C14
28	8A 2 B2	2R 2 C10	10P 4 L18	10A 3 L22	8R 2 B3	10F 5 C10	10F 4 1/2 C6	10F 4 C8	10A 7 C14
29	no ice	5R 2 B10	10P 4 L18	10A 3 L22	10A 2 L5	10F 4 C10	10F 4 C6	10F 4 C8	10A 6 C14

burgh. The data are then issued to users by computer modem and are archived at Corps and NWS offices as chronological listings of the ice observations at each of the sites (e.g., Table 2; Appendix A). The data, however, have two major omissions. The ice observers at some sites often did not collect data on weekends, and they frequently could not determine how far upstream a particular ice type existed. We hope that these data gaps can be reduced in the future. Although these ground observations are available beginning with the 1961–62 winter, the records for the seven consecutive winters from 1979–80 to 1985–86 are most complete and are used in this study.

Since it is difficult for a user to visualize and understand the distribution of ice conditions from tables, we developed a way to graph the data. Graphs of ice observations for the Allegheny (Fig. 2a) and Monongahela (Fig. 2b) Rivers during the 1985–86 winter that employ our method are shown here. Other methods have been used in the past to graph river-ice conditions (Bates et al. 1968, Michel 1971, Starosolszky 1985, Canadian Coast Guard 1986).

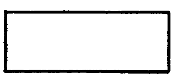
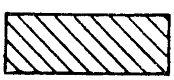
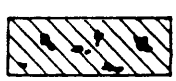
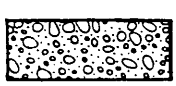
Our review of the Corps' ice code (Table 1) indicated that most of the information given can be displayed graphically, although in preparing the hand-drawn graphs (Fig. 2a and b), it was necessary to drop the ice structure element of the code, and to reduce the number of amount and type categories for the sake of readability. Amount was reduced from eleven categories to four: 0 (area clear of ice), 1 through 5 tenths (10–50%), 6 through 9 tenths (60–90%), and 10 tenths (100%). Type was reduced from six to three: running or floating ice; stationary, stopped, jammed or formed locally (any one of the four); and shore ice. We also included discharge and air temperature data to show the relationships between temperature, discharge and ice conditions.

Aerial videotapes

Videotapes (1/2-in. VHS) of the rivers were taken vertically with a Panasonic 777 video camera fitted with a 12:1 zoom lens. A Cessna 172 fixed-wing aircraft, flying at an altitude between 2000 and 3500 ft above the river, depending on cloud conditions and the width of the river, carried the camera. An experienced ice interpreter viewed the tapes on a TV monitor and visually classified ice conditions into six units (Table 3) that were readily identifiable, that satisfactorily described the range of ice that usually occurs on these rivers, and that did not require ground truth data for verification. The interpreter did not attempt to infer characteristics from the tapes that could only be measured on the ground (e.g., porosity, strength or ice thickness).

Boundaries between the units were mapped and the area of each unit was measured. For units comprising both ice and open water—*solid ice cover with open-water areas, fragmented ice with open-water areas* and *ice floes or frazil slush and pans*—the surface concentration of ice was also visually estimated.

Table 3. Ice conditions as observed on videotapes (from Gatto et al. 1986).

Map unit	*Description*
	River is ice-free, no ice apparent.
	River is completely covered (100%) with ice; no individual ice pans, blocks or chunks are visible; ice may be snow-covered.
	River is partially covered with solid ice (as described above) but has open (ice-free) areas.
	River is completely covered (100%) with ice that has distinct, variably sized, individual ice pans, blocks or chunks.
	River is partially covered with fragmented ice (as described above) but has open (ice-free) areas.
	River is primarily open (ice-free) with floating ice floes, slush or pans.

Landsat images

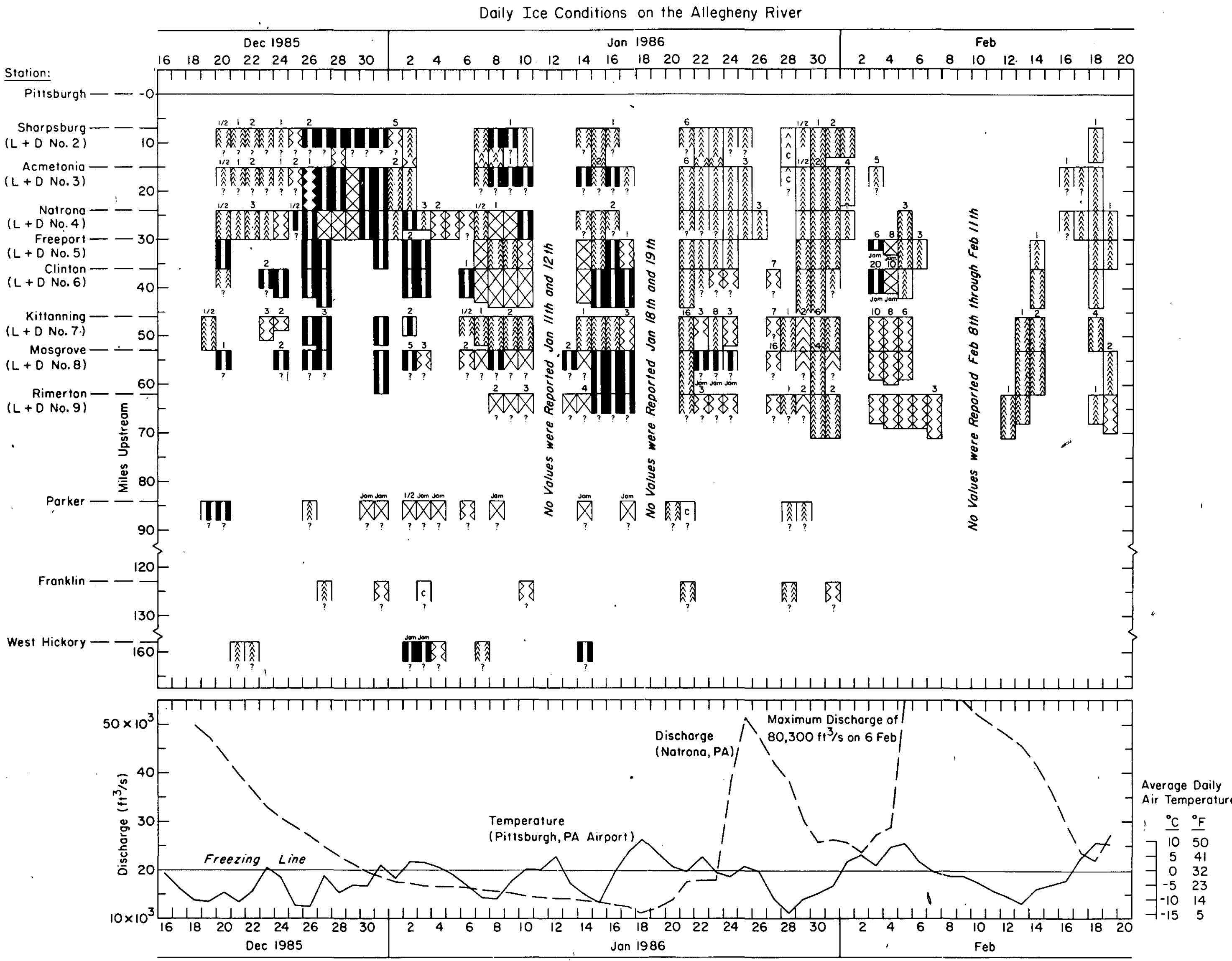
Five Landsat satellites have provided images of the rivers since 1972. Each Landsat has two imaging sensors: either a Multispectral Scanner (MSS) with an Instantaneous Field of View (IFOV) of approximately 260 by 260 ft and a Return Beam Vidicon (RBV) with an IFOV of either 262 by 262 ft or 131 by 131 ft, or a MSS (same IFOV) and a Thematic Mapper (TM), with an IFOV of 98 by 98 ft. Gray tones and patterns in river ice are most visible to the eye on images from the 0.6- to 0.7-µm MSS, 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).

Images of the same location were taken every 18 days by Landsat 1, 2 and 3. When more than one was operating simultaneously, images of the same location were taken about every 9 days. During simultaneous Landsat 4 and 5 operations, images of the same location were taken every 8 days; images were taken every 16 days when one satellite was operating.

We analyzed black and white Landsat film positives (9 by 9 in.) using traditional photographic interpretation techniques. No special computer enhancements or analytical techniques were used (Gatto 1985). Reaches of the rivers appeared as black, gray or white with textures and patterns within these tones sometimes apparent, but the subtleties that differentiate the six ice conditions that are visible on videotapes were not apparent on Landsat images. To determine which types of river ice usually produced these tones, textures and patterns, we compared ice conditions shown on aerial photographs (Gatto and Daly 1986) and videotapes taken on dates as close as possible to those for which Landsat images were available.

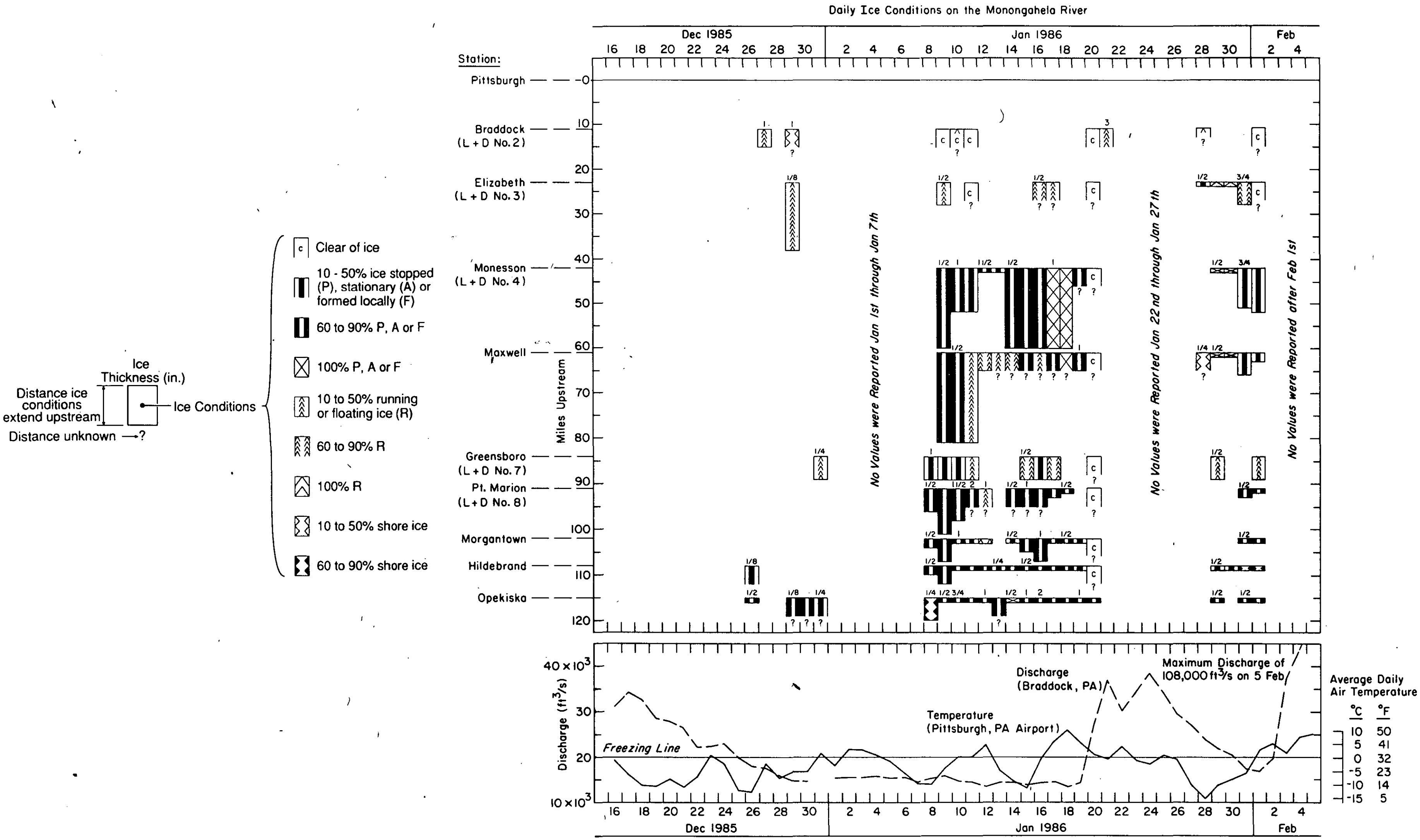
These comparisons show that when the river appeared black on an image and had no discernible textures and patterns, the river was open (ice free). It is possible, however, that thin, transparent ice, which appears black from above and cannot be distinguished from open water in Landsat images, covered part or all of particular river reaches in some instances. Ice conditions that appear gray on Landsat images can vary from fragmented ice (usually thin) with large, interspersed open areas to ice floes, pans or slush mixed with open areas. The gray tone usually had a patchy or mottled appearance, or showed textures or patterns.

When the river appeared white (or nearly white), ice conditions could vary from solid to



a. Allegheny River.

Figure 2 . Daily ice conditions observed during the 1985–86 winter with air temperatures (U.S.Department of Commerce 1985 and 1986) and river discharges (U.S. Department of the Interior 1985 and 1986).



b. Monongahela River.

Figure 2 (cont'd).

fragmented ice (usually thicker than gray ice). A white tone could include scattered open water areas that are smaller than the Landsat sensor IFOVs, or fewer open water areas than occur where a gray tone is observed. A white tone could also mean that the ice was snow-covered. For example, thin ice in a Landsat scene may be transparent, appear black and be classified as open water. This same ice cover viewed after a light snowfall would appear white.

RESULTS

Ice conditions from ground observations

The Corps and NWS ice observations for the winters from 1979–80 through 1985–86 (Appendix A) were examined to determine the dates of initial ice formation and final clearance of ice on the Allegheny and Monongahela Rivers. First ice occurred as early as 19 December and as late as 20 January on the Allegheny, and as early as 21 December and as late as 3 February on the Monongahela. Final ice was observed as early as 8 February and as late as 20 March on the Allegheny, and as early as 20 January and as late as 4 March on the Monongahela.

Although ice formed on the rivers during all seven winters, the severity of the ice conditions varied each season. Both rivers had the least ice cover in the 1982–83 winter, and the most in 1983–84. During four of the winters, ice formed on the Allegheny River earlier than on the Monongahela, and during all seven winters, ice remained on the Allegheny from 1 to 20 days longer than on the Monongahela. An inspection of the total number of days that ice was observed at each of the L&D sites revealed that approximately the lower 20 miles of the Monongahela and the lower 10 miles of the Allegheny River have the fewest number of days with ice.

The type and structure of ice given in the ice code (Table 1) made it possible to note the times and locations of ice jams and the frequency of running or stationary ice throughout the winter. Also, we could statistically summarize the percent of ice coverage on the rivers.

Ice jams were recorded on the Allegheny at the following locations (Fig. 1): above Rimerton in January 1981, above Mosgrove in March 1982, at Parker in January 1985, and near Natrona in February 1985. An ice jam was observed on the Monongahela in January 1984 at Maxwell.

Ice on both rivers is generally in motion; there are frequently changing intervals of either solid or partial ice cover with occasional occurrences of open water throughout the winter. A comparison between complete and partial ice covers indicates that, on the Allegheny River above Rimerton, a complete ice cover occurs approximately during 75% of the total days when ice is reported. In contrast, below Acmetonia, a complete ice cover is observed during only about 27% of the total days. On the Monongahela River near Opekiska, a complete ice cover occurs during about 70% of the days when ice is reported, and near Elizabeth and Braddock, about 21%.

Comparisons of river ice observations

It is clear that information on ice type (including movement), thickness and structure (Table 1) can only be obtained by ground observations, although inferences regarding some of these characteristics could be made from aerial videotapes by an experienced interpreter. Because of the dynamic nature of river ice and the limited view upstream of a ground observer, the ground observations apply only for the location near the observation site and only as far upstream as is visible, although the ice conditions as seen near the dams were usually assumed to persist upstream. Sometimes other upstream observers reported ice conditions beyond the view of the observer at the locks and dams.

The aerial videotapes give more accurate information on the areal coverage and extent of different ice types than do the ground observations. Landsat images also show the areal distributions of ice as do the videotapes, but with much less detail and frequency. We have compared data from these three data sets collected during 1984–85 and 1985–86 to illustrate their advantages and disadvantages.

Winter of 1984–85

Ground observers reported ice on the Allegheny River for 49 days from 10 January to 25 February (Fig. A6) and on the Monongahela River for 37 days from 14 January to 20 February (Fig. A13). Ice was observed on videotapes taken of the lower 7 miles of the Allegheny River on 11 days from 23 January to 24 February. A 28 February tape showed no ice. Ice was apparent on videotapes of the lower 66 miles of the Monongahela River taken on five days from 28 January to 24 February. A 16 January Landsat image was the only one taken this entire winter when ice was present. There were no days this winter when ground observations, videotapes and Landsat images were acquired on the same day.

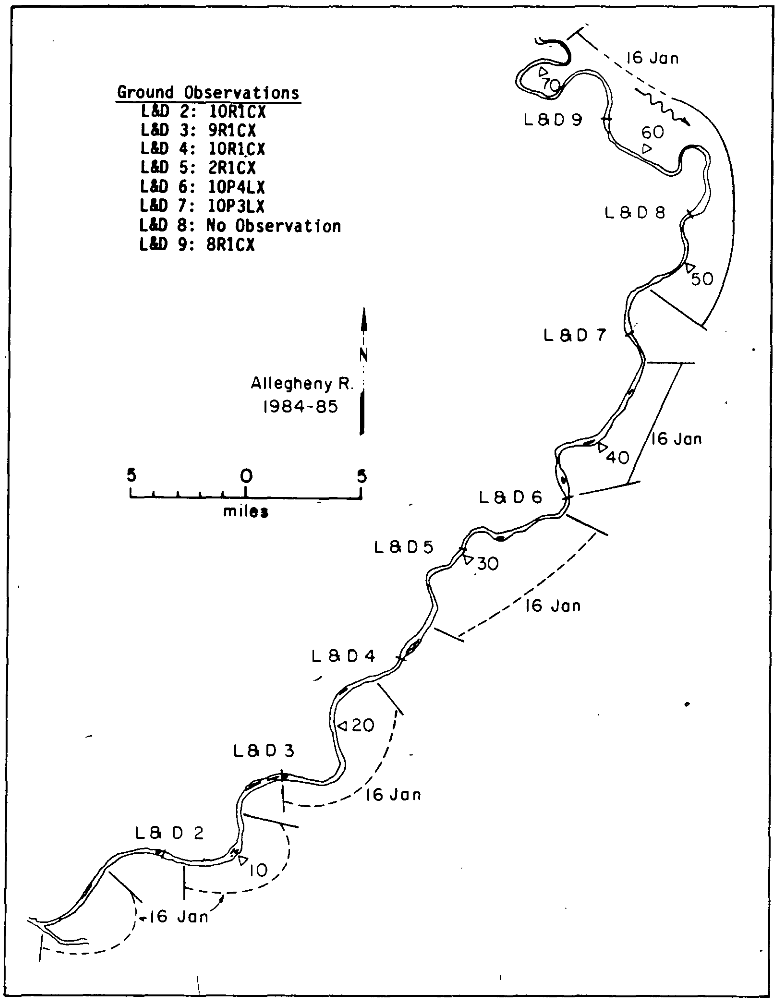
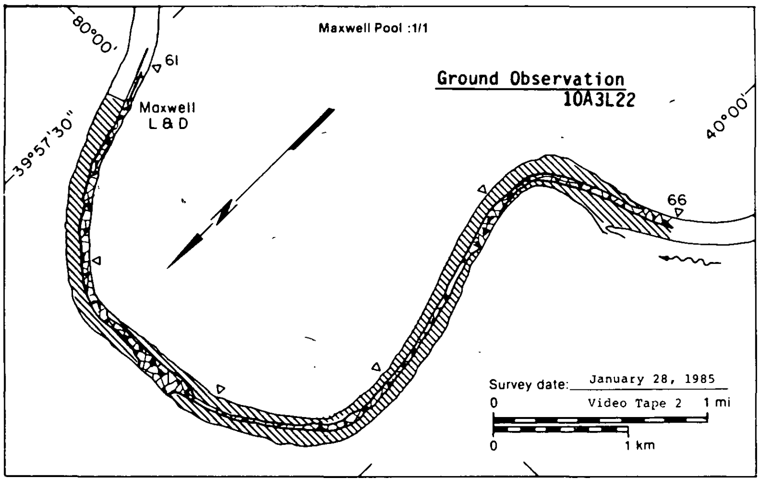


Figure 3. Ice conditions on the Allegheny River on 16 January 1985 as observed by ground observers and on a Landsat image (dashed line is gray ice, solid line is white ice).

