Hydrologic And Hydraulic Warning Times For The South Branch of The Potomac River West Virginia

Analysis of Existing Systems and Recommendations for Improvement

Prepared For

INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

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INTRODUCTION

The communities of Moorefield and Petersburg are located along the South Branch of the Potomac River in Grant and Hardy Counties, West Virginia. Flooding in the area has occurred periodically through the years, frequently resulting in costly damage to homes and businesses. The most recent flood occurred in November 1985 when extremely high flows passed through the two communities and throughout the upper reaches of the South Fork, North Fork South Branch and South Branch South Fork of the Potomac River. The flood inundated large sections of both Moorefield and Petersburg causing damages estimated at almost $59 million and the loss of three lives.

This report is part of a two staged study. The first stage examines the existing flood warning capabilities and makes recommendations for improvement. The second stage will involve preparation of flood response plans under current and improved conditions.

The first task of this study is to determine the capabilities of flood warning by an evaluation of the amount of warning time available.

The second task provides a description of how the Integrated Flood Observing and Warning System (IFLOWS) works in the South Fork Potomac River Basin. Emphasis is focused on how IFLOWS can provided increased capability of reducing property damage and risk to businesses, homes and citizens of Moorefield and Petersburg, West Virginia.

Finally, this study report develops recommendations for improvement of the flood warning system in the South Fork Potomac River Basin.

The second study phase will include the development of a Flood Emergency Plan for Moorefield and Petersburg, WV with proposed levees and protective works, now being studied by the Baltimore District Corps of Engineers, in place and;

the development of a Flood Emergency Plan for Moorefield and Petersburg, without proposed levees and protective works. Development of the flood emergency plan will involve close cooperation with officials and citizens of Grant and Hardy Counties and Petersburg and Moorefield, West Virginia.

Purpose of this study

This review is based on analysis of past storms and reports and analysis from the Baltimore District of the Corps of Engineers, a Corps reconnaissance report for flood mitigation at Moorefield and Petersburg, and published records obtained from the United States Geological Survey, (U.S.G.S.) in West Virginia. Information and data were also obtained from the National

Weather Service, Soil Conservations Service, a U.S.G.S. Report on the 1985 Flood and a study by Dr. Andrew Miller, University of Maryland.

LEAD TIME ANALYSIS

Physiography of the South Branch of the Potomac River Above Moorefield, West Virginia

The South Branch of the Potomac River is located in Northeastern West Virginia. The river originates in the Appalachian Mountains and meanders through wide valleys and a well developed flood plain. The flood plain varies in width from 10,000 feet to 3,000 feet and narrows to 500 feet at Petersburg Gap. Petersburg, is located 5 miles downstream from the confluence of the North Fork with the mainstream of the South Branch Potomac River. The average slope of the river is 15 ft./mile although immediately upstream of Petersburg the river has a sharp 42 ft./mile drop. Downstream the river slope is 5 ft./mile. Lunice Creek enters the South Branch just downstream of Petersburg. Mill Creek also enters the South Branch downstream of Petersburg.

The map in Figure 1, shows the stream configuration of the North Fork South Branch, the South Fork South Branch and the South Fork Potomac River in West Virginia. Circles on this map are the locations of communities and the triangles are the location of river recording gages. River recording gages provide a permanent record of river levels. The location of the river recording gage at Petersburg, is shown on the map as a star. Locations of automatic recording rain gages, as part of the Integrated Flood Observing and Warning System, are shown as squares on the map.

The South Fork of the South Branch flows into the South Branch near Moorefield. The South Branch flows through a narrows about 5 miles downstream of Moorefield at Falling Springs Gap, near Old Fields, West Virginia in an area called The Trough. The floodplain narrows to 500 feet, or less, at the Trough.

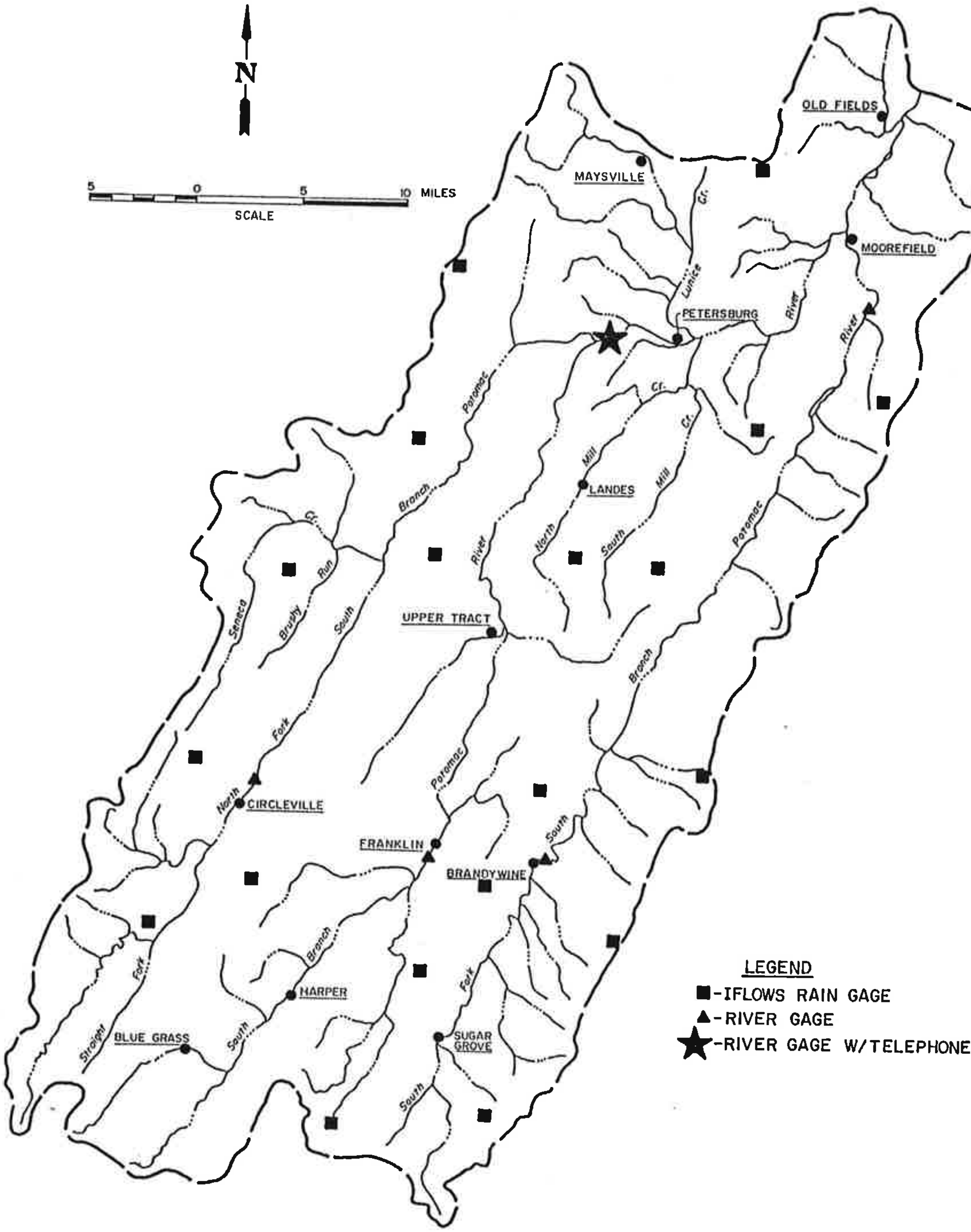


FIGURE 1
RAIN AND RIVER GAGES
POTOMAC RIVER, WEST VIRGINIA

River Gages

River gages or water stage recorders are placed at selected locations in a river basin to provide a record of the time and height of water levels in rivers and streams.

USGS water-stage recorders are located at the following locations:

Gage Location	Drainage (sq. mile)
South Branch Potomac at Franklin, WV	182
South Branch at Petersburg, WV (estimated)	642
South Fork South Branch at Brandywine, WV	102
South Fork South Branch near Moorefield,WV	283
South Branch near Springfield, WV	1,471

A National Weather Service telemark and a Corps of Engineers data collection platform are located at Petersburg and Springfield, WV. At these locations, river stage data can be obtained in real time. It should be noted that the gage upstream of Petersburg is the only gage in the South Branch River Basin upstream of Petersburg and Moorefield that can be remotely interrogated to obtain river level information.

The Integrated Flood Observing and Warning System (IFLOWS), when completely operational, will also be able to provide rainfall information in real time.

Sources of Flooding

Flooding can be caused by excessive runoff along the South Branch at Petersburg, Lunice Creek, Johnson Run, Mill Creek, and other lowland areas near Petersburg, and along the South Fork and the South Branch at Moorefield. Flooding can also occur from poor drainage at bridge underpasses, on roads and streets and in flat lowland areas.

Maps of Moorefield (Figure 2), and Petersburg (Figure 3), show the location of streets, rivers, creeks, runs and waterways.

