NOAA Technical Report NOS CS 8

STATUS OF ACQUISITION OF REAL-TIME RIVER OBSERVATIONS AND FORECAST GUIDANCE FOR NOS ESTUARINE NOWCAST/ FORECAST SYSTEM DEVELOPMENT

Silver Spring, Maryland
May 2000

noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Coast Survey Development Laboratory
Marine Modeling & Analysis Programs

Office of Coast Survey
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

The Office of Coast Survey (CS) is the Nation's only official chartmaker. As the oldest United States scientific organization, dating from 1807, this office has a long history. Today it promotes safe navigation by managing the National Oceanic and Atmospheric Administration's (NOAA) nautical chart and oceanographic data collection and information programs.

There are four components of CS:

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The Marine Chart Division collects marine navigational data to construct and maintain nautical charts, Coast Pilots, and related marine products for the United States.

The Hydrographic Surveys Division directs programs for ship and shore-based hydrographic survey units and conducts general hydrographic survey operations.

The Navigation Services Division is the focal point for Coast Survey customer service activities, concentrating predominantly on charting issues, fast-response hydrographic surveys and Coast Pilot updates.

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LIST OF ACRONYMS

AFOS	Automated Field Operations and Services
AHOS	Automatic Hydrologic Observing System
AHPS	Advanced Hydrologic Prediction System
AWIPS	Advanced Weather Interactive Processing System
CADAS	Centralized Automatic Data Acquisition System
CH3D	Curvilinear Hydrodynamics in Three Dimensions
C3PO	Chesapeake Bay Three-Dimensional Physical Oceanographic Forecast System
COFS	Coastal Ocean Forecast System
CS	Calibration System
CSDL	Coast Survey Development Laboratory
DOH	Development and Operations Hydrologist
EMC	Environmental Modeling Center
ESP	Extended Streamflow Prediction
FTP	File Transfer Protocol
GOES	Geostationary Operations Environmental Satellites
HADS	Hydrometeorolgical Automated Data System
HIC	Hydrologist in Charge
HPC	Hydrometeorological Prediction Center
IFP	Interactive Forecast Program
IHFS	Integrated Hydrologic Forecast System
LDADS	Local Data Acquisition and Dissemination System
MARFC	Middle Atlantic River Forecast Center
MMAP	Marine Modeling and Analysis Programs
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NWIS	National Water Information System
NWS	National Weather Service
NWSRFS	National Weather Service River Forecast System
OCS	Office of the Coast Survey
ODAAS	Operational Data Acquisition and Archiving System
OMB	Ocean Modeling Branch
OFS	Operational Forecast System
QPF	Quantitative Precipitation Forecasting
RFC	River Forecast Center
SHEF	Standard Hydrometeorological Exchange Format
SQL	Structured Query Language
USGS	United States Geological Survey
WARFS	Water Resources Forecasting System
WCM	Warning Coordination Meteorologist
WFO	Weather Forecast Office
WGRFC	Western Gulf River Forecast Center
WHFS	WFO Hydrologic Forecast System

ABSTRACT

The Marine Modeling and Analysis Programs (MMAP) Branch of the National Ocean Service's Coast Survey Development Laboratory develops techniques and technology for accurately predicting water levels, currents, salinity, temperature, and other oceanographic and meteorological parameters within ports and estuaries along the East Coast and Gulf Coast of the United States. These estuarine nowcast/forecast systems are developed at MMAP and transferred to NOS's Center for Operational Oceanographic Products and Services (CO-OPS) to produce operational forecast products for use by the marine community in support of NOAA's strategic goals to promote safe navigation and sustainable healthy coasts.

In order to produce accurate, high-resolution nowcasts and forecasts of estuarine conditions, these model systems need to incorporate real-time observations and forecasts of meteorologic, oceanographic and hydrologic parameters. One essential hydrologic parameter for which access to data is difficult is river flow into the ports and estuaries. Two government agencies are responsible for providing river flow information to the nation: the United States Geological Survey (USGS) maintains a real-time reporting system for the national stream gaging network and NOAA's National Weather Service produces daily river forecasts. In the past, individual model developers at MMAP have developed their own systems to acquire real-time river observations, and in one case, forecasts.

These individual efforts have provided information necessary for the development of estuarine nowcast/forecast systems. However, we now need to take a more comprehensive approach to ensure that coastal and estuarine model developers have access to these essential hydrologic parameters.

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1. INTRODUCTION

1.1. Purpose

The Marine Modeling and Analysis Programs (MMAP) branch of the National Ocean Service's Coast Survey Development Laboratory is responsible for developing and testing experimental estuarine nowcast/forecast systems for major ports and estuaries along the East Coast of the United States and the Gulf of Mexico. These nowcast/forecast systems are developed in order to provide products and services for the coastal marine community, especially in support of safe and efficient navigation and the utilization and protection of the coast. The estuarine nowcast/forecast system models are developed and tested at MMAP and then are transferred to NOS's Center for Operational Oceanographic Products and Services (CO-OPS) for operational implementation. The CO-OPS products from these nowcast/forecast systems will include accurate, high resolution analyses and short-term forecasts of oceanographic parameters such as currents, water levels, salinity and temperature. The products will benefit commercial, military and recreational mariners, National Weather Service (NWS) marine forecasters and other members of the marine community.

Like all forecast models, these estuarine nowcast/forecast systems are dependent on access to accurate and timely real-time observations and short-term forecasts of atmospheric, oceanographic, and hydrologic variables. In this case, the primary types of data needed are oceanographic real-time information and short-term ocean forecasts, meteorological real-time observations and model forecasts, as well as real-time observations and short-term forecasts of hydrological parameters. This technical report addresses MMAPs current use of and need for one of the important hydrological parameters, real-time river observations and river forecasts, for three MMAP nowcast/forecast systems being developed for Chesapeake Bay, the Port of New York/New Jersey, and Galveston Bay, as well as other estuaries for which forecast systems will be developed in the future.

1.2. Hydrologic Information in Estuarine Modeling

The river flow into an estuary can be a critical factor for analyzing and forecasting oceanographic conditions. The amount of freshwater entering a semi-enclosed estuary system has an impact on the salinity and temperature of the estuary, which in turn influences the flow and strength of currents. These impacts become much more pronounced during floods and prolonged periods of drought, when the water level of the estuary can also be affected by river flow.

At the present time, model developers at MMAP have refined estuarine nowcast/forecast systems with the use of accurate meteorological and oceanographic information. The traditional approach toward hydrology in the models has been to use average daily inflows or monthly climatological data of stream flow for an estuary or the coastal ocean at a steady state (Schmalz, 1994; Kelley et al., 1999). As the sophistication of the models improves, the need for more accurate hydrologic data has become apparent. There have been some individual efforts by model developers to acquire river observations and forecasts for a few specific points relevant to their area of study. However, there is no comprehensive plan or arrangement for acquiring real-time river observations and forecasts for the future development of nowcast/forecast systems.

