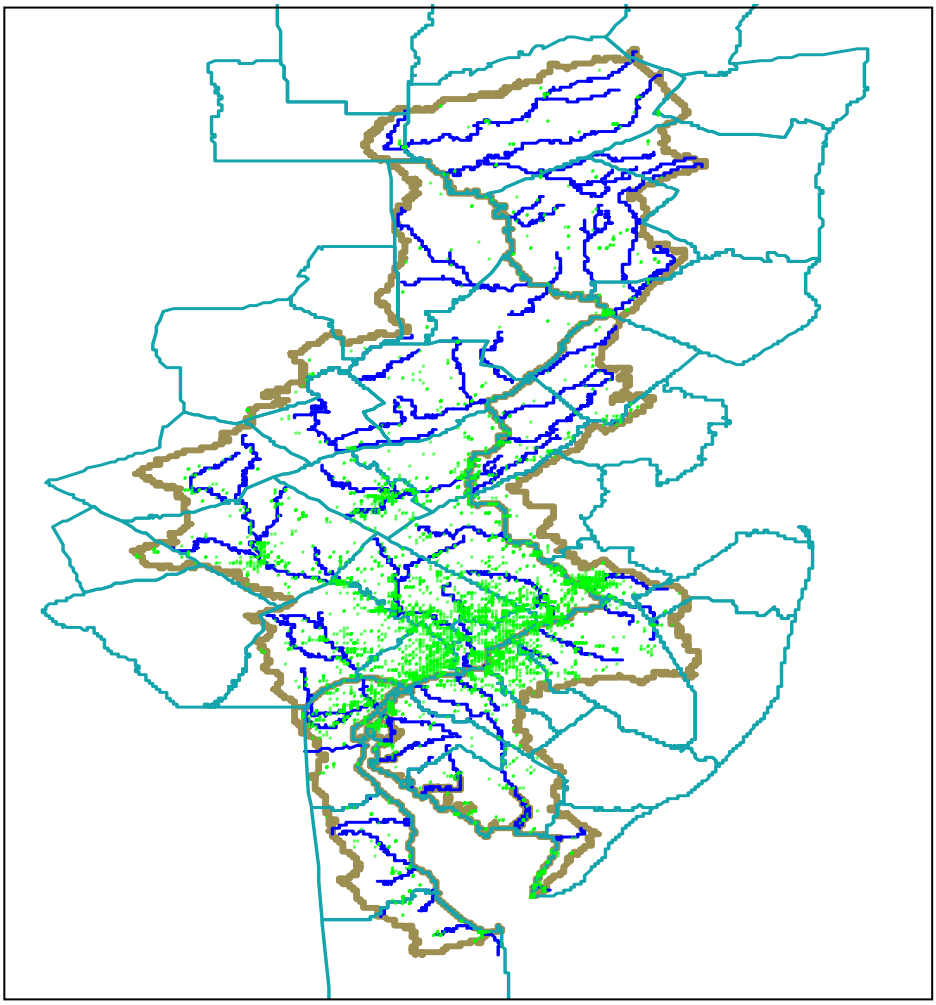
BACKGROUND

Flood Damage in the Delaware River Basin

Flooding affects all watersheds in the Delaware River Basin. But flood damage potential is a function of human development of the floodplains. The Flood Insurance Claims data maintained by the Federal Emergency Management Agency (FEMA) indicate the distribution of flood damage during the past 25 years. Flood insurance claims reflect only a small fraction of total flood damage because only a small portion of floodplain property owners actually purchase flood insurance. However, enough claims have been filed to provide a picture of where flood damage has occurred during the course of the flood insurance program.

Figure 1 shows the general location of over 10,000 flood insurance claims in the Delaware River Basin for the period of record since the late 1970's. Two important points are: 1) not all flood prone structures have flood insurance coverage; and 2) flood insurance claims often occur in headwater areas and can result from stormwater damage as well as stream flooding. The density of claims reflects population density, the degree of development in floodplains, the number of policy holders, and flooding frequency. Floodplain property acquisition programs, while a growing and effective method in reducing flood losses, have been limited to a handful of watersheds in the Delaware Basin. In the long term, these programs can permanently eliminate flood insurance claims and disaster loans.