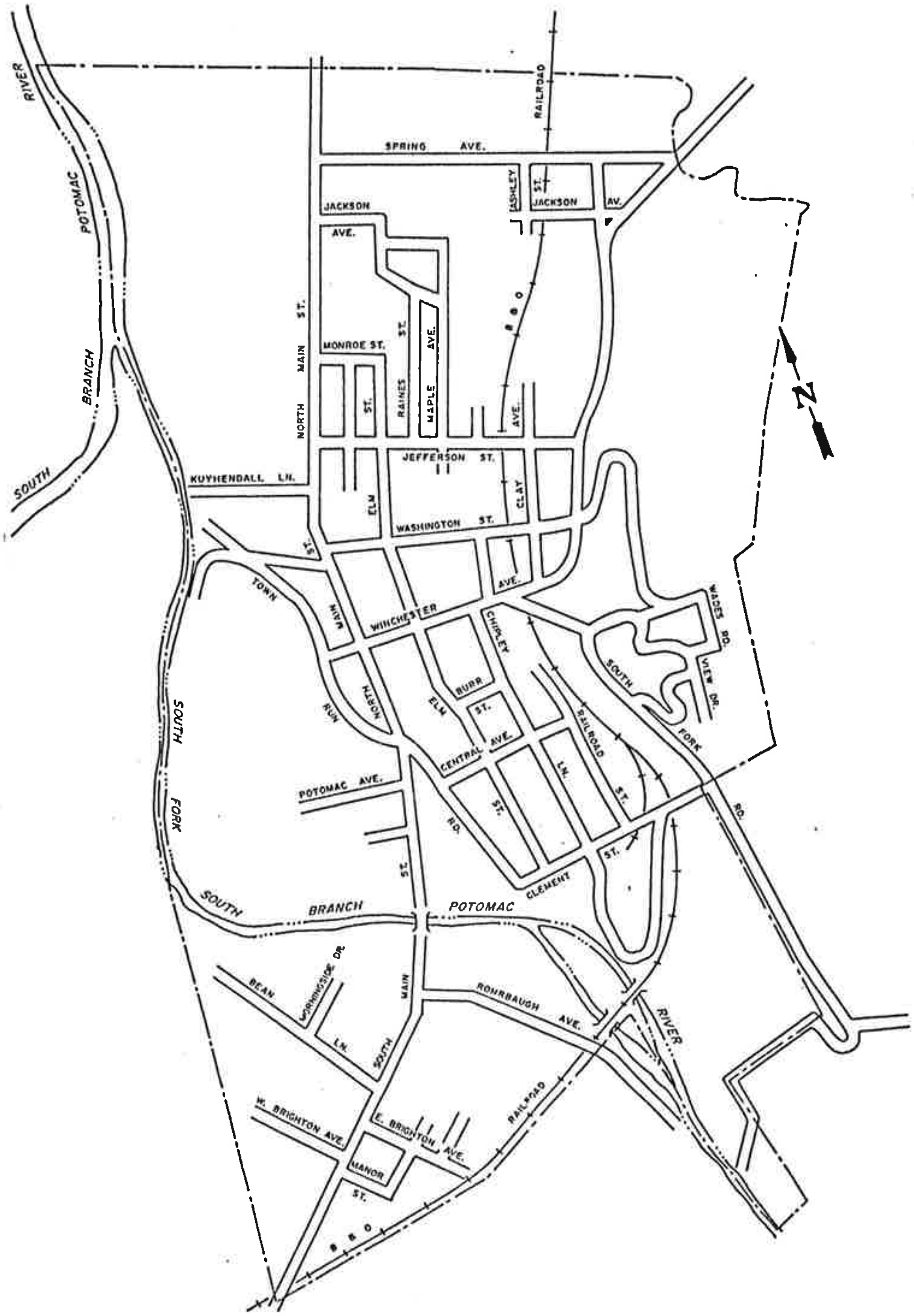


FIGURE 2
MOOREFIELD, WEST VIRGINIA

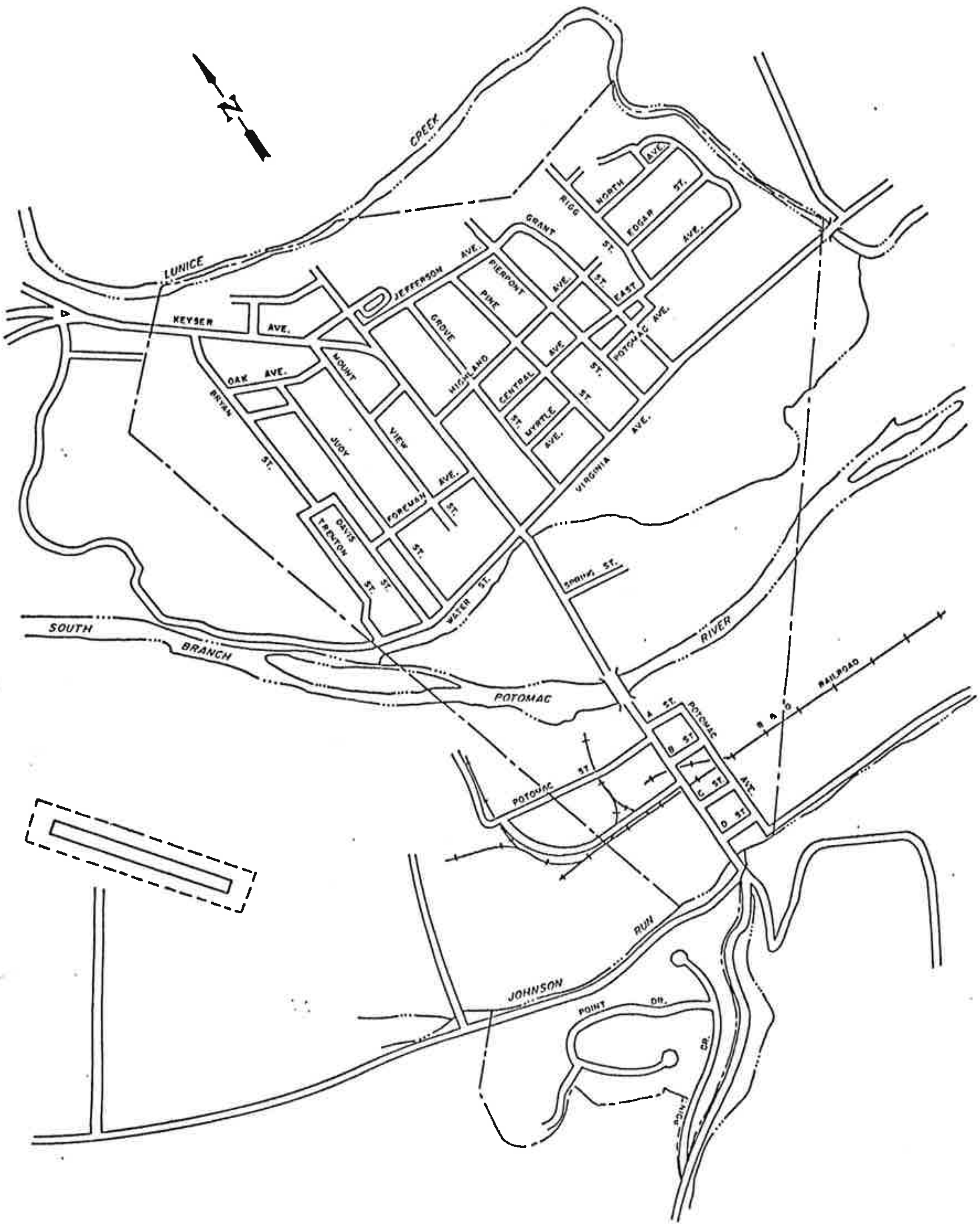


FIGURE 3
PETERSBURG, WEST VIRGINIA

Flood Characteristics - Time to Crest

Flooding along the South Fork and South Branch of the Potomac River in the vicinity of Petersburg and Moorefield occurs periodically. Typically, floods in Petersburg and Moorefield have very high velocities and rise and fall rapidly. These sudden rises and falls are due to the steep terrain upstream in the watershed. Floods may occur at any time of the year. The most typical causes of floods are intense thunderstorms, hurricanes, tropical storms or heavy rainfall on a snow pack with a high water equivalent. Flooding normally occurs along small creeks and streams such as Lunice Creek, Patterson Creek and Mill Creek before the South Branch River will flood. These flashy streams and creeks crest with the occurrence of heavy rainfall because of the small contributing areas and steep slopes of the channels. Most of the time there is no lag time or warning time available for these small flashy creeks. In Petersburg, Mill Race Run and Johnson Run, run parallel to the South Branch and crest with the occurrence of heavy rainfall.

Although flooding and crest times along the South Branch are quick reacting, they are long enough for some effective warning.

Using precipitation and streamflow data obtained from the Baltimore District of the Corps of Engineers, hydrologic analysis was conducted to determine crest times. Floods which occurred in August 1955, March 1963 and October 1976 were used to determine travel time.

Crest times range from 9 to 11 hours at Petersburg (average equals 10 hours) 7 to 8 hours at Brandywine, 11 to 14 hours at Moorefield (average equals 14 hours) and 26 to 28 hours at Springfield. These crest times are from the middle (center of rainfall mass) of the heaviest rainfall to the observed crest.

The National Weather Service Middle Atlantic River Forecast Center in Harrisburg, PA uses a unit hydrograph which peaks in 15 hours at both Petersburg and Moorefield. Although slightly longer, the peak times at Petersburg and Moorefield are probably variable according to rainfall rates and the spatial distribution of rainfall within the basin. There are some indications of non-linearity between rainfall and runoff in the river basin. This means that crest times may be shorter for heavier rainfall and runoff amounts than for light runoff response. Table 1, Crest Times in Previous Floods in the South Branch Potomac River Basin, West Virgnia, on page 8, shows crest times determined by this study and analysis by the Soil Conservation Service. The stormsanalyzed are in the 20 to 30,000 cubic feet per second range which rank as a 10 year flood.

TABLE I

CREST TIMES IN PREVIOUS FLOODS IN THE SOUTH FORK POTOMAC RIVER BASIN, WEST VIRGINIA

Storm	Rainfall/ Time	Peak Flow* Cubic ft./sec.	Peak Gage Height	Time to Crest**	Location
August 1955	4.0" in 15 hrs.	20.3		9 hours	Petersburg
		17.1		11 hours	Moorefield
		73.4		28 hours	Springfield
March 1963	7.8" in 14 hrs.	27.0	14.8	9 hours	Petersburg
		4.5	8.0	7 hours	Brandywine
		7.5	8.2	14 hours	Moorefield
		52.9	22.2	27 hours	Springfield
Oct. 1976	2.3" in 15 hrs.	28.0	15.1	11 hours	Petersburg
		7.0	8.9	8 hours	Brandywine
		9.7	9.0	14 hours	Moorefield
		58.0	23.4	26-27 hrs.	Springfield

*Flow in Thousands of cubic feet per second
*Crest time was computed from the middle of heavy rainfall to the crest time.

Many runoff events or floods which occur on the Potomac River Basin are due to complex storms. In fact, most floods analyzed are the result of a series of several bursts of rainfall amounts which occurred over a 15 hour period. Multiple storms can produce multiple surges along the rivers and worse, the crest may occur while it is raining. Complex storm floods are difficult to predict and may result in little warning lead time.

The 1985 Flood

Rainfall

Rainfall amount and distribution are difficult to evaluate for this flood. Rainfall data was collected and analyzed through a bucket survey by the Soil Conservation Service following the flood.

Total rainfall for the October 30 to November 6 storm period is shown in Figure 4 . The greatest amount of storm rainfall, about 11 inches, occurred in North Central Pendelton County.

Hourly precipitation data can sometimes be used to provide additional information about flood performance. Figure 5, shows rainfall accumulation at Mathias, WV and Figure 6, shows rainfall accumulation at Moorefield. These two key NWS hourly precipitation gage locations in the basin report two-day storm precipitation amounts of 6.60 inches at Mathias, WV and 4.40 inches at Moorefield. Neither of these gages, however, were located in the area of the greatest rainfall. This is shown by comparing total rainfall of up to 11 inches for October 30 to November 6, 1985 in Figure 4. It should be noted that the heaviest concentration of rainfall occurred between 3:00 pm and 10:00 pm on November 4 at Mathias and between 4:00 pm and midnight on November 4th at Moorefield.