There are two primary sources for the river information necessary for estuarine nowcast/forecast systems development. The United States Geological Survey (USGS) maintains the national stream gaging network and makes available on the Internet real-time observations from over 7,000 gaging stations nationwide at http://water.usgs.gov. River forecasts are the responsibility of NOAA's NWS, which is mandated by law to provide flood warnings and river forecasts for the nation. The 13 River Forecast Centers (RFC) within the NWS generate river forecasts for 4,000 locations nationwide on a daily basis. The emphasis and interest of both of these hydrologic information programs is on predicting and studying times of low and high water to provide information to water resource managers and to issue warnings of hazardous flood or drought conditions to the general public.

The next two chapters will discuss the generation of real-time and forecast river flow information and how this information is and can be obtained by NOS/CSDL for use in the development of estuarine nowcast/forecast systems.

2. REAL-TIME RIVER OBSERVATIONS

2.1. Source: The United States Geological Survey

The United States Geological Survey (USGS) within the U.S. Department of the Interior, is the agency responsible for collecting, archiving and disseminating data from the National Stream Gaging Network (Mason and Yorke, 1997). The stream gaging stations in the network are set up by more than 700 federal, state, local and private interests who are partners with the USGS in the stream gaging program and all are used to monitor river flow and conditions for a number of different water quality and water resource management purposes. The USGS has been operating this stream gaging network since 1887 to provide water resources information to Federal, State and local agencies for planning and operating water resources projects and regulatory programs. Over the history of the stream gaging program, the collected data has been used to study hydrologic characteristics of streams and change over time, and now provides a large database of baseline information for flood frequency predictions.

All stream gaging stations in the program report on the river stage and discharge at least once per day. Sixty percent (4,200) of the gaging stations report every 4 hours, using two different methods. Many stream gaging stations use satellite radio transmitters to broadcast stage data to the two geostationary operations environmental satellites (GOES), operated by NOAA. The data are re-transmitted by a domestic satellite and received by the USGS, its partner agencies and other users. The other real-time stations are obtained through an automatic telephone dial-up, and the gaging stations is queried every 4 hours by the USGS offices. All of these real-time stations report stream stage every 4 hours. A limited number of stations also report on the conductivity and temperature of the stream.

The USGS is responsible for collecting all of this real-time data and making it available to the public. The provisional data is made available in real-time on the USGS Internet site, which updates once an hour with the new observations for the stations reporting that hour. Each gaging stations station reports once every four hours, so data available is never more than four hours old. Later, the data are quality controlled at the USGS and published in the official yearly water reports series Water Resources Data - [State Name] for the water year, which runs from October 1 through September 30. The reports are published 6 months to 1 year after the end of the water year (USGS Circular 1123).

2.2. Data Format and Availability

Water level is reported in stage (feet) relative to flood stage and, where possible, the stage measurement is converted to discharge in cubic feet per second. Stage is defined as the height of the water surface above a reference elevation while the discharge is defined as the volume of flow passing a specified point in a given interval of time, which includes the volume of water and any sediment or other solids mixed in with the water. The USGS maintains stage-discharge conversion tables and calculate the discharge for the stage reported by the stream gaging stations. These conversion tables are checked and updated frequently to account for changes in the equation due to changes in stream morphology. Measurements are made every 6-8 weeks to verify that the stage-discharge relation has not changed. For gaging stations where the stream morphology changes rapidly, measurements are taken as frequently as once a week (USGS Circular 1123). Stream gaging stations in tidally influenced areas of rivers do not have stage-discharge conversion tables because the stage is not the only factor influencing the quantity of water passing a specific point. Because it must be calculated, discharge data is not transmitted by satellite but is available from the USGS in near real-time on their Internet site.

The USGS water office is organized and reports the river gaging stations data through 50 state water offices. Within each state, the gaging stations are organized by watershed and stream. There are some differences between state offices in the format and manner of data being made available in real-time on the Internet site.

2.3. Requirements of Estuarine Nowcast/Forecast Systems

Observed river discharge is an important variable needed for input into the estuarine nowcast/forecast systems models. The seasonal and annual fluxes of freshwater into semi-enclosed ports and estuaries effects the water level, salinity, temperature and currents.

There are specific requirements for the format of river observations that can be used by the estuarine models. First, the data must be in discharge, not stage, as the important variable is the quantity of water entering the estuary. This qualification means that the data must be converted to discharge by the USGS before they can be used in estuarine nowcasts/forecasts. Second, in order to be able to produce accurate nowcasts and forecasts, the river observations should be available in real-time or near real-time on an hourly to daily basis (See Table 2.1).

Table 2.1. Real-Time River Observation Requirements for Nowcast/Forecast Systems.

Prediction System	Required Variables	Frequency	Timeliness
NOAA Coastal Ocean Forecast System	1) Stage 2) Estimated Discharge	Once a day for the previous 24 hours *Future: Twice a day for the past 12 hours*	1-2 hours past 0000 UTC *Future: 0000 and 1200 UTC*
NOS/CSDL/MMAP Estuarine Nowcast/Forecast Systems	1) Stage 2) Estimated Discharge 3) Water Temperature 4) Salinity	Every hour	10 to 20 minutes after the top of the hour

Third, the location of the stations is important. The estuary forecasts need the river gaging stations observations at the point on each stream closest to its mouth but upstream of any tidal influence. This is because no stage-discharge conversions are calculated for gaging stations in tidal areas. At some points, it may be necessary to include additional stream gaging stations on tributaries to the main stream if major tributaries enter the stream below the gaging stations used.

See Appendix A for tables containing the river gaging stations observations identified for use in three MMAP estuarine nowcast/forecast systems.

2.4. River Observations Currently Obtained by NOS/CSDL

Galveston Bay

The model developer currently working on an estuarine nowcast/forecast system for Galveston Bay in Texas has acquired river observations for three stream gaging stations on streams emptying into the Bay: Buffalo Bayou, the Trinity River and Lake Houston (See Figure 2.1). This has been accomplished through direct communication between the developer and the NWS Western Gulf River Forecast Center (WGRFC). Through an agreement, the WGRFC pushes all the hourly data for the river gaging stations observations for the past 24 hours to CSDL every day over the Internet. The river observations are transmitted as discharge measurements and are input directly into the experimental Galveston Bay nowcast/forecast system.

Chesapeake Bay

The model developers working on estuarine nowcast/forecast systems for the Chesapeake Bay have used a different approach to obtain river observations. They have written a UNIX shell script which accesses the USGS World Wide Web site and pulls out the discharge data for eight tributaries to Chesapeake Bay: the Nanticoke, the Choptank, the Susquehanna, the Patuxent, the Potomac, the Pamumkey, the Rappahannock, and the James Rivers. (See Figure 2.2). The script is run once a day and the real-time discharge data is archived in an SQL database at MMAP. This approach works smoothly as long as the USGS does not change the address of the web pages used. These observations have been acquired and archived since January 2000 and are currently being input into the experimental Chesapeake Bay 3-Dimensional Physical Oceanography model (C3PO).