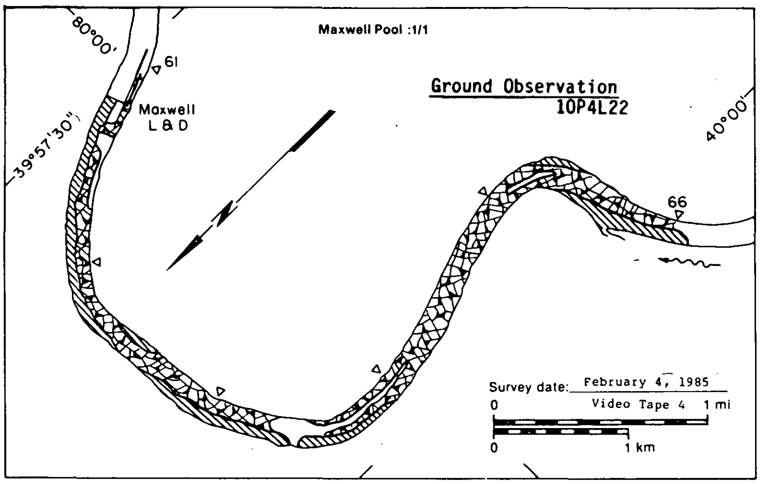
The 16 January Landsat image showed that 70% of the Allegheny River below L&D 6 was covered with gray ice and 30% was open (Fig. 3). White ice and gray ice covered 88% of the river upstream of L&D 6 to river mile 72, while 12% of this section was open. Ground observations made on 16 January at the four L&D sites below L&D 6 showed 1-in.-thick, clear, running ice covering 20–100% (average coverage 80%) of the river some unknown distance upstream from each site. Between L&D 6 and L&D 8 was 3- to 4-in.-thick, layered, stopped ice covering all of the river and extending upstream an unknown distance. Above L&D 9 (some unknown distance) was 1-in.-thick, clear, running ice covering 80% of the river.

The gray ice apparent on the Landsat image was composed of this thin, clear, moving ice, while the white ice consisted of the thicker, layered ice that was stopped. When used together, Landsat and ground observations provide details of the ice and its extent upstream not available from either source alone.

The 16 January Landsat image showed only 6 miles of gray ice on the Monongahela River above Opekiska L&D. The ground observation at Opekiska L&D showed shore ice, 1/2 in. thick and clear, covering 70% of the river some unknown distance upstream. Ground observers also reported 1/8- to 1/4-in.-thick, clear, locally formed ice and shore ice covering 10% of the river for unknown distances upstream of L&D 7, L&D 8 and



a. 28 January 1985.



b. 4 February 1985.

Figure 4. Ice conditions on the lower 5 miles of Maxwell Dam pool, Monongahela River, as observed on videotapes and by ground observers (see Table 3 for definitions of ice symbols).

Morgantown L&D. No other ground observations were made. It is not surprising that this thin, clear ice below Opekiska L&D was not apparent on the Landsat image.

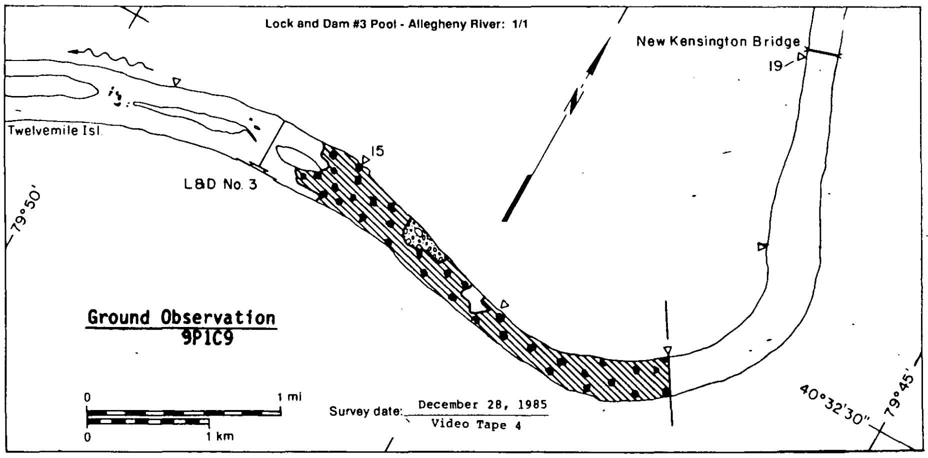
Ice conditions 5 miles upstream of Maxwell L&D on the Monongahela River as observed from videotape and the ground were compared for 28 January and 4 February. The videotape from 28 January shows 69% of this reach covered with solid ice, 28% with fragmented ice with interspersed open areas and 3% open water. The ground observer at Maxwell reported 100% of the river covered with stationary ice, 3 in. thick and layered, and extending 22 miles upstream (Fig. 4a). The 4 February tape shows 27% of this reach covered with solid ice, 62% covered with fragmented ice with interspersed open areas and 11% being open water (Fig. 4b). A Maxwell ground observer reported on 4 February that 100% of the river was covered with stopped ice that was 4 in. thick and layered, extending 22 miles upstream.

For the first 5 miles upstream of Maxwell L&D, the tapes and ground observations showed nearly complete ice cover on both dates, with the ground observer reporting stationary ice on 28 January and stopped ice on 4 February. This suggests that the ice was moving between 28 January and 4 February, which would explain why the 4 February tape (Fig. 4b) showed more fragmented ice than the 28 January tape (Fig. 4a). As with Landsat and ground observations, the videotapes and ground observations are also complementary and provide a more detailed view of ice conditions than either one alone.

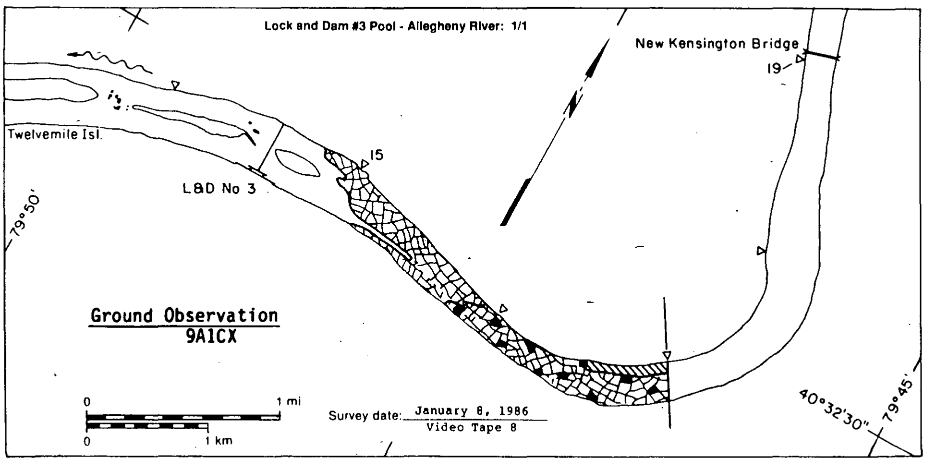
Winter of 1985–86

Ground observers reported ice on the Allegheny River for 63 days from 19 December to 19 February (Fig. 2a, A7) and on the Monongahela River for 39 days from 26 December to 1 February (Fig. 2b, A14). Videotapes were taken of the lower 17 miles of the Allegheny River and of the lower 13 miles of the Monongahela River on 9 days when ice was apparent from 28 December to 28 January. Landsat images taken on 3 and 19 January and 4 and 20 February were not useful because the ground was cloud-covered. The only Landsat image that showed ice was taken on 8 March 1986, after the last videotape was taken and the last ground observation was made.

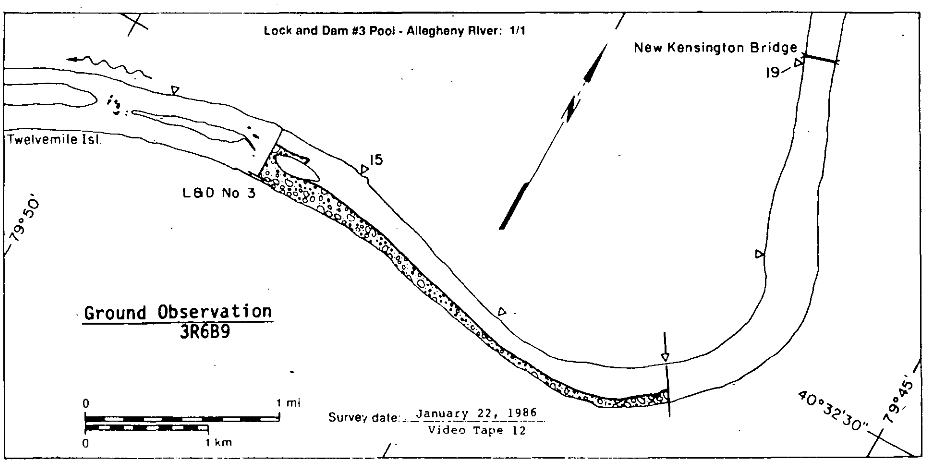
The 8 March Landsat image showed gray ice on 92% of the Allegheny River above L&D 8, on



a. 28 December 1985.



b. 8 January 1986.



c. 22 January 1986.

Figure 5. Ice conditions on the lower 2.5 miles of L&D 3 pool, Allegheny River, as observed on videotapes and by ground observers (see Table 3 for definitions of ice symbols).

32% of the Allegheny at L&D 4 pool, and on 11% of the Monongahela River at L&D 2 pool. Since no ground observations or videotapes were taken on this day, we cannot compare them to the Landsat-derived data. However, we can compare data from videotapes and ground observations from other days.

Ground observers at the Allegheny River L&D 3 would have a visual range of at least 2.5 miles upstream of the dam, which is the extent of the videotape coverage for this pool. On 28 December 1985, the videotape showed 82% of this reach covered by solid ice with interspersed open areas, 4% covered by ice floes, slush and pans, and 14% open water (Fig. 5a). The ground observer reported 90% of the river covered with 1-in.-thick, clear ice that was stopped, and that extended upstream 9 miles. On 8 January, the videotape showed 4% solid ice, 33% fragmented ice, 37% fragmented ice with interspersed open areas, and 26% open water (Fig. 5b). The ground observer reported a 90% cover of stationary, 1-in.-thick, clear ice that extended an unknown distance upstream. On 22 January (Fig. 5c), video showed 39% covered with ice floes, slush and pans, and 61% open water. The ground observer reported 30% coverage with running ice that was 6 in. thick and breaking, and that extended 9 miles upstream.

Computer-generated graphs

It became obvious during preparation of Figure 2 that because of the extensive hand-drafting required, use of the future ground observations would be limited. To expedite preparation of graphs of future data, a computer graphics program was developed to use the same ice codes as were used to prepare the hand-drawn graphs. In the computer-generated graphs (Fig. 6; Appendix A), the order of the L&D locations is reversed (see Fig. 1), the ice code symbols are slightly different (see Fig. 2), and ice thicknesses were not included because of space limitations. The use of a multi-colored diagram will allow thickness to be added (Bilello et al. 1988).

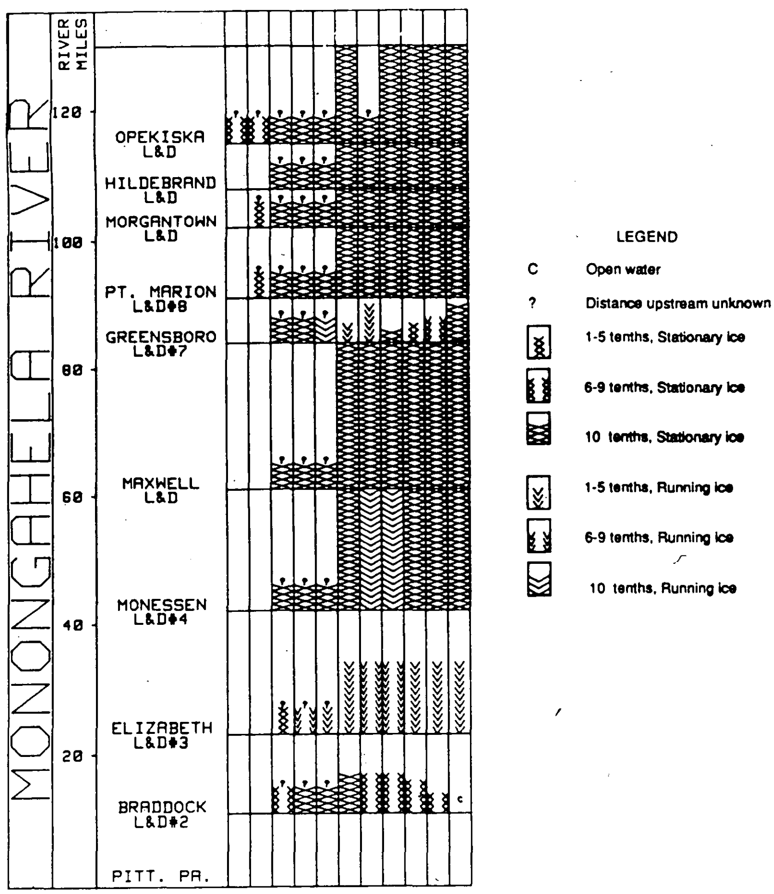


Figure 6. Part of the computer-generated diagram of daily ice conditions, Monongahela River, January 1985.

SUMMARY AND CONCLUSIONS

The river ice conditions on the Allegheny and Monongahela Rivers were highly variable, as shown by the graphs of the ground observations. The observed ice was largely in motion, although there was much stationary ice and major periods of open water. The graphs provide a convenient way of showing these wide variations, in space and time.

Each method of observation—ground, aerial video and Landsat—has certain advantages and disadvantages (Table 4). Ground observations have the advantage that data on thickness, movement and structure can be frequently obtained, and, generally, ground observations are not affected by the weather. The major limitation of ground observation is the line-of-sight of the observer, which is often no more than several miles. Given the wide variability of ice conditions, this limitation can be critical.

Aerial video observation has the advantages of providing detailed views of large river reaches, at frequent intervals, and at reasonable cost. The video image is relatively easy to interpret, but training or experience is essential. The disadvantages are the lack of ice thickness and the adverse effect of bad weather, especially low cloud ceilings. Given these restrictions, aerial video is perhaps the best means of closely observing ice conditions on large rivers and, when combined with ground observations, the two methods provide an excellent means of recording and analyzing river ice.

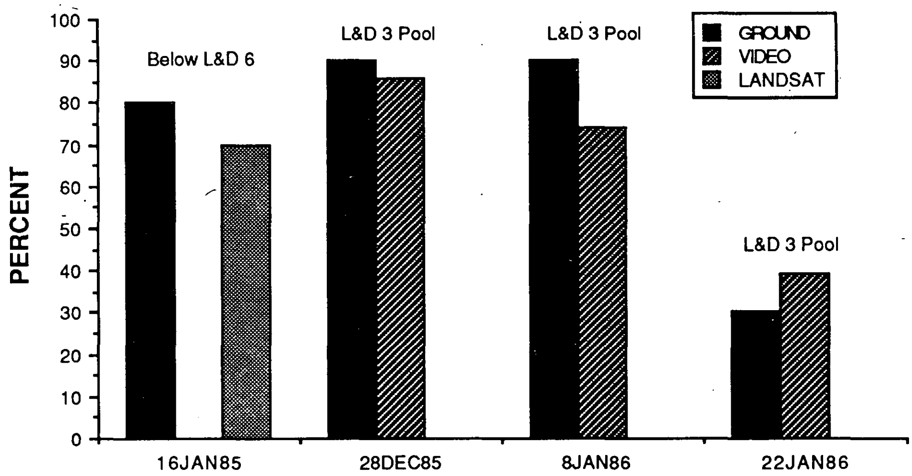
Landsat imagery has the advantage of providing images of large reaches of a river that can be easily interpreted. There is a good data base of usable images starting in 1972. Disadvantages are the infrequent coverage, the obscuration by clouds and poor resolution of the images, which limit the level of detailed information. Thin, clear ice, for example, is often undetected. Ice conditions determined from Landsat are recorded as either white or gray in tone so that ice details that are obtained by either ground observers or aerial videos are not apparent from Landsat images.

Despite differences in the detail obtainable from the three methods, they generally agree on the overall extent of ice coverage. For example, the total percentage of selected pools covered by ice as determined on selected dates is shown in Figure 7. It can be seen that, except for 16 January 1985 on the Monongahela River, the methods are within 15% of each other. The Landsat observation on 16 January 1985 (Fig. 7b) indicates much more ice than the ground observation.

