Service Assessment

Northeast Floods of January 1996

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
Office of Hydrology
Silver Spring, Maryland

Incident: Flood Northeast U.S. 1996

Date of Incident: January 1996 **Date Final Report Issued:** March1998

Incident Cost: **$** 1.5 billion **Fatalities:** 33

Maximum Intensity: NA

Executive Summary

An unusually intense rainfall and rapid snowmelt on January 18-19, 1996, resulted in major flooding on rivers from Virginia to New York and Vermont, and in the upper reaches of the Ohio River drainage. Above-average snow cover over the region and high melt rates produced by above freezing temperatures, high relative humidity, and high wind speeds produced large snowmelt contributions to the flood. Record flood crests were set in Pennsylvania, New York, West Virginia, and Maryland. The Delaware River crested at its highest stage since Hurricanes Connie/Diane in 1955. The Hudson crested as its highest stage since 1977. The Ohio River at Pittsburgh, the Susquehanna River at Wilkes-Barre, and the Potomac River at Little Falls, Virginia, all crested at the highest stages since Hurricane Agnes in 1972.

Description of Flooding

A succession of snowstorms brought significant and widespread snow accumulation across much of the northeastern United States by Wednesday, January 17, 1996. Snow depths of 40-50 inches were common from central Pennsylvania into New York State. From southern Pennsylvania, across Maryland and West Virginia into Virginia, snow depths averaged 12 inches or more, with significantly higher amounts in the mountains. A strong storm system then moved through the eastern United States January 18-19, 1996, bringing heavy precipitation as well as high temperatures, humidity, and winds into the Ohio, Susquehanna, and mid-Atlantic drainages. Mean areal basin average rainfall varied from 1.2 inches to slightly over 3 inches, with some individual gages reporting over 4 inches. At most locations, the intense rain lasted for only about 6 hours. The heavy rains combined with significant snowmelt, and in some cases ice jams, to produce major flooding in Pennsylvania, West Virginia, New York, Virginia, Maryland, Vermont, Ohio, and New Jersey.

The magnitude of the flooding varied between basins, but it was a major event throughout the area. More than 100,000 people were evacuated in the Wyoming Valley region of the Susquehanna River Basin in Pennsylvania. The entire town of Marlinton, West Virginia (1,100 people) on the Greenbrier River was evacuated. Many evacuations also took place in the Allegheny, Susquehanna, and Finger Lakes drainages in Pennsylvania and New York. The Ohio River at Pittsburgh had its highest crest (crest was affected by ice) since Hurricane Agnes in 1972 (Table 1). On the

Susquehanna River at Wilkes-Barre, the crest of 34.5 feet on Saturday, January 20, exceeded all past floods except for Hurricane Agnes in 1972. Record floods occurred on Loyalsock Creek at Loyalsock, Pennsylvania; the Greenbrier River at Marlinton, West Virginia; Wills Creek at Cumberland, Maryland; and Opequon Creek at Martinsburg, West Virginia. Record crests were also observed on the Lower Conemaugh River, Lower Mahoning River, West Branch Clarion River, Aughwick Creek, Towanda Creek, Tunkhannock Creek, and Frankstown Branch (Little Juniata), all in Pennsylvania.

Table 1. *Selected Northeast Flood Crests - January 1996*

	Flood Stage -	Crest -	
Location	ft (m)	ft (m)	Comment
Ohio River			
@ Pittsburgh	25 (7.6)	34.6 (10.5)	Highest Since Hurricane Agnes, 1972 (crest affected by ice)
Susquehanna River			
@ Wilkes-Barre	22 (6.7)	34.5 (10.5)	Highest Since Hurricane Agnes, 1972
Susquehanna River			
@ Harrisburg	17 (5.2)	24.7 (7.5)	Highest Since Hurricane Eloise, 1975
Delaware River			
@ Trenton	20 (6.1)	22.2 (6.8)	Highest Since Hurricane Connie, 1955
Potomac River			
@ Little Falls	10 (3.0)	19.0 (5.8)	Highest Since Hurricane Agnes, 1972
James River			
@ Richmond	12 (3.7)	20.6 (6.3)	Highest Since 1987
Hudson River			
@ Albany	11 (3.4)	15.5 (4.7)	Highest Since 1977

As flood waters began to recede, there were reports of flood-related deaths. A total of 33 deaths was reported with 18 in Pennsylvania, 10 in New York, 1 in West Virginia, 3 in Virginia, and 1 in Vermont. Based on the widespread nature of the flooding and comparisons to historical floods, it is estimated that total flood-related damages exceeded $1.5 billion.