Port of New York/New Jersey

The nowcast/forecast system in development for the Port of New York/New Jersey presently uses one real-time river observation and climatology of four rivers to set boundary conditions for the model. The developer uses a shell script program to get the river observation for the Hudson River at Poughkeepsie, New York, from the USGS web site. The data for this station are available only in stage because it is located in a tidally influenced part of the river. The developer also plans to begin getting real-time observations for several other stations from the USGS web site, via the same method as the Chesapeake Bay modelers, in the near future for use in an experimental three-dimensional barotropic nowcast model.

See Figure 2.3 for a map of the Port of New York/New Jersey region and real-time observation points relevant to the estuarine nowcast/forecast system. See Table 2.2 for the current use of river observations in the three MMAP estuarine nowcast/forecast systems in development.

Table 2.2. Real-Time River Observations Currently Used in Nowcast/Forecast Systems.

Prediction System	River Information	Number of Rivers	Model Use
NOAA Coastal Ocean Forecast System	Monthly Climatology	15 Rivers and the Gulf of St. Lawrence	Modification of Salinity at mouth of river or estuary
NOS Chesapeake Bay	Monthly Climatology	9 Rivers	Modification of Water Level
Chesapeake Bay Experimental C3PO	1)Monthly Climatology 2) Past 24 hour discharge observations	1) 9 Rivers 2) 8 Rivers	Modification of salinity, water level and currents
Chesapeake Bay Experimental CH3D	Monthly Climatology	9 Rivers (missing 2)	Modification of salinity, water level and currents
NOS Port of New York/New Jersey Experimental	Yearly Climatology	4 Rivers	Modification of water level and currents
NOS Galveston Bay Experimental	Past 24 hour discharge observations	3 Rivers	Modification of salinity, water level and currents

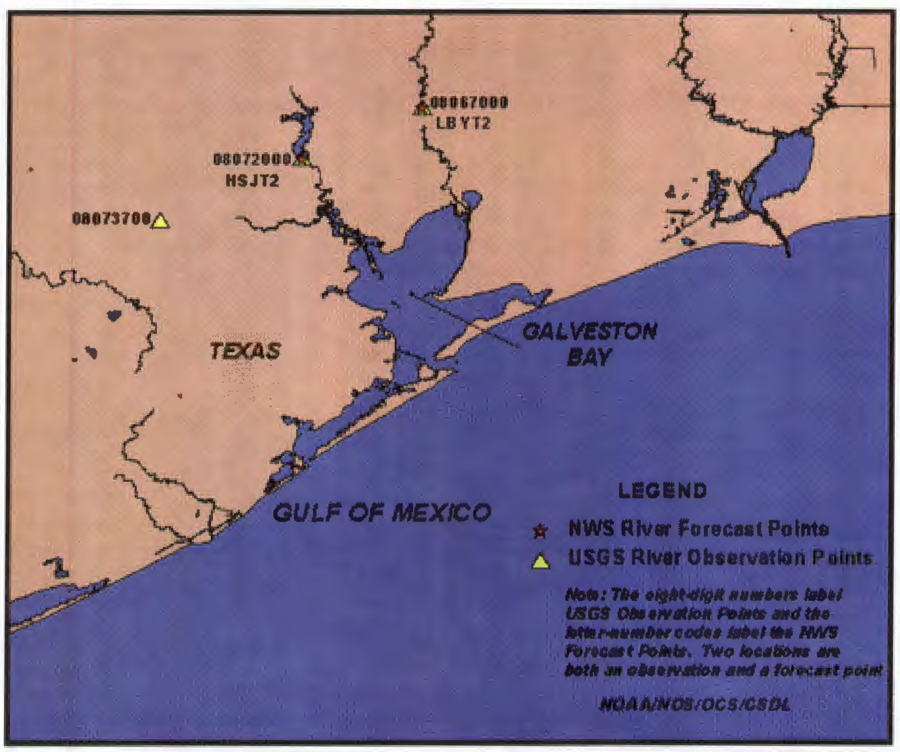

Figure 2.1. River Observation Points and River Forecast Points Identified for use in the Galveston Bay Estuarine Nowcast/Forecast Systems.

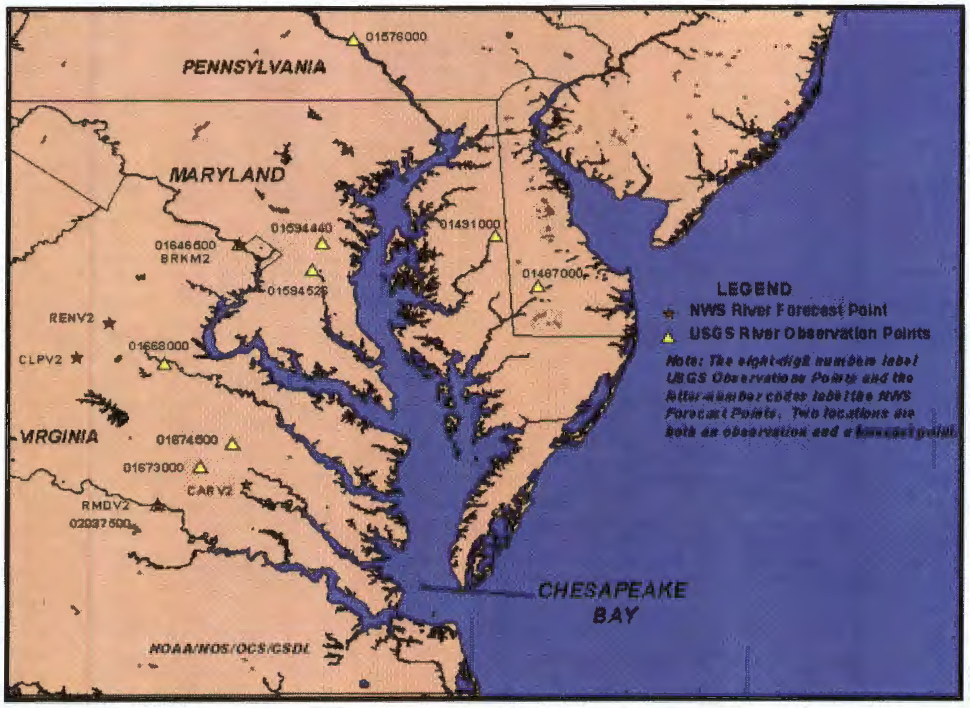

Figure 2.2. River Observation Points and River Forecast Points Identified for use in Chesapeake Bay Estuarine Nowcast/Forecast Systems.