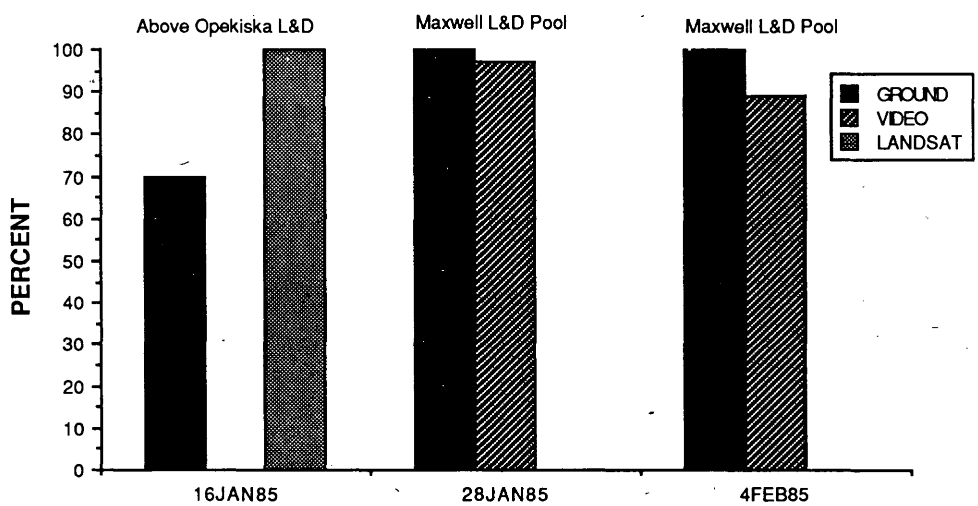
This study has illustrated the importance of three observation techniques for monitoring river-ice conditions. Each method provides useful data and, when analyzed together, they give a more

Table 4. Advantages and disadvantages of the three data sets.

	Advantages	*Disadvantages*
Landsat	– Synoptic view of large reaches of the river	– Poor IFOV gives limited, not detailed information
	– Good data base of images since 1972	– Infrequent acquisition – Cloud cover can obscure river
	– Easy to interpret images	– Snow cover obscures ice
Video	– View of large reaches of the river	– Cannot provide ice thickness
	– Good IFOV gives as much detail as is required	– Cannot acquire tapes if cloud ceiling is too low
	– Easy to interpret, but experienced interpreter is required	– Snow cover obscures ice
	– Frequent acquisition	
Ground	– Detailed ice data	– Limited horizontal view
	– Frequent observations	– Data quality depends on observer
	– Not weather-dependent	– Data must be graphed to be useful



a. Allegheny River.



b. Monongahela River.

Figure 7. Percent of river ice cover as observed on the ground, from videotapes and from Landsat images.

complete understanding of a dynamic river-ice regime than would be possible with one method alone.

With the computer-graphics capability developed for this study, there may be increased use of the ground observations if they are quickly graphed and available for rapid dissemination where navigation on ice-prone rivers throughout the winter is required. This potential for expanded use of these data may result in the receipt of better and more complete information from the ice observers.

LITERATURE CITED

Bates, R.E., D. Saboe and M. Bilello (1968) Ice conditions and prediction of freeze-over on streams in the vicinity of Ft. Greely, Alaska. USA Cold Regions Research and Engineering Laboratory, Special Report 121.

Bilello, M.A., J.J. Gagnon and S.F. Daly (1988) Computer-generated graphics of river ice conditions. Hampton, Virginia: Science and Technology Corporation, STC Technical Report 2280.

Canadian Coast Guard (1986) Ice maps for Trois Rivieres Sorel et Grondines. Quebec, Canada: Garde Cotiere, Bureau des Glaces.

Gatto, L.W. (1985) Ice conditions on the Ohio and Illinois Rivers, 1972–85. *IEEE International Geoscience and Remote Sensing Symposium Digest*, **2**:856-961.

Gatto, L.W., and S.F. Daly (1986) Ice conditions along the Allegheny, Monongahela and Ohio Rivers, 1983–84. USA Cold Regions Research and Engineering Laboratory, Internal Report 930 (unpublished).

Gatto, L.W., S.F. Daly and K.L. Carey (1986) Ice atlas, 1984–85, Ohio, Allegheny and Monongahela Rivers. USA Cold Regions Research and Engineering Laboratory, Special Report 86-23.

Michel, B. (1971) Winter regime of rivers and lakes. USA Cold Regions Research and Engineering Laboratory, Monograph III-B1a.

Starosolszky, O. (1985) Ice and river engineering. In *Developments in Hydraulic Engineering-3* (P. Novak, Ed.). New York: Elsevier Applied Science Publishers, pp. 175–219.

U.S. Department of Commerce (1985 and 1986) Climatological Data, Pennsylvania—Monthly and Annual Summaries. Asheville, N.C.: National Oceanic and Atmospheric Adminstration Environmental Data Service, National Climatic Center.

U.S. Department of Interior (1985 and 1986) U.S. Geological Survey—Water Resources Data for Pennsylvania. Water year 1985 and 1986, Allegheny River at Natrona, Pennsylvania, and Monongahela River at Braddock, Pennsylvania.

APPENDIX A: ICE CODE RECORDS AND COMPUTER-GENERATED GRAPHS OF DATA

LEGEND

C	Open water
?	Distance upstream unknown
	1-5 tenths, Stationary ice
	6-9 tenths, Stationary ice
	10 tenths, Stationary ice
	1-5 tenths, Running ice
	6-9 tenths, Running ice
	10 tenths, Running ice

Allegheny River

1979-80

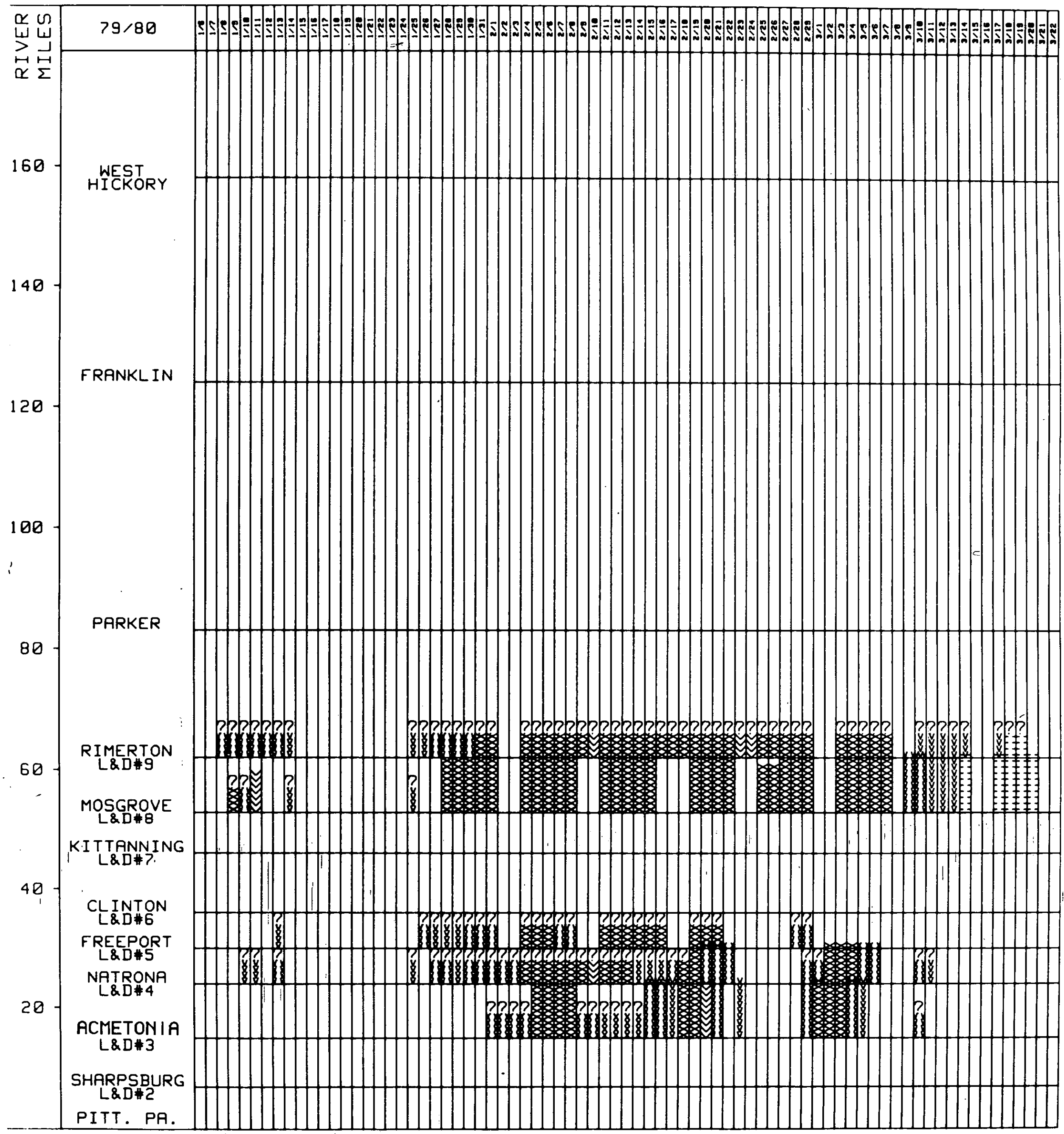
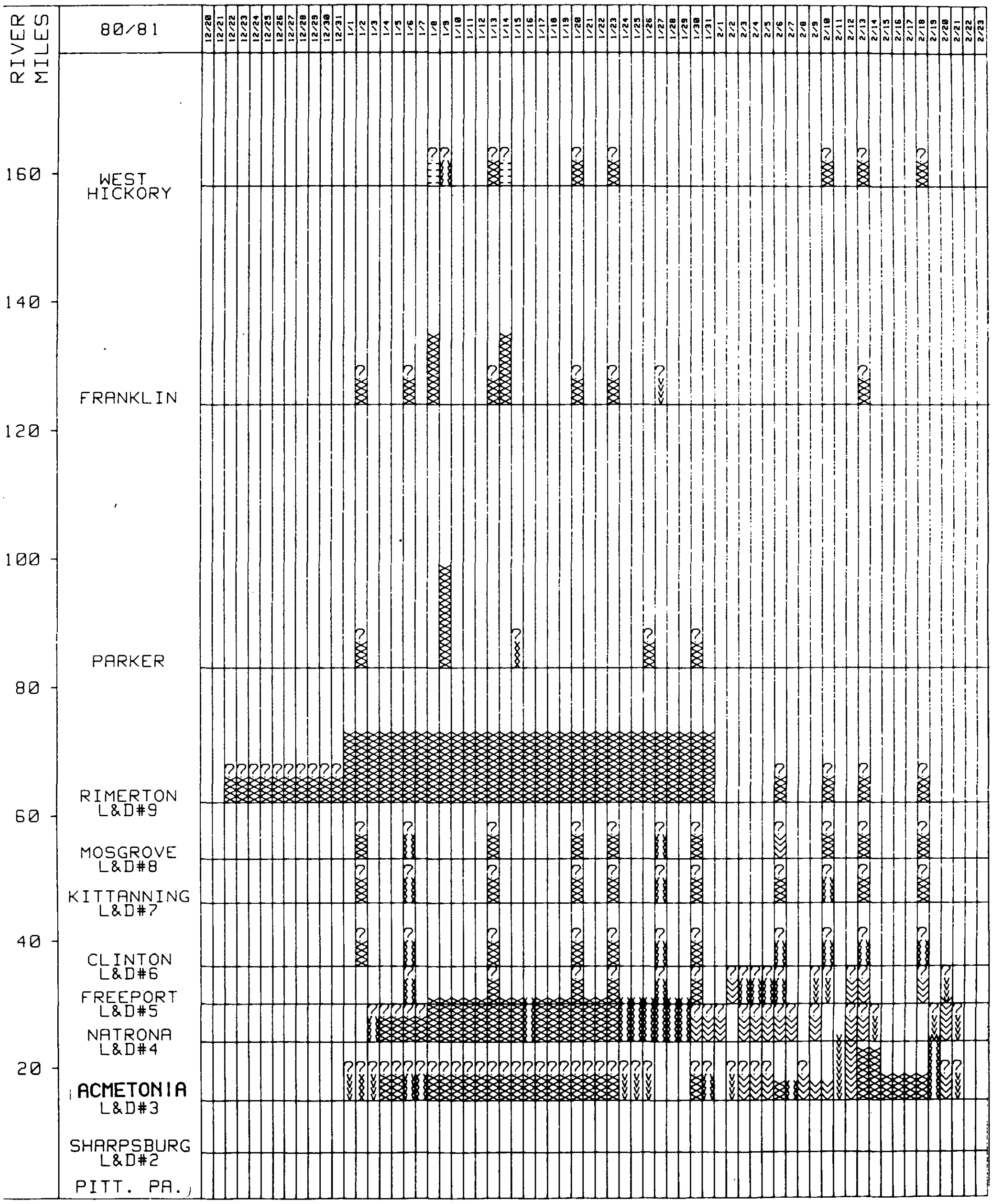


Figure A1.

DATE	SHRPSBRG	ACMTONIA	NATRONA	FREEPORT	CLINTON	KITTANNG	MOSGROVE	RIMERTON	PARKER	FRANKLIN	W. HICK
1/6											
1/7											
1/8								9R1CX			
1/9							10P1LX	9R1CX			
1/10			5R1CX				8R1CX	9R1CX			
1/11			1R1CX				10J3L6	6R1CX			
1/12								6R1CX			
1/13			9R2TX	2R2CX				6R1CX			
1/14							1R1CX	1R1CX			
1/15											
1/16											
1/17											
1/18											
1/19											
1/20											
1/21											
1/22											
1/23											
1/24											
1/25			1R1CX				5R1CX	4R1CX			
1/26				8R1CX				4R1CX			
1/27			8R1CX	5R1CX				9R1CX			
1/28			6R1CX	5R1CX			10P3C8	9R1CX			
1/29			5R1CX	5R1CX			10P3C8	9R1CX			
1/30			8R1CX	8R1CX			10P3C8	9R1CX			
1/31			8R1CX	9R1CX			10P3C8	10J3LX			
2/1		7P2CX	8R1CX	8R1CX			10P3C9	10J3LX			
2/2		7P2CX	9R1CX								
2/3		9P2CX	9R2CX								
2/4		9P2CX	10P2CX	10P1CX			10P5C9	10J5LX			
2/5		10A2C9	10P2CX	10P1CX			10P5C9	10J5LX			
2/6		10A2C9	10P2CX	10P1CX			10P5C9	10J6LX			
2/7		10A2C9	10P2CX	8R1CX			10P5C9	10J6LX			
2/8		10A2C9	10P2CX	8R1CX			10P5C9	10J6LX			
2/9		7A2CX	10P2CX					10J6LX			
2/10		6A4CX	10R1CX					10J6LX			
2/11		5P4CX	10P1CX	10P2CX			10P6C9	10J6LX			
2/12		5P4CX	10P1CX	10P3CX			10P6C9	10J6LX			
2/13		5P4CX	10P1CX	10P3CX			10P6C9	10J6LX			
2/14		5P5CX	5P2CX	10P3CX			10P6C9	10J9LX			
2/15		6R4B9	5P4CX	10P3CX			10P6C9	10J9LX			
2/16		6R4B9	5P4CX	10P3CX				10J9LX			
2/17		4R4B9	7P4CX					10J9LX			
2/18		10P4C9	10P4CX					10J9LX			
2/19		10P4C9	10P4C6	10P3CX			10P6C9	10J9LX			
2/20		10R4C9	8P4C6	10P3CX			10P5C9	10J9LX			
2/21		8R6C9	8P4R6	10P2CX			10P5C9	10J9LX			
2/22			8P4T6				10P4C9	10J9LX			
2/23		3R2T9						10J9LX			
2/24								10J9LX			
2/25							10P4C7	10J9LX			
2/26							10P4C7	10J9LX			
2/27							10P4C8	10J9LX			
2/28				9R1CX			10P4C8	10J9LX			
2/29		9R1C9	9R1CX	9R1CX			10P4C8	10J9LX			
3/1		10P1C9	9R2CX								
3/2		10P2C9	10P2C6								
3/3		10P2C9	10P2C6				10P5X8	10J10LX			
3/4		8P2C9	10P2C6				10P5X8	10J10LX			
3/5		5R2T9	8P2T6				10P4X8	10J10LX			
3/6			7P2T6				10P4X8	10J10LX			
3/7							10P4X8	10J10LX			
3/8											
3/9							9R4X9				
3/10		7R4TX	9R2TX				8R4T9	1R5LX			
3/11			1R2TX				5R4T9	1R5LX			
3/12							5R4T9	5R1CX			
3/13							5R4T9	3R2LX			
3/14							2S4T9	1R2LX			
3/15											
3/16											
3/17							2S4T9	1R3TX			
3/18							2S4T9	1S4TX			
3/19							2S4T9	1S2TX			
3/20							1S4T9				
3/21											
3/22											


RIVER MILES
80/81
160
140
120
100
80
60
40
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WEST HICKORY
FRANKLIN
PARKER
RIMERTON L&D#9
MOSGROVE L&D#8
KITTANNING L&D#7
CLINTON L&D#6
FREEPORT L&D#5
NATRONA L&D#4
ACMETONIA L&D#3
SHARPSBURG L&D#2
PITT. PA.

Figure A2.