Snow Cover and Snowmelt

The abnormally large snow cover that accumulated over the northeastern United States in the weeks prior to the flood event was the result of a number of storms and below normal temperatures that inhibited snow melt in the weeks prior to the flood. The "Blizzard of 96," which occurred from January 6-8, 1996, was a major contributor to the snow cover from Virginia, across Maryland, and through much of Pennsylvania and New Jersey. Following the blizzard, two additional storms dumped up to 3 feet of snow across portions of the Catskills of New York and northeast Pennsylvania adding to near record November through December snow falls in this region. During the period before the flood event, January 14-17, above freezing temperatures occurred over most of the area. Significant snowmelt occurred west of the Appalachian mountains. The snow cover was also partly depleted in parts of Virginia and eastern Maryland prior to the flood event. Over portions of Pennsylvania, New York, and New Jersey, this warming period caused some ripening (warming and preliminary melting) of the snow cover, but there was little reduction in the water equivalent. An estimate of the water equivalent of the snow cover over the primary flood area on the morning of Thursday, January 18, using all available data, ranged from zero inches in the far southeastern portion of the area to over 5 inches in areas from south-central Pennsylvania to the Catskill Mountains of New York.

On the morning of Thursday, January 18, unprecedented snowmelt occurred just prior to the onset of the heavy rains associated with warmer temperatures in the western portion, and continued through the afternoon of Friday, January 19, in the eastern portion of the region. For example, at Binghamton, New York, just over 3 inches of water equivalent was reported before the event, and the snow was gone at the site by mid-morning on Friday, January 19. Changes in water equivalent of 3-5 inches were typical in open, non-wooded areas. Generally, any given area experienced between 18- 30 hours of high snowmelt rates. The rapid snowmelt was caused primarily by the turbulent transfer of latent and sensible heat due to the high temperatures, dew points, and wind speeds. By taking the difference between the estimated water equivalent before and after the event, the estimated snowmelt contribution to the flooding, on a watershed basis, was in the range of 2.5- 5 inches.

Forecasts and Warning Services

The Northeast Floods of January 1996 created challenges for all National Weather Service (NWS) offices involved in issuing timely and accurate watches, advisories, warnings, statements, and other public products. Hundreds of river forecasts were issued under very complicated and unprecedented conditions.

Public forecasts and warning products issued by NWS offices in areas impacted by this major flood event accurately highlighted the weather as it developed across their areas of responsibility. Most products were well written, timely, and contained good call-to- action statements. Outlook statements issued earlier in the week provided the public, media, and public safety officials with information concerning flood potential. Since state and local emergency managers from New York, Pennsylvania, New Jersey, Maryland, West Virginia, and Virginia were still mobilized due to the recent blizzard, it was fairly easy for most of them to prepare to handle a flood event; however, on- going disaster mobilization taxes resources.

Flood watches were posted by the NEXRAD Weather Service Forecast Office (NWSFO) Pittsburgh, Pennsylvania, for selected rivers of eastern Ohio and west central Pennsylvania on Wednesday, January 17, and extended for all of east central Ohio, western Pennsylvania, and northern West Virginia on Thursday, January 18. Also on January 18, watches were posted by NWSFO Charleston, West Virginia, for a significant portion of West Virginia and the New River Valley of southwest Virginia. Additional watches were issued on Thursday afternoon, by NWSFOs in Buffalo and Albany for central and eastern New York, and by NWSFO Baltimore, Maryland/Washington, DC, for portions of Virginia, West Virginia, and Maryland. NWSFO Philadelphia, Pennsylvania, issued a flood watch for extreme southeast Pennsylvania and portions of New Jersey, Maryland, and Delaware on Thursday afternoon, and for the remainder of eastern Pennsylvania and New Jersey early Friday morning.