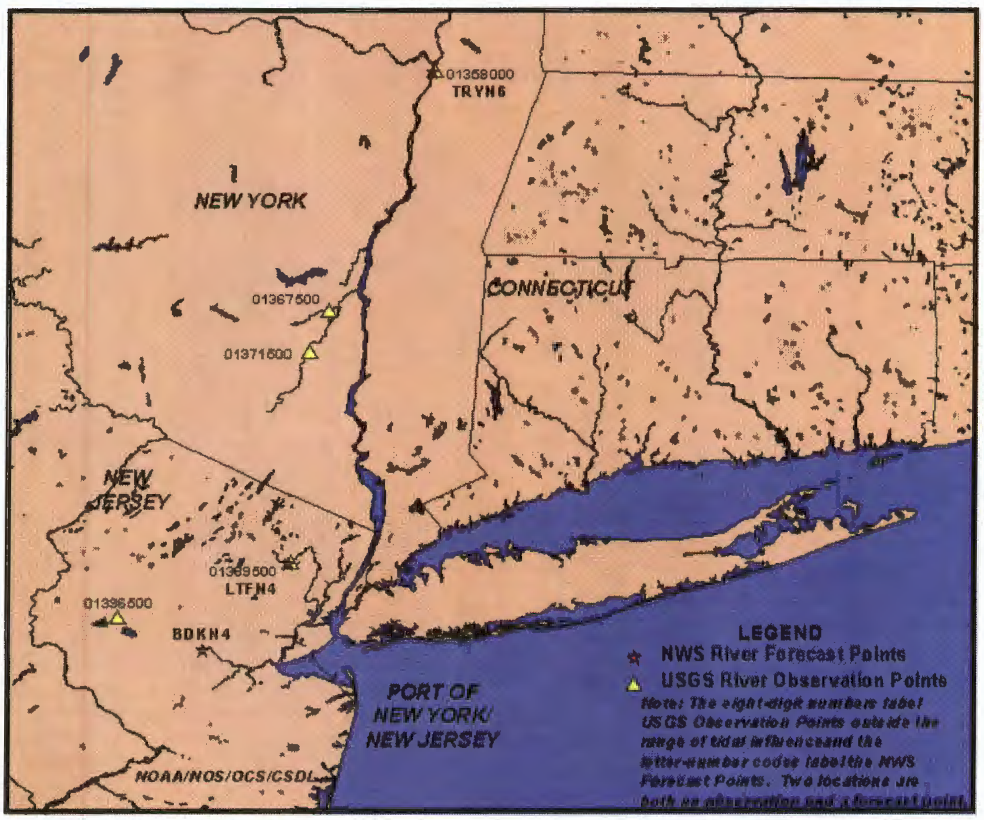

Figure 2.3. River Observation Points and River Forecast Points Identified for use in the Port of New York/New Jersey Estuarine Nowcast/Forecast Systems.

2.5. Other Initiatives to Obtain River Observations

CSDL/MMAP has been working with the Ocean Modeling Branch (OMB) of NWS/NCEPs Environmental Modeling Center (EMC) on ways to obtain river observations. NCEP/EMC/OMB is interested in river gaging stations observations for the COFS (Coastal Ocean Forecast System) oceanographic model for the US East Coast. NCEP/EMC/OMB has established contacts at USGS and CSDL/MMAP has presented the real-time river observation needs of both COFS and estuarine nowcast/forecast systems to the USGS. The USGS has been working to set up an internet ftp site which will included the observations which CSDL/MMAP and NCEP/EMC/OMB have identified as necessary for these models. See Appendix B for a list of stations. The system, called NWISWeb, is expected to become operational in 2000.

NOS/CSDL/MMAP has also established a direct communication with the local NWS Weather Forecast Office (WFO) in Sterling, Virginia. The hydrologist at WFO Sterling has begun posting the RFC river guidance products, which also contain the present stage in feet, for rivers in the Chesapeake Bay region on LDADS (Local Data Acquisiton and Dissemination Server), and CSDL uses ftp to pull the files to a local workstation. These products contain the river stage and are retrieved once a day through ODAAS, the Operational Data Acquisition and Archiving System at MMAP. These forecast products are generated in SHEF (Standard Hydrometeorological Exchange Format). At the present time, these are not used in estuarine models because they are not converted into discharge.

3. RIVER FORECASTS AND FORECAST GUIDANCE

3.1. Source: NWS River Forecast Centers

Since 1890, NOAA's National Weather Service has been mandated by law to forecast stream flow for the nation and issue warnings of floods which could be destructive to life and property. In the mid-1940's, the NWS established regional RFCs throughout the country to fulfill this service. Since 1985, the National Weather Service River Forecast System (NWSRFS) has been used by all RFCs to provide daily river and flood forecasts. Following the reorganization of the NWS in the 1990's, there are 13 RFCs nationwide. Each of the 13 RFC's is responsible for a major hydrologic region of the United States. They produce forecasts for strategic points along major rivers and tributaries to monitor flood potential and provide information on water resource availability. Together, the RFCs issue daily forecasts for 4000 points nationwide and issue flood and drought warnings when necessary (Mason and Weiger, 1995). The RFCs generate the forecast guidance using the NWSRFS and the guidance is then sent to the 119 local NWS WFOs nationwide. The WFOs are responsible for using the river forecast guidance from the RFCs to issue river forecasts and warnings to the public.

3.2. Production of River Forecasts: The NWSRFS

The NWS River Forecast System has four major components which: store and retrieve data, process the data into the correct form, perform the scientific calculations and handle the output. The scientific calculations are carried out by river forecast models, and the forecaster can select which models to use and in which order through the basin, based on the local hydrology and forecaster experience. This makes the NWSRFS a flexible and adaptable system while coordinating and standardizing the river forecast process nationwide. Since the mid-1990's, the NWSRFS has been available locally at the RFCs on a network of UNIX workstations which has also allowed the implementation of a more interactive forecast interface called the Interactive Forecast Program (IFP) which gives the forecaster more control over the river forecast process (NWS, 1996).

The data input to the NWSRFS system includes weather observations, precipitation gaging stations, radar information, quantitative precipitation forecasts (QPF) and real-time river observations via the stream gaging network of the USGS. The river observations are first received at the NWS Office of Hydrology in Silver Spring, Maryland, by satellite telemetry directly, and processed by CADAS (the Centralized Automatic Data Acquisition System) before being sent to the regional RFCs. The observations used and the forecasts produced are in stage (feet) relative to flood stage. The NWS does not convert the forecasts to flow for a general public product, although they have access to the USGS stage-discharge curves and can convert when necessary. The primary purpose of the forecasts, mandated by law, is to accurately predict floods (NWS, 1996). Flood prediction is done by comparing the river levels to the pre-determined flood stage in feet, and the flood warnings are issued from the119 local WFOs based on RFC guidance.