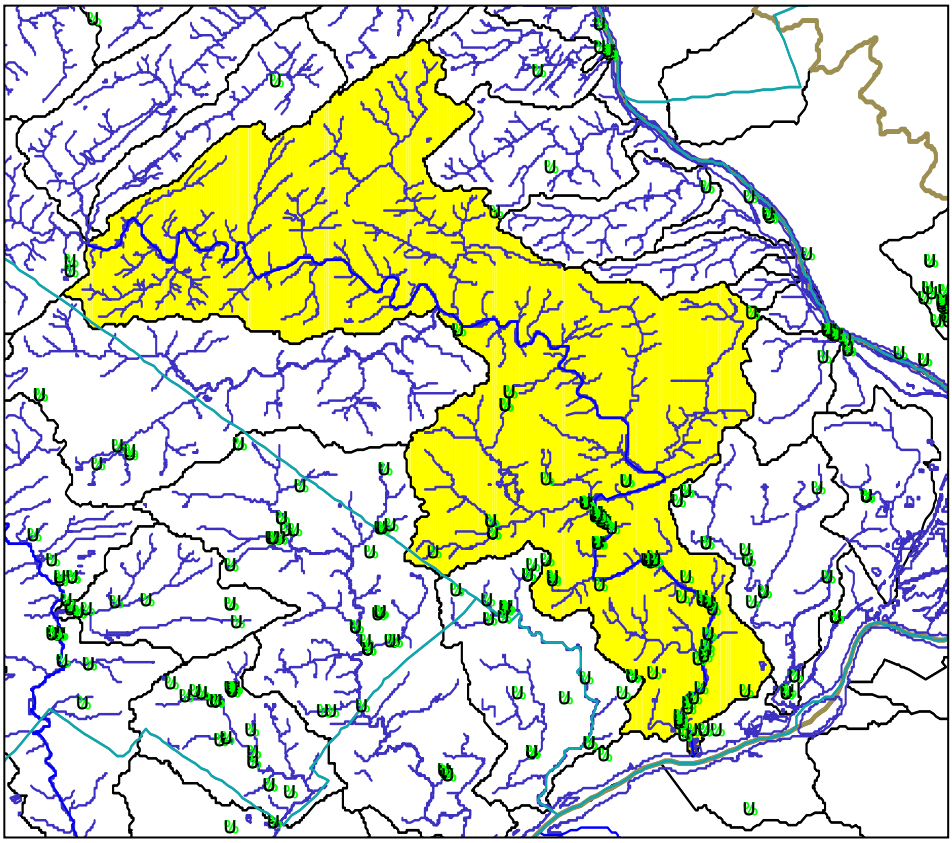
Figure 1: Distribution of Flood Insurance Claims in the Delaware River Basin
Source: Federal Emergency Management Agency



Repetitive Flood Insurance Claims

Repeat flood insurance claims indicate areas where floodplain occupancy continues despite frequent flood damage. Figure 2 provides the location of repeat flood insurance claims in the Neshaminy Creek Basin, in Southeastern Pennsylvania. This watershed experienced severe damage during Hurricane Floyd and funding for the acquisition of a number of flood prone properties has been secured. Note that a number of repeat claims are in headwater areas.

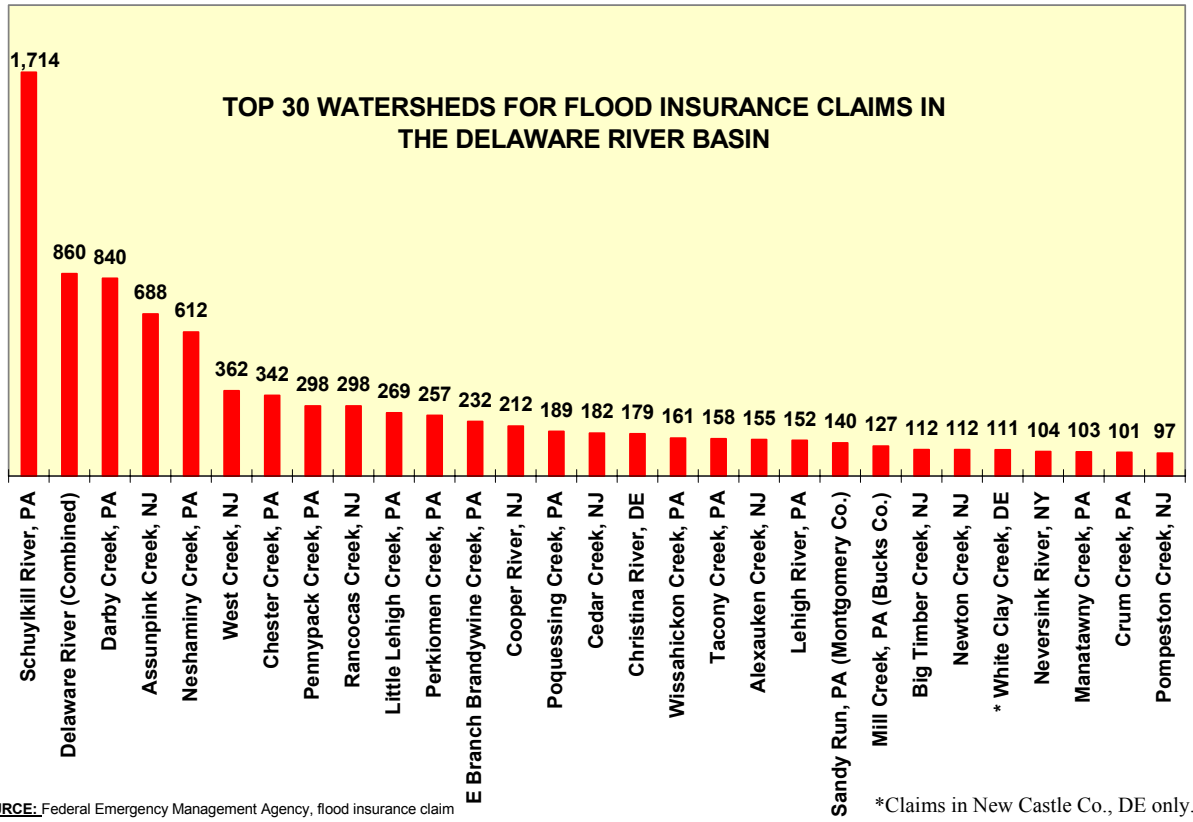
Figure 2: Repeat Flood Insurance Claims in the Neshaminy Creek Basin, Bucks County, PA
Source: Federal Emergency Management Agency