Quantitative Precipitation Forecasts (QPF)

Areal average 24-hour Quantitative Precipitation Forecasts (QPF) issued on Thursday, January 18, by the NWSFOs in Pittsburgh, Pennsylvania, and Charleston, West Virginia, ranged from 0.25-0.5, and 0.5-1 inch, respectively. QPFs released early Friday morning, January 19, by NWSFOs Pittsburgh, Pennsylvania; Philadelphia, Pennsylvania; Albany, New York; and Baltimore, Maryland/Washington, DC, contained amounts ranging from 0.25-0.75 inch.

All QPF products were later updated after heavier precipitation amounts were observed as the storm system moved into and across the region on Friday morning. Doppler Weather Surveillance Radar (WSR-88D) precipitation estimates, the National Center for Environmental Prediction (NCEP) numerical model, and the Hydrologic Prediction Center (HPC) value-added QPFs underestimated the amount of rainfall as revealed by the gage observations, although the HPC value-added QPFs represented a significant improvement over the model QPFs.

Data

Automated and manual data networks and equipment had performance problems during this flood event; sporadic equipment problems and many critical outages of automatic and manual gage networks were noted during this event that impacted data acquisition. Many unheated tipping bucket precipitation gages became blocked with snow due to the heavy snowfall from the previous weekend. River gages were affected by ice jams, and there was water in several gage houses which washed out or contaminated the antifreeze.

All offices are equipped with a state-of-the-art WSR-88D, which provides an areal assessment of rainfall amounts based on returned power processed through a series of hydrometeorological algorithms. The radars at Binghamton, New York; State College, Pennsylvania; and Philadelphia, Pennsylvania, did a good job of providing reasonably accurate rainfall amounts.

In general, WSR-88D precipitation products underestimated the rainfall by a factor of 2 or more. In most areas, forecasters were able to make adequate manual adjustments to the estimates based on comparison to rain gage reports. Most forecasters who worked this event were pleased with the precipitation products generated by the WSR-88D. While rainfall estimates were not perfect, they provided a good representation of the rainfall patterns when compared to rain gage measurements. Rainfall estimates provided by these radars, along with critical rainfall reports from cooperative observers, were crucial to the issuance of early Flood and Flash Flood Warnings. The Susquehanna Flood Forecast and Warning System is a nonstructural flood mitigation measure that was implemented in 1985; it provided significant additional data which helped the NWS issue timely watches and warnings.

Preparedness and Coordination

All office Station Duty Manuals (SDM) were up to date and provided the staff with specific information concerning office operations and actions during both river and flash flood events. All SDMs, along with NWS Form E-19, depicted flood-prone and flood inundation areas.

Specific hydrologic drills had been accomplished by all offices to ensure all office personnel were trained to handle any type of flooding. Most drills had been completed within the past 6 months. Hydrologic service drills and staff training are usually conducted by the Service Hydrologist (SH) and/or Warning Coordination Meteorologist (WCM).

During the past year, numerous outreach activities and hazardous weather training, focusing on flooding and severe weather, were provided by NWSFOs in Pittsburgh, Pennsylvania; Baltimore, Maryland/Washington, DC; Philadelphia, Pennsylvania; and Charleston, West Virginia; and by NWSOs in Binghamton, New York; State College, Pennsylvania; and Wilmington, Ohio. Extensive coordination between the RFCs and their respective HSAs was also accomplished during this period. All offices have an excellent line of communication with County Warning Area (CWA) media, and emergency management and other public safety officials. During this flood event, several spotter groups were activated due to the possibility of severe weather Friday morning, January 19, but they were also used to report flood conditions and precipitation amounts.

Media and User Response

Overall, media coverage relating to the Northeast Floods of January 1996 -- the worst flooding in more than 10 years across the mid-Atlantic region—was positive. News stories focused on the cause and extent of the flooding, human interest stories, and recovery efforts, and they accurately highlighted the weather as it developed across the region.