FIGURE 4

SOUTH BRANCH RIVER BASIN,
RAINFALL DISTRIBUTION AND RAIN GAGES

Rainfall, October 30 - November 6, 1985
After Jacobson, 1987

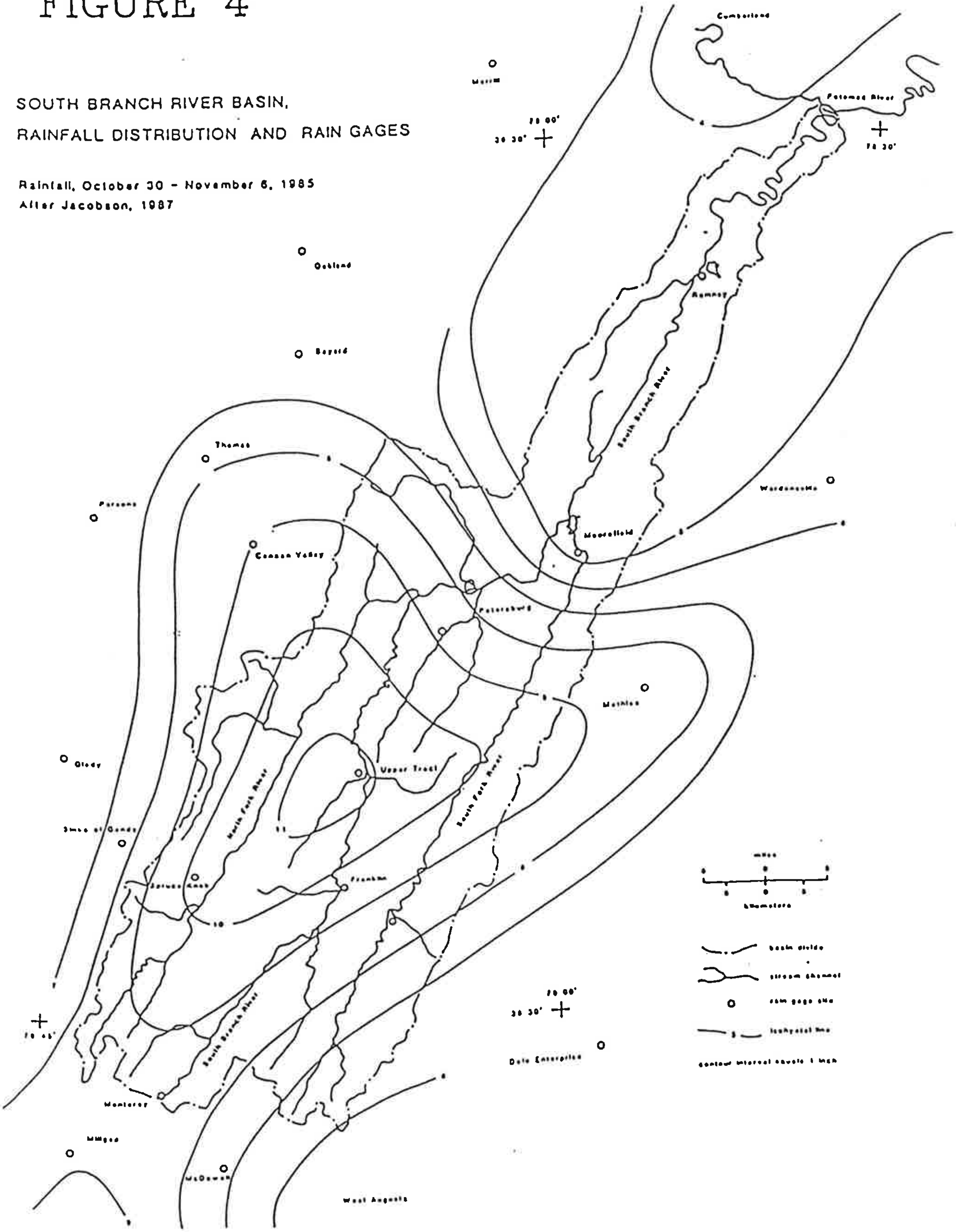
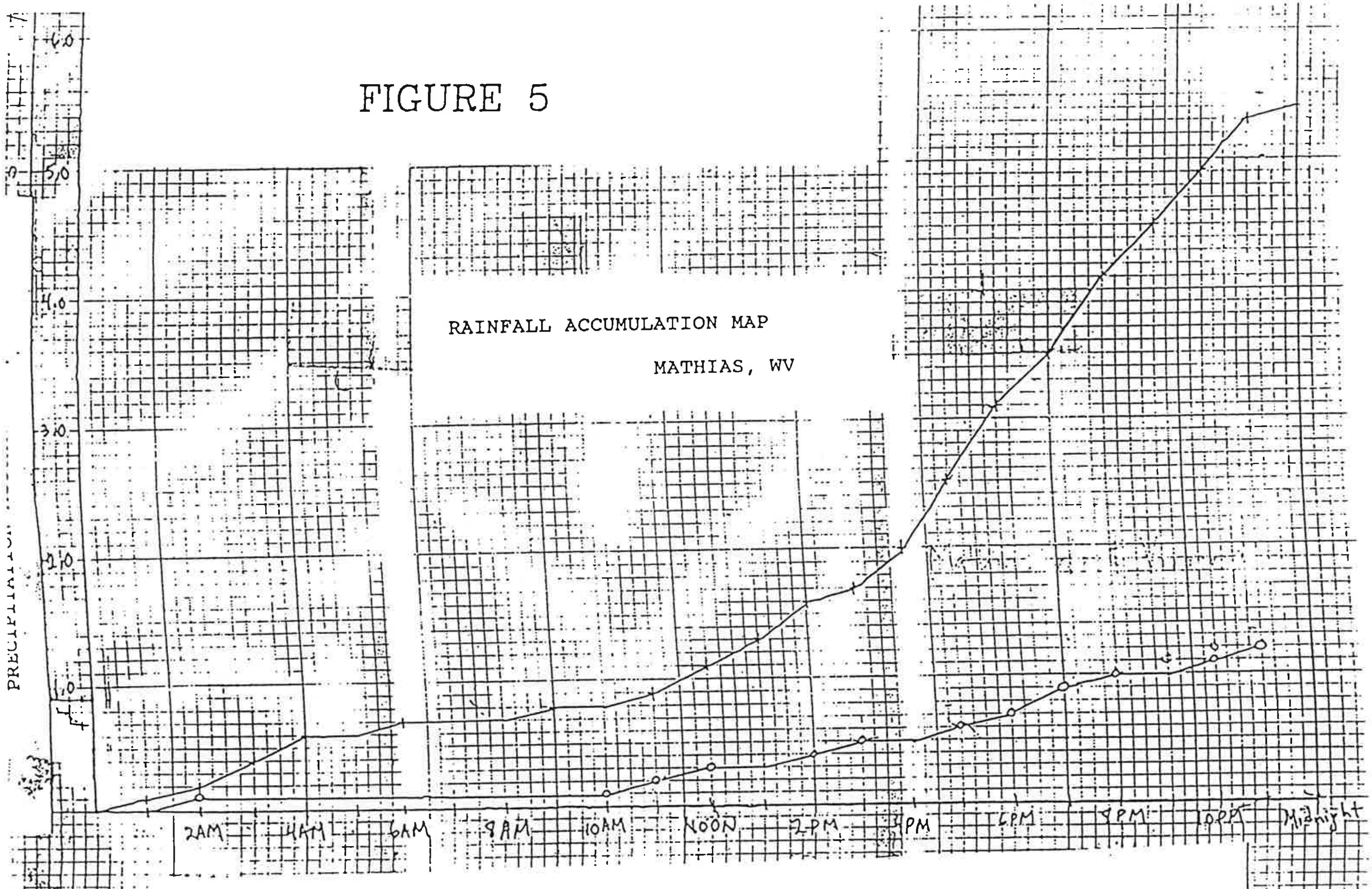