3.3. Data Format and Availability

The RFCs forecast river stages for a select group of points on a daily basis, providing forecasts which range from 24 to 72 hours depending on location. During times of flooding, the number of forecast points is expanded to provide more detailed guidance and more accurate warnings.

Each RFC determines the length of their forecasts and the number of points they forecast for, based on the hydrologic characteristics of the region and the public need for river forecast guidance. The forecast products are then sent through the internal NWS AWIPS server to the local WFOs. See Appendix F for an example of the internal NWS river guidance message. At the WFOs, there are hydrologists on staff who can edit the river forecast guidance based on their knowledge of the local hydrology and issue warnings and forecast guidance directly to the public. See Appendix G for an example of the official guidance produced by the WFOs. The forecast guidance which the WFOs receive from the RFCs and the guidance they issue as a public product is all in river stage. During floods, RFCs may also supply WFOs with estimates of forecast river discharge at strategic points along a stream, but these discharge forecasts are not included in the public product. The NWS currently does not produce any official products with river discharge. The NWS internal products are issued in Standard Hydrometeorological Exchange Format (SHEF) (see Appendix E) and the products for the public are issued as text.

3.4. Requirements of Estuarine Nowcast/Forecast Systems

In order to be able to incorporate river forecasts into forecast systems for ports and estuaries, they must follow the same format requirements as real-time observations. Another important requirement is to have forecasts of discharge. While all official NWS river products report on river stage, they have the capability to convert stage to discharge, and NOS can acquire stage-discharge curves from the USGS to do the same conversion. Another requirement for estuarine forecasts is a sufficiently long forecast period. The forecast period for a point is determined by the RFC issuing the guidance and can be different for various locations in the watershed. All points forecast on a daily basis are available out to 24 hours, which is the minimum requirement for estuarine forecast systems. However, access to 48 to 72 hour forecasts would become necessary as estuarine model developers extend the forecast periods of their models (See Table 3.1). NOS nowcast/forecast systems also require the river forecasts in intervals of three to six hours throughout the forecast period. Most RFCs produce forecasts for up to 48 or 72 hours for all points, but do not include the extended forecasts in the official river forecast guidance. Therefore, the most efficient way for NOS to acquire river forecast guidance is to request the RFCs to include forecasts out to 72 hours in their official guidance, create a river guidance specifically for NOS use, or to establish a direct link with the RFCs to receive an experimental product produced for use in estuarine and coastal forecasting.

The location of the forecast points is also important. The useful data for estuary forecasting is the forecast point farthest downstream on rivers which are tributaries to the port or estuary. See Appendix A for tables with the river forecast points identified for use in three estuarine nowcast/forecast systems. There are fewer river forecast points than real-time river observations, and forecasts may not be issued for some of the smaller tributaries on a daily basis, but only during flood conditions. Therefore, during normal or low flow conditions, there will be fewer river forecasts than observations available for estuary models, but during flood conditions, there may be more forecasts available.

Table 3.1. River Forecast Guidance Requirements for Nowcast/Forecast Systems.

Prediction System	Required Variables	Forecast Horizon	Timeliness
NOAA Coastal Ocean Forecast System	1) Stage 2) Discharge	48 hours	1 - 2 times per day
NOS Estuarine Nowcast/Forecast Systems	1) Stage 2) Discharge	48 hours	2 times per day

3.5. River Forecasts Currently Obtained by NOS/CSDL

Galveston Bay

The model developer for Galveston Bay has made personal contacts with the NWS Western Gulf River Forecast Center (WGRFC) in Fort Worth, Texas. The developer has an agreement with WGRFC where they transfer river forecasts for two of their daily forecast points to him once a day by an ftp push over the Internet (See Figure 2.1). The format of the river forecasts for one of the points is river stage in feet and for the other point is river discharge. The developer converts the stage measurement into discharge with a conversion table obtained from the USGS before using it in the Galveston Bay model.

Chesapeake Bay

River forecasts are also obtained for rivers in the Chesapeake Bay region. Through an agreement with the hydrologist at the NWS WFO in Sterling, Virginia, NOS receives an internal NWS river forecast guidance product (.rvf products). These products contain the forecast river stage out to 24 hours at all points except one, which is forecast out to 48 hours. See Figure 2.2 for a map of forecast points which the model developers would like to include in the nowcast/forecast systems. The .rvf products are retrieved once a day by ODAAS, the Operational Data Acquisition and Archiving System at NOS/CSDL/MMAP. At the present time, these are not used in the Chesapeake Bay estuarine models because they are not converted into discharge. See Table 3.2 for the current status of use of river forecasts in estuarine forecast systems. The .rvf products are being retrieved from Sterling and archived on CSDL's ODAAS system for three river basins: the Potomac, the Susquehanna, and the James/Appomattox.

Port of New York/New Jersey

At the present time, the nowcast/forecast system in development for the Port of New York/New Jersey does not use any river forecasts from the NWS. See Figure 2.3 for a map of the region and river forecast points relevant to the estuarine nowcast/forecast system.

Table 3.2. River Information Currently Used for Forecasts in the Nowcast/Forecast Systems.

Prediction System	River Information	Number of Rivers	Model Use
NOAA Coastal Ocean Forecast System	Monthly Climatology	15 Rivers and the Gulf of St. Lawrence	Modification of Salinity at mouth of river or estuary
NOS Chesapeake Bay	Monthly Climatology	9 Rivers	Modification of Water Level
Chesapeake Bay Experimental C3PO	1)Monthly Climatology 2) Past 24 hour discharge observations	1) 9 Rivers 2) 8 Rivers	Modification of salinity, water level and currents
Chesapeake Bay Experimental CH3D	Monthly Climatology	9 Rivers (missing 2)	Modification of salinity, water level and currents
NOS Port of New York/New Jersey	Yearly Climatology	4 Rivers	Modification of water level and currents
NOS Galveston Bay	3 day forecasts from NWS RFC, received once a day	2 Rivers	Modification of salinity, water level and currents

3.6. Other Initiatives to Obtain River Forecast Guidance

The most effective way to obtain accurate river forecast guidance in units of discharge necessary for estuarine modeling is directly through the regional NWS River Forecast Centers, as is being done for the Galveston Bay model. The NWS Office of Hydrology and the NWS Eastern Region Headquarters agreed that the most efficient means of establishing a system for providing river forecasts to estuarine forecasts for the Chesapeake Bay region was through direct contact with the hydrologists at the Middle Atlantic River Forecast Center (MARFC) in State College, Pennsylvania. The Hydrologist in Charge and the Development and Operations Hydrologist at MARFC has been contacted about NOS's interest in obtaining river forecasts for experimental estuarine forecast systems for the Chesapeake Bay. The next step in this process is to communicate the needs of estuarine nowcast/forecast systems in development and either establish an internal NOAA product that will supply the information to NOS, or to gain access for NOS to the internal NWS products in real-time.