Flood Insurance Claims Sorted by Watershed

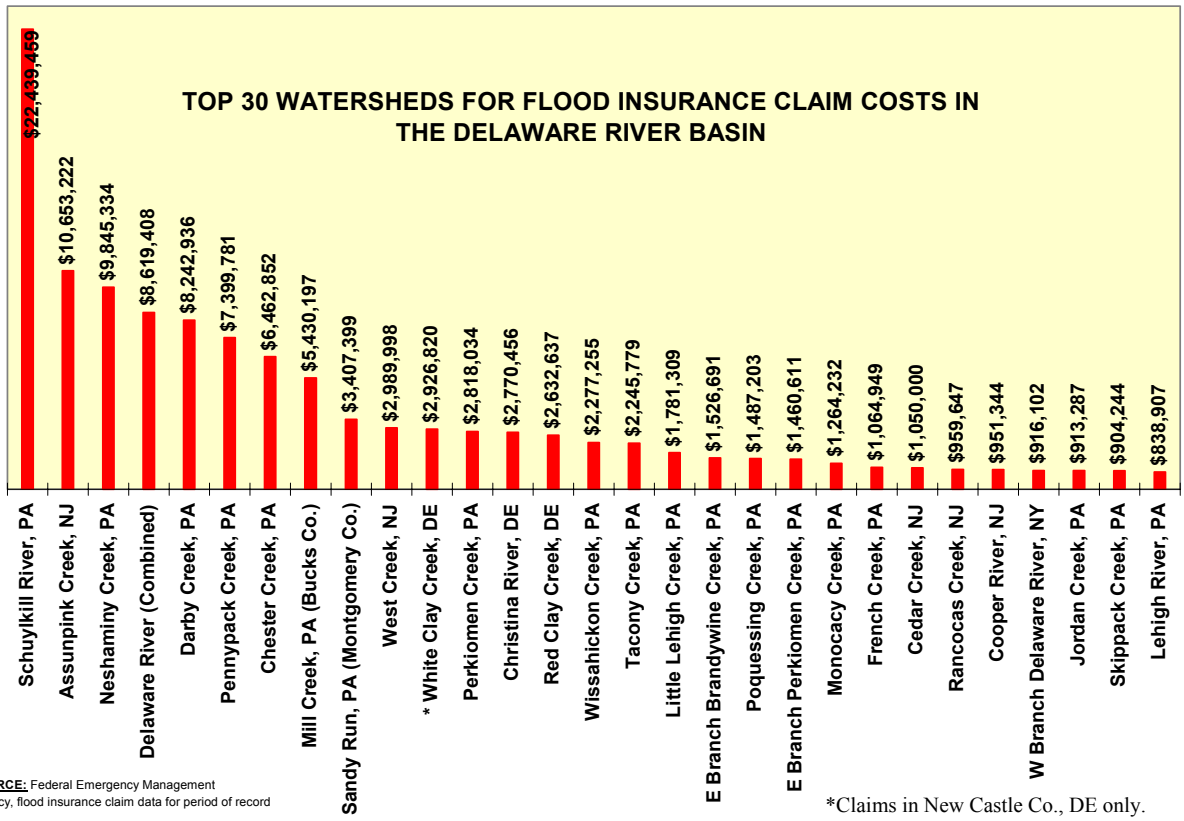
A relative measure of flood insurance claims activity is provided by Figure 3. The two charts show a ranking of the top 30 Delaware River Basin watersheds in terms of the number of flood claims and the total dollars paid for these claims for the period of record. This is a relative measure of where flood damage has occurred during the claims data period of record, but represents only a fraction of the actual damages. The results for the Delaware River may seem surprising relative to other smaller watersheds. A major reason for this is that the Delaware experienced only one major flood event (in 1996) since the 1955 flood, which occurred prior to the establishment of the flood insurance program. Damage along the main stem Delaware from a repeat of the 1955 flood has been estimated at over $600 million. It is also noted that flooding from tropical storm Agnes, which heavily damaged the Schuylkill River Basin, occurred prior to the flood insurance program.

Figure 3: Ranking of Watersheds by Flood Insurance Claims



SOURCE: Federal Emergency Management Agency, flood insurance claim data for period of record

*Claims in New Castle Co., DE only.



SOURCE: Federal Emergency Management Agency, flood insurance claim data for period of record

*Claims in New Castle Co., DE only.

The preceding flood insurance claims information is an indicator of the flood damage distribution during the past 25 years. It is not an accurate indicator of flood damage potential where major flooding has not occurred during this period. It complements previous studies, flood insurance mapping and land cover data as a means of identifying flood warning needs. Although the basin's streams have been the subject of study over the years, and the flood potential has been documented, the flood insurance claims provide an additional measure of damage history and can contribute to the evaluation of the flood warning system.

The Importance of Flood Warning in Flood Loss Reduction

Flood warning is a necessary piece of the overall flood loss reduction picture. Emergency personnel and the occupants of a floodplain must have lead time in order to react to an imminent flood threat. Effective flood warning provides that lead time.

Flood warning is not a substitute for the other means of reducing flood losses such as flood proofing, floodplain property acquisition, floodplain regulations, or structural measures. Rather, it complements these programs and is required in recognition of the degree of floodplain development that currently exists. It is important to note that the benefits of flood warning extend beyond the floodplain to emergency services personnel, to the families of floodplain occupants, and to those who may be traveling through a floodplain.