FIGURE 5

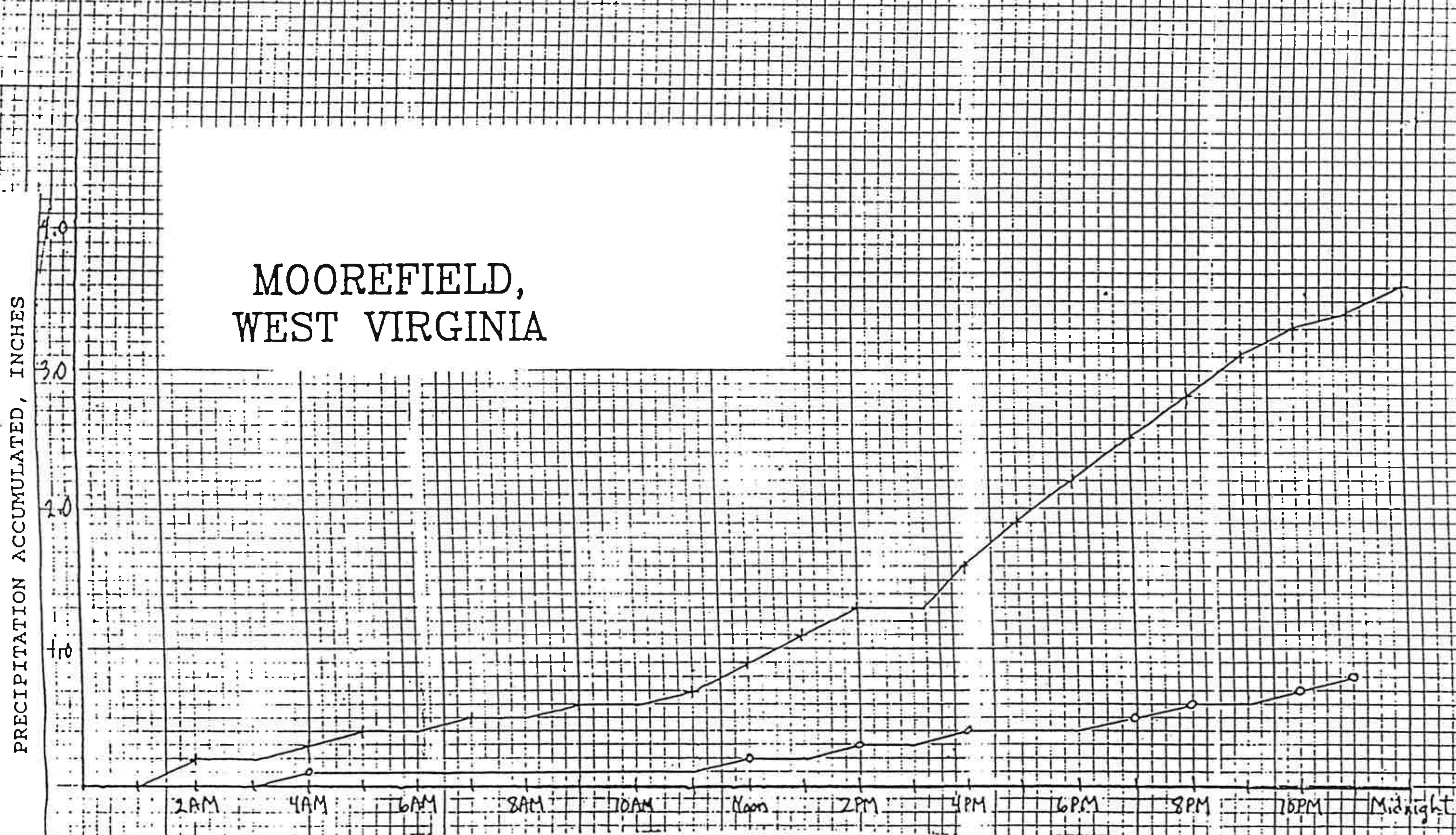


ACCUMULATED PRECIPITATION FOR HOURLY INTERVALS

O NOVEMBER 3, 1985

\+ NOVEMBER 4, 1985

FIGURE 6



ACCUMULATED PRECIPITATION FOR HOURLY INTERVALS

O NOVEMBER 3, 1985

\+ NOVEMBER 4, 1985

Flood Levels

The November 1985 flood, which ranked as a 400 year flood, destroyed the Petersburg gage. The time to crest(s) for the 1985 flood are not known. Peak flows and stages are estimated from flood marks. The storms and floods analyzed had fairly even rainfall over the basin in time and space. This means that storms that occur primarily upstream of the basin will have longer crest times while storms that occur downstream in the river basin will cause shorter crest times than those computed in this study. Also, more intense (shorter duration) storm rainfall will cause quicker crests while longer duration storms will extend crest times.

Soil Conservation Service hydrograph analysis was conducted for the headwaters of the North Fork at Circleville (107 square miles) and Riverton (140 square miles). The times to peak, or crest, computed by the TR20 technique was 4 hours for Circleville and 6 hours for Riverton. Using the same technique, simulation of the November 4-5, 1985 flood were run for Circleville and Riverton. Computed hydrographs are shown in an Appendix. The computed flows are shown in Table II.

TABLE II

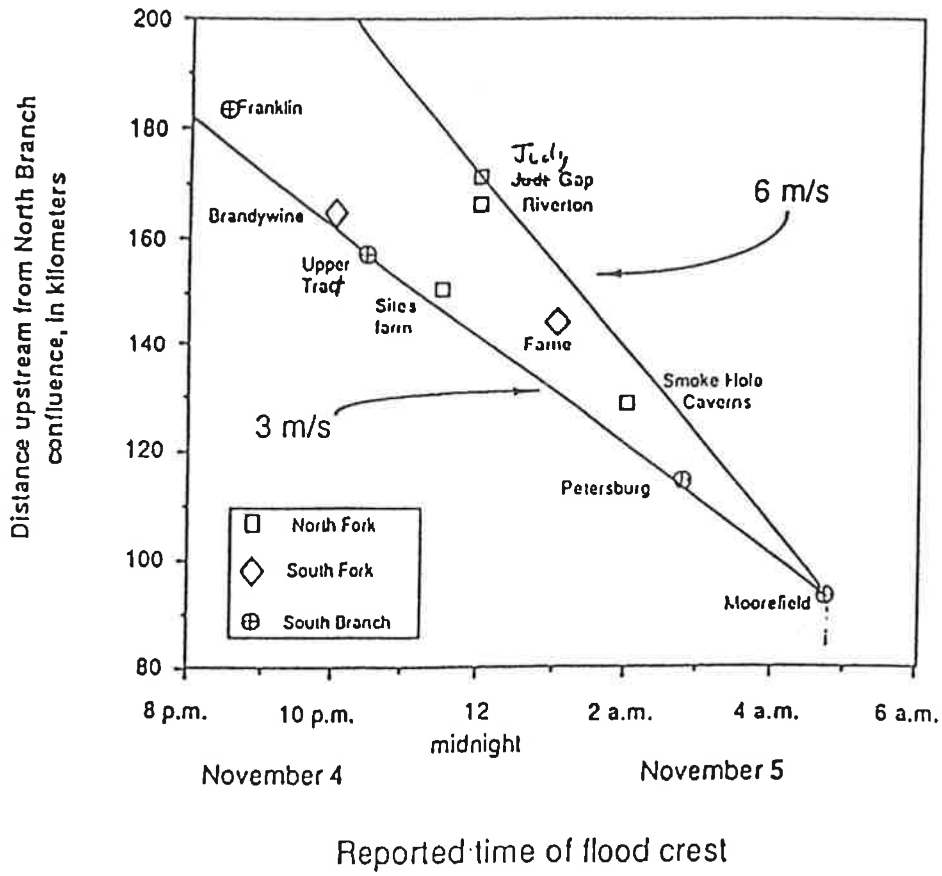
COMPUTED ESTIMATED FLOW
FOR NOVEMBER 4 AND 5, 1985 FLOOD

STATION	VELOCITY FEET PER SECOND	ESTIMATED FLOW (CUBIC FEET PER SECOND)
Circleville		35,361
Riverton		45,500
Franklin	4.0	44,000
Petersburg	4.6	130,000
Brandywine		40,500
Moorefield	3.4	110,000
Springfield	4.0	240,000

The 1985 flood was caused by a complex storm event.

Estimated crest times for the November, 1985 flood were compiled by Dr. Andrew J. Miller, University of Maryland. Since hydrologic data is incomplete for the November flood, Dr. Miller used a number of interviews to assemble probable crest times. As expected, slightly faster crest times were recorded for the 1985 flood. Figure 7 shows the reported time of flood crests obtained by Dr. Miller from the interviews.

FIGURE 7



Time to Flood Stage

The time it takes for a flood to reach its peak, or crest, is one factor to use in evaluating the time available for taking flood protective actions. The time to reach flood stage, however, is the most useful information in flood warning. When the river exceeds flood stage, problems begin. This beginning flood stage can be defined as the stage minor flooding or severe inconvenience begins in the reach of the gage.

The flood stage at Petersburg, West Virginia is 12 feet while at Moorefield it is 10 feet. The time to flood stage is less than the time to crest for a flood unless the river crests at flood stage. The time to flood stage will vary according to the amount of runoff. Here are some examples for floods on the main stem of the South Branch:

	Flood	Time to Flood Stage (hours)	Time to Crest (hours)
Flood Stage 12 feet at Petersburg WV	March, 1963	5 hours	9 hours
	October, 1976	4 hours	11 hours
Flood Stage 10 feet at Moorefield,WV	March, 1963	5 hours	14 hours
	October, 1976	5 hours	14 hours

Note: Historical records indicate a similar 10-14 hour crest time for floods on the South Fork at Moorefield.

Warning Lead Time

Warning lead time is the time available to respond to a flood. Warning lead time consists of:

Warning Time = Tl - Tc - Tp

Tl = Watershed lag time - start of heavy rainfall to crest
Tc = Reporting delay time
Tp = Forecast preparation time

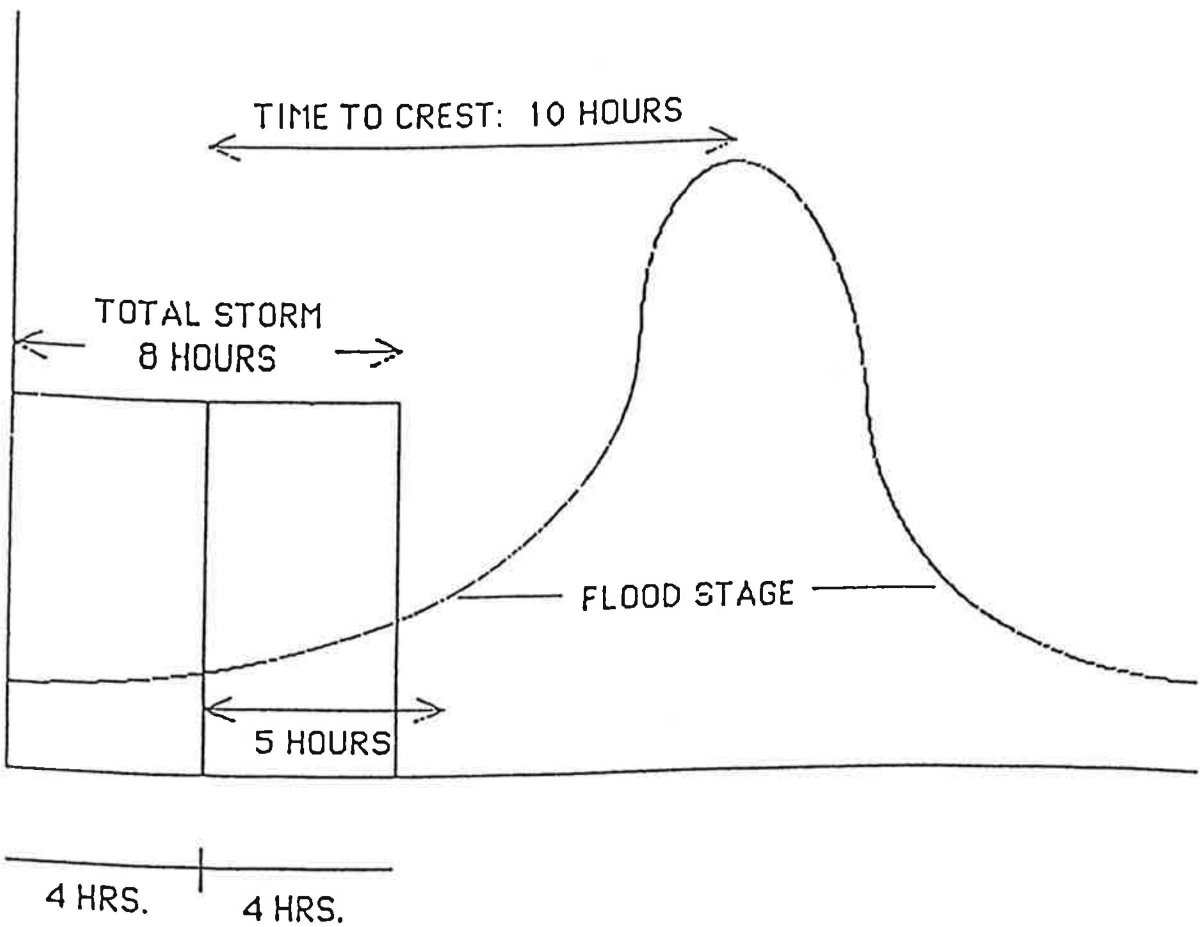
Note: The time to beginning flood stage is usually less than the time to reach the crest flood stage.