4. SUMMARY AND CONCLUSION

The NOS's Marine Modeling and Analysis Programs (MMAP) branch is responsible for developing and testing forecast models for ports and estuaries in support of NOAA's strategic goals to promote safe navigation and sustainable healthy coasts. The estuarine forecast models are developed and tested at MMAP and then transferred to NOS's Center for Operational Oceanographic Products and Services (CO-OPS) to produce operational forecast products for use by the marine community.

The products produced from these systems will include high resolution analyses and forecasts of meteorological and oceanographic parameters, including but not limited to water levels, currents, water temperature and salinity. The primary users of these unique products will be military, commercial and recreational mariners as well as NWS marine forecasters and others in the marine community. As with all forecast models, estuarine forecast models can only be as accurate as the data they incorporate. Increasing the capabilities and the accuracy of predictions of oceanographic parameters from these estuarine nowcast/forecast systems requires the use of more accurate real-time and forecast river discharge. In order to accomplish this, NOS must establish long-term cooperative relationships with the USGS and the NWS.

ACKNOWLEDGMENTS

The following people made important contributions to this report. Dr. John Kelley has led the effort to acquire river observations and forecasts for NOS/CSDL. He provided much guidance and advice on both the technical and written aspects of the report. Also at NOS/CSDL, Dr. Richard Schmalz, Dr. Eugene Wei and Dr. Tom Gross provided important information on their regional models and gave helpful suggestions in the review process. Dr. Zhen Li supplied information on her successful program written to get information from the USGS web site. In addition, Dr. H. Jean Thiebaux at NOAA/NWS/NCEP/EMC contributed advice and information on her efforts to establish a connection with the USGS. Finally, I would like to thank the reviewers of this report at NOS/CSDL for their helpful and insightful comments.

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APPENDIX A. TABLES OF RIVER OBSERVATIONS AND FORECASTS IDENTIFIED FOR USE IN THREE ESTUARINE NOWCAST/FORECAST SYSTEMS - PORT OF NEW YORK/NEW JERSEY, GALVESTON BAY, AND CHESAPEAKE BAY

Table A.1. Port of New York/New Jersey River Observations. * means station is tidally influenced, therefore real-time observations available in stage only.

USGS ID	Location	State
01389500	Passaic River at Little Falls	NJ
01396500	South Branch Raritan River near High Bridge	NJ
01358000	Hudson River at Green Island	NY
01367500	Rondout Creek at Rosendale	NY
01371500	Wallkill River at Gardiner	NY
01372058*	Hudson River below Poughkeepsie	NY

Table A.2. Port of New York/New Jersey River Forecasts. * means no real-time observation data is available through the USGS for this NWS forecast point.

USGS ID	NWS ID	Location	State	RFC	WFO	Forecast
01389500	LTFN4	Passaic River at Little Falls	NJ	MARFC	KPHI	24 hours
01403000*	BDKN4	Raritan River Below Calco Dam at Bound Brook	NJ	MARFC	KPHI	24 hours
01358000	TRYN6	Hudson River at Troy	NY	NERFC	KALY	54 hours

Table A.3. Galveston Bay River Observations.

USGS ID	Location	State
08073700	Buffalo Bayou at Piney Point	TX
08072000*	Lake Houston near Sheldon	TX
08067000	Trinity River at Liberty	TX

Table A.4. Galveston Bay River Forecasts. * means available in stage only, converted to discharge with USGS stage-discharge conversion tables.

USGS ID	NWS ID	Location	State	RFC	WFO	Forecast
08072000*	HSJT2	Lake Houston near Sheldon	TX	WGRFC	KHGX	72 hours
08067000	LBYT2	Trinity River at Liberty	TX	WGRFC	KHGX	72 hours

Table A.5. Chesapeake Bay River Observations.

USGS ID	Location	State
01487000	Nanticoke River near Bridgeville	DE
01491000	Choptank River near Greensboro	MD
01570500	Susquehanna River at Harrisburg	PA
01576000	Susquehanna River at Marietta	PA
01594440	Patuxent River near Bowie	MD
01594526	Western Branch at Upper Marlboro	MD
01646500	Potomac River at Little Falls near Washington	DC
01668000	Rappahannock River near Fredericksburg	VA
01673000	Pamumkey River near Hanover	VA
01673638	Cohoke Mill Creek at Lestor Manor	VA
01674500	Mattaponi River near Beulahville	VA
02037500	James River near Richmond	VA

Table A.6. Chesapeake Bay River Forecasts.

USGS ID	NWS ID	Location	State	RFC	WFO	Forecast
01646500	BRMKM2	Potomac at Little Falls near Washington	DC	MARFC	KLWX	48 hours
01570500	HARP1	Susquehanna at Harrisburg	PA	MARFC	KCTP	48 hours
01664000	RENV2	Rappahannock at Remington	VA	MARFC	KLWX	24 hours
01667500	CLPV2	Rapidan at Culpeper	VA	MARFC	KLWX	24 hours
02035000	CARV2	James at Cartersville	VA	MARFC	KAKQ	24 hours
02037500	RMDV2	James near Richmond	VA	MARFC	KAKQ	48 hours
02039500	FMRV2	Appomattox at Farmville	VA	MARFC	KAKQ	24 hours

APPENDIX B. TABLE OF USGS STREAM GAGING STATIONS IDENTIFIED FOR COASTAL AND ESTUARINE NOWCAST/FORECAST SYSTEMS DEVELOPED BY NOS/CSDL AND NCEP

Table B.1. Stream gaging stations.

USGS ID	Location	State
01021000	St. Croix River at Baring	ME
01022500	Narraguanus River at Cherryfield	ME
01038000	Sheepscot River at North Whitefield	ME
01049500	Cobbossee Strait at Gardiner	ME
01059000	Androscoggin River near Auburn	ME
01060000	Royal River at Yarmouth	ME
01072100	Salmon Falls at Milton	NH
01073500	Lamprey River near Newmarket	NH
01073587	Exeter River near Brentwood	NH
01100000	Merrimack River at Lowell	MA
01101000	Parker River at Byfield	MA
01102000	Ipswich River at Ipswich	MA
01104000	Charles River at Waltham	MA
01114500	Pawtuxent River at Cranston	RI
01117500	Pawcatuck River at Wood River Junction	RI
01127000	Quinebaug River at Jewitt City	CT
01170500	Connecticut River at Montague City	MA
01193500	Salmon River near East Hampton	CT
01196500	Quinnipiac River at Wallingford	CT
01205500	Housitanic River at Stevenson	CT
01208500	Naugatuck River at Beacon Falls	CT
01372058	Hudson River below Poughkeepsie (stage only)	NY
01358000	Hudson River at Green Island	NY
01367500	Rondout Creek as Rosendale	NY
01371500	Wallkill River at Gardiner	NY
01335754	Hudson River above Lock 1 near Waterford	NY
01357500	Mowhawk River at Cohoes	NY
01389500	Passaic River at Little Falls	NJ
01396500	South Branch Raritan near High Bridge	NJ
01408120	North Branch Metedeconk River at Lakewood	NJ
01411000	Great Egg Harbor River at Folosm	NJ
01411500	Maurice River at Norma	NJ
01463500	Delaware River at Trenton	NJ
01474500	Schuylkill River at Philadelphia	PA
01477000	Chester Creek near Chester	PA

