J7.6 OVERVIEW AND STATUS OF THE HYDROLOGIC FORECAST SYSTEM IN THE NATIONAL WEATHER SERVICE WEATHER FORECAST OFFICES

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1. INTRODUCTION

In 1996, the National Weather Service (NWS) delivered the first set of Advanced Weather Interactive Processing System (AWIPS) workstations to a limited number of NWS field offices. The software provided with this limited-function release included the Weather Forecast Office (WFO) Hydrologic Forecast System (WHFS), which performs operations in support of the Hydrology program at WFOs (Roe, 1998). Since then, AWIPS has been deployed at all NWS WFOs and the WHFS functionality has grown dramatically, with new functionality added with each AWIPS software release.

The software and its associated relational database have been expanded to address operations outside the traditional domain of the WFO Hydrology program, and now shares the same database structure and provides support for selected operations at the River Forecast Centers (RFCs). The WHFS now encompasses the full range of hydrologic activities, from ingesting, decoding, and posting data, to performing quality control and event monitoring of the data, to providing tabular and graphical data visualization tools, to basic hydrologic modeling capabilities, to generating and issuing products to external customers.

With the national implementation of the WHFS, the need for field support led to the establishment of a dedicated operational support team. The support team, the development team, and a requirements and management team all work together to support the current and future demands of this mission-critical system. This paper describes the current status of the WHFS, in terms of field implementation and support operations, and future activities for the WHFS.

2. CURRENT CAPABILITIES

The WHFS is a coordinated set of software applications which perform operation-critical functions for the NWS hydrology program. A graphical overview of the WHFS software applications is given in Figure 1. The following subsections describe the functional areas of the WHFS, and list which application(s) shown in Figure 1 addresses the area. The functional areas are described in a front-to-back order, where the front-end is the data ingest and storage, the "middle" is the data processing and analysis, and the back-end is the creation and distribution of data products to external destinations.

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2.1 Data Ingest

As an operational system, the WHFS is constantly ingesting, decoding, and storing data from a high-volume input data stream. These data includes real-time hydrometeorological data that can be categorized as being either for station locations, such as a river gage station, or for areas, such as gridded precipitation fields. The hydrometeorological data ingested by the WHFS is received in different formats and from different sources. Most of the "point" data are in the Standard Hydrometeorological Exchange Format (SHEF) (NWS, 1998). The SHEFdecode application decodes and posts the data into the relational database which is at the heart of the WHFS (Office of Hydrologic Development, 2000).

Another data format supported by the WHFS ingest processes is the METAR format, which is used to encode NWS Automated Surface Observation Systems (ASOS) surface observations. These data are decoded and converted into SHEF by the Metar-to-SHEF application, thereby allowing METAR data to be easily posted into the WHFS database. Additionally, gridded estimates of precipitation from WSR-88D radars are ingested, decoded, and stored by the DPAdecode application. These Digital Precipitation Array (DPA) binary products are used as the primary source of areal precipitation estimates.

All data ingested by the WHFS are received via AWIPS communications mechanisms, primarily the Satellite Broadcast Network (SBN) or the Wide Area Network (WAN). In addition, radar products are received through a special dedicated link to nearby radars connected to the local AWIPS installation. Offices also receive data from local sources via the Local Data Acquisition and Dissemination (LDAD) system which has a dedicated connection to the local AWIPS installation. Regardless of their source, any SHEF, METAR, and radar products can be processed by the WHFS by simply placing the relevant encoded data files in designated file directories.

2.2 Data Management

Essentially all data in the WHFS are stored in a single relational database known as the Integrated Hydrologic Forecast System (IHFS) Database (Glaudemans, 2002). Each application function directly queries or updates the database as necessary so that all functions are accessing the same, single copy of the data. The IHFS database contains these major categories of data: operational observations and forecasts for stations;