Both the reporting delay time and forecast preparation time can introduce significant delays in warning people. The reporting delay time (Tc) during the 1985 flood was significantly high.

The introduction of automatic reporting rain gages as part of the Integrated Flood Observing and Warning System (IFLOWS) program increases warning lead time by reducing reporting delay. Some reduction in forecast preparation time will also occur. However, two locations have crest times which may be too short for effective warning. On the South Branch at Petersburg crest time of 10 hours and at a Moorefield a crest time of 14 hours may be too short. If flood recognition does not occur until half way through the storm, then only 5 hours is available. By the time this forecast is disseminated to emergency action officials, only a few hours may be available. Figure 8 shows the relationship between crest lead time and flood stage lead time at Petersburg.

FIGURE 8

Relationship Between
Potential Lead Time and Actual Lead Time
at Petersburg, W.V.



Crest times determined in this study are from the middle of each flood producing storm. Storms are typically complex and twelve to fifteen (12 to 15) hours in length. Flood forecast would normally not be issued during the middle of a storm duration and intensity. Therefore, waiting until near the end of a storm, i.e. most of the storm rainfall has occurred significantly reduces actual warning lead time by six (6) hours. In this realistic situation flood stage will be exceeded before the river crests. This analysis shows a very short warning lead time of one (1) hour before flooding occurs and another five (5) hours before it crests.

Since there is so little warning lead time available on the smaller tributary streams such as Lunice Creek and Mill Creek, and storms in the middle or lower portions of the South Branch River Basin additional actions will be needed to provide as much warning lead time as possible.

Expansion of warning lead time can be achieved by using forecast rainfall and observation of rainfall and stream levels. These methods will be useful in providing early warning if early recognition of possible flood producing precipitation is combined with reduced time needed to prepare a forecast (Tp) and reporting delay time (Tc).

Local rainfall observation and stream and road patrols can be used to detect early rises in stream levels. When these efforts are started early in a storm they can provide a supplemental means of early detection of possible flood conditions.

THE INTEGRATED FLOOD OBSERVING AND WARNING SYSTEM (IFLOWS)

The IFLOWS System

In order to combat the devastation of flash floods, the National Weather Service and the State of West Virginia established the Integrated Flood Observing and Warning System (IFLOWS). IFLOWS combines existing computer technology with advanced forecasting and computer software techniques to provide timely guidance and advice to both state and local authorities responsible for the provision of emergency services.

There are basically four parts to the IFLOWS system that combine equipment, technology and human resources. Not all of the parts noted below are in place and completely operational at this time. These parts consist of:

1. Rainfall or other precipitation detection and recording equipment. Information from stream and river gages is planned to be added to the IFLOWS system at a later date. It is not part of the system at the present time.

2. A communications system to transfer this and other information to locations where it can be used.

3. Computers (and appropriate software) that can be used to convert data transmitted over the system into understandable information.

4. Person or persons at the county and community level who understand how the system operates and can take local flood warning actions as a result of the information obtained from the system.

The following describes the location and status of the IFLOWS system in the South Branch Potomac River Basin in West Virginia.

Current Status of IFLOWS

At this time IFLOWS is an evolving system with several state and federal agencies and county governments involved in its' development. Following is a report of the status of development at the time that this report is prepared. It is expected that the status will change as more work is completed on each of the component parts of the system.

IFLOWS Equipment

The IFLOWS system consists of automated precipitation or rainfall recording gages (rain gages) to which are attached a radio transmitter. The radio transmits a report of the amount of rainfall as it occurs. The principal of its operation is simple. A tipping bucket tips when it is filled with .01 inch of rainfall. The tipping action activates an electrical signal which transmits this information over a radio transmitter attached to each gage.

Automated IFLOWS rain gages are installed in most of the South Branch Potomac River Basin and part of the radio systems which transfer rainfall data to other locations is in place and is being tested and adjusted. The location of IFLOWS automated rain gages are shown as black squares in Figure 1.

Computers at County Offices

Radio receivers and small desk top computers are used at county warning centers to receive the radio signal from the rain gages and convert signals into useful information. An example of IFLOWS precipitation reports is shown in Figure 2. The information is stored at raingage sites or in the computer which can be programed to provide rainfall for varying time periods such as every 15 minutes, every 1 hour, etc. IFLOWS radio receivers and computers are located in the following locations in the upper South Branch Potomac River Basin in West Virginia:

Pendelton County Jail Keepers House in Franklin, WV

Grant County Court House in the Communications Center, Petersburg, WV

Hardy County Court House Moorefield, WV

Statewide Radio Systems

A network of radio systems capable of transferring IFLOWS rainfall and other information throughout West Virginia is planned. This network uses radio relay towers and links via several existing radio systems including the Public Radio System and the Emergency Medical Services radio system to create a network or backbone communications system. This system will link together National Weather Service offices at Charleston, West Virginia and Pittsburgh, Pennsylvania, the West Virginia Office of Emergency Services at Charleston, West Virginia, FLOOD WARNING POINTS IN PENDELTON, GRANT AND HARDY COUNTIES and flood warning systems in adjoining states.

Other Flood Warning Equipment and Systems

There is a network of river gages located in the Upper Potomac River Basin installed and operated by the U.S. Geological Survey. The location of these gages and the rain gages used in the IFLOWS system are shown in Figure 9. River gages are marked as a black triangle on the map. The National Weather Service has a remote sensing capability on one of these gages located upstream of Petersburg. Telephone linkages provide a means of remote interrogation to determine water level. This gage has a star noting its' location. Other river gages provide a record of water levels only. They do not have remote sensing capability.

Local Personnel to Operate IFLOWS

In order for IFLOWS to successfully provide flood warnings to residents and businesses in the communities that it serves, two actions must take place. An individual or individuals must know how to operate the computer and understand the information that is being received. Secondly, individuals operating the system must know what actions to take to warn those affected.

The National Weather Service and the West Virginia Office of Emergency Services have asked county governments to take actions in cooperation with the development of the IFLOWS. Grant, Hardy and Pendelton counties have signed memorandum of agreement with the National Weather Service for operations of the system. Each county is also requested to assign a flash flood coordinator to be responsible for operation of the IFLOWS system at the county level. This is an important step in making the system most effective. Pendelton County has assigned a coordinator. Grant and Hardy County have not assigned a coordinator.