According to the National Weather Service, effective flood warning can reduce economic flood damage by up to 10 percent. It is particularly important in reducing the loss of life due to flooding. Approximately half of flood related deaths occur in automobiles and the lead time for closing roads is provided by flood warning. The benefit to cost ratio of flood warning improvements in the neighboring Susquehanna River Basin has been estimated at 12.5 to 1 by the National Weather Service. This does not include the additional benefits of the stream and precipitation gages and real time telemetry used for the management of water resources.

Flood Warning Coordination and Partnership

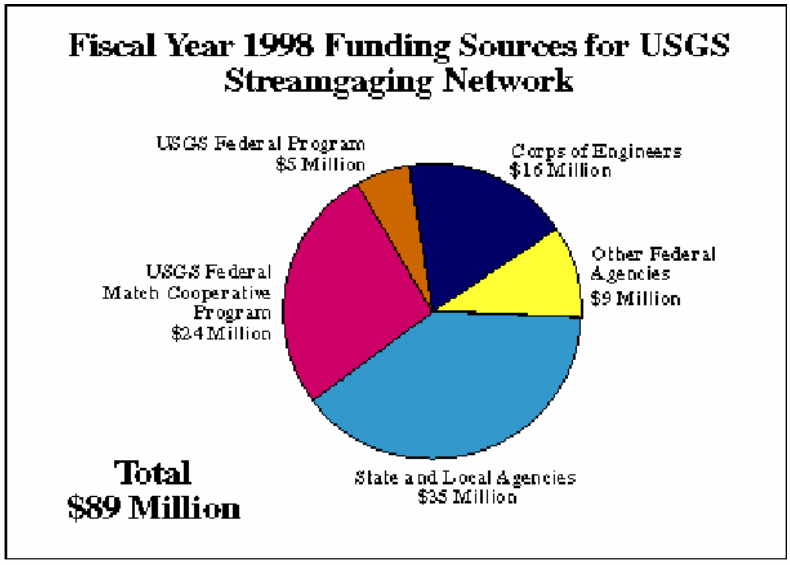
The river flood warning system in the Delaware River Basin is comprised of several elements and is coordinated and funded by numerous organizations at the federal, state and local levels. It is the responsibility of the National Weather Service (NWS) to provide flood forecasts and issue flood warnings. The NWS uses rainfall observations, streamflow and stage data, and computer modeling to forecast flood levels at river forecast points during storm events. These forecasts are distributed from the NWS's Mid-Atlantic River Forecast Center in State College, PA to Weather Service Offices in Binghamton, NY, and Mt. Holly, NJ.

The NWS flood forecasts are then broadcast to state and county emergency offices and to the public over emergency management communications systems, NOAA Weather Radio, television and radio, and the Internet. State and county emergency managers relay the information to emergency personnel at the municipal level. It is the local level at which road closures, evacuation, and rescue actions are implemented. In addition to river flood warning, the NWS also issues flash flood warnings which are transmitted over NOAA Weather Wire to emergency managers and also placed on the Internet.

The stream gaging program is operated by the U.S. Geological Survey, who also coordinates the funding for the program. Figure 4 shows the national breakdown for stream gage funding. Most stream gages in the Delaware River Basin are cost shared through a cooperative funding program between the U.S. Geological Survey, U.S. Army Corps of Engineers, the Basin States of Delaware, New Jersey, Pennsylvania, and New York, the Delaware River Basin Commission, and some utilities and industries. The NWS coordinates the precipitation network which is also funded cooperatively in some cases.

The funding for the stream gages is an annual issue, and flood warning capabilities are reduced when gages are discontinued.

Figure 4: Funding Sources for the USGS Stream Gage Network
Source: U.S. Geological Survey



Source: USGS *A New Evaluation of the USGS Streamgaging Network*, A Report to Congress, Nov. 1998

Clearly, successful flood warning in a large river basin such as the Delaware is not accomplished in isolation. It depends on a network of equipment, organizations and communication which must be functional at all times. Funding for the elements of the flood warning system comes from federal, state, local and private sources. The list of members of the Delaware River Basin Commission's Flood Advisory Committee, provides some measure of the types of organizations involved with flood warning in the basin. The representation is as follows:

Delaware Department of Natural Resources and Environmental Control
New Jersey Department of Environmental Protection
New York Department of Environmental Conservation
Pennsylvania Department of Environmental Protection
New York City Department of Environmental Protection
Delaware Emergency Management Agency
New Jersey Office of Emergency Management
New York Office of Emergency Management
Pennsylvania Emergency Management Agency
Federal Emergency Management Agency
U.S. Department of Agriculture Natural Resources Conservation Service
U.S. Geological Survey
National Weather Service
U.S. Army Corps of Engineers
National Park Service
Delaware River Joint Toll Bridge Commission
Hydroelectric Industry
Local Water Resources Agency – University of Delaware

Each of these organizations has financial and operational responsibilities in some component of the flood warning process, whether in the funding of gages or in forecasting and evacuation activities.

In addition to the entities listed, each of the basin's 42 counties and 868 municipalities has emergency responsibilities. Local officials interact with police officers and fire personnel, often volunteers, who are responsible for evacuation and rescue operations.