DATE	SHRPSBRG	ACMTONIA	NATRONA	FREEPORT	CLINTON	KITTANNG	MOSGROVE	RIMERTON	PARKER	FRANKLIN	W. HICK
12/20											
12/21											
12/22								10F2CX			
12/23								10F2CX			
12/24								10F2CX			
12/25								10F2CX			
12/26								10F2CX			
12/27								10F2CX			
12/28								10F2CX			
12/29								10F2CX			
12/30								10F2CX			
12/31								10F2CX			
1/1		1R3CX						10F1C10			
1/2		1P3CX			10F1XX	10F1XX	10F1XX	10F1C10	10J10XX	10J10XX	
1/3		5R3CX	6R1CX					10F5C10			
1/4		10P1CX	10P1CX					10F5C10			
1/5		10P2CX	10F2LX					10F5C10			
1/6		9R2CX	10F3LX	8P3XX	8P3XX	9P3XX	9P3XX	10F5C10		10J10XX	
1/7		6P2CX	10F3LX					10F6C10			
1/8		10P3CX	10F4L6					10F6C10		10J30L10	10S12LX
1/9		10P4CX	10F4L6					10F6C10	10P20X15		7R10XX
1/10		10P4CX	10F5L6					10F6C10			
1/11		10P5CX	10F6L6					10F6C10			
1/12		10P5CX	10F7L6					10F8C10			
1/13		10P6LX	10F7L6	10P6XX	10P6XX	10P6XX	10P6XX	10F8C10		10J10XX	10J10XX
1/14		10P9LX	10F7L6					10F8C10		10J30L10	1S1XX
1/15		10P9LX	10F7L6					10F8C10	5P10BX		
1/16		10P9LX	9F7L6					10F8C10			
1/17		10P9LX	10F7L6					10F8C10			
1/18		10P7LX	10F7L6					10F8C10			
1/19		10P7LX	10F7L6					10F9C10			
1/20		10P7LX	10F7L6	10P5XX	10P5XX	10P5XX	10P5XX	10F9C10		10J10XX	10J10XX
1/21		10P7LX	10F7L6					10F9C10			
1/22		10P7LX	10F6L6					10F9C10			
1/23		10P7LX	10F6L6	10P6XX	10P6XX	10P6XX	10P6XX	10F9C10		10J10XX	10J10XX
1/24		2R7TX	7F6L6					10F9C10			
1/25		2R7TX	7F6L6					10F9C10			
1/26		1R7TX	7F6L6					10F9C10	10A8XX		
1/27			7F6L6	8R6XX	8R6XX	8R6XX	8R6XX	10F9C10		3R8XX	
1/28			7F6L6					10F9C10			
1/29			6F5L6					10F7C10			
1/30		10P1CX	10R1CX	10P4XX	10P4XX	10P4XX	10P4XX	10F7C10	10J10XX		
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2/5		10R2CX	10R1CX	8R3CX							
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2/7		6J6L2	10R1CX								
2/8		10J8LX									
2/9		10J6L2	10R2CX	4R2TX							
2/10		10J6L2		4R2TX	6R5XX	8R5XX	10P5XX	10P5XX			10J8XX
2/11		1R6T9									
2/12		10R1C9	10R2CX	10R1CX							
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2/14		10R1C7	3R1CX								
2/15		10P2L3									
2/16		10J5L3									
2/17		10J5L3									
2/18		10J5L3		10R13TX	8P5XX	10P5XX	10P5XX	10P5XX			10J8XX
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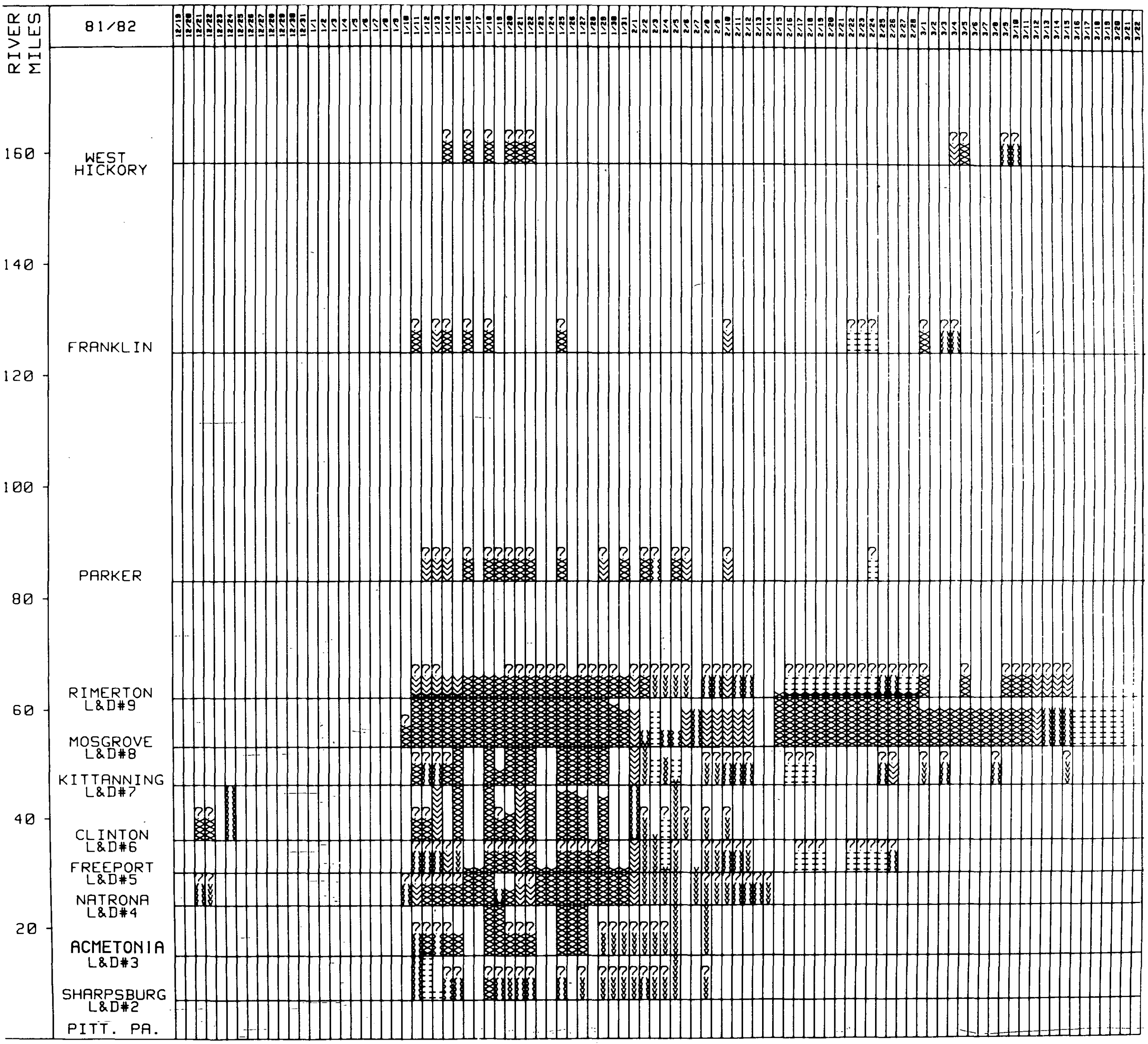
2/22											
2/23											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FRANKLIN
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PARKER
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MOSGROVE L&D#8
KITTANNING L&D#7
40
CLINTON L&D#6
FREEPORT L&D#5
NATRONA L&D#4
20
ACMETONIA L&D#3
SHARPSBURG L&D#2
PITT. PA.

Figure A3.

DATE	SHRPSBRG	ACMTONIA	NATRONA	FREEPORT	CLINTON	KITTANNG	MOSGROVE	RIMERTON	PARKER	FRANKLIN	U. HICK
12/19											
12/20											
12/21			7R1CX		10P1CX						
12/22			2R1TX		10P1CX						
12/23											
12/24					7R2C9						
12/25											
12/26											
12/27											
12/28											
12/29											
12/30											
12/31											
1/1											
1/2											
1/3											
1/4											
1/5											
1/6											
1/7											
1/8											
1/9											
1/10			8R1LX				10P1FX				
1/11	8R2X8	9P5LX	10R3LX	8R1CX	10F4CX	10F3CX	10P3C9	10R2CX		10P1XX	
1/12	10S5L8	10P6LX	10P4CX	9R2CX	10P4CX	8R1CX	10P4X9	10R2CX	10J2XX		
1/13	10S2X1	9L6CX	10P4CX	8R1CX	10R4X9	6R1CX	10P5X9	10R2CX	10J2XX	10J2XX	
1/14	7S4LX	10P6LX	10P5CX	10R5CX		10P3LX	10P6X9	10R1C3	10J2XX	10P2XX	10J2XX
1/15	8P1CX	10P6L3	10P5CX	4R2CX	10P6L9	10P3L7	10P6X9	10R1C3			
1/16			10P5C6				10P6X9	10P4C3	10J2XX	10P2XX	10J2XX
1/17			10P6C6				10P6X9	10P4C3			
1/18	10P6CX	10P8L9	10P7C6	10P10LX	10P8H9	10P5L7	10P7X9	10P4C3	10J2XX	10J2XX	10J2XX
1/19	8P6LX	10P8L9	9J7L2	10P10LX	10J8XX	10J2L2	10P8X9	10P4C3	10J2XX		
1/20	5P6XX	10P8LX	10J7L2	10J10LX	10J8X4	10P5L7	10P8L9	10J8LX	10J2XX		10J2XX
1/21	8P7LX	10P8LX	10R7XX	10J10LX	10J8L9	10P5L7	10P8X9	10J8LX	10J2XX		10J2XX
1/22	8P7LX	10P8LX	10R7XX	10P10LX	10P8L8	10P5L7	10P8C8	10J8LX	10J2XX		10J2XX
1/23			10P7C6				10P9X9	10J8LX			
1/24			10P7C6				10P9X9	10J8LX			
1/25	8P8CX	10P8C9	10P7C6	10P10LX	10P8L8	10P5C7	10P9B9	10J8LX	10J2XX	10P2XX	
1/26		10P9C9	10P7C6	10P10LX	10P8L8	10P6C7	10P9B8	10P8C3			
1/27	3R1CX	10P9C9	10P7C6	10P10LX	10J10L7	10P6C7	10P9C8	10J10LX			
1/28			10P7C6	10P10LX		10P6C7	10P9C8	10J10LX			
1/29	2R1BX	3P7CX	10P7C6	10P10L5	10J10L7	10P5C7	10P10X8	10J10LX	10R2XX		
1/30	1R1BX	3R5XX	10P7C6				10P10X7	10J10LX			
1/31	1R1BX	2R5XX	10P7C6				10J14X6	10P8C3	10P2XX		
2/1	2R7TX	2R7CX	10R7L6	10R8T6	8R8T9	10R8T7	10J14L6	10R12LX			
2/2	9R5LX	3R7LX	3R7L6	4R3T6	2R8TX	1R8T7	9J14T2	10P3CX	10J2XX		
2/3	2R5LX	1R6LX	1R7C6	1R2T6		1S8T4	10J14T6	1R10LX	8S2XX		

DATE	SHRPSBRG	ACMTONIA	NATRONA	FREEPORT	CLINTON	KITTANNG	MOSGROVE	RIMERTON	PARKER	FRANKLIN	U. HICK
2/4	1R4LX	1R7LX	1R6L6	2S2L6	2S8TX	1F8T4	8J14T2	1R8LX			
2/5	1R4X8	1R6X9	1R6T6	3R2TX	1R8X10	1S8T4	8J14T2	1R1CX	10P2XX		
2/6					1R8XX		10J14T6	1R1CX	10J2XX		
2/7			4R6T6				9J14T6				
2/8	1R4CX	4R2C9	1R2LX	5R1CX	4R1CX	5R1CX	10J14T6	9R2CX			
2/9			1R2LX	2R1TX		4R1CX	10J14T6	8R1CX			
2/10			5R1CX	7R1CX	2R1TX	7R1CX	10J10T6	10R1CX	10J2XX	10J2XX	
2/11			8R2LX	9R1CX		7R1CX	10J14T6	9R2LX			
2/12			8R2LX	5R1CX		8R1CX	10J14T6	9R2LX			
2/13			6R2LX								
2/14			4R2LX								
2/15							10P14L9				
2/16						1S8TX	10P14L9	1S12LX			
2/17				1S6TX		1S8TX	10P14L9	1S12LX			
2/18				1S6TX		1S8TX	10P14L9	1S12LX			
2/19				1S6TX			10P14L9	1S12LX			
2/20							10P14L9	1S12LX			
2/21							10P14L9	1S12LX			
2/22				1S6TX			10P14L9	1S12LX		10J10XX	
2/23				1S6TX			10P14L9	1S12LX		10J10XX	
2/24				1S6TX			10P14L9	1S12LX	10J10XX	10J10XX	
2/25				1S6TX		8R1CX	10P14L9	9R1CX			
2/26				9R1CX		10R1CX	10P14L9	9R1CX			
2/27							10P14L9	1S12LX			
2/28							10P14L9	1S12LX			
3/1						5R1CX	10P14L6	10J12XX		10J5BX	
3/2							10P14L6				
3/3						9R1CX	10P14L6			9R5TX	
3/4							10P14L6			9R5TX	10J5XX
3/5							10P14L6	10J12XX			10J5XX
3/6							10P14L6				
3/7							10P14L6				
3/8						9R1CX	10P14L6				
3/9							10P14L6	10J12XX			9R5TX
3/10							10P14L6	10J12XX			9R5TX
3/11							10P14L6	10J12XX			
3/12							10R14L6	10J12XX			
3/13							9R14L6	10J12XX			
3/14							8R14L6	10J12XX			
3/15						1R5TX	6R14X6	10J12XX			
3/16							5S14X6				
3/17							4S14X6				
3/18							3S14X6				
3/19							2S14X6				
3/20							1S14X6				
3/21											
3/22											

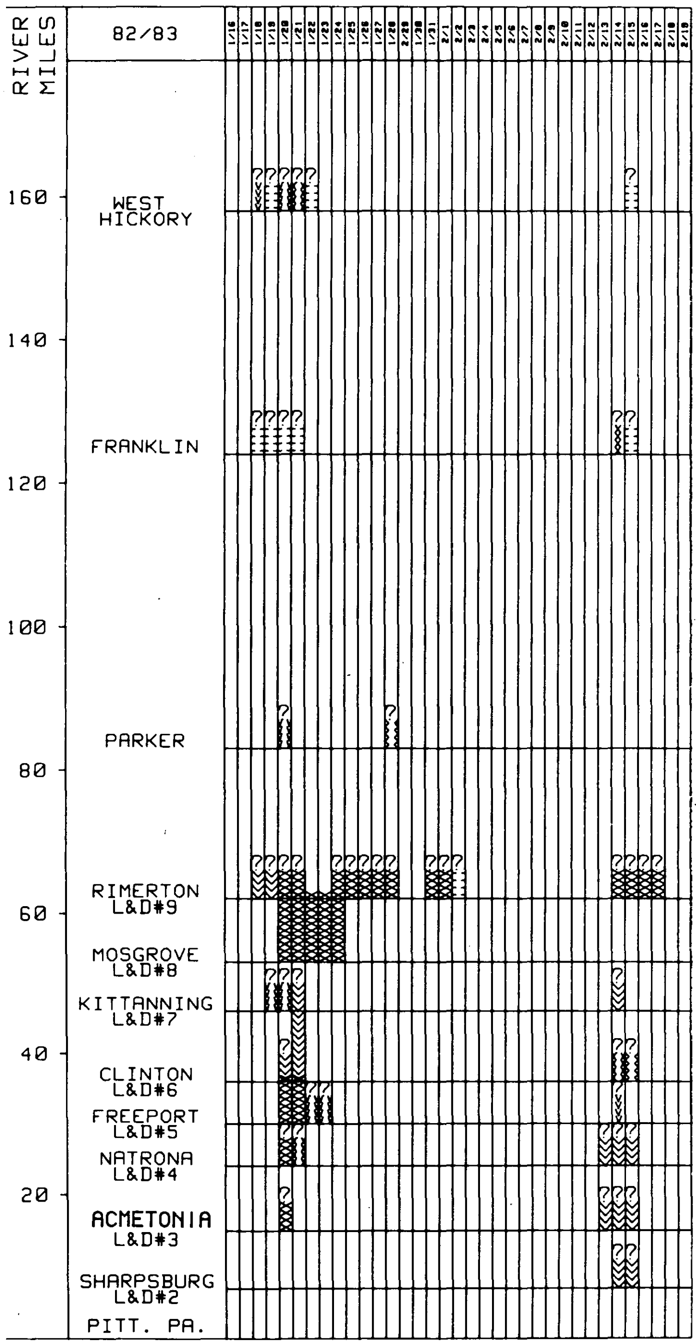
RIVER MILES
82/83
160
WEST HICKORY
140
FRANKLIN
120
100
PARKER
80
RIMERTON L&D#9
60
MOSGROVE L&D#8
KITTANNING L&D#7
40
CLINTON L&D#6
FREEPORT L&D#5
NATRONA L&D#4
20
ACMETONIA L&D#3
SHARPSBURG L&D#2
PITT. PA.

Figure A4.

DATE	SHRPSBRG	ACMTONIA	NATRONA	FREEPORT	CLINTON	KITTANNG	MOSGROVE	RIMERTON	PARKER	FRANKLIN	W. HICK
1/16											
1/17											
1/18								10R1CX		1S1XX	1R1XX
1/19						7R1CX		10R1CX		2S1XX	3S1XX
1/20		10A1CX	10A1CX	10A1C6	10R1CX	7R1CX	10P1C9	10P1CX	8R1XX	4S1XX	7R1XX
1/21			6A1CX	10P1C6	10R1C9	10R1CX	10P1C9	10P1CX		4S1XX	7F1XX
1/22				8R1CX			10P1C9				3S1XX
1/23				8R1CX			10P1C9				
1/24							10P1T9	10P1CX			
1/25								10P1TX			
1/26								10P1TX			
1/27								10P1TX			
1/28								10P1TX	7S1XX		
2/29											
1/30											
1/31								10P1TX			
2/1								10P1TX			
2/2								1S1TX			
2/3											
2/4											
2/5											
2/6											
2/7											
2/8											
2/9											
2/10											
2/11											
2/12											
2/13		10R1CX	10R1CX								
2/14	10R1CX	10R1CX	10R1CX	4R1CX	9F1CX	10R1CX		10P1CX		2F1XX	
2/15	10R1CX	10R1CX	10R1CX		8S1CX			10P1CX		2S1XX	1S1XX
2/16								10P1TX			
2/17								10P1TX			
2/18											
2/19											

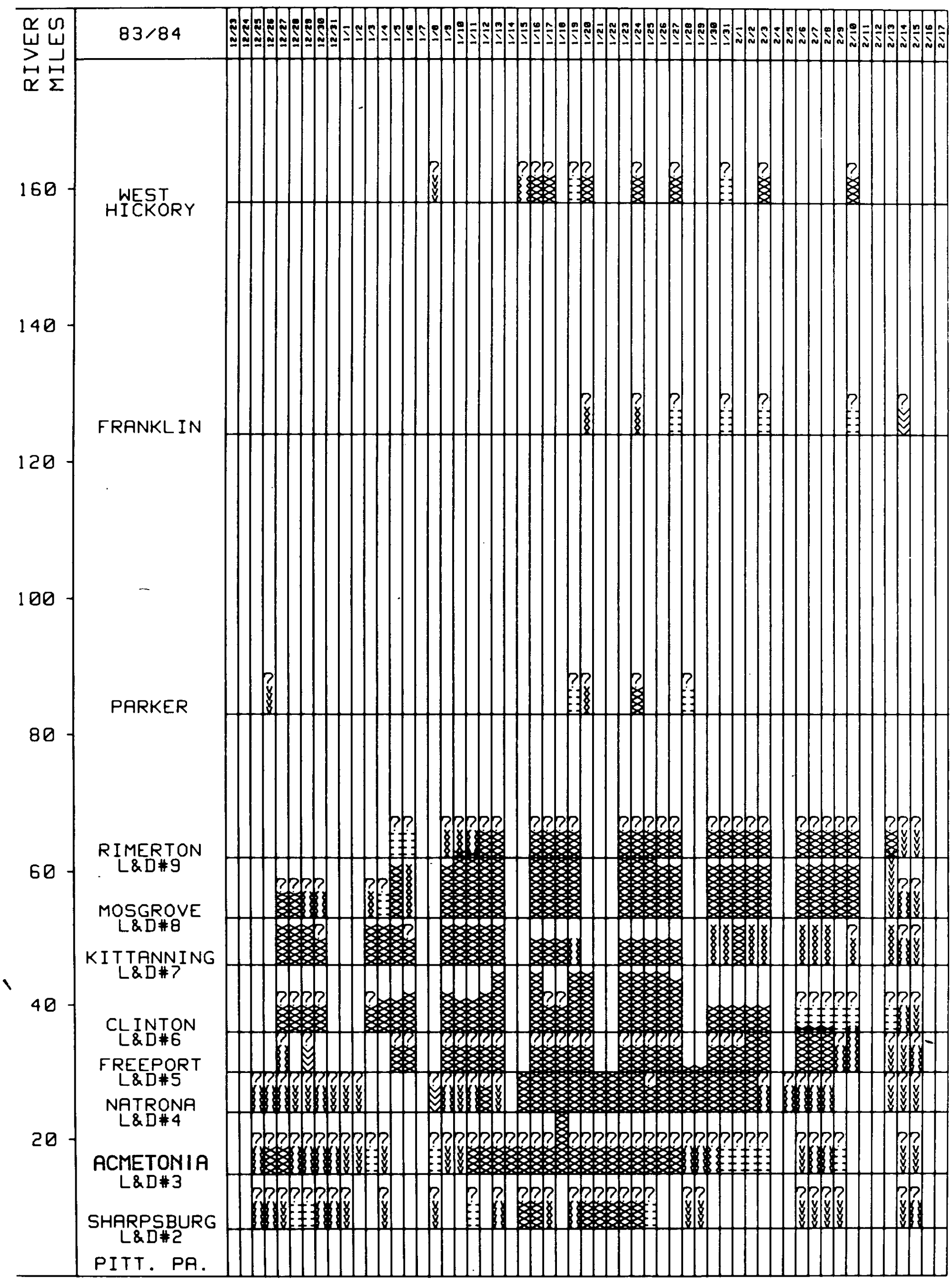
RIVER MILES
83/84
160
WEST HICKORY
140
FRANKLIN
120
100
PARKER
80
RIMERTON L&D#9
60
MOSGROVE L&D#8
KITTANNING L&D#7
40
CLINTON L&D#6
FREEPORT L&D#5
NATRONA L&D#4
20
ACMETONIA L&D#3
SHARPSBURG L&D#2
PITT. PA.

