NATIONAL WEATHER SERVICE RIVER FORECAST SYSTEM

Total River and Hydrologic Forecasting System

NWSRFS Overview

SYSTEM OVERVIEW

National Weather Service River Forecast System

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Chapter 1

Introduction

Background

The National Weather Service River Forecast System (NWSRFS) is a robust river and hydrologic forecast system. As such, the system includes all the necessary hydrologic and routing models as well as data handling and presentation systems. The NWSRFS has been in operation for over 20 years and is constantly refined and improved. The NWSRFS is used in the United States and in other countries throughout the world including Peoples Republic of China, Panama, Republic of South Africa, Nicaragua, and El Salvador.

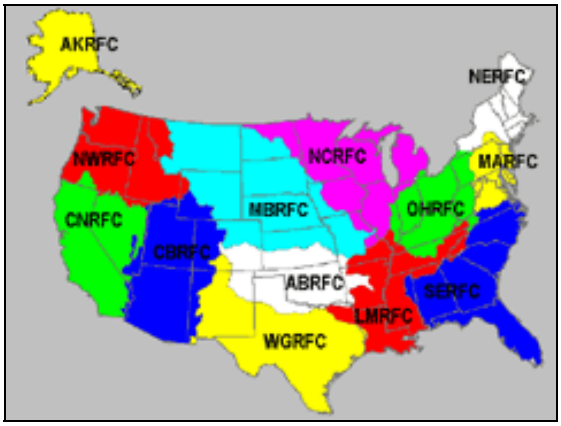
The U.S. National Weather Service (NWS) provides river and flood forecasts and warnings in the United States for protection of life and property and by providing basic hydrologic forecast information for environmental and economic well-being. The Office of Hydrologic Development supports the NWS hydrologic mission through the design, development, testing, and implementation of a physically-based hydrologic forecasting system – the NWSRFS.

Thirteen River Forecast Centers (RFCs) develop hydrologic forecasts for the U.S. The RFCs use the NWSRFS to make short-term forecasts (a day to a week in advance) of river flows and floods and long-term probabilistic river outlooks (a week to months in advance) in support of water supply management and flood mitigation. The RFCs are staffed by approximately 150 hydrologists and provide a variety of hydrologic forecasting services. Products generated by the RFCs include:

- Flood forecasts
- General river forecasts used for navigation, recreation and other purposes
- Reservoir inflow forecasts
- Water supply forecasts
- Spring (e.g., snowmelt) flood forecasts
- Various types of flash flood guidance

The RFCs also provide a variety of other services – development of forecast procedures as required and when requested; development and implementation of new hydrologic forecast techniques; and improvement of computer systems, data handling techniques, and hydrologic monitoring network hardware.

The general public is the primary user of RFC products. However, other government agencies, irrigation interests, hydroelectric power producers, recreation, fish and wildlife, water navigation, and other commerce all benefit from and use hydrologic forecasts.



U.S. River Forecast Centers - Areas of Responsibility

NWSRFS Structure

The NWSRFS is a collection of interrelated software procedures that perform a wide variety of hydrologic/hydraulic and data management operations. Operations form the scientific heart of the NWSRFS and therefore must be easily called on, utilized and organized. Operations in NWSRFS are functions that represent one scientific algorithm, such as snow, soil moisture, or river routing procedures. In general, an operation in the NWSRFS is a set of functions that performs actions on a time series. Typically an operation describes the equations of motion governing the flow of water through a portion of the hydrologic cycle. There are also operations to display results, or to perform utility functions.

Hydrologic operations in NWSRFS are organized into an 'operations table' to specify the physics of water movement for any sub-basin. The order in which operations are computed depends on the hydrometeorological conditions of the sub-basin modeled. Forecasters can use their hydrologic expertise to determine the best sequence of scientific algorithms or operations to model each sub-basin. In this way, NWSRFS provides a generalized river forecasting system that can be used to model basins in any hydroclimatic regime.

Examples of the types of operations included in the NWSRFS are as follows.

Types of Operations	**Operations Included**
Snowmelt Models	HYDRO-17 Snow Model
Rainfall/Runoff Models	Sacramento Soil Moisture Accounting
	NWS RFC Antecedent Precipitation Index Models (Ohio, Middle Atlantic, Central, Colorado Basin
	Xinanjiang Soil Moisture Accounting
Temporal distribution of runoff	Unit Hydrograph
Channel losses or gains	Simplified Loss/Gain Method
	Consumptive use
Routing models	Lag and K
	Muskingum
	Layered Coefficient
	Tatum
	Dynamic wave routine models (DWOPER/ FLDWAV)
Baseflow simulation	Baseflow simulation model
Reservoir regulation	Single, independently controlled reservoir under various modes of operation
	Multiple reservoirs operated jointly
Adjustment procedures	Simplified flow adjustment and blend
Stage/discharge conversion	Single valued rating curves with log or hydraulic extensions and loop ratings
Time series manipulations	Computation of mean discharge
	Weight time series

	Look-up tables
Plot displays	Instantaneous discharge plot
	Operational plot
	Water year daily flow plot
Statistical functions	Calibration statistics package
Water balance	Water balance analysis

Scientific algorithms are organized into modular functions so that the functions can be shared, unchanged, among major components of the NWSRFS. Because of the modular nature of the functions which make up any operation, functions need to be shared among the programs which form the NWSRFS. This allows new scientific techniques to be developed in the structure specified for an operation, and once tested to be immediately available for use in forecasting with the NWSRFS.