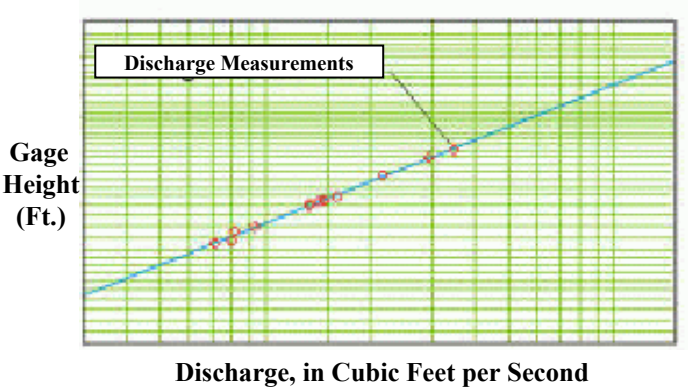
A key component of a successful flood warning system is communication with the public. Media plays an essential role in informing the public of flood forecasts, and the media must coordinate with the NWS and emergency managers to relay flood information. But the public must be capable of interpreting the flood message. Adequate lead time, knowledge of the location of property with respect to the forecast flood, and knowledge of the hazards of driving in flood waters, are minimum requirements for responding to a flood. The failure in any of these links in the warning system hinders flood warning.

Multiple Benefits of the Flood Data Collection Network

Precipitation and Stream Gages as a Flood Warning Tool

Effective flood warning is not possible without the collection and rapid transmission of precipitation and streamflow data. The NWS's river flood forecasts are limited to those streams where precipitation and stream gages are in good working order and are equipped with telemetry for "near real time" data collection. The maintenance of stream gages is critical to flood warning. Stream gages are especially important because they are used to reference flood height and to develop the stage-discharge or "rating" curve which relates predicted streamflow to flood stage elevation. An example of a stage discharge curve is provided in Figure 5.

Figure 5:
Stage-Discharge Curve
Source: U.S. Geological Survey



Additional Benefits of Gages

Stream and precipitation gages have multiple uses in water resources management and provide many benefits in addition to flood warning.

Precipitation gages are used during both wet and dry periods to determine the hydrologic status of watersheds. Precipitation deficiency is the first indicator of drought and monitoring of precipitation helps flag potential declines in streamflow and ground water levels. The data collected by precipitation gages are also used in studies for drought and flood risk assessment as well as climate change, and non-point pollution loading.

Stream gages operated by the USGS have provided flow records for over 100 years. Most stream gages have recently been incorporated by the USGS into a real time reporting system available on the Internet (see Figure 8 for this network). The information provided by stream gages is used in:

. Water supply allocation
. Design of storage reservoirs and water supply facilities
. Implementation of clean water initiatives
. Design of waste water treatment facilities and waste water discharge limits
. Design of Total Maximum Daily Loads (TMDL's) for water quality management
. Water quality sampling programs
. Design of boating, fishing and other recreational facilities
. Real time reporting of recreational conditions for fishing and boating
. Fish stocking programs
. Incremental flow analysis and habitat assessment
. Drought monitoring and management, and drought risk assessment
. Risk assessment for flood mitigation and property acquisition programs
. Studies of the surface and ground water system and hydrologic characterization
. Calibration of computer models used in hydrologic simulation

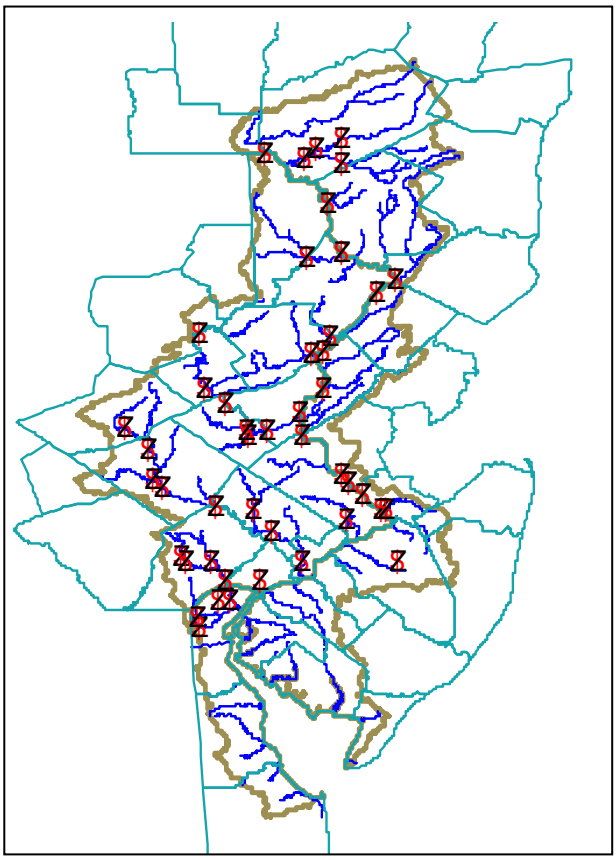
The important functions and benefits of the stream gages are not widely appreciated and have only recently been publicized through outreach programs.