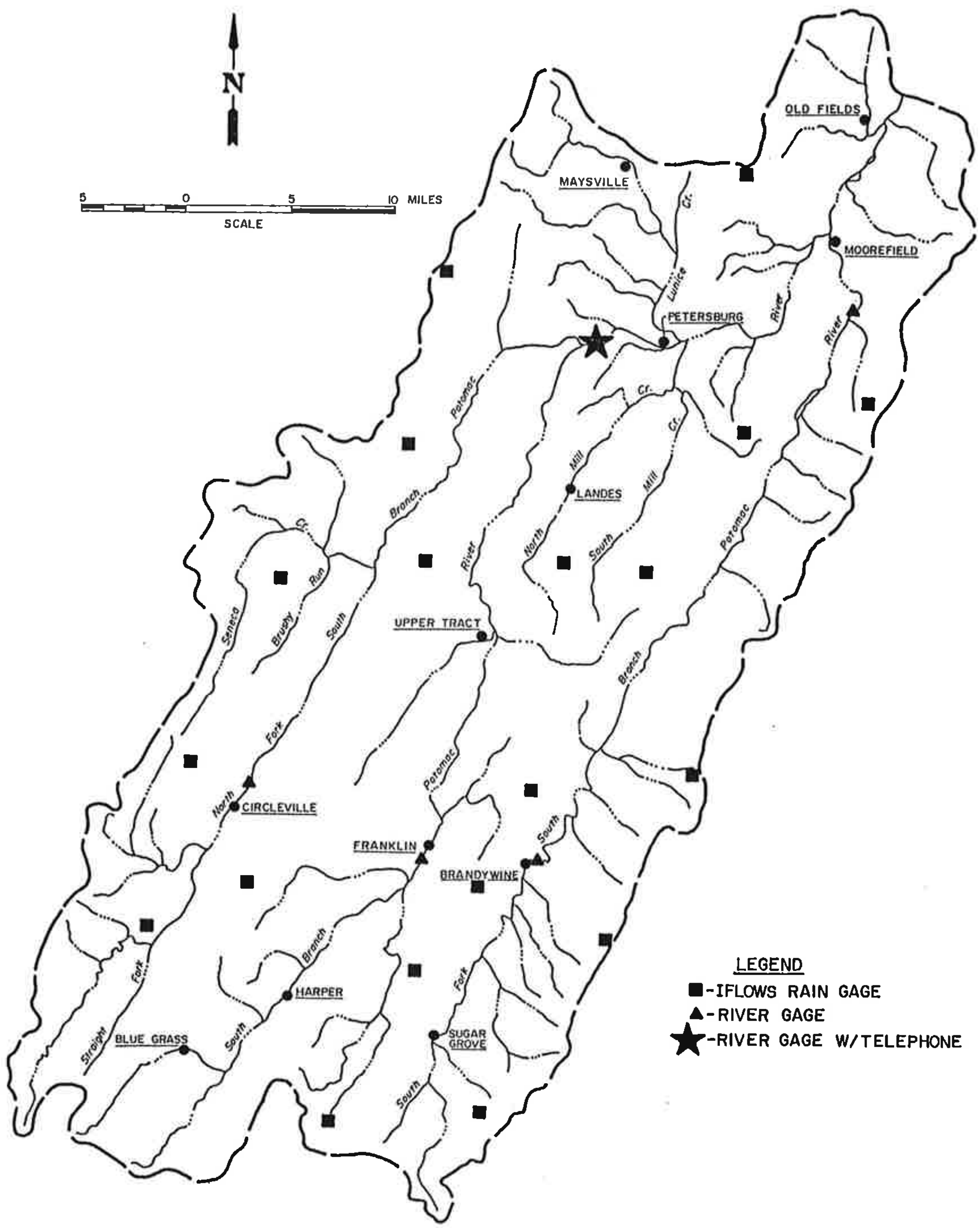


FIGURE 9
RIVER AND IFLOWS RAIN GAGES
POTOMAC RIVER, WEST VIRGINIA

FIGURE 10

EXAMPLE OF IFLOWS RAINFALL REPORTS

Rainfall Ending At 11/10/88 13:00 EST, Run At 11/10/88 12:54 EST   Page 7

LID	ST	COUNTY	Name	Start: 11/09 13:00 End: 11/10 13:00	Start: 11/08 13:00 End: 11/09 13:00	Start: 11/07 13:00 End: 11/08 13:00	Start: 11/06 13:00 End: 11/07 13:00	Start: 11/05 13:00 End: 11/06 13:00	Start: 11/04 13:00 End: 11/05 13:00	Start: 11/03 13:00 End: 11/04 13:00	Start: 11/02 13:00 End: 11/03 13:00	Start: 11/01 13:00 End: 11/02 13:00	Start: 10/31 13:00 End: 11/01 13:00	Start: 10/30 13:00 End: 10/31 13:00	Start: 10/29 13:00 End: 10/30 13:00	Start: 10/28 13:00 End: 10/29 13:00	Start: 10/27 13:00 End: 10/28 13:00	Total
3527	WV	KANAWH	AARON'S FORK	0.20	0	0.04	0.04	0.12	0.64	0	0	0	0	0	0	0	0.04	1.08
3528	WV	KANAWH	POLLY HOLLOW	0.12	0	0.04	0.04	0.08	0.60	0	0	0	0	0	0.04	0	0.04	0.96
3529	WV	KANAWH	BEE MOUNTAIN	0.28	0	0.08	0.08	0.12	0.60	0	0	0	0	0	0	0	0.16	1.32
3568	WV	LOGAN	LOMI	0.20	0	0.08	0.12	0.16	1.24	-	0	0.04	-	0	0	0.16	-	2.00
3569	WV	LOGAN	BOARDHSE HOLLOW	0.04	0.04	0	0.04	0	0.04	0.04	0	0	0.04	0.04	0	0.04	0.04	0.36
3570	WV	LOGAN	DARK HOLLOW	0.04	0	0.12	0.04	0.24	0.96	0	0	0	0	0	0	0	0.12	1.52
3571	WV	LOGAN	BLAIR MOUNTAIN	0.04	0	0	0.04	0	0.04	0	0	0	0	0.04	0	0	0	0.16
3572	WV	LOGAN	PERRY FORK	0.20	0	0.08	0.08	0.28	0.88	0	0	0	0	0	0	0	0.04	1.56
3573	WV	LOGAN	BUFFALO CREEK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3574	WV	LOGAN	LORADO	0	0	0	0	0	0.04	0	0	0	0	0	0	0.04	0	0.08
3575	WV	LOGAN	STONE COAL	0.12	0	0.12	0.16	0.32	0.84	0	0	0	0	0	0	0	0	1.56
3585	WV	LOGAN	RIGHT FORK NORTH	-	-	0	-	-	0.20	-	-	-	0	-	0.04	-	-	0.24
3586	WV	LOGAN	LAUREL HOLLOW	0.20	0	0.08	0.04	0.32	0.92	0	0	0	0	0	0	0	0.08	1.64
3587	WV	LOGAN	MIDDLE FORK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3588	WV	LOGAN	COW CREEK	0.28	-	0.08	0.04	0.28	0.92	-	-	-	-	-	-	-	0.04	1.64
3556	WV	MCDOWE	BISHOP	0.04	0	0	0.04	0	0	0	0.04	0	0	0.04	0	0	0.04	0.20
3557	WV	MCDOWE	JENKINJONES	0	0	0	0	0.04	0	0	0.04	0	0	0	0	0.08	0	0.16
3558	WV	MCDOWE	ASHLAND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3559	WV	MCDOWE	SANDLICK CREEK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3560	WV	MCDOWE	BIG CREEK	0.04	0.04	0.04	0.12	0.08	0.16	0	0	0.04	0	0	0	0	0	0.52
3562	WV	MCDOWE	OLGA #2 LOOKOUT	0	0	0.12	0	0.04	0.12	0	0	0	0	0	0	0	0.04	0.32
3563	WV	MCDOWE	MUDHOLE BRANCH	0.08	0	0	0	0	0	0	0	0	0	0	0	0.08	0	0.16
3564	WV	MCDOWE	MITCHEM CEMETARY	0	0	0.12	0.12	0.20	0.48	0.08	0	0	0	0	0	0	0	1.00
3565	WV	MCDOWE	JACKSON FLATS	0.16	0	0.08	0.08	0.16	0.76	0	0	0	0	0	0	0	0	1.24
3566	WV	MCDOWE	OLGA #3 LOOKOUT	-	-	0.12	0.04	0.16	0.44	-	-	0.04	-	-	-	-	-	0.80
3567	WV	MCDOWE	RIFFE BRANCH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3513	WV	MINGO	MILLSTONE	0.12	-	0.04	0.12	0.16	1.08	-	-	-	-	-	-	-	0.16	1.68
3514	WV	MINGO	SHARON HEIGHTS	-	-	-	0.04	0	-	-	-	-	-	0.04	-	-	-	0.08
3561	WV	MINGO	SANDY GAP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3590	WV	MINGO	BUFFALO MOUNTAIN	0.20	0	0.08	0.04	0.16	1.04	0	0	0.04	0	0	0	0	0.08	1.64
3591	WV	MINGO	GRANT BRANCH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3592	WV	MINGO	RIGHTHAND WEST	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3593	WV	MINGO	BIG MUNCEY	0.24	0	0.08	0.08	0.48	1.28	0	0	0.04	0	0.08	0	0	0.08	2.36

Fine Tuning IFLOWS

Most of the equipment needed to operate IFLOWS is installed, however all of the equipment must be tested. For example, transmitting equipment on the rain gages must be carefully adjusted, antennae on relay towers and county receivers must be aligned, computers must be programed and adjusted. This fine tuning is currently underway.

The IFLOWS communications network will provide, when completed, a transfer of rainfall data from one county to another or throughout a river basin. It will also enable National Weather Service offices to more reliably and quickly issue flood warning information to users at the county and local level.

In addition to the transfer of rainfall information, the IFLOWS communication networks are planned to provide a voice radio capability for transfer of information between users of the system.

Note: These systems are not completed at this time, and all of the proposed capabilities of the system, as noted above, are not operational.

A detailed review of the requirements and needs of county and local government in implementing flood warning systems will not be reviewed in this report. It will need to be reviewed, in following efforts which have a goal of developing a flood emergency plan for Moorefield and Petersburg, West Virginia.

Advantages of IFLOWS Over Existing Flood Warning Systems

When operating properly, IFLOWS has the capability of giving local county or other local government offices real time rainfall information. The computers located at county offices will be able to see reports on rainfall very soon after it has fallen on the ground. This system will provide a number of observation points in the Upper South Branch of the Potomac River Basin that were not present before. In addition this will enable local officials to continuously monitor a storm as it is occurring thereby decreasing the time needed to issue a flood warning.

With properly functioning automated rain gages now available, a communications system to support it, computers with appropriate software and local trained personnel the IFLOWS system can provide earlier flood warning and improved reliability and timeliness of flood damage reduction actions.

If any of the parts of the system are not operating as designed, or there are no trained personnel to understand how the computer system operates and what to do with the information when it is received, IFLOWS will have limited potential of providing timely flash flood warnings.

RECOMMENDATIONS FOR IMPROVEMENT IN FLOOD WARNING SYSTEMS IN THE SOUTH FORK POTOMAC RIVER BASIN

Those reading this report should keep in mind that flood warning time is short, risk to life is high and flood impacts are severe. Flood warning improvements will provide benefits whether a levee is constructed or not, and flood warnings will be needed to install closures and other actions if a levee is constructed.

This report takes into consideration the present level of development of flood forecasting equipment, communications and organization. The recommendations for improvement are given as an addition to existing conditions.

<u>Level I - Minimum Level of Flood Warning Improvements</u>

A minimum level of flood warning improvements consists of improvements in the river and stream gaging system. This includes the installation of additional equipment on four (4) existing U.S. Geological Survey gaging stations that are presently in place, but currently provide only limited use to flood forecasting because they are either not equipped with equipment data transfer river or stream level information to other locations. It is also recommended that this equipment be added to the single river gage located above Petersburg, WV that has telemetry equipment attached to it, but does not have the capability of the equipment described below. The equipment to be added to these river gages is called "Event Type" reporting equipment which allows the gage to automatically report changes in river levels of 1/2 foot or less. This would provide an early alert to changing river conditions and is very helpful in early detection and monitoring of river levels.

<u>Location of Added Equipment</u>

It is recommended that equipment be added to the following gages:

1. Near Circleville, WV in the North Fork South Branch
2. Near Franklin, WV in the South Branch
3. Near Brandywine in the South Fork South Branch
4. Near Moorefield in the South Fork South Branch
5. Near Petersburg, WV in the South Branch.

Cost of Added Equipment

The cost of this added equipment is as follows:

Item	Cost
Event Type Gage* 5 @ $5,500	$ 27,500
Yearly Maintenance Cost $200.00 per year (5 Gages)	1,000
Total First Year Cost	$ 28,500
Recurring Cost (Yearly)	$ 1,000

*Event type gages include the following equipment: combination rain and river gage, directional antenna, battery, solar panel and lightning detection.

Level II - Advanced Level of Flood Warning Improvements

The advanced level of flood warning improvement is in addition to the items listed in the minimum level of improvement.

An advanced level of flood warning improvement consists of improvements that will improve the accuracy, timeliness and reliability of flood forecasts. This is done through either of two alternative approaches.

Alternative One - is the development of a hydrologic model and training of personnel to carry out flood forecasting at the local level.

Alternative Two - is to contract for this service from a private forecast service.

Cost of Alternative One
Development of a Local Forecast Procedure

Item	Cost
Calibrate a hydrologic model for the five river gages	$ 20,000
Training (yearly)	$ 3,000
Yearly Software and variable updates	$ 6,000
Total First Year Cost	$ 29,000
Recurring Cost (Yearly)	$ 9,000

Cost of Alternative Two
Contract Forecast Services

Item	Cost
Set up and calibrate 6 gages	$ 10,000
Yearly Fee/service for 6 gages	$ 6,000
Total First Year Cost	$ 16,000
Recurring Cost (Yearly)	$ 6,000

Level III - Sophisticated - State of the Art Level of Improvements

The sophisticate or state of the art level of development is in addition to the level of development achieved in the previous two levels of development.

The sophisticated level of development combines the capabilities of flood warning with a delivery system (using a Computerized Emergency Information System) which can show through computer enhancement what will be flooded at each variable flood stage (flood inundation maps). This system will provide more timely evaluation of flood risk, more rapid flood warning and permit the concentration of resources in a phased evacuation effort. This system can be added to either thorough local development or contract services as noted in Level II.