The February 4 issue of Newsweek credited the NWS for the advance warnings of the flooding:

"Modernized equipment allowed the National Weather Service in January to warn the eastern U.S. of flash floods up to 24 hours before major rivers crested. State-of-the-art Doppler radars monitored rainfall, while a new computer network let the service swap data in real time with states and counties."

On Monday and Tuesday before the event, all NWS offices in the region issued Flood Potential Statements so the public and media were aware that spring-like ice jam flooding would occur. Throughout the flood-ravaged areas, the primary sources of information for most citizens were radio and television broadcasts. Most radio and television stations aired watches and warnings as soon as they received them. All local Emergency Broadcast System (EBS) radio and television stations aired watch and warning information beginning Thursday before the event.

As a result of the significant impact of the major flooding in Pennsylvania, a special State House committee reviewed the operations of the NWS and other state and Federal agencies. The five-member bipartisan committee, which held hearings in Charleroi and Williamsport, Pennsylvania, concluded that the NWS provided timely watches and warnings.

Summary

The Northeast Floods of January 1996 provided many challenges for all NWS offices involved with the flood. In spite of the rapid onset and complexity of this event, the warnings and forecasts provided by NWS personnel, in cooperation with emergency managers and the media, provided excellent service to the public and specialized users. The NWS did an outstanding job in recognizing the flood potential, a full 5 days in advance, and getting the word out to the public, emergency services, and hydrologic agencies so that they could take the necessary actions to prepare for and fight the flood.

In spite of the outstanding efforts of the NWS, the media, and the emergency management community, there were 33 fatalities. In an effort to mitigate potential future losses, one responsibility of the disaster survey team is to review operations, highlighting positive aspects and identifying any weaknesses.

Recommendations

FINDING 1.1: There is no objective method to use all of the available snow observations to determine a best estimate of the areal snow water-equivalent and to use this estimate to adjust the value computed by the snow models at RFCs. There are also a minimal amount of water-equivalent observations available to develop such an estimate. Areal estimates of water-equivalent are provided by the NOHRSC based on airborne snow survey data, but these estimates do not take into account other snow measurements or terrain information. A technique has been developed for use in the mountainous areas of the western United States. This technique is referred to as the Snow Estimation and Updating System (SEUS). The SEUS estimates of water equivalent can be combined with model-computed values in a manner that preserves the information content of both quantities.

RECOMMENDATION 1.1: A SEUS or similar type procedure is needed for the eastern United States so that snow measurements can objectively be used to update the RFC snow model. In order to more effectively implement such a procedure, it would be helpful to have additional water-equivalent measurements, especially from airborne snow surveys, during periods with significant snow cover.

FINDING 1.2: The NWSRFS operational forecast program does not contain an option to adjust snowmelt computations during rain-on-snow events. This prevents a forecaster from increasing melt rates during rain periods and/or periods with abnormally high wind speeds, such as occurred during this event.

RECOMMENDATION 1.2: A run-time modification should be added to the NWSRFS forecast program that will allow UADJ values to be modified by the forecaster. The adjustment should be capable of being varied period by period, as is currently the case with the correction to the nonrain melt factor.

FINDING 1.3: The NWSRFS snow model functions best when calibrated for individual watersheds. Global calibration causes inaccurate estimates of snow accumulation and melt rates under normal conditions and makes it difficult for a forecaster to make rational adjustments during periods of abnormal snowmelt. Also, objective updating techniques rely on a properly calibrated model.

RECOMMENDATION 1.3: The SNOW-17 model should be calibrated so that the parameter values will provide reasonably accurate simulations of the accumulation and melting of the snow cover. Regional calibration of the model is a reasonable first step. The calibrations should use data that have been adjusted for topographic conditions. The operational implementation of the calibration results should be done in a manner that does not create a bias between the historical and operational data networks.