The NWSRFS has been designed to be modular, so that components could be developed by a number of individuals and then combined into a total system. References in the program code to system-specific routines are isolated so that the entire NWSRFS can be ported from one hardware/operating system platform to another with minimum effort (it is currently supported in Hewlett-Packard UNIX and LINUX operating systems, with a MS Windows™ version also available but not supported by the NWS). Routines which perform scientific algorithms are separated from input/output routines so that the science could be run on any computer without needing changes in the reading or writing of information from the computer system.

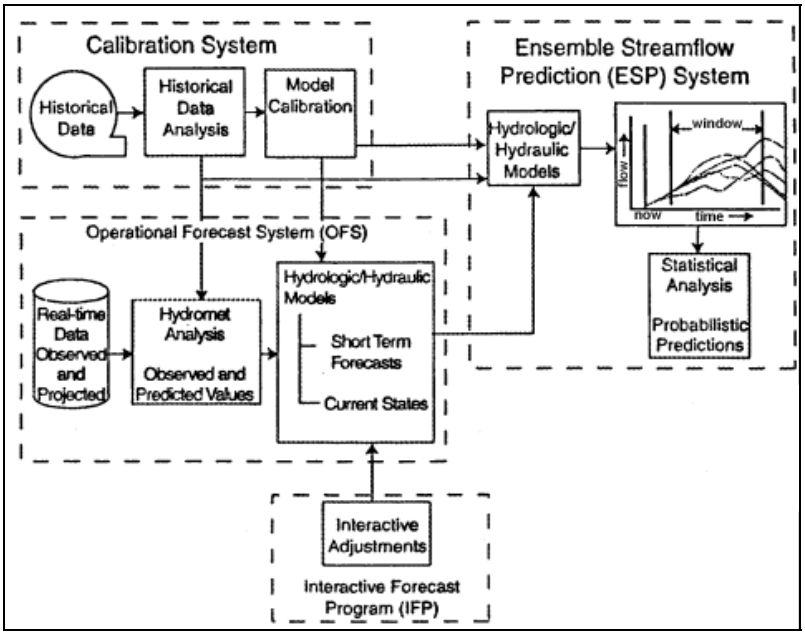
Chapter 2

System Overview

The National Weather Service River Forecast System (NWSRFS) is a collection of interrelated software capable of performing a wide variety of hydrologic and hydraulic functions. NWSRFS has many components and is changed and improved as new components are added and existing components are modified. The purpose of this overview of the NWSRFS is to show the interactions among the major systems comprising NWSRFS and to briefly describe the functions performed by each system.

NWSRFS Systems

NWSRFS contains three major systems that use the same hydrologic and hydraulic models. In addition to these systems, the Interactive Forecast Program module has been added to augment the Operational Forecast System and provide the forecaster with a tool. for interactive program control.



NWSRFS Major Systems

The NWSRFS Systems have these primary functions:

Operational Forecast System

- Generate short-term river and flood forecasts using calibrated model parameters
- Maintain model state variables

Calibration System

- Generate time series based on historical data
- Determine model parameters

Ensemble Streamflow Prediction System

- Generate probabilistic forecasts extending weeks or months into the future using current model states, calibrated model parameters, and historical time series

The NWSRFS is a modular system that allows the hydrologist to select from a variety of models and to configure them in a manner that is descriptive of the basin. All of the hydrologic models are available to the Calibration, Operational Forecast, and Ensemble Streamflow Prediction systems.

Operational Forecast System

OFS is a continuous river forecasting system which provides the forecaster with predictions of river flow to use in producing flood forecasts and other hydrologic products. The system stores observed and forecast point data (e.g., precipitation, temperature, river stage) performs various preprocessor functions on the observed data (e.g., computes mean areal precipitation, mean areal temperature, performs stage to discharge conversion), and produces forecast products (e.g., plots of predicted, simulated and observed river stage at selected forecast points. Model parameter values are normally determined using the Calibration System (see following discussion) and transferred to the Operational Forecast System through a manual preparation step. This manual preparation is needed to add the description of operations for a given forecast (e.g., blend routines, different plot options).

Once the models have been calibrated for a basin, they can be used operationally with real-time hydrometeorological data to forecast river flows and stages. The OFS contains three major components that are needed for operational river forecasting - Data Entry, Preprocessor, and Forecast. The **Data Entry Component** is a set of programs that transfer hydrometeorological data from a variety of sources to the observed data base. The **Preprocessor Component** reads raw station data, estimates missing data as required and then uses these data to calculate mean real-time series of precipitation, temperature, and potential evapotranspiration for a particular river basin. These processed time series are used by the **Forecast Component** to perform requested hydrologic and hydraulic simulations. The Forecast Component stores

parametric data for the models, as well as information that describes the basin connectivity of the river system. The Forecast Component also maintains an account of the current model states. These states describe the hydrologic condition of the basin including the snow cover, soil moisture, and channel storage. These states are needed as starting points for subsequent forecasts.