USGS ID	Location	State
01479000	White Clay Creek near Newark	DE
01480000	Red Clay Creek at Wooddale	DE
01481500	Brandywine Creek at Wilmington	DE
01487000	Nanticoke River near Bridgeville	DE
01491000	Choptank River near Greensboro	MD
01570500	Susquehanna at Harrisburg	PA
01576000	Susquehanna at Marietta	PA
01594440	Patuxent River near Bowie	MD
01594526	Western Branch at Upper Marlboro	MD
01646500	Potomac River at Little Falls near Washington	DC
01668000	Rappahannock River near Fredericksburg	VA
01673000	Pamumkey River near Hanover	VA
01673638	Cohoke Mill Creek at Lestor Manor	VA
10674500	Mattaponi River near Beulahville	VA
02037500	James River near Richmond	VA
02080500	Roanoke River at Roanoke Rapids	NC
02082585	Tar River at NC97 at Rocky Mount	NC
02083000	Fishing Creek near Engfield	NC
02091814	Neuse River at Ft. Barnwell	NC
0209205053	Swift Creek near Streets Ferry	NC
02092554	Trent River at Pollocksville	NC
02093000	New River near Gum Branch	NC
02105769	Cape Fear River at Lock 1	NC
02105900	Hood Creek near Leland	NC
02110815	Waccamaw River at Hagley Landing	SC
02135210	Pee Dee River at L. Topsaw Landing	SC
02176500	Coosawhatcie River near Hampton	SC
02197320	Savannah River near Jackson	SC
02236125	St. Johns River at Astor	FL
08067000	Trinity River at Liberty	TX
08072000	Lake Houston near Sheldon	TX
08073700	Buffalo Bayou at Piney Point	TX

APPENDIX C. REFERENCE WEB SITES

The Northeast River Forecast Center, Taunton, MA:
http://tgsv5.nws.noaa.gov/er/nerfc/

The Middle Atlantic River Forecast Center, State College, PA:
http://marfchp1.met.psu.edu/

The Southeast River Forecast Center, Peachtree, GA:
http://www.nwsserfc.noaa.gov/

The Lower Mississippi River Forecast Center, Slidell, LA:
http://www.nwslmrfc.noaa.gov/

The West Gulf River Forecast Center, Fort Worth, TX:
http://www.srh.noaa.gov/wgrfc/

The National Weather Service Office of Hydrology, Silver Spring, MD:
http://www.nws.noaa.gov/oh/

The United Stated Geological Survey Water Resources Division, Reston, VA:
http://water.usgs.gov/

APPENDIX D. CONTACTS

Dr. Jean Thiebaux, NCEP/EMC/OMB. Statistician. She is working with the USGS to have an USGS fto site for NOS and NCEP to obtain real-time river observations for use. She is located in Camp Springs, Maryland.
(301)763-8000 x7216
Jean.Thiebaux@noaa.gov

Harry F. Lins, USGS/Water Resources Division/Office of Surface Water. He is Jean Thiebaux's main contact at the USGS and has agreed to write the code to set up a system for NOS and NCEP to get real-time river flow information. His office is in Reston, Virginia.
(703)648-5712

Dr. Thomas Baumgardner, Hydrologist in Charge at MARFC in State College, PA. He was suggested as a contact by the NWS Eastern Region director, Sol Summer, and Curt Barrett of the NWS Office of Hydrology.
(814)234-9701
Thomas.Baumgardner@noaa.gov

Melody Paschetag, Hydrologist at WFO Sterling, Virginia. She and Steve Zubrick at Sterling post their river forecasts on the LDADS server which we can access.
(703)260-0107 x234
Melody.Paschetag@noaa.gov

Robert Shedd, Contact for information about the SHEF format of NWS hydrologic data and transmission by GOES.
(508)824-5116
Robert.Shedd@noaa.gov

Lawrence Cedrone, NWS's Office of Hydrology, Hydrologic Services Division. He is a contact for information on NWS data streams and the HADS system.
(301)713-0624 x108
Lawrence.Cedrone@noaa.gov

APPENDIX E. EXAMPLE AND EXPLANATION OF SHEF

Example: SHEF (Standard Hydrometeorlogical Exchange Format) transmission of river observation data:

SRUS20 KWOH 021824

RRSTAR

:&&HADS SOR REPORT FOR USER TAR

.E NINM1 990802 DH1530/PCIRG/DIN15/3.53/3.53/3.53/3.53/3.53/3.53/3.53

.E1 3.53/3.53/3.53/3.53/3.53

.E NINM1 990802 DH1530/HGIRG/DIN15/1.49/1.49/1.49/1.48/1.48/1.48/1.48

.E1 1.48/1.47/1.47/1.47/1.47

.E NINM1 990802 DH1615/TAIRG/DIN60/ 63/ 64/ 63

.E BLBN6 990802 DH1500/HGIRG/DIN60/11.65/11.66/11.66/11.67

.E HRDM3 990802 DH1430/HGIRG/DIN15/18.90/18.90/18.90/18.91/18.90/18.89

.E1 18.90/18.91/18.90/18.89/18.91/18.91/18.89/18.89/18.90/18.90

:&& THE ABOVE DATA WERE GENERATED BY THE FOLLOWING SOR REPORTS

:&& SOR2 SOR1

Description:

The data are identified by location, time and interval of data collection. The location and date are specified in the first two fields, followed by a data stream. The time, data type, and interval of collection are specified, followed by the actual data. Each data point is separated by a back-slash. A colon precedes lines with data descriptions

Definition of codes:

KWOH = Source of data stream (NWS Office of Hydrology)
.E = SHEF format specifier
.E1 = continuation of the previous line of data
NINM1 = NWS Station identifier
990802 = date of data transmitted (yymmdd)
DH1615 = time of data collection (Dhhhmm)
HGIRG = Height of river (river stages in ft)
PCIRG = Precipitation accumulated from a specific date to present
TAIRG = Air temperature (dry bulb) in degrees F
DIN15 = Interval at which data was taken (DINmm)

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APPENDIX F. EXAMPLE OF AN INTERNAL NWS RIVER FORECAST GUIDANCE ISSUED BY THE RFCS FOR THE WFOS