FINDING 1.4: Currently, there is no method of using meteorological variables, other than air temperature, either to perform snowmelt computations or to identify and correct for periods with abnormal snowmelt rates. With all the uncertainties involved, it is difficult to determine the proper correction to the melt rate based on hydrograph response. The lack of such a method also prevents the RFCs from making quantitative predictions when meteorological forecasts suggest the possibility of abnormal melt rates.

RECOMMENDATION 1.4: Procedures need to be developed to use meteorological variables other than air temperature to estimate the amount of snowmelt, especially during periods of abnormal melt rates. This could involve utilizing such variables directly in the snowmelt calculations or developing a method of using the variables to determine reasonable corrections to be applied to the SNOW-17 model on a regional basis. There is some evidence from past studies that it would be difficult to get quality estimates of energy exchange variables for each individual watershed from the available real-time and historical data, and unless quality estimates are available, energy exchange computations could even result in worse estimates of snowmelt on an overall basis than just utilizing air temperature. Perhaps some of the newer remote sensing techniques could be used to get quality estimates of the energy exchange variables. The regional approach might involve generating corrections at synoptic stations and then interpolating the corrections to individual watersheds. The corrections would probably be applied only if abnormal melt rates were indicated. Both methods require that the snow model be properly calibrated to each watershed. The development of either method would be a sizable task, but should greatly improve the RFCs ability to respond to abnormal snowmelt situations.

FINDING 1.5: Presently, it is difficult for the forecaster to visualize what is occurring inside the hydrologic models. Without knowing what portions or equations of the model are currently being used, it is difficult, in many cases, to make a rational decision as to the proper adjustment to apply to bring the model computations in line with observations.

RECOMMENDATION 1.5: Displays should be added to the NWSRFS Interactive Forecast Program (IFP) allowing the forecaster to see what is taking place inside the snowmelt and rainfall-runoff models.

FINDING 1.6: There has been insufficient training on certain aspects of the physics of a snow cover for hydrologists at the RFCs, especially in regard to liquid water retention in the pack and energy exchange at the surface.

RECOMMENDATION 1.6: Additional training should be provided to the RFCs on the physics of snow ablation.

FINDING 1.7: The precipitation estimates for this event were generally low in the mountainous areas in part because orographic influences are not used in the computation of MAP values. Also, there was no easy way for the forecasters to visualize how precipitation was varying as a function of the terrain.

RECOMMENDATION 1.7: The RFCs need to use procedures in the mountainous portions of their areas that account for the effect of terrain on precipitation. This should also be done in the case of temperature. In addition, improved displays need to be used that will depict the interaction between the precipitation and the terrain for the current event and compare this to isohyetal analyses based on historical data.

FINDING 1.8: Estimates of computed antecedent moisture condition values were generally too low for this event because of the algorithms used in the event API models used by both RFCs. This resulted in model computed peak flows to be as much as 20 percent lower than would be expected based on water balance considerations.

RECOMMENDATION 1.8: The RFCs should make a transition to using a continuous, water balance rainfall-runoff model containing the basic physics of water retention and movement in the soil and using evapotranspiration estimates to compute changes in soil-moisture between events.

FINDING 1.9: It would be extremely valuable, prior to an event such as this, to be able to generate predictions that quantified uncertainty so that reliable statements could be made concerning the likelihood of exceeding critical river levels.

RECOMMENDATION 1.9: The NWS should continue a strong emphasis on developing and implementing the technology contained in AHPS and the PQPF procedures currently being developed under the guidance of Eastern Region Headquarters.

FINDING 2.1: Accurate and up-to-date NWS Form E-19s contain a wealth of information concerning record flood stages and other flood history for each forecast point within the HSA.

RECOMMENDATION 2.1: NWSFO's and NWSO's should routinely update all E-19's and after each major flood event within their HSA. Since many gage heights reached near record stages, all E-19s should be updated to reflect the conditions that resulted from this flood event. Also, E-19's should be made available to appropriate internal and external users.

FINDING 2.2: Given the uncertainty associated with routine QPFs, updates are needed whenever an earlier forecast is under or overestimating basin average precipitation. Coordination is required between the RFC and the Weather Forecast Offices (WFO) for updating river forecasts when needed.