Cost of Level III
Sophisticated - State of the Art Level Development

Item	Cost
Establish Base Station at Petersburg and Moorefield 2 @ $3,000	$ 6,000
Uninterruptable power supply 2 @ $1,500	1,500
Computer software	3,800
Mapping/database	4,000
Maintenance Cost (Yearly)	1,000
Total First Year Cost	$ 15,500
Recurring Cost (Yearly)	$ 1,000

FINDINGS

HYDROLOGIC AND HYDRAULIC WARNING TIMES FOR THE SOUTH BRANCH OF THE POTOMAC RIVER

Very little lead time is available to forecast floods for most of the tributary creeks of the South Fork of the Potomac River above Petersburg and Moorefield, West Virginia. At the most, 2-3 hours of lead time would be available. NWS flash flood warnings are the only source of warning information now. If this level of service is satisfactory, nothing further is recommended. More lead time from flash flooding can be obtained by using rainfall forecasts as input into categorized flood forecast models or procedures which must be developed. This capability could be developed at IFLOWS computer sites or achieved through procurement of a flood forecast service.

Although time to crests along the Upper Potomac River are long enough that effective response can be achieved along the Potomac River at Petersburg and Moorefiled, the time to flood stage is only a few hours.

To expand warning time rainfall forecasts can be added to operation of a local flood warning system using IFLOWS software via vendor ALERT software or private flood forecast service.

Improved Forecast Capability

The expansion of IFLOWS in the upper Potomac River Basin should improve the quality of forecasting and recognition of flood threats. Sampling rainfall is important but additional capability will be required by communities to recognize flood threats early enough so that actions can be taken. The addition of a hydrologic model to forecast Petersburg, Brandywine, Franklin and Moorefield is required. The next step is the capability to put future rainfall into the model to obtain forecasts based on probable forecast rainfall. Finally, the ability to relate crest stage forecasts to flood inundation is important. The use of flood stage inundation maps or flood profiles can determine the severity and extent of flooding that is forecast.

Redundancy in forecasting methods and procedures is a useful tool to increase the reliability of flood warning. Since there is so little warning lead time available in the Upper Potomac River Basin the following combination of methods and resources is recommended:

A. Use of a flood forecasting service.

B. Use of the best in flood forecasting modeling

C. The most effective use of real time rainfall information available through the IFLOWS system can be obtained through well trained staff or volunteers to operate the system.

D. Local organization and a well trained local effort to monitor stream levels early and continuously during so as to detect as quickly as possible any rapid rise in stream levels.

E. A phased program of flood warning system improvement in the South Branch Potomac River Basin is recommended. This program of improvement includes the following:

   Minimum Level of Improvement - Installation of additional equipment to 5 U.S. Geological Survey river gaging stations. "Event Type" reporting equipment allows the gage to automatically report changes of river level of 1/2 foot or less. The cost of these improvements is $28,500 plus a yearly recurring cost of $1,000.

   An advanced Level of Flood Warning Improvement which include additions that will improve the accuracy, timeliness and reliability of flood forecasts. Two alternative methods are indicated with one including the development of a hydrologic model and the training of personnel to carry out flood forecasting. The cost of this alternative is $29,000 plus a yearly recurring cost of $9,000. The other alternative includes contracting for this service from a private forecast service with initial cost of $16,000 plus annual recurring cost of $6,000.

   The most sophisticated - State of the Art Level of Development combines the capabilities of flood warning, included in the above sections, with a delivery system (Using a Computerized Information System) which can show what will be flooded at each variable flood stage (flood inundation maps). The system will provide more timely evaluation of flood risk and more rapid flood warning. The initial cost of this improvement is $15,500 with an annual recurring cost of $1,000

Each of the phases of improvement are incremental with each level of improvement needed for the development of the next level of improvement.

Using a combination of these efforts will reduce flood detection time and increase flood warning lead time.

REFERENCES

River Stage and Precipitation Data from the Baltimore District, Corps of Engineers.

Reconnaissance Report for Flood Mitigation at Petersburg, West Virginia.

NWS/MARFC Unitgraph information for South Branch/Potomac River by Michael Mark, National Weather Service, Harrisburg, PA,

USGS Report on the 1985 Flood

Preliminary Draft Report on 1985 Flood by Dr. Andy Miller, University of Maryland

Hydrologic Data computed by SCS, Morgantown, WV. by Thomas Parkey, Hydraulic Engineer.

Hourly Climate Data, West Virginia, November 1985.

APPENDIX

TECHNICAL REPORT

Flood hydrographs prepared by the U.S. Department of Agriculture, Soil Conservation Service, Morgantown, WV using TR 20 technique.

RUNOFF--VOLUME--ABOVE--BASEFLOW 1.00--WATERSHED--INCHES, 8575.28 CFS-HRS, 741.72 ACRE-FEET; BASEFLOW = 0.0 CFS

OPERATION ADDHYD CROSS SECTION 18
INPUT HYDROGRAPHS= 5,6 OUTPUT HYDROGRAPH= 7

PEAK TIME(HRS) 3.95 PEAK DISCHARGE(CFS) 10361.79 PEAK ELEVATION(FEET) (NULL)

TIME(HRS) FIRST HYDROGRAPH POINT = 0.0 HOURS TIME INCREMENT = 0.20 HOURS DRAINAGE AREA = 107.17 SQ.MI.

TIME(HRS)											
0.0	DISCHG	0.0	66.28	283.63	723.28	1323.35	1991.75	2671.81	3316.46	3949.82	4603.39
2.00	DISCHG	5279.21	5971.89	6677.87	7392.75	8112.90	8826.72	9476.73	9973.58	10252.18	10352.56
4.00	DISCHG	10360.93	10337.80	10303.96	10239.61	10120.51	9942.62	9711.37	9435.31	9119.86	8772.45
6.00	DISCHG	8400.10	8009.30	7606.16	7196.64	6786.19	6379.93	5982.40	5596.84	5225.43	4870.05
8.00	DISCHG	4532.03	4212.16	3910.72	3627.63	3362.51	3114.76	2883.63	2668.28	2467.84	2281.45
10.00	DISCHG	2108.21	1947.27	1797.81	1659.05	1530.24	1410.70	1299.77	1196.87	1101.44	1012.97
12.00	DISCHG	931.00	855.11	784.88	719.96	659.95	604.64	553.58	506.53	463.15	423.32
14.00	DISCHG	386.65	352.96	322.02	293.63	267.60	243.73	221.87	201.85	183.53	166.78
16.00	DISCHG	151.46	137.46	124.67	112.99	102.34	92.63	83.78	75.72	68.38	61.71
18.00	DISCHG	55.64	50.14	45.14	40.61	36.51	32.79	29.44	26.40	23.67	21.20
20.00	DISCHG	18.97	16.97	15.17	13.55	12.10	10.79	9.62	8.58	7.64	6.80
22.00	DISCHG	6.05	5.38	4.78	4.25	3.77	3.35	2.97	2.63	2.33	2.07
24.00	DISCHG	1.83	1.62	1.43	1.27	1.12	0.99	0.87	0.77	0.68	0.60
26.00	DISCHG	0.53	0.46	0.41	0.36	0.32	0.28	0.24	0.21	0.19	0.16
28.00	DISCHG	0.14	0.12	0.11	0.09	0.08	0.07	0.06	0.05	0.04	0.04
30.00	DISCHG	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.0		

RUNOFF VOLUME ABOVE BASEFLOW = 0.94 WATERSHED INCHES, 64891.12 CFS-HRS, 5362.60 ACRE-FEET; BASEFLOW = 0.0 CFS

OPERATION REACH CROSS SECTION 19
INPUT HYDROGRAPH= 7 OUTPUT HYDROGRAPH= 5
LENGTH = 18900.00 FEET INPUT = COEFFICIENTS RELATED TO CROSS SECTIONAL AREA, X= 0.02, M= 1.67

MODIFIED ATT-KIN ROUTING COEFFICIENT = 0.19 PEAK TRAVEL TIME = 1.40 HOURS

PEAK TIME(HRS) 5.34 PEAK DISCHARGE(CFS) 9668.45 PEAK ELEVATION(FEET) (NULL)

TIME(HRS) FIRST HYDROGRAPH POINT = 0.0 HOURS TIME INCREMENT = 0.20 HOURS DRAINAGE AREA = 107.17 SQ.MI.

TIME(HRS)											
0.0	DISCHG	0.0	0.0	12.60	64.13	189.44	405.01	706.67	1080.27	1505.40	1970.11
2.00	DISCHG	2478.74	3004.66	3568.77	4159.85	4774.46	5409.14	6058.86	6708.64	7329.34	7885.00
4.00	DISCHG	8354.11	8735.62	9040.21	9280.46	9462.80	9587.83	9655.27	9665.93	9622.08	9526.59
6.00	DISCHG	9383.21	9196.30	8970.63	8711.21	8423.27	8112.03	7782.72	7440.45	7089.95	6735.47
8.00	DISCHG	6380.82	6029.33	5683.86	5346.75	5019.92	4704.82	4402.52	4113.75	3838.95	3578.28
10.00	DISCHG	3331.74	3099.13	2880.14	2674.38	2481.35	2300.53	2131.36	1973.26	1825.66	1687.97
12.00	DISCHG	1559.65	1440.13	1328.91	1225.48	1129.37	1040.14	957.34	880.58	809.47	743.63
14.00	DISCHG	682.74	626.45	574.45	526.46	482.20	441.40	403.82	369.23	337.41	308.15
16.00	DISCHG	281.27	256.59	233.94	213.17	194.12	176.67	160.70	146.07	132.70	120.47
18.00	DISCHG	109.30	99.10	89.79	81.30	73.56	66.52	60.11	54.27	48.98	44.16

PEAK TIME(HRS)	PEAK DISCHARGE(CFS)	PEAK ELEVATION(FEET)
8.88	731.90	(NULL)
14.21	1082.45	(NULL)
20.47	6039.45	(NULL)
33.24	36493.90	(NULL)

FIRST HYDROGRAPH POINT = 0.0 HOURS TIME INCREMENT = 0.20 HOURS DRAINAGE AREA = 107.17 SQ.MI.