Figure A5.

DATE	SHRPSBRG	ACMTONIA	NATRONA	FREEPORT	CLINTON	KITTANNG	MOSGROVE	RIMERTON	PARKER	FRANKLIN	W. HICK
12/23											
12/24											
12/25	6R1CX	6R1CX	7R1CX								
12/26	9R2CX	10P2CX	8R2CX						4R1XX		
12/27	5R2CX	10P2CX	8R1CX	6A2CX	10A2CX	10P8L5	10P4LX				
12/28	2S4CX	7P2CX	4R1CX		10A2CX	10P8L5	10P4LX				
12/29	3S4CX	7R5CX	1R2CX	10R3TX	10A2CX	10P8L5	9P4LX				
12/30	9R5CX	7R5CX	7R2CX		10A4CX	10P8LX	9P4LX				
12/31	7R5CX	7R5LX	3R2CX								
1/1	2R5CX	3R3CX	1R1CX								
1/2		1R1CX	1R1CX								
1/3		1S3CX			10A5LX	10P8L5	5P4BX				
1/4	1R5CX	1R5CX			10A5L4	10P8L5	3S4BX				
1/5				10A3CX	10A5L4	10P8L5	10J4B7	2S2LX			
1/6				10A3CX	10A5L5	10P8LX	3J4B7	2S2LX			
1/7											
1/8	2R3CX	2S3LX	10R2CX								5R1XX
1/9		1R2TX	7R1CX	10A3CX	10A5L5	10P8C5	10J4B7	4F1CX			
1/10		2R2TX	3R2TX	10A3CX	10A5L4	10P8L5	10J4T9	4F1LX			
1/11	3S3LX	10A1CX	9R1CX	10A3CX	10A5L4	10P8L5	10J4B9	8P1LX			
1/12		10A3CX	10A2CX	10A3CX	10A5L5	10P8L5	10J4B9	10P1CX			
1/13	7R1CX	10A3CX	3R1CX	10A3CX	10A5L8	10P8L5	10J4B9	10P1CX			
1/14		10A3CX									
1/15	10A1CX	10A3CX	10A4C5								8S1XX
1/16	10P1CX	10P4CX	10A4C5	10P3CX	10A5L8	10A1C3	10J4C9	10P3CX			10P1XX
1/17	5P1CX	10P4CX	10P4C5	10P3CX	10A5LX	10A1C3	10J4C9	10P3CX			10J1XX
1/18		10P4C9	10P4C5	10P3CX	10A5LX	10A1C3	10J4C9	10P4CX			
1/19	9P2CX	10P5CX	10P4C5	10P3CX	10A5L8	8A2C3	10J5C9	10A5LX	5S1XX		10J1XX
1/20	10P2CX	10P5CX	10P4C5	10P4CX	10A6L8				1F1XX	3P1XX	10P1XX
1/21	10P3CX	10P6CX	10P5C5								
1/22	10P4CX	10P7CX	10P6C5								
1/23	10P4CX	10P7CX	10P7C5	10P4CX	10A6L8	10A5B3	10J8L9	10A11LX			
1/24	10P4CX	10P7CX	10P7C6	10P4CX	10F6L8	10A5C3	10J8L9	10A11LX	10P1XX	3P1XX	10P1XX
1/25	3S4LX	10P7CX	10P7CX	10A3CX	10F5L8	10A5L3	10J7L9	10A11LX			
1/26		10P7CX	10P7C6	10A3CX	10F5L8	10A5B3	10J9L7	10A11LX			
1/27		10P7CX	10P7C6	10A4CX	10F5L7	10A5P3	10J9L7	10A11LX		2S1XX	10P1XX
1/28	3R4CX	6R5CX	10P7C6						3S1XX		
1/29	1R5CX	8R7CX	10P7C6								
1/30		7S7CX	10P7C6	10A4CX	10F3L3	5P10L5	10J9L7	10A11LX			
1/31		3S7CX	10P7C6	10A4CX	10F3L3	5P10L5	10J9L7	10A11LX		2S1XX	10J1XX
2/1		3S7CX	10P7C6	10A4CX	10F3L3	10P10L5	10J9L7	10A11LX			
2/2		3S7CX	10P7C6	10A4C6	10F4L3	5P10L5	10J9L7	10A11LX			
2/3		3S7CX	7A7CX	10A4C6	10F4L3	5P10L5	10J8L7	10A11LX		2S1XX	10P1XX
2/4											
2/5			7A7CX								
2/6	1R1CX	1R1CX	8R1CX	10A3C6	3S4LX	4P10L5	10J8L7	10A11LX			
2/7	5R1CX	7P4CX	8R1CX	10A3C6	3S4LX	4P10L5	10J8L7	10A11LX			
2/8	4R1CX	6R5CX	8R1CX	10A3C6	3S4LX	4P10L5	10J8L7	10A11LX			
2/9	3R1CX	3S5CX		6A3CX	3S4LX		10A8L7	10A12LX			
2/10				6A2T6	3S4LX	4P4LX	10J8L7	10A12LX		2S1XX	10P1XX
2/11											
2/12											
2/13			1R1TX	1R3TX	3S4LX	4P10L5	3R4L9	10A10LX			
2/14	3R4CX	5R4TX	3R1TX	1R3LX	7R5LX	6R10LX	6P9LX	3R4TX		10R1XX	
2/15	6R4TX	1R6TX	4R1TX	8R4TX	1R6TX	2R5TX	1R9TX	3R2TX			
2/16											
2/17											

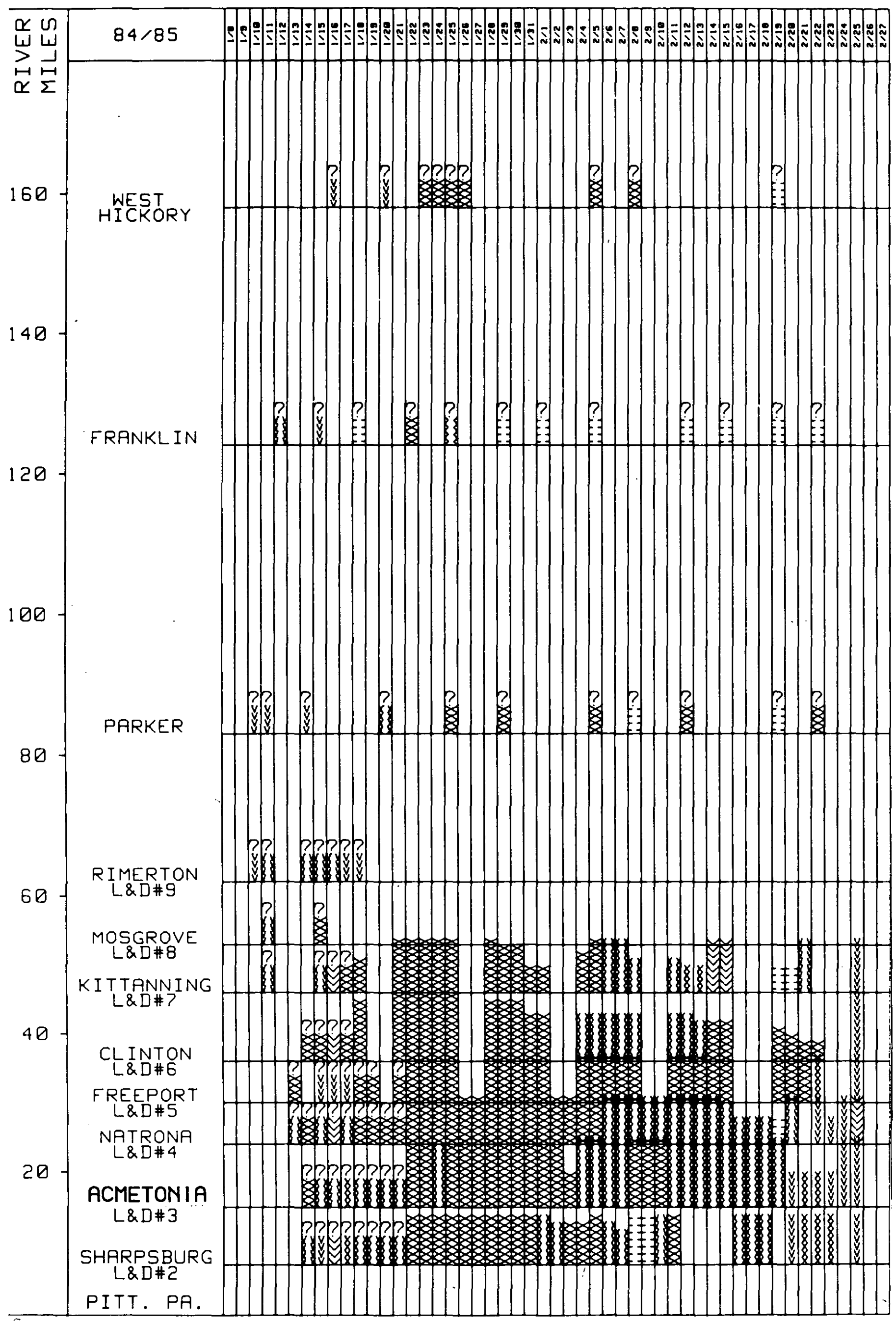
RIVER MILES
84/85
160
140
120
100
80
60
40
20
WEST HICKORY
FRANKLIN
PARKER
RIMERTON L&D#9
MOSGROVE L&D#8
KITTANNING L&D#7
CLINTON L&D#6
FREEPORT L&D#5
NATRONA L&D#4
ACMETONIA L&D#3
SHARPSBURG L&D#2
PITT. PA.

Figure A6.

DATE	SHRPSBRG	ACMTONIA	NATRONA	FREEPORT	CLINTON	KITTANNG	MOSGROVE	RIMERTON	PARKER	FRANKLIN	U. HICK
1/8											
1/9											
1/10								5R2BX	1R1XX		
1/11						8R1CX	8R1TX	8R1TX	2R1XX		
1/12										8R1XX	
1/13			8R1CX	10A1CX							
1/14	7R1CX	10A1CX	10A1CX		10P1CX			6R1CX	1R1CX		
1/15	3R1CX	8A1CX	9R1CX	5R1CX	10P2LX	8R1CX	10A1CX	8R1CX		5R1XX	
1/16	10R1CX	9R1CX	10R1CX	2R1CX	10R4LX	10R3LX		8R1CX			1R1XX
1/17	5A1CX	5A1CX	8R1CX	2R1CX	10P4LX	10P1CX		5R1CX			
1/18	6P1CX	9A1CX	10P2CX	10P2CX	10P4L8	10P1C4		5R1CX		2S1XX	
1/19	6P1CX	9P1CX	10P2CX	10P2CX							
1/20	9P2CX	9P2CX	10P2CX						9P1XX		5R1XX
1/21	9P3CX	9P2CX	10P3CX	10A3CX	10P5L9	10P5C7					
1/22	10P4C6	10P3C9	10P3C6	10A3C6	10P6L9	10P5L7				10P1XX	
1/23	10P4C6	10P3C9	10F4C6	10A3C6	10P7L9	10P5L7					10P1XX
1/24	10P4C6	8J3C8	10F4C6	10A3C6	10P7L9	10P5L7					10P1XX
1/25	10P4C6	10P4C9	10J4C6	10A4C6	10P7L9	10P5L7			10P1XX	6S1XX	10P1XX
1/26	10P4C6	10P4C9	10P4C6								10P1XX
1/27	10P4C6	10P4C9	10P6C6								
1/28	10P4C6	10P4C9	10P6C6	10A4C6	10P7L8	10P5L7					
1/29	10P4C6	10P4C9	10P6C6	10A4C6	10P7L8	10P5L6			10J1XX	2S1XX	
1/30	10P4C6	10P4C9	10P6C6	10A5C6	10P7L8	10P5L6					
1/31	10P4C6	10P4C9	10P6C6	10A5C6	10P6L6	10F4C3					
2/1	8P4C6	10P4C9	10P6C6	10A5C6	10P6L6	10F4C3				5S1XX	
2/2	6P4C5	10P5L9	10P6C6								
2/3	10P4C5	10P5C4	10P6C6								
2/4	10P4C5	8P6C9	10P6C6	10A5C6	6P5L6	10A2C5					
2/5	10P5C6	8P6C9	10P6C6	10A5C6	6P5L6	10A2C7			10J1XX	3S1XX	10P1XX
2/6	8P5C5	8P6C9	9P6C6	10A5C6	6P5L6	8A2C7					
2/7	8P5C4	8P6C9	9P6C6	10A5C6	6P5L6	8A2C7					
2/8	2S5C6	10P6C9	9P6C6	10A5C6	6P5L6	7A2C4			1S1XX		10P1XX
2/9	3S5C6	10P6C9	9P6C6								
2/10	9R1C6	10P6C9	9P7C6								
2/11	10P1C6	8A6C9	8P7C6	10A5C6	6P6L6	7A2C4					
2/12		8A6C9	8P7C6	10A5B6	6P5L6	5A2C3			10P1XX	2S1XX	
2/13		8A6C9	8P7C6	10A5C6	6P4L5	4A2C3					
2/14		8A7C9	8P7C6	10A5C6	10A4L5	10R1C7					
2/15		8A7C9	8P7C5	10A5C6	10P4L5	10R1C7				3S1XX	
2/16	8A1C6	8A7L8	8P7C3								
2/17	8A1C6	8A7C9	8P7C3								
2/18	8A1C6	8A7C9	8P6L3								
2/19		8A7C9	1S4C3	10A5C6	10P4L4	1S1C3			10J1XX	2S1XX	2S1XX
2/20	3R3B6	4R8B4	8R1C6	10A5C6	10P4L3	1S1C3					
2/21	3A3B6	4A8B4		10A5C6	10P4L2	7R1C7					
2/22	3A3B6	4A8B4	1R4T6	2A5T6	10P4L2				10J1XX	1S1XX	
2/23	3A3B6	1R8T4	2R4T3								
2/24		1R6T9	2R3T6								
2/25	5R8T6	4R8T9	10R8T6	3R5T6	3R5T9	3R5B7					
2/26											
2/27											

1985–86

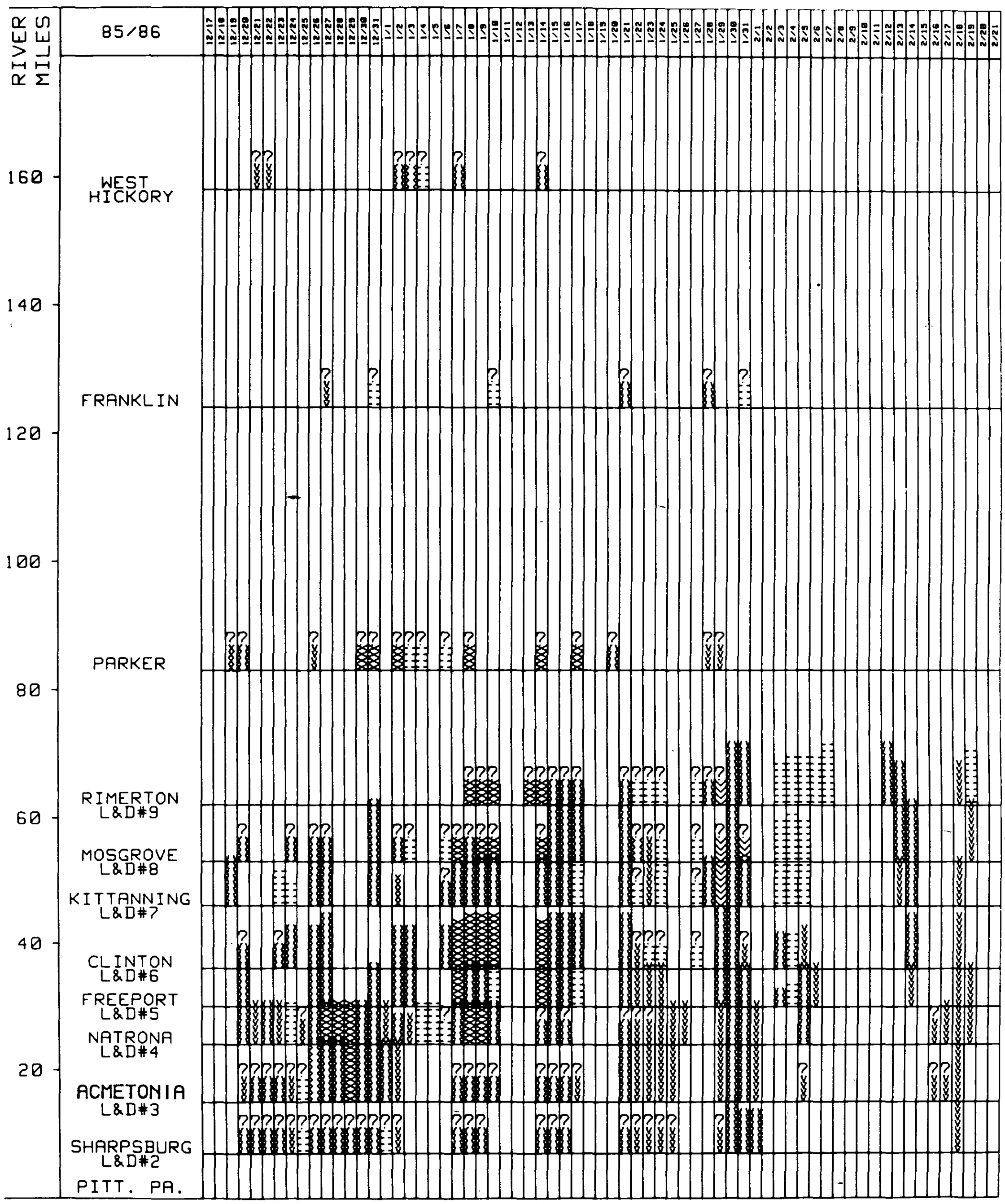

Figure A7.