RECOMMENDATION 2.2: Offices need closer coordination in issuing updated or amended routine QPF products. The HAS function can serve as a catalyst in coordinating updates between the RFC and WFO.

FINDING 2.3: Use of short-term QPF information can significantly enhance the accuracy and lead time of Flash Flood Warnings.

RECOMMENDATION 2.3: Offices should make conscious efforts to develop and use short-term QPF forecasts in the Flash Flood Warning decision-making process.

FINDING 2.4: NWS field offices need a workstation-based hydrologic program to quickly compute headwater-type forecasts for their HSA. The Advanced Weather Interactive Processing System (AWIPS) will include the WFO Hydrologic Forecast System (WHFS) which will ultimately contain a site-specific hydrologic model.

RECOMMENDATION 2.4: AWIPS should be implemented as quickly as possible.

FINDING 2.5: NWSOs and NWSFOs require additional hydrologic information.

RECOMMENDATION 2.5: RFCs, in cooperation with NWSOs and NWSFOs, should provide, as appropriate, more hydrologic information (e.g., complete hydrographs, flow, etc.). Improved communications (including graphical) systems must be developed in order to provide additional hydrologic information.

FINDING 2.6: The Pennsylvania statewide distribution of NWS products is issued by message header code through their distribution system, not by county code. This caused county public safety officials to be saturated with warnings that did not apply to their county, or warnings were not received at all.

RECOMMENDATION 2.6: The NWS and Pennsylvania EMA should work to correct this dissemination problem so warning distribution in Pennsylvania can target appropriate counties. Emergency managers should also explore obtaining Emergency Management Weather Information Networks (EMWIN) for their county emergency dispatch or 911 centers.

FINDING 2.7: Emergency managers want a variety of well-coordinated hydrologic information in a timely and uniform fashion.

RECOMMENDATION 2.7: RFCs should, in cooperation with NWSOs and NWSFOs, begin providing products, including probabilistic information, in a more uniform format.

FINDING 2.8: Although most offices correctly issued many flood and flash flood watches, warnings, and advisories, there is still some confusion as to what information the products should contain, how to incorporate this information in the short-term forecast, and what information should be contained in Flood/Flash Flood Statements versus the short-term forecast.

RECOMMENDATION 2.8: Many new AFOS headers are being added for specialized products. WSH should look at ways to eliminate some product headers and provide the user with fewer products that give all necessary information instead of issuing many products for specialized situations.

FINDING 3.1: WSR-88D precipitation estimates were very good at Binghamton, New York; and State College, Pittsburgh, and Philadelphia, Pennsylvania. Those stations used the precipitation estimates to generate hydrologic products. WSR-88D precipitation amounts were poor at Baltimore, Maryland/Washington, DC, due to beam blockage to the west.

RECOMMENDATION 3.1: Each field office should conduct local hydrologic studies to determine how best to evaluate WSR-88D generated precipitation values based on storm type, beam blockage, and other effects. As more experience is gained in this area, future Operational Support Facility (OSF) software builds should incorporate some form of probability on the accuracy of precipitation measurements from different storm types. Better scan strategies, improved Z/R relationships for meteorological events, improved calibration of WSR-88Ds, and the use of multi-sensor in calibration all need to be investigated.

FINDING 3.2: RFC/Hydrometeorological Analysis and Support (HAS) forecasters do not have the means to generate and/or loop regional/national composite reflectivity or rainfall radar products. HAS forecasters currently dial-up radars individually and routinely encounter transmission problems, busy signals, and premature termination of data inquiry by the remote RPG being accessed. Additionally, this process is very time-consuming, and the data is limited to those WSR-88Ds whose surveillance area intersects the RFC's umbrella of responsibility. Consequently, HAS forecasters have limited access to WSR-88D data, and they are relegated to generating a mental composite of the available data. The ability of forecasters to directly access and loop composite WSR-88D data (in near real time) within and beyond their forecast area is crucial to monitoring the development and evolution of precipitation systems and generating a mosaicked QPF. Further, the capability to display and loop regional/national radar products would also be of significant benefit to NWSFO and NWSO forecasters.