The Existing Flood Data Collection Network in the Delaware River Basin

Flood Forecast Points

There are presently 46 river flood warning forecast points used by the NWS in the Delaware River Basin. These are shown in Figure 6. A total of 42 of the forecast points are located at USGS stream gages**.** The four remaining sites on the Delaware River are at bridges owned

Figure 6: River Flood Forecast Points in the Delaware River Basin
Source: U.S. Geological Survey (status as of 4/01)



and maintained by the Delaware River Joint Toll Bridge Commission. The bridges are located at Phillipsburg, NJ, Stockton, NJ, New Hope, PA, and Washington's Crossing, NJ-PA. The bridges are staffed around the clock and water levels are measured hourly during flood events. Figure 6 indicates that the existing flood forecast points are generally located on the major rivers and tributaries of the basin, where the greatest flood warning lead time can be provided. The factors that are considered in developing gages as flood warning points include drainage area, telemetry, and downstream flood potential. It is also necessary to know the relationship between gage height and flood stage.

There are over one hundred and sixty continuous record stream gages in the Delaware River Basin. The gages in the basin that are equipped with recorders or wire weight gages are shown in Figure 7. These include tide gages. The gages which serve as the basin's 46 flood forecast points are also shown in Figure 7.

Figure 7: Delaware Basin Stream Gages and Flood Forecast Points
Source: U.S. Geological Survey (status as of 4/01)

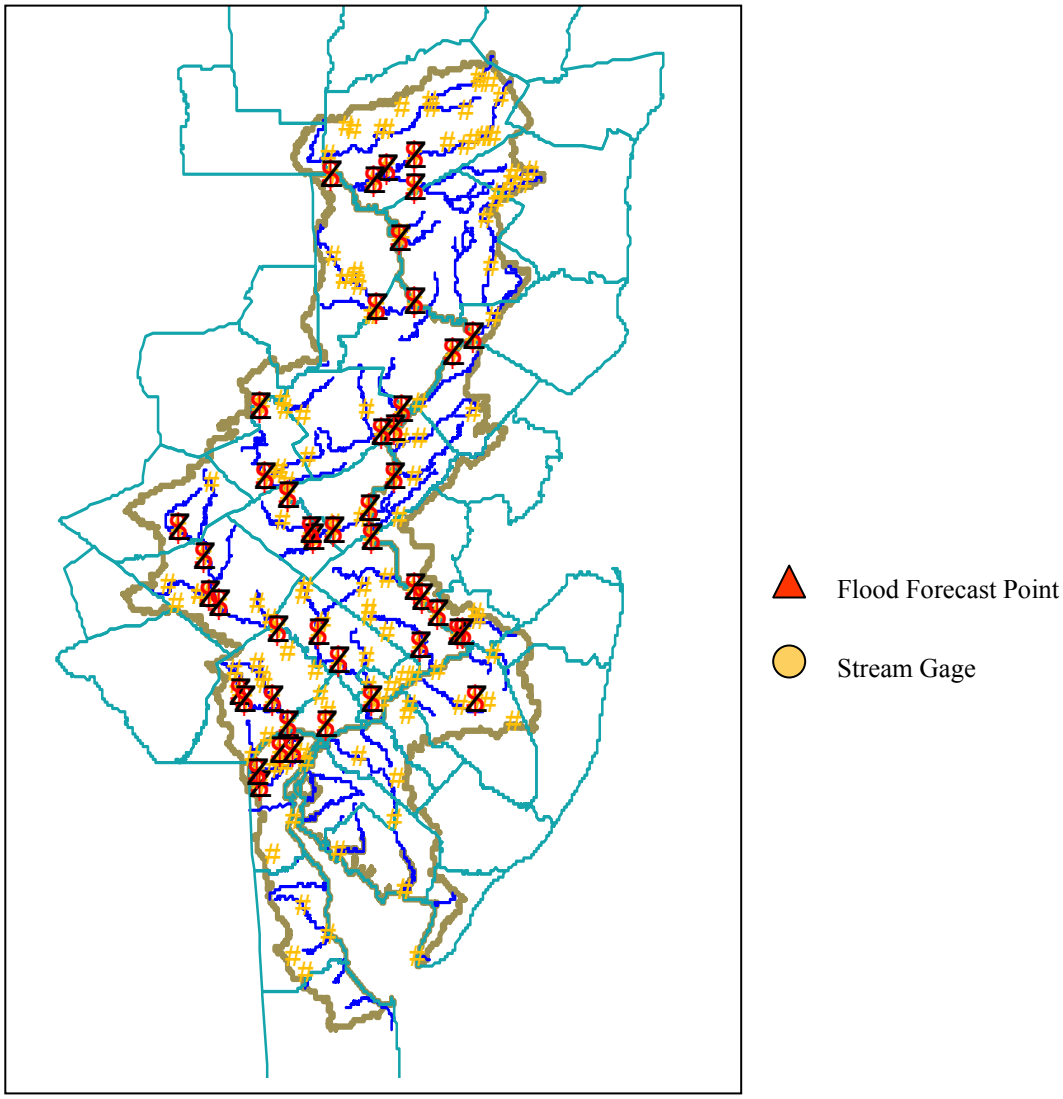
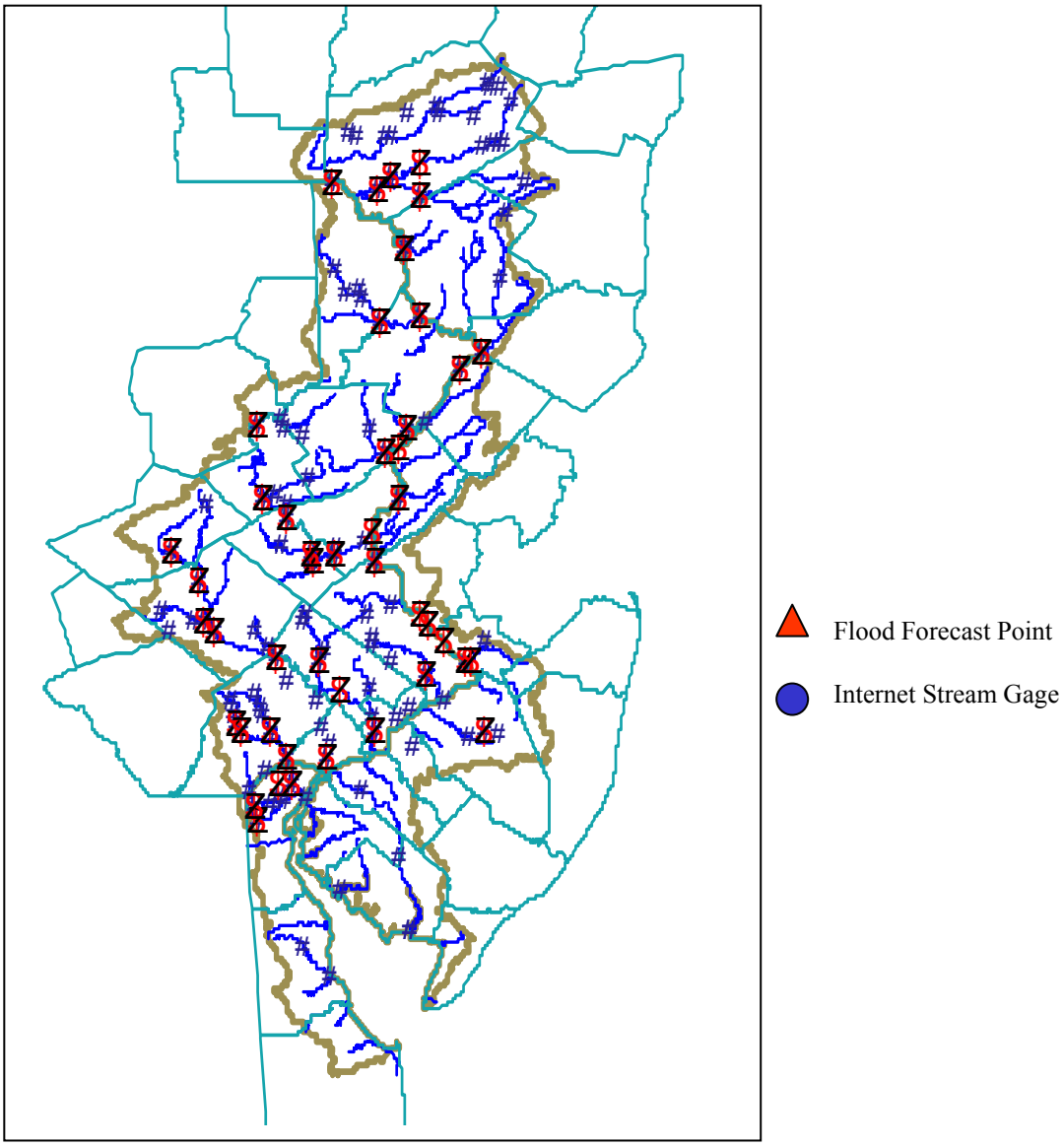