DATE	SHRPSBRG	ACMTONIA	NATRONA	FREEPORT	CLINTON	KITTANNG	MOSGROVE	RIMERTON	PARKER	FRANKLIN	W. HICK
12/17											
12/18											
12/19						7R1C7			2F1XX		
12/20	6R1CX	5R1CX	6R1C6	9A1C6	9R1CX		9A1CX		6F1XX		
12/21	6R1CX	9R1CX	5R1C6								5R1XX
12/22	8R2CX	9R2CX	6R3L6								5R1XX
12/23	6R2LX	6R2LX	5R3L6		9P2LX	2S3L5					
12/24	1R1LX	1R1LX	1S3L6		9F2L6	2S2L3	6A2CX				
12/25	1S1CX	1S2LX	5P1CX								
12/26	8P2CX	9S1C9	9P2C6	9A1C6	9F2C6	9F2C6	9A3CX		2R1XX		
12/27	8P2CX	9P1C9	10P2C6	9A2C6	9P2L8	9F3C7	9A5CX			3R1XX	
12/28	8P2CX	9P1C9	10P2C6								
12/29	8P2CX	10P1C9	10P2C6								
12/30	8P2CX	9P1C9	9P2C6						10J1XX		
12/31	8F2CX	9P1C9	9P2C6	9A2C6		8F3C6	9A6C9		10J1XX	1S1XX	
1/1	1S5LX	6R2C9	4R2B6								
1/2	5R5LX	1R2C9	7P3C4	9A2C6	9P2L6	2F2L4	7A5CX		10J1XX		9J1XX
1/3			5R3C4	9A2C6	9P2L6		4S3CX		10J1XX		9J1XX
1/4			1S2C6						10J1XX		2S1XX
1/5			1S2C6								
1/6			1S2CX		9P1L6	9R1CX	3S2CX		3S1XX		
1/7	9R1CX	8R1CX	9R1C6	10A1C6	10P1L7	9R1C6	10A3CX				8R1XX
1/8	9A1CX	9A1CX	10A1C6	9R1C6	10P2L8	9R1C7	9A4CX	10P2CX	10J1XX		
1/9	9A1CX	9A1CX	10A1C6	6R1C6	10P2L8	9R2C7	10A5CX	10P2LX			
1/10		9A1CX	6A1C6	1S1C6	10P2L8	9R2B7	10A4CX	10P3LX		3S1XX	
1/11											
1/12											
1/13								10P3LX			
1/14	9R1CX	9A1CX	9R1CX	10A1B6	10P1C7	9R1C7	10P3CX	10P4LX	10J1XX		6F1XX
1/15	9R2CX	9R2CX	9R1C6	9R1C6	9P1C8	9R1C7	9P3C9	9P5LX			
1/16	9R1CX	9A2CX	9R2CX	9A1C6	9P2C8	9R1C7	9P4C9	9P6LX			
1/17		4R2LX		2S1C6	9P2C8	1S3B7	9P4C9	9P6LX	10J1XX		
1/18											
1/19											
1/20									8R1XX		
1/21	9R6TX	9R6T9	8R2TX	9R10T6	9R16B8	9R16B7	9R16B9	8R3LX		7R1XX	
1/22	5R6BX	3R6B9	2R3LX	2R2B6	2R8BX	1S3LX	7S16BX	1S3LX			
1/23	1R6TX	1R6T9	1R3LX	2R2C6	1S8BX	2R8B7	5J16BX	2S3LX			
1/24	1R6TX	1R6T9	2R3L6	1R3T6	1S10PX	2S3L7	4J16BX	2S3LX			
1/25	1R6TX	1R3T9	1R3L6								
1/26			1R3T6								
1/27					1S7BX	1S7BX	1S16BX	1S3LX			
1/28						9R1C7		8R1LX	1R1XX	8R1XX	
1/29	5R1CX	5R1C9	4R1C6	8R1C6	9R4L9	10R2C7	10R2CX	10R2LX	1R1XX		
1/30	6R1T8	7R2T9	8R3T6	8R1T6	9R6L9	9R6L7	9R4C9	9R2L9			
1/31	8R2T6	7R2T9	8R3T6	8R1C6	5R6LX	8R6L7	10R5CX	9R2L9		1S1XX	
2/1	8R2C6	5R4T8	2R1T6								
2/2											
2/3				9J6L2	9J20L5	2S10L7	3S4C6	2S2L6			
2/4				10J8L3	10J10L5	2S8L7	3S4C7	1S2L7			
2/5		3R5LX	7R3T6	9R8T6	1R6T6	1S6L7	3S4C6	1S2L7			
2/6				1R8T6—				1S2L7			
2/7								1S3L9			
2/8											
2/9											
2/10											
2/11											
2/12								6R1C9			
2/13						5R1C7	9R2C9	9R1C6			
2/14				5R1L6	9R2L8	9R2C7	9R3C9				
2/15											
2/16		3R1CX	5R3CX								
2/17		5R1TX	5R3T6								
2/18	2R1T7	3R1T9	1R3T6	5R2T6	1R1T8	1R4L7		2R1L6			
2/19			1R1T6	1R1T6			1R2C9	1S1L8			
2/20											
2/21											

Monongahela River

1979-80

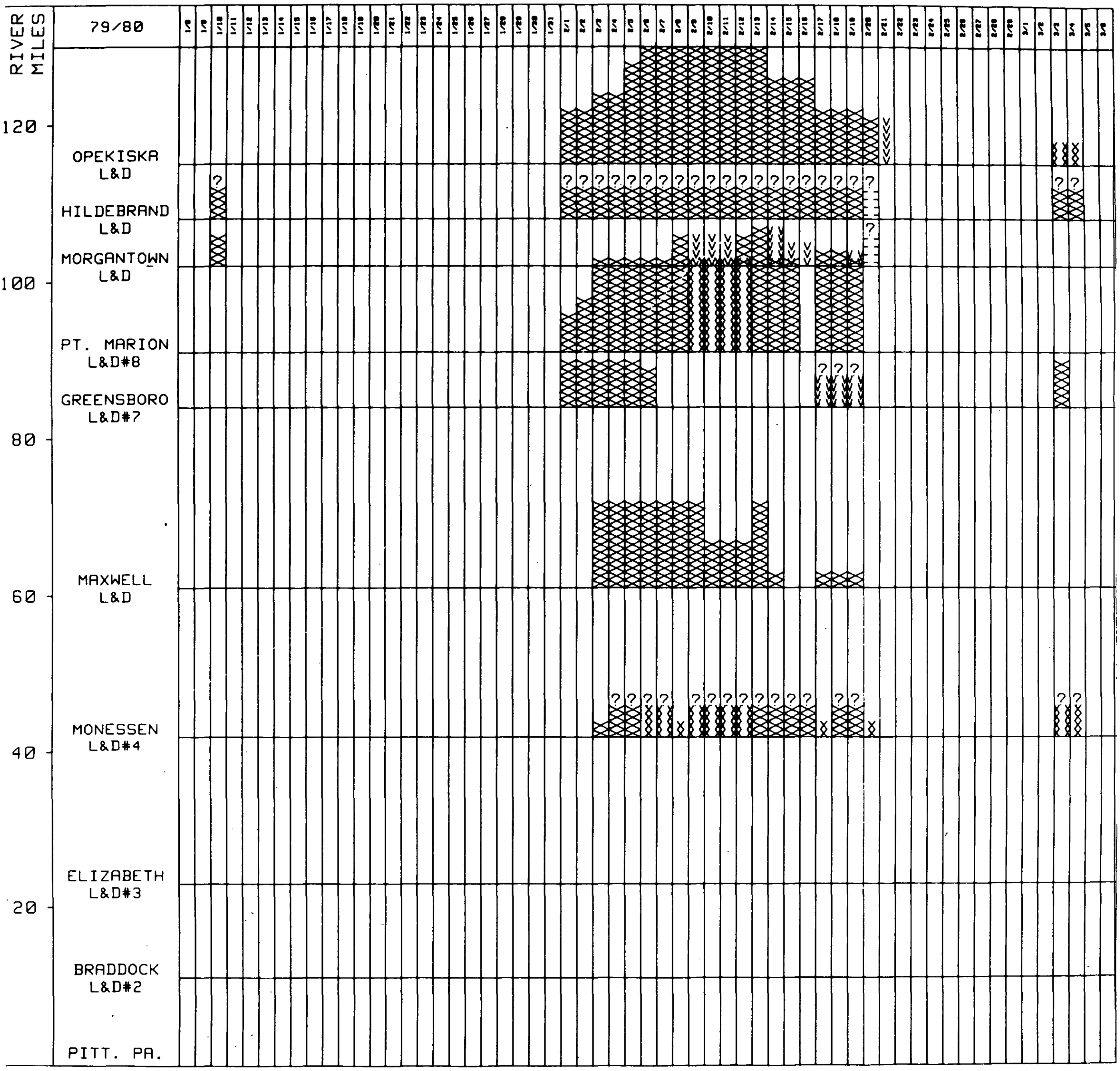

Figure A8.

DATE	BRADDOCK	ELIZBETH	MONESSEN	MAXWELL	GRNSBORO	PT. MAR	MGANTOWN	HLDBRAND	OPEKISKA
1/8									
1/9									
1/10							10A1T3	10A1XX	
1/11									
1/12									
1/13									
1/14									
1/15									
1/16									
1/17									
1/18									
1/19									
1/20									
1/21									
1/22									
1/23									
1/24									
1/25									
1/26									
1/27									
1/28									
1/29									
1/30									
1/31									
2/1					10A1X5	10F1X4		10A1XX	10A1X6
2/2					10A1X5	10A1X6		10A1XX	10A1X6
2/3			10A1X1	10A1X10	10A1X5	10A1X11		10A1XX	10A1X8
2/4			10A1XX	10A1X10	10A2X5	10A1X11		10A1XX	10A1X8
2/5			10A1XX	10A1X10	10A1X5	10A2X11		10A1XX	10A1X12
2/6			3A1XX	10A1X10	10A1B4	10A2X11		10A2XX	10A2X14
2/7			7A1XX	10A1X10		10A1X11		10A2XX	10A2X14
2/8			3A1X1	10A1X10		10A1X11	10A2X3	10A2XX	10A2X14
2/9			9A1XX	10A1X10		9A1T11	5R2X3	10A2XX	10A2X14
2/10			8A1XX	10A2X5		9A1T11	5R2X3	10A2XX	10A2X14
2/11			7A1XX	10A1X5		9A1T11	5R1X3	10A2XX	10A2X14
2/12			9A1XX	10A1X5		9A1T11	10A2X3	10A2XX	10A2A14
2/13			10A2XX	10A1X10		10A1X11	10A2X4	10A2XX	10A3X14
2/14			10A2XX	10A1X1		10A1X11	7R2X4	10A3XX	10A3X10
2/15			10A2XX			10A1X11	5R1X2	10A2XX	10A3X10
2/16			10A2XX				5R1X2	10A2XX	10A3X10
2/17			5A2X1	10A1X1	9R1XX	10A1X11	10A1X1	10A2XX	10A3X6
2/18			10A2XX	10A1X1	9R1XX	10A1X11	10A1X1	10A3XX	10A3T6
2/19			10A2XX	10A1X1	9R1XX	10A1X11	7R1X1	10A3XX	10A3T6
2/20			5A2X1				5S1XX	5S1XX	10A3T5
2/21									5R3T5
2/22									
2/23									
2/24									
2/25									
2/26									
2/27									
2/28									
2/29									
3/1									
3/2									
3/3			7F1XX		10F1X5			10F1XX	7F1X2
3/4			5F1XX					10F1XX	5F1X2
3/5									
3/6									

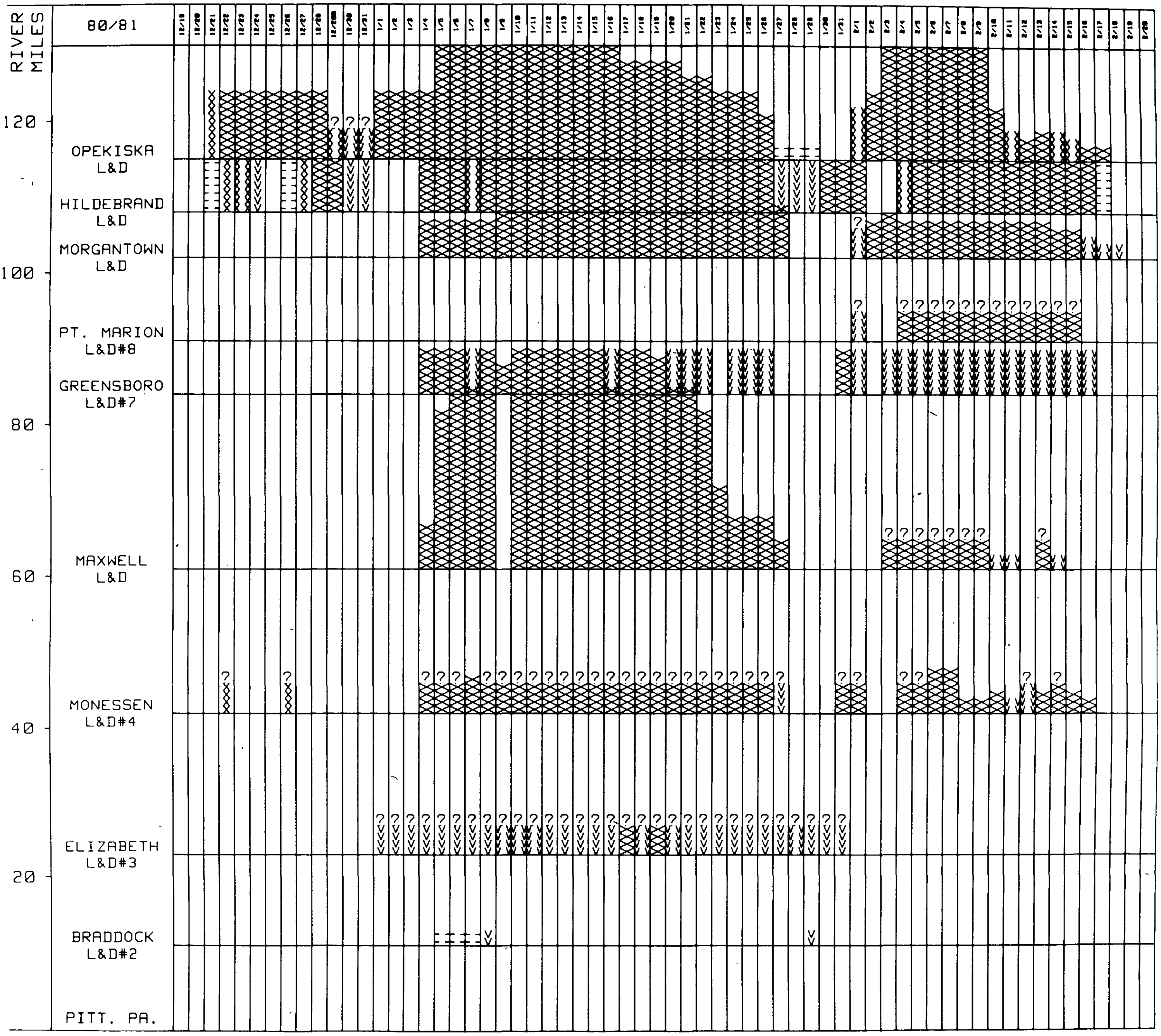
RIVER MILES
80/81
120
OPEKISKA L&D
HILDEBRAND L&D
MORGANTOWN L&D
100
PT. MARION L&D#8
GREENSBORO L&D#7
80
MAXWELL L&D
60
MONESSEN L&D#4
40
ELIZABETH L&D#3
20
BRADDOCK L&D#2
PITT. PA.

Figure A9.