RECOMMENDATION 3.2: Provide RFC/HAS forecasters and NWSFO/NWSO forecasters with high temporal and spatial resolution, national, real-time, WSR-88D reflectivity, and rainfall mosaics.

FINDING 3.3: The current system for the transmission of DCP data does not adequately meet the operational needs of the RFCs and NWSFOs/NWSOs. The current NWS system for receipt and decoding of DCP data cannot decode partial DCP transmissions which do occasionally occur.

RECOMMENDATION 3.3: The NWS needs to coordinate closely with other agencies to ensure random reports are being sent from all DCPs. The criteria for random reporting must be set at levels which are useful to the NWS. Also, the NWS needs to investigate decoding partial DCP transmissions.

FINDING 3.4: Before and during the event, critical automatic precipitation gages were out of service due to jamming by snow. Either these gages were not available for liquid precipitation measurements or the information was in error.

RECOMMENDATION 3.4: The NWS should continue to pursue fielding an all-weather type of automatic precipitation gage, such as a digital weighing or heated rain gage, that can be used on Limited Automated Remote Collectors (LARC), Automatic Remote Collectors (ARC) and Automated Surface Observing System (ASOS) equipment. Every effort should be made to repair critical gage equipment and keep all gages operational.

FINDING 3.5: Ice jam and flow information collected by Data Acquisition Program Managers (DAPM) and state and local agencies sometimes does not reach the NWS.

RECOMMENDATION 3.5: The NWS should work with state and other Federal agencies to establish a common network of river watchers who will report ice conditions and thickness on a routine basis.

FINDING 3.6: Local community gage networks (ALERT, IFLOWS, Manual, etc.) worked well in this event to provide advanced notification of flooding and rain; to provide WSR-88D precipitation verification; and to fill the gaps between the Federal network of gages.

RECOMMENDATION 3.6: All field offices should continue to enlist the assistance of County Warning Area (CWA) volunteers to fill the gap in data sparse areas. WCMs and SHs must also continue to work with communities prone to flooding in developing automated or manual precipitation networks.

FINDING 3.7: In some cases, there were no backup systems for critical inoperative gage sites or sites that had been discontinued.

RECOMMENDATION 3.7: The NWSOs/NWSFOs need to establish backup observers and install staff gages at critical gage locations. When a gage is inoperative the RFC still needs to obtain reliable data during critical events such as this one. Backup systems such as wire weight and staff gages could be employed. Those backup gages could be read by local citizens, public safety officials, or cooperative observers. All offices should develop backup and equipment restoration plans, ensure that reasonable and cost effective priorities are set to repair inoperative gages, and explore ways to reactivate gage sites discontinued due to funding shortfalls.

FINDING 3.8: Federal and state funding for data acquisition is reduced annually. Local, state, and Federal government agencies are constantly under pressure just to maintain their current networks.

RECOMMENDATION 3.8: Local, state, and Federal government officials should continue to stress the importance of providing the necessary funds to maintain and expand these extremely important data sources.

FINDING 3.9: The number of stations in the NWS's cooperative observing program has been declining as sites close down and routine coop data collection is unreliable.

RECOMMENDATION 3.9: There are currently many reliable and dedicated cooperative observers participating in the NWS climate data collection program, but many more are needed to meet hydrologic forecast needs, supplement ASOS data, and satisfy user requests for environmental information. Recruitment programs for observers should be developed by field offices and NWS Headquarters (WSH). An increase in the number of volunteers would enhance the NWS's national cooperative program and would improve county forecast and warning capabilities. National Remote Observation System Automation (ROSA) expansion to at least one ROSA cooperative observer per county should be pursued.

FINDING 3.10: The SKYWARN and snow measurement networks at Binghamton, New York, and Pittsburgh and State College, Pennsylvania, worked extremely well in providing rain gage information to the staff via phone and amateur packet radio systems.