Interactive Forecast Program

The Interactive Forecast Program (IFP) augments the Operational Forecast System. The major components that make up the IFP include the hydrologic models in the NWSRFS and the graphical user interface that allows interactive program control. The IFP allows the forecaster to use hydrologic expertise and judgment to develop a forecast while streamlining the tasks required to produce the forecast.

Example IFP Display with Input and Output Time Series Displays

Through the displays, the forecaster can interactively make changes to the parameters, data, or current conditions used for hydrologic simulation and quickly see the results of those changes. The changes can be categorized into those affecting time series and those affecting a specific hydrologic model.

Calibration System

The Calibration System is used to investigate the performance of various hydrologic techniques using historical data both for pure research purposes and for calibration of hydrologic models

(estimating parameters) used in the Operational Forecast System. Historical data access programs are available to inventory archived hydrometeorological data and convert the data from the archive format to a standard data file format. Calibration preprocessor programs are available to compute mean areal values of precipitation (MAP) and temperature (MAT) from point values. A utility program is available to manage and analyze data in the data files.

The programs used to calibrate the hydrologic models are:

- The **Manual Calibration Program –** operates by applying hydrologic models with user-specified values for all parameters.

- The **Interactive Calibration Program** – displays simulated and observed hydrographs and model states to enable rapid and visually oriented Manual Calibration Program runs, thus enhancing the calibration process.

- The **Automatic Parameter Optimizer –** operates in a similar manner as the Interactive Calibration Program, but includes a procedure to automatically adjust parameter values to improve the streamflow simulation.

The calibration software is intended for use on just one segment of a river system at a time. A major river system is calibrated a basin at a time, with a typical calibration run spanning multiple years of historical data. In contrast, the Operational Forecast System operates on an entire river system, but for comparatively short time periods.

The Calibration System performs the tasks needed to process historical hydrometeorological data and to estimate model parameters for a specific basin. The models simulate snow accumulation and ablation, calculate runoff, distribute runoff to the basin outlet, and channel route streamflow. As part of the calibration procedure, for a particular basin, the simulated streamflow is statistically and visually compared to the observed streamflow to determine the necessary model parameter adjustments. The ideal model parameters are those with which the model simulated streamflow most closely matches the observed streamflow.

The Calibration System, through the Interactive Calibration Program, includes capabilities for Graphical User Interface (GUI) based interactive control of the hydrologic parameter calibration process within a multiple graphical display windows environment. This capability, together with strategic use of a multi-parameter pattern search optimization algorithm, increases the efficiency of the calibration of hydrologic model parameters.

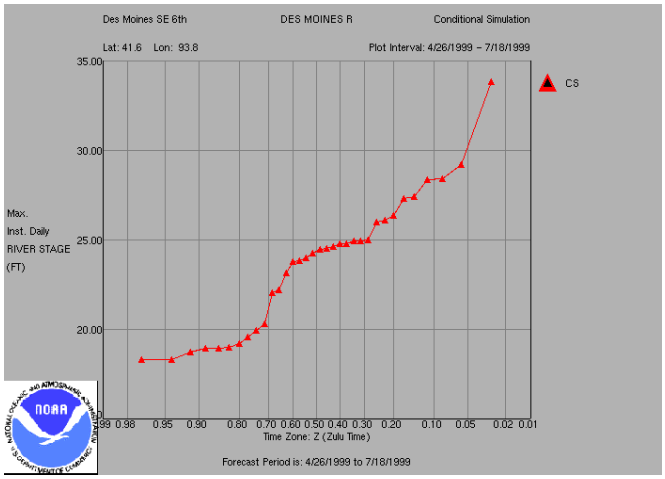
Ensemble Streamflow Prediction System

The Ensemble Streamflow Prediction System (ESP) produces probabilistic forecasts of hydrologic variables extending weeks or months into the future. ESP assumes that historical meteorological data are equally likely to occur in the future. It accesses files in the Operational Forecast System for an estimate of the current hydrologic state, and uses historical meteorological data to create many equally likely sequences of future hydrologic conditions, each starting with

current conditions. The generated streamflow time series can then be analyzed for products such as peak flows, minimum flows, flow volumes, and river stages, for any period in the future.

A statistical analysis is performed using the values obtained from each year's simulation in order to produce a probabilistic forecast for the streamflow variable. This analysis can be recreated for different forecast periods and additional streamflow variables of interest. Short-term quantitative forecasts of precipitation and temperature can be used to weight the years of simulated streamflow based on the similarity between the climatological conditions of each historical year and the current year.

The ESP System allows flexibility in the streamflow variables which can be analyzed, the capability to make forecasts over short and long time periods, and the ability to incorporate forecast meteorological data (e.g., seasonal outlooks of precipitation) into the procedure. Because of the flexibility and conceptual basis of ESP, it has many applications including water supply and drought analysis.



ESP Outputs – Probability Plots