DATE	BRADDOCK	ELIZBETH	MONESSEN	MAXWELL	GRNSBORO	PT. MAR	MGANTOWN	HLDBRAND	OPEKISKA
12/19									
12/20									
12/21								3S1C6	5F1T8
12/22			3F1CX					3F1C6	10P1C8
12/23								7F1X6	10P1C8
12/24								2R1X6	10P1R8
12/25									10P1C8
12/26			3F1CX					5S1C6	10P1C8
12/27								5F1X6	10P1C8
12/28								10P1X6	10P1C8
12/20								10P1X6	9P1TX
12/30								5R1X6	9R1TX
12/31								2R1X6	9R1TX
1/1		5R1XX							10A1T8
1/2		5R1XX							10F1T8
1/3		5R1XX							10A1T8
1/4		5R1XX	10A1XX	10F1X5	10F1X5		10F1X4	10F1X6	10A1C8
1/5	5S1X1	5R2XX	10A1XX	10A1X20	10X1X5		10A1X4	10A1X6	10A2C14
1/6	4S1X1	4R2XX	10A1XX	10A2X23	10A1X5		10A2X4	10A2X6	10A2X14
1/7	5S2X1	5R2XX	10A2X4	10A2X23	8R1X5		10A2X4	8A2X6	10A2X14
1/8	4R1X1	4R3XX	10A3XX	10A2X23	10A1X5		10A3X4	10A2X6	10A2X14
1/9		7R3XX	10A3XX		10A1X3		10A4X5	10A4X6	10A2X14
1/10		7R3XX	10A3XX	10A2X23	10A2X5		10A4X5	10A4X6	10A2X14
1/11		7R3XX	10A4XX	10A2X23	10A2X5		10A4X5	10A4X6	10A3X14
1/12		5R3XX	10A5XX	10A2X23	10A3X5		10A4X5	10A4X6	10A3X14
1/13		3R2XX	10A5XX	10A3X23	10A3X5		10A4X5	10A4X6	10A3X14
1/14		5R3XX	10A5XX	10A3X23	10A3X5		10A4X6	10A4X6	10A3X14
1/15		3R3XX	10A4XX	10A3X23	10A3X5		10A4X6	10A4X6	10A3X14
1/16		2R3XX	10A6XX	10A3X23	9R3B5		10A4X6	10A4X6	10A4X14
1/17		10A5XX	10A6XX	10A3X23	10A2X5		10A4X6	10A5X6	10A4X12
1/18		7R5XX	10A6XX	10A3X23	10A1X5		10A4X6	10A5X6	10A4X12
1/19		10A5XX	10A6XX	10A3X23	10A1X4		10A5X6	10A5X6	10A4X12
1/20		7R6XX	10A7XX	10A3X23	9R1X5		10A4X6	10A5X6	10A4X12
1/21		3R6XX	10A7XX	10A3X23	9R1X5		10A4X6	10A5X6	10A4X10
1/22		2R5XX	10A8XX	10A3X20	9R1X5		10A4X6	10A5X6	10A4X10
1/23		2R5XX	10A8XX	10A3X10			10A4X6	10A4X6	10A4X8
1/24		2R4XX	10A8XX	10A3X6	9R1X5		10A4T6	10A4X6	10A4X8
1/25		1R4XX	10A8XX	10A3X6	9R1X5		10A3T6	10A3X6	10A3X8
1/26		1R4XX	10A8XX	10A3X6	9R1X5		10A3T6	10A3X6	10A2B5
1/27		1R1XX	5R8XX	10A3X3			10A3T6	5R3B6	5S1T1
1/28		7R4XX						2R2B6	5S1X1
1/29	1R2X1	1R1XX						2R2B6	5S1X1
1/30		1R1XX						10F1X6	
1/31		1R1XX	10F1XX		10F1X5			10F1X6	
2/1			10A1XX		9R1X5	9R1XX	9R1XX	10F1X6	9A1C6
2/2							10A1X4		10A1C8
2/3				10F1XX	9R2X5		10A1X5		10A1C14
2/4			10A1XX	10A1XX	9R2X5	10A1XX	10A1X4	9A1X6	10A2X14
2/5			10A2XX	10A2XX	9R2X5	10A2XX	10A2X4	10A2X6	10A3X14
2/6			10A2X5	10A2XX	9R1B5	10A4XX	10A3X4	10A3X6	10A3X14
2/7			10A2X5	10A2XX	9R1X5	10A4XX	10A3X4	10A3X6	10A3X14
2/8			10A2X1	10A2XX	9R1X5	10A4XX	10A3X4	10A3X6	10A2X14
2/9			10A3X1	10A2XX	9R3X5	10A5XX	10A4X4	10A4X6	10A2X14
2/10			10A3X2	8R1T1	9R2X5	10A5XX	10A4X4	10A3X6	10A2L6
2/11			9R3B1	8R1B1	9R2X5	10A4XX	10A3X4	10A2X6	9A2L3
2/12			8R1BX		9R2X5	10A2TX	10A3X4	10A3X6	10A2L2
2/13			10A2X2	10A2XX	9R2X5	10A2XX	10A4X4	10A3X6	10A3L3
2/14			10A3XX	9R1B1	9R1X5	10A2XX	10A3X3	10A3X6	9A3L3
2/15			10A3X2		9R1B5	10A2BX	10A2T3	10A3X6	9A3L2
2/16			10A3X1		8R1B5		8R2T2	10A3X6	10A2L1
2/17							7R2T1	1S1B6	10A1T1
2/18							5R2T1		
2/19									
2/20									

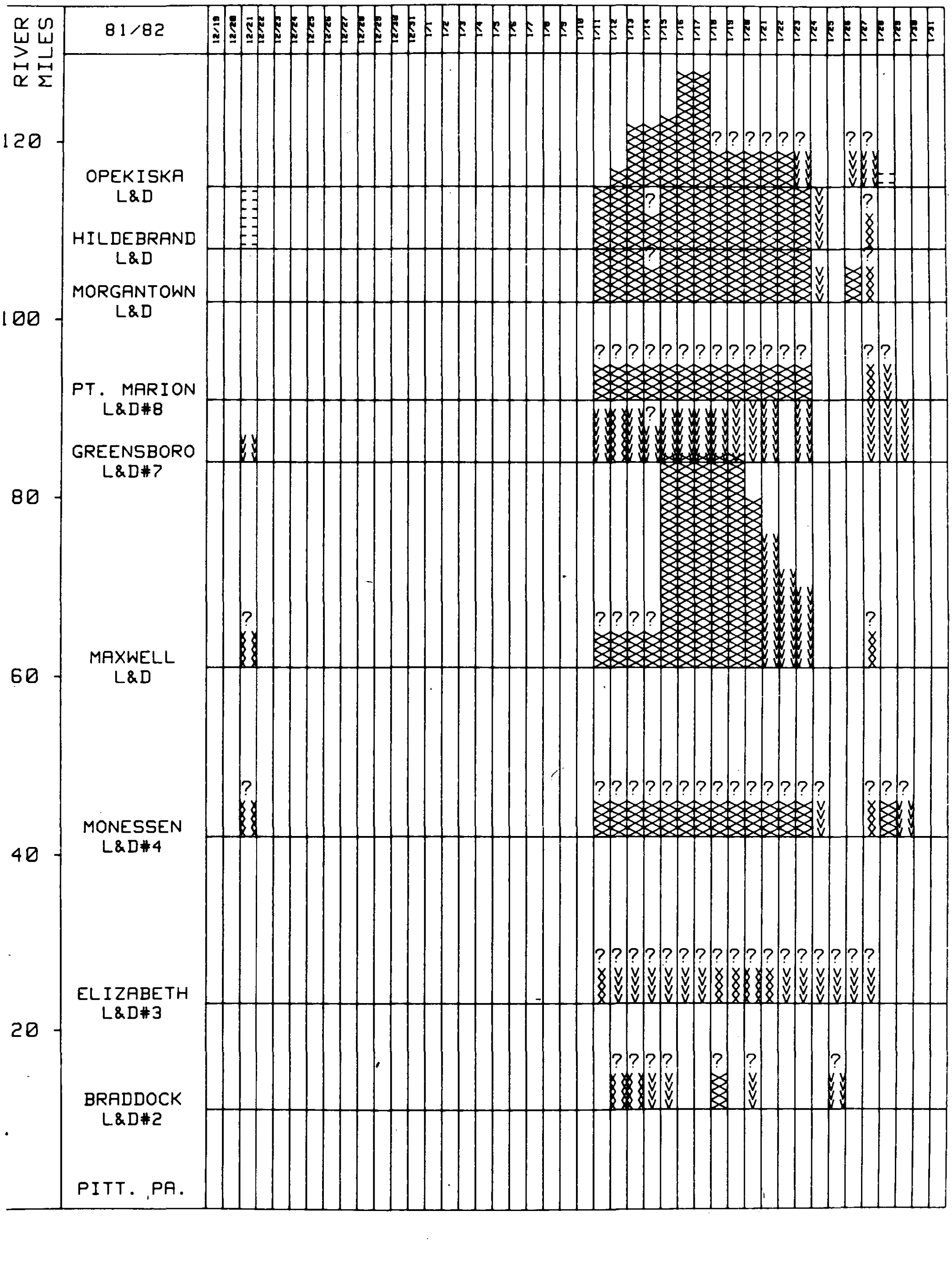
RIVER MILES
81/82
120
OPEKISKA L&D
HILDEBRAND L&D
MORGANTOWN L&D
100
PT. MARION L&D#8
GREENSBORO L&D#7
80
MAXWELL L&D
60
MONESSEN L&D#4
40
ELIZABETH L&D#3
20
BRADDOCK L&D#2
PITT. PA.

Figure A10.

DATE	BRADDOCK	ELIZBETH	MONESSEN	MAXWELL	GRNSBORO	PT. MAR	MGANTOWN	HLDBRAND	OPEKISKA
12/19									
12/20									
12/21			7F1XX	7F1XX	7R1X2			5S1X6	
12/22									
12/23									
12/24									
12/25									
12/26									
12/27									
12/28									
12/29									
12/30									
12/31									
1/1									
1/2									
1/3									
1/4									
1/5									
1/6									
1/7									
1/8									
1/9									
1/10									
1/11		1A2XX	10A1XX	10A1XX	8R1X5	10A1XX	10A1X5	10A1X6	
1/12	8P3HX	1R2CX	10A2CX	10A2CX	8A1L5	10A2CX	10A2C5	10A1C6	10A1H1
1/13	9P3XX	1R1XX	10A2XX	10A2XX	9R1X5	10A2XX	10A2X5	10A2X6	10A1X6
1/14	2R3BX	2R1BX	10A3CX	10A2CX	9R1BX	10A2CX	10A2CX	10A3CX	10A1C6
1/15	1R3XX	3R1BX	10A3LX	10A2L23	9R2B5	10A3CX	10A2C5	10A2C6	10A2C7
1/16		3R1XX	10A3XX	10A2L23	9R2B5	10A4CX	10A2C5	10A3C6	10A2C12
1/17		3R3XX	10A4XX	10A4X23	9R2X5	10A5XX	10A4X5	10A3X6	10A3X12
1/18	10A3CX	3A3BX	10A5LX	10A4L23	7R2B5	10A6CX	10A4C5	10A4C6	10A3CX
1/19		4A4XX	10A5XX	10A4X23	5R3X6	10A6XX	10A4X5	10A4X6	10A4XX
1/20	2R3LX	6P3HX	10A5LX	10A4L18	3R3B6	10A6CX	10A4C5	10A4C6	10A4CX
1/21		4A2XX	10A5XX	9R4X14	9R3X6	10A4XX	10A4X5	10A4X6	10A4XX
1/22		4R2XX	10A5XX	9R4X10		10A5XX	10A5X5	10A5X6	10A3XX
1/23		4R2XX	10A7XX	9R4X8	9R3X6	10A5XX	10A5X5	10A5X6	9R4XX
1/24		4R6XX	4R7XX				2R5X3	2R5X6	
1/25	6R3BX	1R3BX							
1/26		1R2XX					10A1X3		1R1XX
1/27		1R2BX	1F1BX	1F1BX	4R1B6	5F1CX	5F1CX	5F1CX	8R1CX
1/28			10A2XX		3R1X6	3R1XX			5S1T1
1/29			7R2LX		1R1B6				
1/30									
1/31									

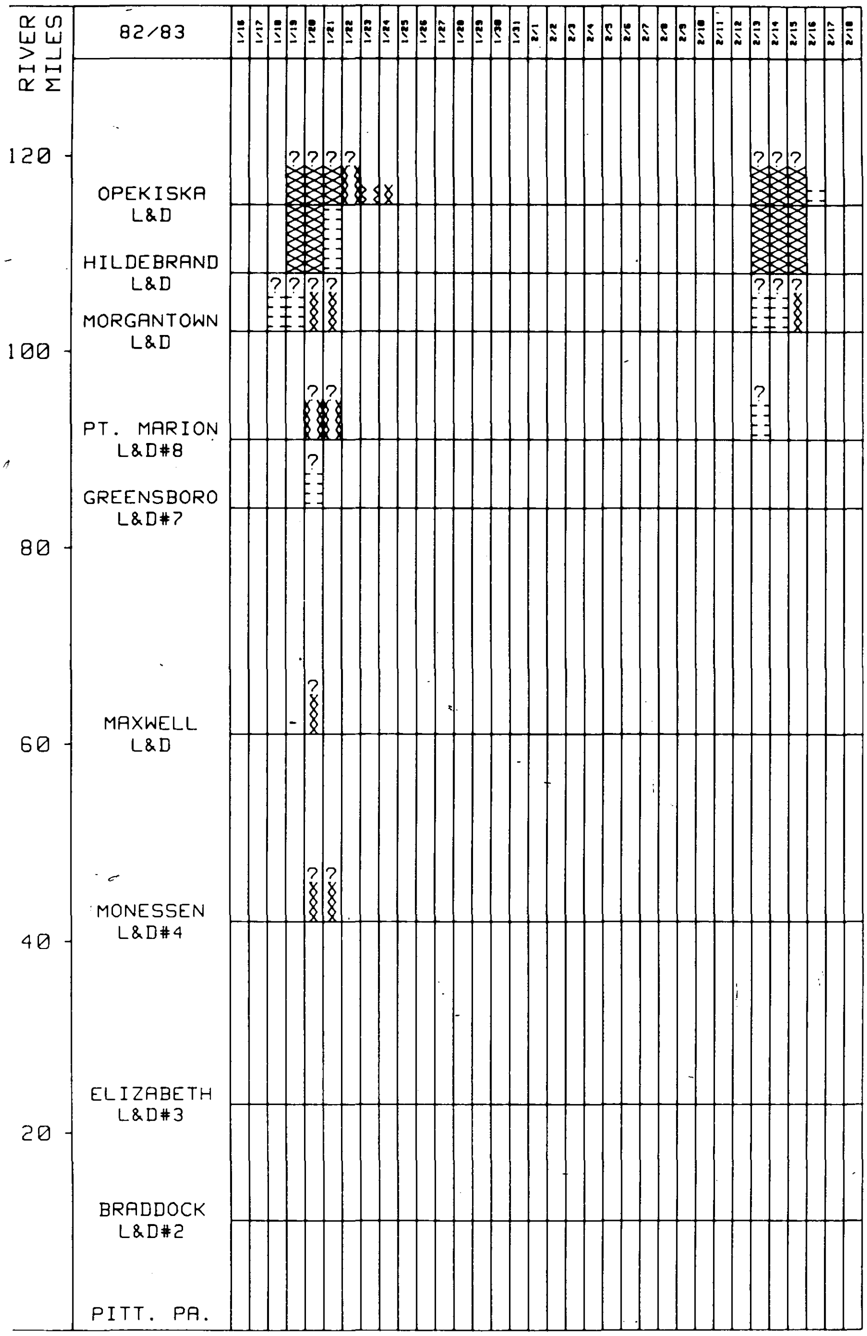
RIVER MILES
82/83
120
OPEKISKA L&D
HILDEBRAND L&D
MORGANTOWN L&D
100
PT. MARION L&D#8
GREENSBORO L&D#7
80
MAXWELL L&D
60
MONESSEN L&D#4
40
ELIZABETH L&D#3
20
BRADDOCK L&D#2
PITT. PA.

Figure A11.

DATE	BRADDOCK	ELIZBETH	MONESSEN	MAXWELL	GRNSBORO	PT. MAR	MGANTOWN	HLDBRAND	OPEKISKA
1/16									
1/17									
1/18							1S1CX		
1/19							1S1CX	10F1C6	10F1CX
1/20			1F1CX	1F1CX	2S1CX	8F1CX	1F1CX	10F1C6	10F1CX
1/21			1F1CX			8F1CX	1F1CX	1S1C6	10F1CX
1/22									9F1CX
1/23									7S1T1
1/24									2F1T1
1/25									
1/26									
1/27									
1/28									
1/29									
1/30									
1/31									
2/1									
2/2									
2/3									
2/4									
2/5									
2/6									
2/7									
2/8									
2/9									
2/10									
2/11									
2/12									
2/13						2S1CX	10S1CX	10F1C6	10F1CX
2/14							10S1CX	10F1C6	10F1CX
2/15							1F1BX	10F1C6	10F1CX
2/16									3S1T1
2/17									
2/18									

1983–84

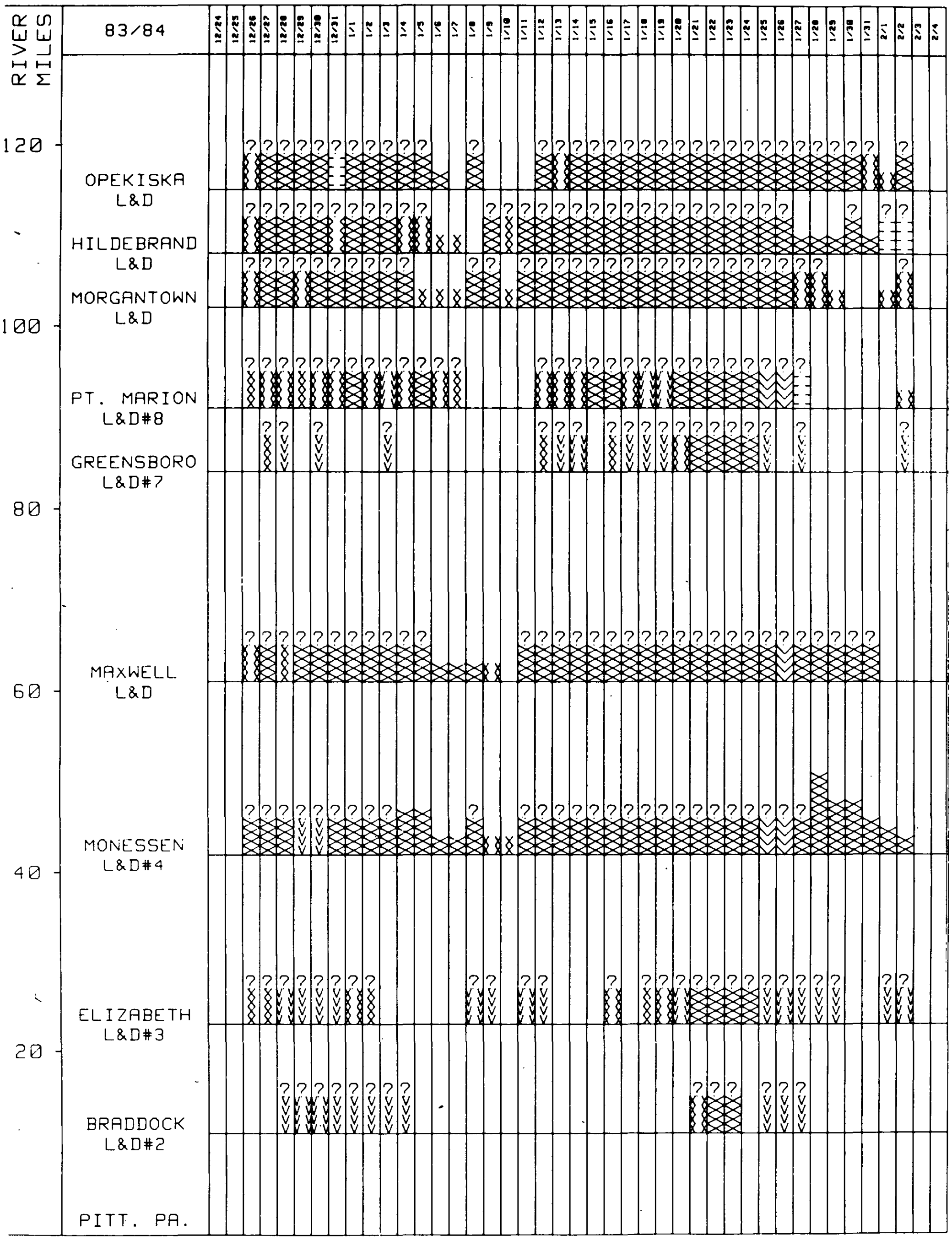

Figure A12.