RECOMMENDATION 3.10: NWS offices should develop SKYWARN to report all aspects of hazardous weather including rain, snowfall, and hydrologic information.

FINDING 3.11: There are areas in many HSAs that are out of range for coverage by NWR broadcasts.

RECOMMENDATION 3.11: NWSO Binghamton, New York, and NWSFO Philadelphia, Pennsylvania, should work with Eastern Region Headquarters, WSH, and local public safety officials to find additional NWR sites and funding to complete transmitter installations.

FINDING 3.12: During the event, some state and county communication systems did not relay complete hydrologic information to local public safety officials.

RECOMMENDATION 3.12: The WCM and other staff members should investigate and correct local communication weaknesses and enhance and build community awareness through outreach efforts, media workshops and many local articles in newspapers.

FINDING 4.1: Even when warned and blocked by signs and barricades, people still drove across flooded roads. At least 10 of the 33 known dead were killed due to crossing flooded roads.

RECOMMENDATION 4.1: The video "Low Water Crossing -- The Hidden Danger" should continue to be given wide distribution to the media, driver's education programs, and public safety officials. A concerted effort must be made by WCMs and Public Safety Officials to include this type of information in school and community preparedness programs.

FINDING 5.1: An increased effort by NWS offices to work with local media and users to inform the public about the complexities involved in predicting and following the crests of such powerful river flooding would result in increased awareness of NWS efforts and responsibilities.

RECOMMENDATION 5.1: NWS should develop a public education program designed to increase awareness of the hydrology forecasting process to aid the media, emergency managers, and other users in understanding the importance of frequent forecast updates.

FINDING 5.2: During this event, there was an intense demand for the hydrologic expertise of the SH not only in the office but also on the telephone.

RECOMMENDATION 5.2: Whenever possible during widespread and high-profile events such as the Northeast Floods of January 1996, each office should designate at least one member of the management team as the main point of contact to the media and emergency management community. Also, hydrometeorology cross training will help ease the demand on the SH and spread hydrologic expertise throughout the office staff.

FINDING 5.3: Broadcasters wanted to receive information from the NWSFO earlier to prepare for their on-air reports.

RECOMMENDATION 5.3: NWS offices should work with their local television stations to determine when products are needed, and, if operationally possible, provide the broadcasters time to review and prepare before going on the air.

FINDING 5.4: Historical information regarding the impact of the flooding would help the media in communicating the severity of the event to the public.

RECOMMENDATION 5.4: NWS should include relevant historical information from the E19s on appropriate hydrologic products. In addition, field offices should consider developing hydrology sections with historical data on NWS home pages to include E19s and other hydrologic data.

FINDING 5.5: Television and radio stations and newspapers often have staff who compile and broadcast forecasts, generally using NWS data and products obtained from private vendors.

RECOMMENDATION 5.5: Before, during, and after significant weather and flood events, NWS offices should work with the public affairs office to prepare materials for the media and others highlighting the performance of NWS during the event. The materials should aim to document, where possible, lives saved and losses reduced by the extensive warnings, new technology, and well-trained NWS staffs.

FINDING 5.6: The Weather Channel did not scroll or place any information contained in Flood/Flash Flood Warnings and Statements unless that information was included in a Special Weather Statement, Zone Forecast, or short-term forecast.

RECOMMENDATION 5.6: WSH should work with The Weather Channel to have Flood Warning and Flash Flood Warning products scrolled the same as other warnings and Special Weather Statements.

FINDING 5.7: Many media do not understand hydrologic forecast techniques and the role of the RFC in the NWS infrastructure.

RECOMMENDATION 5.7: NWS offices should work with state and local media outlets to educate them on the hydrologic/meteorological forecast process. Media representatives are interested in participating in workshops on hydrologic procedures and forecast techniques. These workshops would broaden the media's understanding of NWS forecast systems and allow them to better communicate the process to their audiences. The workshops may result in greater confidence in NWS employees, products, and services and give the NWS an opportunity to coordinate. The NWS should also take advantage of American Meteorological Society (AMS) and American Society of Civil Engineers (ASCE) meetings and other industry forums to educate their media partners.