IME(HRS)											
4.00	DISCHG	0.0	0.0	0.0	0.13	0.92	3.59	9.72	20.87	36.91	57.83
6.00	DISCHG	83.62	114.42	150.47	191.86	238.45	289.92	345.56	404.11	464.70	526.93
8.00	DISCHG	590.30	649.40	695.73	722.01	731.15	729.88	722.55	711.44	694.00	669.11
10.00	DISCHG	638.07	603.21	566.63	530.08	494.54	461.51	435.13	422.34	429.02	452.96
12.00	DISCHG	487.57	531.20	586.03	655.48	739.14	833.35	924.88	999.53	1045.58	1068.95
14.00	DISCHG	1079.79	1082.45	1080.18	1068.65	1044.63	1012.75	988.92	998.75	1065.44	1184.52
16.00	DISCHG	1332.47	1502.15	1694.78	1917.77	2173.05	2453.73	2750.23	3055.01	3362.57	3670.81
18.00	DISCHG	3977.09	4269.41	4523.83	4724.45	4879.25	5006.16	5124.43	5257.95	5424.94	5611.78
20.00	DISCHG	5795.82	5949.39	6032.86	6020.48	5932.72	5809.21	5680.77	5566.69	5471.17	5378.52
22.00	DISCHG	5278.26	5159.94	5008.04	4819.73	4612.98	4404.33	4198.52	3996.59	3793.62	3583.20
24.00	DISCHG	3370.37	3169.32	2999.15	2874.56	2791.60	2741.66	2762.46	2924.66	3287.54	3823.11
26.00	DISCHG	4466.19	5149.15	5836.48	6521.09	7221.46	7943.86	8675.52	9402.25	10100.61	10757.83
28.00	DISCHG	11380.07	11999.79	12671.91	13444.49	14299.80	15191.73	16160.13	17305.60	18721.24	20373.34
30.00	DISCHG	22156.27	23936.65	25607.61	27110.77	28494.54	29811.34	31054.00	32197.07	33168.77	33959.56
32.00	DISCHG	34601.45	35127.50	35561.85	35916.19	36192.81	36392.33	36491.64	36443.87	36212.23	35828.90
34.00	DISCHG	35361.94	34886.85	34474.91	34167.09	33932.07	33731.36	33531.74	33301.83	33047.15	32798.25
36.00	DISCHG	32569.53	32328.46	32013.95	31550.57	30968.95	30319.31	29617.61	28847.14	27977.00	27013.98
38.00	DISCHG	26060.77	24986.89	24020.66	23133.21	22312.63	21540.36	20828.48	20207.24	19716.12	19347.72
40.00	DISCHG	19069.51	18830.60	18550.04	18177.77	17753.25	17319.98	16894.35	16476.62	16049.88	15602.75
42.00	DISCHG	15132.21	14635.49	14096.34	13501.87	12866.87	12219.21	11590.20	11005.48	10479.07	9997.50
44.00	DISCHG	9546.96	9128.55	8746.36	8417.52	8144.75	7920.43	7735.59	7583.12	7458.68	7360.29
46.00	DISCHG	7281.72	7202.84	7091.18	6920.55	6700.05	6456.51	6203.76	5943.50	5669.30	5376.84
48.00	DISCHG	5070.31	4757.90	4445.92	4139.18	3840.91	3552.91	3276.15	3011.38	2759.51	2521.28
50.00	DISCHG	2297.45	2088.64	1894.93	1716.02	1551.50	1400.77	1263.13	1137.79	1023.91	920.62
52.00	DISCHG	827.07	742.41	665.89	596.79	534.45	478.26	427.64	382.07	341.07	304.20
54.00	DISCHG	271.07	241.32	214.61	190.66	169.20	150.00	132.85	117.55	103.93	91.82
56.00	DISCHG	81.08	71.55	63.10	55.63	49.02	43.18	38.03	33.48	29.47	25.93
58.00	DISCHG	22.81	20.06	17.63	15.49	13.59	11.92	10.44	9.13	7.98	6.96

RUNOFF VOLUME ABOVE BASEFLOW = 7.19 WATERSHED INCHES, 497019.44 CFS-HRS, 41073.68 ACRE-FEET; . BASEFLOW = 0.0 CFS

55.00	DISCHG	9212.93	8396.92	7711.79	7133.23	6616.42	6137.67	5673.11	5217.21	4777.97	4371.00
60.00	DISCHG	4012.37	3712.84	3475.31	3295.54	3164.78	3072.69	3009.34	2966.41	2937.44	2917.78
65.00	DISCHG	2904.11	2894.31	2886.94	2881.09	2876.17	2871.82	2867.78	2863.92	2860.15	2856.41
70.00	DISCHG	2852.65	2848.88	2845.09	2841.29	2837.49	2833.65	2829.77	2825.81	2821.72	2817.45
75.00	DISCHG	2812.97	2808.28	2803.40	2798.37	2793.22	2787.99	2782.72	2777.43	2772.12	2766.82
80.00	DISCHG	2761.54	2756.29	2751.06	2745.86	2740.68	2735.54	2730.43	2725.36	2720.32	2715.28
85.00	DISCHG	2710.22	2705.14	2700.00	2694.81	2689.58	2684.32	2679.04	2673.76	2668.47	2663.18
90.00	DISCHG	2657.88	2652.55	2647.17	2641.71	2636.13	2630.42	2624.60	2618.68	2612.68	2606.64
95.00	DISCHG	2600.58	2594.55	2588.57	2582.66	2576.80	2571.02	2565.29	2559.63	2554.09	2548.68
100.00	DISCHG	2543.39	2538.18	2532.98	2527.68	2521.96	2515.15	2506.98	2497.84	2488.27	2478.58
105.00	DISCHG	2468.94	2458.91	2445.01	2420.78	2388.90	2354.52	2321.04	2290.83	2265.11	2244.08
110.00	DISCHG	2227.33	2214.09	2203.44	2194.40	2184.95	2173.81	2161.51	2146.00	2131.37	2119.17
115.00	DISCHG	2109.48	2101.60	2094.24	2085.44	2073.13	2057.04	2038.86	2020.18	2000.32	1978.47
120.00	DISCHG	1957.47	1939.77	1925.84	1915.07	1906.53	1899.49	1893.43	1888.05	1883.18	1878.64
125.00	DISCHG	1874.31	1870.11	1865.99	1861.88	1857.77	1853.61	1849.41	1845.17	1840.87	1836.53
130.00	DISCHG	1832.17	1827.80	1823.38	1818.94	1814.50	1809.99	1805.45	1800.67	1795.07	1787.63
135.00	DISCHG	1777.44	1764.33	1745.02	1732.60	1715.92	1699.39	1683.17	1667.29	1651.61	1636.33
140.00	DISCHG	1621.73	1608.18	1595.95	1585.16	1575.75	1567.52	1560.16	1553.09	1545.43	1536.38
145.00	DISCHG	1525.74	1514.03	1502.09	1490.24	1476.68	1458.10	1436.11	1413.12	1390.29	1367.46

UBROUTINE ADDHYD   CROSS SECTION   35

HYDROGRAPH, TZERO=   0.0   DELTA T= 0.50   DRAINAGE AREA= 275.45

TIME		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.46	15.73	76.31
0.0	DISCHG	0.0	0.0	0.0	898.02	1164.01	1426.73	1679.30	1906.51	2669.91	2178.08
5.00	DISCHG	2.5.02	398.62	638.25	2385.09	2536.65	2799.23	3134.31	3402.03	3533.67	3536.55
10.00	DISCHG	2244.89	2303.10	2334.69	4536.48	5425.50	6436.60	7501.30	8400.27	8982.47	9421.96
15.00	DISCHG	3493.65	3567.92	3918.88	11217.65	11509.68	11813.76	11795.96	11476.42	11115.09	10938.23
20.00	DISCHG	9995.02	10645.80	11030.03	13268.98	14610.78	15814.94	17069.09	18594.96	20557.01	23283.88
25.00	DISCHG	10868.39	11118.18	11985.19	38978.16	41599.27	43907.45	45829.93	47477.54	48951.90	50926.96
30.00	DISCHG	27203.70	31613.86	35761.35	62006.62	62271.65	62326.94	61861.28	61065.93	60251.52	59769.33
35.00	DISCHG	54311.32	58065.28	60830.77	58234.44	57345.66	56569.57	55823.93	55302.42	55068.66	54928.44
40.00	DISCHG	59661.51	59592.21	59068.26	48729.29	46034.02	43253.39	40456.28	37729.36	35092.98	32546.35
45.00	DISCHG	54376.16	52976.64	51072.55	22894.43	20748.34	18831.70	17159.85	15688.65	14349.85	13090.53
50.00	DISCHG	30057.82	27603.12	25201.83	8871.06	8114.22	7471.68	6914.05	6409.26	5931.89	5469.11
55.00	DISCHG	11893.46	10773.37	9758.59	3888.30	3617.96	3406.20	3247.16	3131.90	3050.76	2994.82
60.00	DISCHG	5021.47	4599.50	4217.64	2900.66	2891.60	2884.69	2879.11	2874.35	2870.07	2866.08
65.00	DISCHG	2956.73	2930.86	2913.11	2850.94	2847.16	2843.37	2839.57	2835.74	2831.89	2827.96
70.00	DISCHG	2862.24	2858.47	2854.71	2810.80	2806.03	2801.09	2796.01	2790.83	2785.55	2780.32
75.00	DISCHG	2823.94	2819.75	2815.38	2759.16	2753.92	2748.71	2743.52	2738.36	2733.23	2728.14
80.00	DISCHG	2775.02	2769.72	2764.43	2707.91	2702.80	2697.64	2692.43	2687.19	2681.92	2676.64
85.00	DISCHG	2723.08	2718.03	2666.77	2655.46	2650.10	2644.68	2639.16	2633.52	2627.76	2621.89
90.00	DISCHG	2671.36	2666.07	2603.89	2597.85	2591.85	2585.90	2580.02	2574.20	2568.44	2562.74
95.00	DISCHG	2615.94	2609.93	2546.31	2541.65	2535.82	2530.57	2525.02	2518.69	2511.18	2502.62
100.00	DISCHG	2557.14	2551.66	2474.21	2464.33	2451.99	2432.25	2404.67	2372.51	2339.29	2307.85
105.00	DISCHG	2493.38	2483.83	2237.41	2222.11	2209.87	2199.75	2190.18	2179.66	2168.00	2153.92
110.00	DISCHG	2283.01	2256.53	2115.28	2106.32	2098.45	2090.08	2079.26	2065.09	2048.28	2030.18
115.00	DISCHG	2139.36	2126.23	1968.99	1949.98	1934.19	1921.64	1911.73	1903.71	1896.99	1891.16
120.00	DISCHG	2010.95	1990.25	1876.73	1872.44	1868.26	1864.14	1860.02	1855.88	1851.70	1847.48
125.00	DISCHG	1885.97	1881.21	1834.55	1830.19	1825.79	1821.36	1816.93	1812.45	1807.92	1803.24
130.00	DISCHG	1843.21	1838.90	1782.50	1770.91	1756.85	1741.28	1724.93	1708.42	1692.05	1676.04
135.00	DISCHG	1797.99	1791.37	1629.84	1615.79	1602.90	1591.36	1581.15	1572.28	1564.39	1557.06
140.00	DISCHG	1660.23	1644.76	1531.25	1520.19	1508.52	1496.71	1483.83	1467.41	1447.38	1427.76
145.00	DISCHG	1549.55	1541.09								