Figure 8 shows the locations of the Delaware River Basin stream gages that are accessible on the Internet. All 118 of these gages are equipped with satellite telemetry. Real time stream stage and flow information is available to all Internet users via the USGS web pages and a large number of web sites that are linked to the USGS site.

Figure 8: USGS Internet Stream Gages with Flood Forecast Points Shown
Source: U.S. Geological Survey (status as of 4/01)

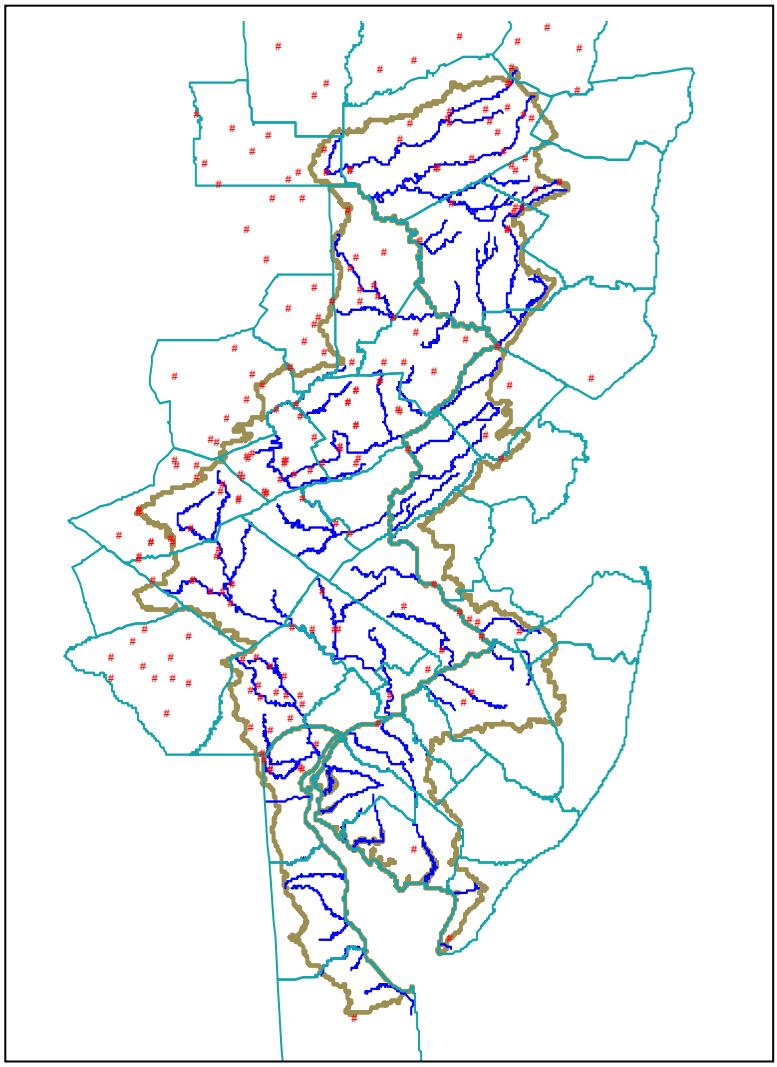


Precipitation Gages

Figure 9 shows the locations of most of the Delaware River Basin's precipitation gages. Not shown are volunteer observation points and sites where data are collected by schools. To be usable during freezing weather, the gages must be heated. The gages shown are owned and operated by either the USGS, NWS or the City of New York. Many of the gages shown are not used by the NWS due to differences in instrumentation and telemetry. Additional inventory work is needed to fully characterize all precipitation gages and determine the instrumentation and telemetry requirements for adding stations to the network used by the NWS.

Preliminary inventory work shows that there are gaps in precipitation monitoring in some of the watersheds. Advances in Doppler radar technology have made it possible to estimate precipitation from radar echoes. This has great potential for quickly estimating rainfall totals in headwater areas. Precipitation gages are required to verify radar precipitation estimates.

Figure 9: Precipitation Gages Within and Adjacent to the Delaware River Basin
Sources: National Weather Service, U.S. Geological Survey, NYCDEP
Water Resources Agency - University of Delaware (status as of 4/01)



Snow Survey Data

Snow core sampling to determine the water equivalency of snow cover is conducted by the City of New York in the city's reservoir watersheds and by the U.S. Army Corps of Engineers in the watersheds of F.E. Walter, Beltzville, and Blue Marsh Reservoirs. This provides important information for flood potential due to rapid snow melt which can occur during winter and early spring rain storms. Support from the NWS's National Operational Remote Sensing Center also provides snow water equivalent measurements. The NWS reports the water equivalent of observed snow pack on the Internet. Inventory work to further characterize snow core sampling is needed.

River Flood Warning vs. Flash Flood Warning

Because of larger drainage areas, the lead time provided by river flood warning is greater than for flash floods. Flash floods can occur so quickly that there is little time for analysis, forecasting, and response. This requires that the potential for flooding be quickly recognized at the local level based on guidance provided by the NWS and real time data. Rainfall potential and observed rainfall must be translated into a flood forecast before stream stages rise. Programs to assist communities with flash flood warning programs are available through the National Weather Service and the U.S. Army Corps of Engineers.

Doppler radar offers great potential for quickly assessing flash flood threats. As part of the Advanced Hydrologic Prediction Service (AHPS), the NWS is incorporating Doppler radar into flash flood warning. The precipitation gage network is vital in this work.

The Role of Flood Stage Forecast Mapping

Flood stage forecast maps are used to translate forecast flood crests to areas of flood inundation. These maps are potentially valuable to emergency personnel in planning for evacuations and road closures prior to flooding. An example of a flood stage forecast map is shown on page A3 of Attachment A.

Recently, with the advances in GIS technology, the ability to store and query floodplain information concerning highway locations, building footprints, and potential flood damages is possible once the information is assembled. A project to develop such an automated flood forecast mapping capability is in progress as part of a project by the U.S. Army Corps of Engineers in the Susquehanna River Basin. In addition, the NWS is incorporating probability into flood stage forecast mapping through the AHPS program.

Although non-GIS paper flood stage forecast maps have been previously completed for limited portions of the Delaware and Schuylkill Rivers, the new technology and updated hydraulic profiles would greatly improve mapping for these areas.

The practical use of flood stage forecast maps at the local level has not been well proven. Map users at the local level must be able to interpret the maps and have access to a computer equipped with GIS software. The Flood Advisory Committee members have recommended that the mapping be applied to specific flood prone areas of the Delaware River Basin on a prototype basis.

The Advanced Hydrologic Prediction Service (AHPS)

The National Weather Service's AHPS program was initiated in 1997 to provide comprehensive hydrologic forecasts which are visually oriented and incorporate probability. The products are for use in such areas as emergency response, flood control, water supply, hydropower, irrigation, and recreation. Doppler radar, real time data collection, computer modeling, and GIS are used to improve forecasting and present graphic, high quality data and forecasts with specified probability. The probability component enables assessment of risk in decision-making by product users. An AHPS demonstration project has been applied to Des Moines, Iowa and samples of the products are presented in Attachment A.

In the area of flood warning, products include improved flash flood warning for headwaters using Doppler radar, use of probability in both short and longer range flood forecasting, flood stage forecast mapping which is updated for each forecast period, and distribution of graphical products via the Internet. The AHPS program is a national program. Accordingly, application to the Delaware River Basin would be consistent with and support the national effort.