DATE	BRADDOCK	ELIZBETH	MONESSEN	MAXWELL	GRNSBORO	PT. MAR	MGANTOWN	HLDBRAND	OPEKISKA
12/24									
12/25									
12/26		1F1CX	10F1CX	9F1CX		4F1CX	9F1LX	9F1LX	9F1CX
12/27		4P2BX	10F2BX	10P2BX	1A1BX	9F2CX	10F1CX	10F1CX	10F1CX
12/28	5R2BX	9R2BX	10A2LX	5A2BX	3R1BX	9F2CX	10F1CX	10F1CX	10F1CX
12/29	8R3BX	1R1BX	1R2LX	10A3LX		3P2CX	7F1CX	10F1CX	10F1CX
12/30	8R3BX	4R1BX	4R3LX	10A3LX	5R1BX	9P1CX	10P2CX	10P2CX	10J1CX
12/31	4R3BX	5R1BX	10A3LX	10A4LX		9P2CX	10P2CX	6S2CX	10J2CX
1/1	3R3BX	8A2LX	10A3LX	10A4LX		10J3CX	10P2CX	10F2CX	10J2CX
1/2	2R2TX	2P2BX	10A3LX	10A3LX		9J3LX	10P3CX	10F2CX	10J2CX
1/3	2R2TX		10A3LX	10A3LX	1R1BX	9J3LX	10P3CX	10F2CX	10J2CX
1/4	1R1TX		10A3L4	10A2LX		9J2LX	10P3CX	9F2BX	10P2CX
1/5			10A3L4	10A2LX		10J2BX	1P3T1	7F2TX	10P2CX
1/6			10A2T1	10A2L1		9J2LX	1P2T1	3P2T1	10P2C1
1/7			10A2T1	10A2L1		2J2TX	1P2T1	2P2T1	
1/8		8R1BX	10A3LX	10A2L1			10F1CX		10F1CX
1/9		4R1BX	7A2T1	8P2L1			10F1CX	10F1CX	
1/10			5A2T1				1P1T1	1F1TX	
1/11		7R1BX	10A1CX	10A1CX			10F1CX	10F1CX	
1/12		4R1BX	10A1LX	10A1LX	4A1BX	9A1CX	10F1CX	10F1CX	10F1CX
1/13		-	10A1LX	10A1LX	4R1TX	9F1CX	10F1CX	10F1CX	8F1CX
1/14			10A2LX	10A1LX	8R1TX	9F1CX	10F1CX	10F1CX	10F1CX
1/15			10A2LX	10A1LX		10F2CX	10F1CX	10F1CX	10F1CX
1/16		9A1CX	10A3LX	10A2LX	5F1CX	10F3CX	10F2CX	10F1CX	10F2CX
1/17			10A3LX	10A2LX	5R1CX	9F3CX	10F2CX	10F1CX	10F2CX
1/18		2A2CX	10A3LX	10A2LX	2R1CX	9J3CX	10F2CX	10F1CX	10F2CX
1/19		6A1CX	10A4LX	10A3LX	2R1CX	9J3TX	10F2CX	10F1CX	10F3CX
1/20		8R2CX	10A4LX	10A5LX	8P1CX	10F4CX	10F3CX	10F3CX	10F3CX
1/21	9A1CX	10A1CX	10A5LX	10A5LX	10P1CX	10F4CX	10F3CX	10F3LX	10F3CX
1/22	10P1CX	10P2CX	10P5LX	10P5LX	10F2CX	10F4CX	10F3CX	10F3LX	10F4CX
1/23	10P2CX	10P2CX	10P5LX	10P5LX	10F2CX	10F4CX	10F3CX	10F3CX	10F3CX
1/24		10P2CX	10P5LX	10P5LX	10P2CX	10F4CX	10F3CX	10F3CX	10F3CX
1/25	4R2BX	4R1BX	10J5BX	10P5BX	1R2TX	10J4BX	10F3TX	10F3CX	10F2CX
1/26	3R3BX	6R1RX	10J5BX	10J5BX		10J4BX	10F3TX	10F3TX	10F2CX
1/27	1R1BX	2R1BX	10P5BX	10J5BX	1R1CX	1S1BX	8P1TX	10P3B1	10F2TX
1/28		1R1BX	10P5L8	10J5BX			8J2LX	10P2B1	10P2TX
1/29		1R1BX	10P5L5	10J3BX			9P2L1	10P2T1	10F1TX
1/30			10P5L5	10J3BX				10P2TX	10F1TX
1/31			10P5L3	10J3BX				10P2T1	8F1TX
2/1		2R1BX	10P6L2				7F1C1	10S1CX	8F1T1
2/2		6R1BX	10P5L1		2R1TX	8P1L1	9F1CX	10S1CX	10F1CX
2/3									
2/4									

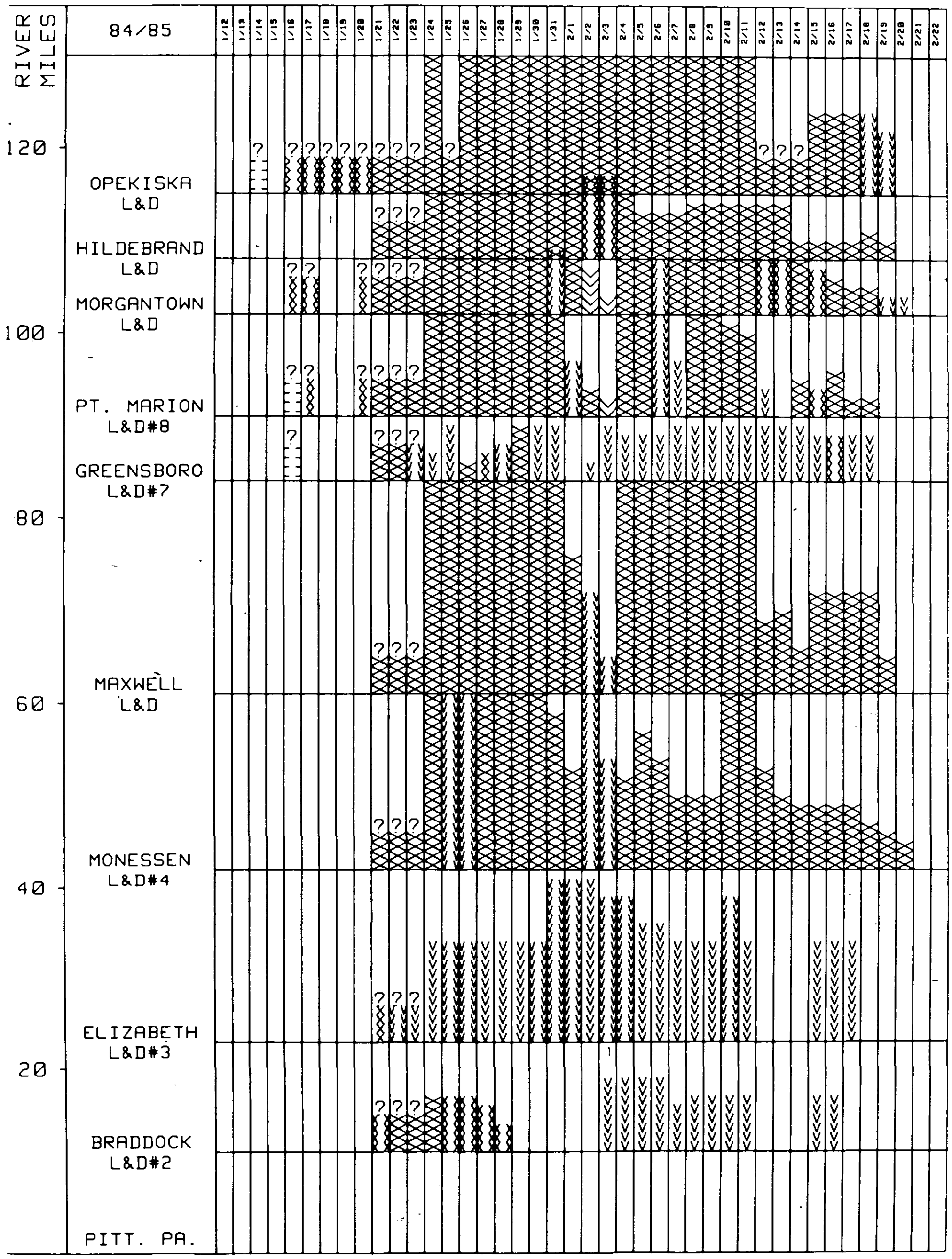
RIVER MILES
84/85
120
100
80
60
40
20
OPEKISKA L&D
HILDEBRAND L&D
MORGANTOWN L&D
PT. MARION L&D#8
GREENSBORO L&D#7
MAXWELL L&D
MONESSEN L&D#4
ELIZABETH L&D#3
BRADDOCK L&D#2
PITT. PA.

Figure A13.

DATE	BRADDOCK	ELIZBETH	MONESSEN	MAXWELL	GRNSBORO	PT. MAR	MGANTOWN	HLDBRAND	OPEKISKA
1/12									
1/13									
1/14									5S1CX
1/15									
1/16					1S1CX	1S1CX	1F1CX		7S1CX
1/17						1F1CX	7F1CX		8F1CX
1/18									8F1CX
1/19									7F1CX
1/20						1F1CX	1F1CX		9A1CX
1/21	9A1CX	2F1CX	10A1CX	10A2CX	10F1CX	10F1CX	10F2CX	10F2CX	10A2CX
1/22	10A1CX	6R1CX	10A2CX	10A3CX	10F1CX	10F4CX	10F4CX	10F4CX	10A3CX
1/23	10A1CX	5R2CX	10A3CX	10A4CX	9R1BX	10F5CX	10F5CX	10F4CX	10A3CX
1/24	10A1C5	5R2C10	10A3C18	10A3C22	1R1C2	10F5C11	10F4C6	10F3C7	10A4C14
1/25	9A2C5	6R3C10	9R3L18	10A1C22	1R1B5	10F5C10	10F4C6	10F3C7	10A3CX
1/26	9A2C5	6R2C10	9R3L18	10A1C22	10A1C1	10F5B10	10F5B6	10F3C7	10A4C14
1/27	9A2C4	2R2C10	10A3L18	10A3L22	5A1B2	10F5C10	10F5C6	10F4C8	10A5C14
1/28	8A2B2	2R2C10	10P4L18	10A3L22	8R2B3	10F5C10	10F5C6	10F4C8	10A7C14
1/29		5R2B10	10P4L18	10A3L22	10A2L5	10F4C10	10F4C6	10F4C8	10A6C14
1/30		8R4B10	10P4L18	10A3L22	1R2T5	10F5C10	10F4B6	10F4C8	10A6C14
1/31		6R4B17	10P4L16	10A3L22	1R1B5	10P4L10	9R4C6	10F4C8	10A5C14
2/1		6R4B17	10A4L10	10A3L14		9R4T5	10P4T5	10F4C8	10A3T14
2/2		5R4B17	9R4B19	9R3B10	2R1T1	10P4T2	10R4T4	8F4T8	10A3T14
2/3	4R3B7	7R4B15	9R4B11	9R4B3	2R3T5	10R4L1	10R4L1	9F5T8	10A4C14
2/4	5R3B7	9R4B15	10P4B9	10P4L22	5R3T4	10P1C10	10P1C5	10F5T8	10A5L14
2/5	3R5L7	4R4B12	10P4L14	10P4L22	5R3T4	10P2C10	10P2C5	10P5T4	10A4L14
2/6	3R5B7	3R4B12	10P4L11	10P2L22	2R2T4	7R2T10	8R2T5	10P4T4	10A4L14
2/7	1R3B4	4R4B10	10P4L7	10P2L22	1R2T5	3R2B5	10P2L5	10P3T4	10A3L14
2/8	1R3B5	3R4B10	10P4L7	10P2L22	3R2B5	10P3L10	10F3L5	10F3L5	10A3L14
2/9	2R3B5	3R4B10	10P4L7	10P3L22	4R2B5	10F4T10	10F4L5	10F3L5	10A5L14
2/10	1R3L5	9R4B15	10P5L18	10A3L22	2R3B5	10F4B9	10F4L5	10F3L5	10A4L14
2/11	1R3B5	3R4B10	10P5L18	10P3B22	2R1T5	10F4B8	10F4L5	10F3L5	10A5L14
2/12			10P5B10	10P3B7	1R1T5	3R2B2	8F3L5	10F3L5	10F5LX
2/13			10P5B7	10P3B8	1R1T5		7F3L5	10F3L5	10F4BX
2/14			10F5B6	10P3B4	1R1T5	10F1B3	10F3L5	10B3L1	10F5BX
2/15	5R4B5	2R4B10	10P5B6	10P3B10	1R2B4	6F1C2	8F3L4	10P3L1	10F4B8
2/16	1R4B5	2R4B10	10P5B6	10P3B10	6F1B4	10F1C4	10F3L3	10P3L1	10F4B8
2/17		2R4B10	10P5B6	10P3B10	1R2B4	10P1B1	10F3L2	10P3L1	10F4B8
2/18			10P5B4	10P3B10	1R2B4	10P1B1	10F3L2	10P3T2	9R3B8
2/19			10P4B3	10P3B3			9R2T1	10P3T1	6R3B6
2/20			10P3B2				1R2T1		
2/21									
2/22									

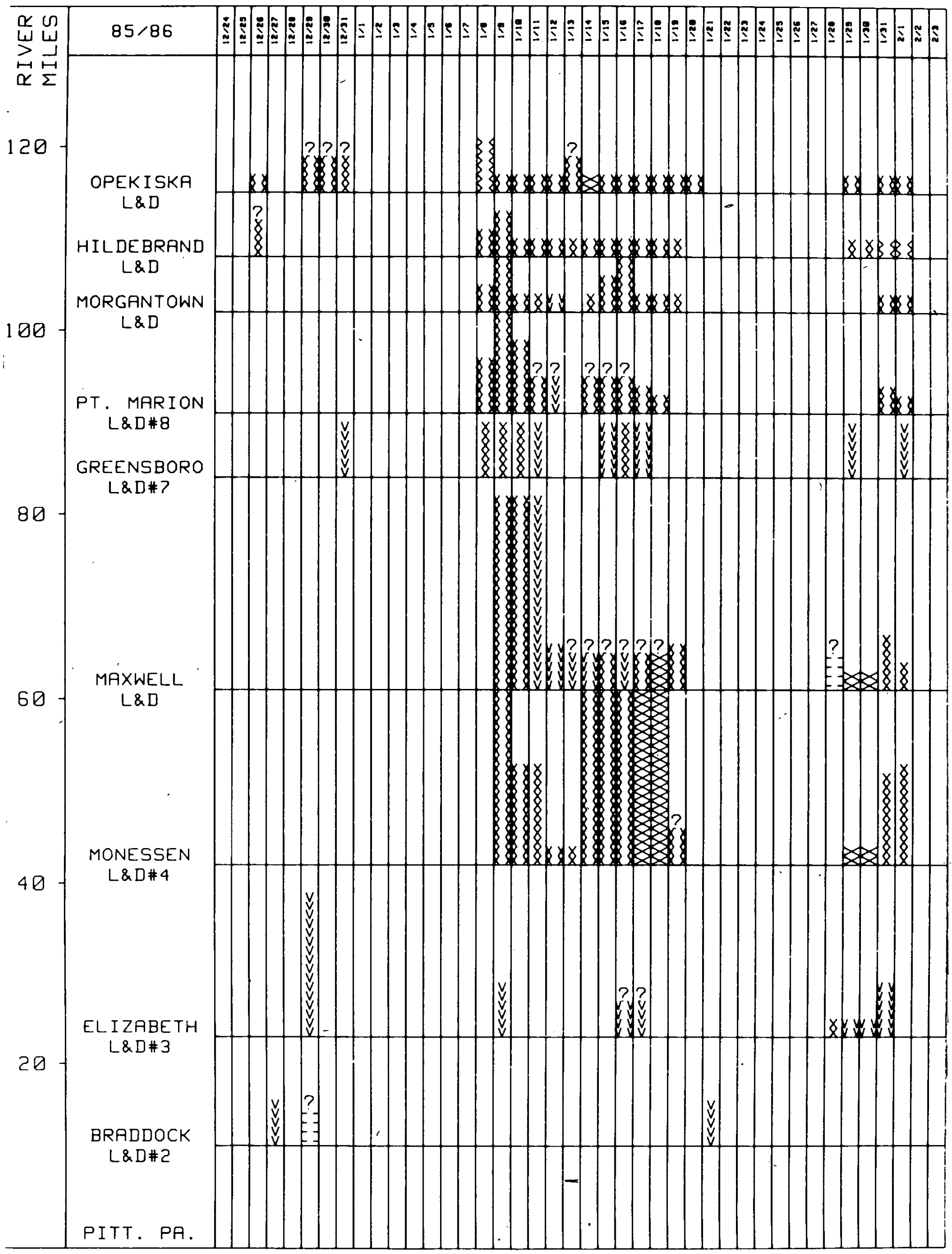
RIVER MILES
85/86
120
100
80
60
40
20
OPEKISKA L&D
HILDEBRAND L&D
MORGANTOWN L&D
PT. MARION L&D#8
GREENSBORO L&D#7
MAXWELL L&D
MONESSEN L&D#4
ELIZABETH L&D#3
BRADDOCK L&D#2
PITT. PA.

Figure A14.

DATE	BRADDOCK	ELIZBETH	MONESSEN	MAXWELL	GRNSBORO	PT. MAR	MGANTOWN	HLDBRAND	OPEKISKA
12/24									
12/25									
12/26								5F1CX	9F1H1
12/27	3R1L4								
12/28									
12/29	1S1TX	2R1B15							9F1CX
12/30									9F1CX
12/31					1R1B5				1F1CX
1/1									
1/2									
1/3									
1/4									
1/5									
1/6									
1/7									
1/8					1A1C5	7F1C5	7F1C2	8F1C2	9S1C5
1/9		1R1B5	8A1L18	8A1B20	4A1C5	9F1C10	9F1C5	9F1C4	9A1C1
1/10			9A1C10	8A1B20	4A1C5	8F2C7	7F1C1	8F1C1	9A1C1
1/11			5A1B10	2R1B20	1R1C5	8F2CX	5F1C1	8F1T1	9A1C1
1/12			9A2B1	8R1B4		3R1BX	7R1T1	6F1T1	9A1B1
1/13			4A2B1	3R1BX				1F1T1	8A1BX
1/14			9A1B18	8R1BX		6F1BX	2F1B1	9F1T1	10F1C1
1/15			9A1B18	9A1BX	7R1C5	8F1BX	7F1C3	9F1C1	9F1B1
1/16		9R1BX	9A2B18	5R2BX	5A1C5	9F1CX	9F1C5	9F1C1	9F2C1
1/17		3R1BX	10A1C18	9P1BX	9R1C5	9F1C2	9F1C1	9F1T1	9F2C1
1/18			10P1C18	10P1BX		9F1T1	8F1T1	8F1T1	9F2C1
1/19			9P1CX	9P1B4			5F1T1	5F1T1	6F1H1
1/20									6F1H1
1/21	1R3T4								
1/22									
1/23									
1/24									
1/25									
1/26									
1/27									
1/28		1F1B1		1S1BX					
1/29		9R1B1	10P1C1	10P1B1	1R1H5			4F1C1	8F1C1
1/30		9R1B1	10P1L1	10P1B1				5F1C1	
1/31		9R1B5	1P1L9	1P1C5		6F1C2	7F1C1	7S1C1	8F1C1
2/1			1P1L10	5P1L2	3R1H5	7F1C1	8F1C1	7S1C1	8F1C1
2/2									
2/3									

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