The first and last lines of the product are codes used by the AWIPS system to transfer information through the NWS. Code to abbreviations:

FS = Flood Stage
CS = Caution Stage
FCST = Forecast
TMW = Tomorrow

This internal guidance product consists of the current observations and the 24 or 48 hour forecast for the Delaware River Basin. The data are coded by location and NWS code and the data are delimited by '/'. Guidance is given in stage. The river flow (discharge) at two strategic points in this basin have been included in the guidance, as has an estimate of precipitation and a caution about a location approaching flood stage. This additional information is used by a hydrologist at the Weather Forecast Office to issue the pubic guidance (Appendix G).

```
ZCZC PITRVFDEL
TTAA00 KRHA 281400
NATIONAL WEATHER SERVICE RIVER FORECAST CENTER, STATE COLLEGE, PA
 957 AM EDT SAT OCT 28 1995
:
:
:          ...DELAWARE RIVER BASIN FORECASTS...
:
:
.B RHA 1028 E DH07/DC1028/YF/YW/HG/DH07/DRD+1/HGIF/DRD+2/HGIF
:
:                         FCST   FCST
:                  OBS 7AM  7AM    7AM
:STATION      HB5ID  FS  CS  TODAY   TMW   NXT DAY  CREST/REMARKS
:
:LEHIGH RIVER
: WALNUTPORT  :WLNP1  8/  /  3.3  / 3.4 /     :
: BETHLEHEM   :BETP1  16/  /  3.3  / 3.5 /    :
:
:LACKAWAXEN RIVER
: HAWLEY      :HWYP1  11/  /  2.7  / 2.8 /    :
:
:BEAVER KILL
: COOKS FALLS :COON6  10/  /  7.2            :STAGE 8.0 AT 9:30
:                             AM. CREST 9 TO 10 FT BY EARLY AFTN
:
:DELAWARE RIVER
: CALLICOON   :CCRN6  12/  /  3.9  / 5.5 /    :
: BARRYVILLE  :BRYN6  17/  /  3.9  / 7.5 / 5.5 :
: PORT JERVIS :PJRN6  18/  /  3.1  / 5.0 /    :
: MONTAGUE    :MNTN4  25/  /  6.2  / 8.0 /    :
: BELVIDERE BR.:BENJ  20/  /  2.8  / 4.3 /    :
: TRENTON     :TRNN4  20/ 15/ 10.7  / 12.0 / 11.5 :
```

:
:SCHUYLKILL RIVER
: PHILADELPHIA :PADP1 11/ 10/ 6.7 / 7.2 / 6.5 :
:
:MEAN DAILY FLOW FORECAST FOR THE DELAWARE RIVER AT TRENTON, NJ FOR THE
:24 HOUR PERIOD BEGINNING AT 7AM:
:
:TODAY= 13000 TOMORROW= 25400 NEXT DAY= 24400
:
:MEAN DAILY FLOW FORECAST FOR THE SCHUYLKILL RIVER AT PHILADELPHIA, PA
:FOR THE 24 HOUR PERIOD BEGINNING AT 7AM:
:
:TODAY= 1700 TOMORROW= 7700 NEXT DAY= 4300
:
.END

THESE FORECASTS ASSUME A CONTINUATION OF PRESENT RESERVOIR RELEASES AND MINOR ADDITIONAL QPF.

RAINFALL AMOUNTS OVER THE PAST 24 HOURS HAVE RANGED FROM 0.50 TO 2 INCHES IN THE UPPER THIRD OF THE DELAWARE BASIN TO 1 TO 2 INCHES OVER THE LOWER TWO THIRDS. A CONCENTRATED AREA OF HEAVY RAIN IN THE VICINITY OF COOKS FALLS WILL CAUSE THAT LOCATION TO APPROACH FLOOD STAGE BY EARLY AFTERNOON. WE WILL CONTINUE TO MONITOR THIS SITUATION.

ELSEWHERE... RAINFALL OF THE PAST 24 HOURS IS EXPECTED TO GENERATE RISES RANGING FROM 2 TO AROUND 4 FEET OVER THE NEXT DAY OR TWO. THE CURRENT RIVER LEVELS INDICATE THAT SIGNIFICANT PROBLEMS WILL NOT OCCUR BECAUSE OF THESE RISES.

.....END MARFC.....
NNNN

APPENDIX G. EXAMPLE OF AN OFFICIAL RIVER FORECAST PRODUCT ISSUED BY A WFO FOR THE PUBLIC

The first three lines of this official river forecast product from the WFO in State College, PA, indicate the origin of the forecast and the NWS forecast zones included in this product. The data are presented in a more comprehensible format for reading than the previous example of an internal NWS product. A short discussion of the precipitation forecast and possible changes in the river flow is also given.

```
FGUS81 KCTP 101636
RVSCTP
PAZ012-018-028-041-045>046-049>050-052-056>057-063-065>066-111600-
RIVER STATEMENT
NATIONAL WEATHER SERVICE STATE COLLEGE, PA
1133 AM EST FRI MAR 10 2000

    ...RIVER FORECASTS FOR CENTRAL PENNSYLVANIA...

                  FS  CS   OBSERVED        FORECAST 7AM   CREST/REMARKS
LOCATION                   STG  DAY  TIME   SAT   SUN

WEST BRANCH SUSQUEHANNA
 RENOVO           16  14   2.8  FRI  06 AM  2.7
 LOCK HAVEN       21  17   9.2  FRI  08 AM  9.1
 WILLIAMSPORT     20  10   3.9  FRI  09 AM  3.7

JUNIATA RIVER
 NEWPORT          22  19   4.8  FRI  11 AM  4.7

MAINSTEM SUSQUEHANNA RIVER
 SUNBURY          24  20  10.8  FRI  08 AM  10.8
 HARRISBURG       17  11   5.5  FRI  11 AM  5.4   5.3

MEAN DAILY FLOW FORECAST FOR THE SUSQUEHANNA RIVER AT HARRISBURG FOR
THE 24 HOUR PERIOD BEGINNING AT 7 AM:

TODAY  41,300  TOMORROW  39,700  NEXT DAY  39,600

THESE FORECASTS ASSUME A CONTINUATION OF PRESENT RESERVOIR RELEASES.
FORECASTED PRECIPITATION THROUGH 12Z SATURDAY IS ZERO.

REPORTED PRECIPITATION FOR THE 24 HOUR PERIOD ENDING AT 8 AM THIS
MORNING WAS GENERALLY ONE TENTH OF AN INCH OR LESS...WITH A FEW
HIGHER AMOUNTS AROUND ONE QUARTER INCH IN THE WEST BRANCH.

STEADY TO SLOWLY FALLING STAGES ARE EXPECTED OVER THE NEXT 24 HOURS
IN THE LOWER SUSQUEHANNA BASIN.

.END/ SKEEN
```