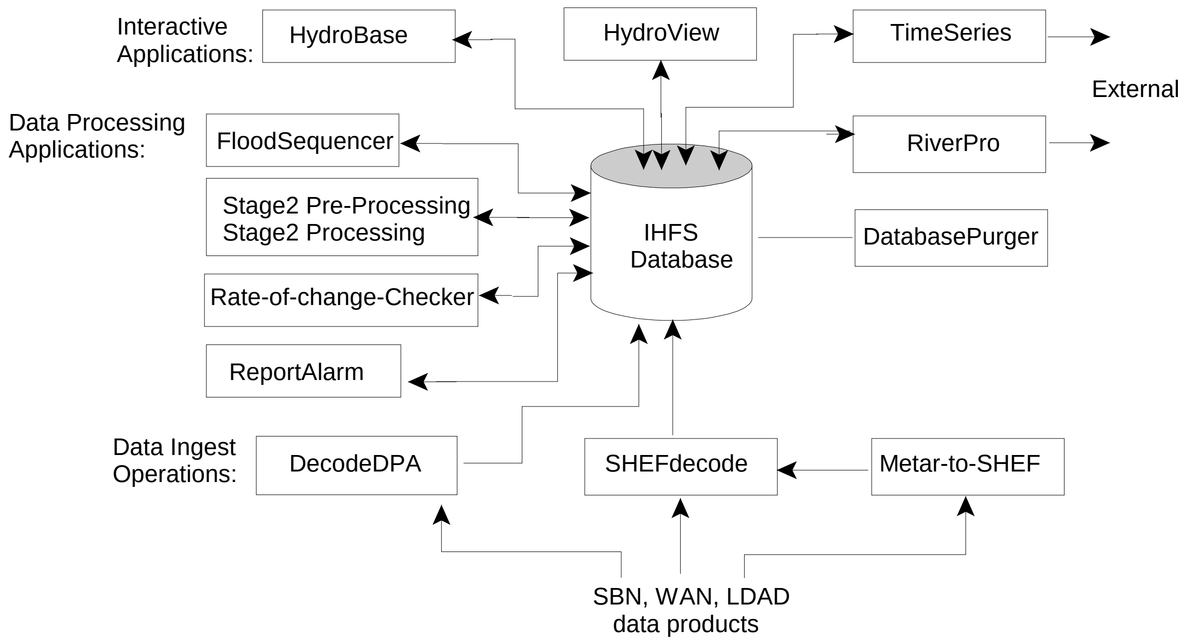

Figure 1. Summary of WHFS Applications

operational radar and precipitation analysis grids; reference data for stations, areas and polygons; and application and database control parameters.

All applications in the WHFS access and depend on the IHFS database. Furthermore, many locally-developed applications exist independent of the formal WHFS software and query the IHFS database. By using published descriptions of the database structure, these local applications have taken advantage of the completeness of the IHFS database design, which accommodates all hydrometeorological data within the SHEF definition.

The interactive HydroBase database management application is the primary interface for management of the reference data and control parameters. The reference data are the data sets that define the stations, areas, and their static attributes. The application control parameters dictate how the operational data sets are processed. Scheduled runs of the DatabasePurge and FilePurge applications purge old data from the relational database and log files, respectively.

The operational data for stations and areas, such as counties or basins, are stored with a full set of associated attributes which follow the SHEF data model. Specifically, for every value, the following SHEF attributes are stored: the station identifier, the time of the observation/forecast, the physical element (e.g. temperature or river stage), the duration (usually instantaneous, but non-zero for elements such as precipitation), the type (e.g. observed or forecast), the source, the extremum (i.e. whether it's a minimum or maximum), an external qualifier code, and a revision indicator code (i.e. whether the value has been revised).

For forecast data, additional attributes indicate the time of the forecast, and any associated probability for the forecast value. Other non-SHEF attributes associated with each value include the quality code indicator, the time the value was posted, and the time and identifier of the data product that contained the value.

2.3 Quality Control

The WHFS applications test the quality of the data value and store the results in the bit-encoded quality code attribute (Office of Hydrologic Development, 2000). Every data value in the IHFS database has an associated quality control code. The initial value of the quality code is based on the data qualifier code defined externally via the SHEF encoding of the value. Often, the SHEF data qualifier is not used, in which case the initial quality code attribute for the value is set to "good".

The WHFS employs a three-tier strategy, in which the quality of a value is defined as either Good, Questionable, or Bad. As their names imply, Bad indicates that the data value is known with certainty to be invalid, and Questionable indicates that the value has failed at least one test that raises suspicions about the validity of the value, but is not known with certainty to be Bad. If a quality code value indicates Good, then the value is either truly "good", or it has not been identified as being Questionable or Bad by failing either an internal test or being identified by external sources as being "bad". Incoming data are tested and if the data fails the quality test, the quality code is set accordingly. The user can control whether this Bad data is commingled with the regular data, or is directed to a table for storing rejected data (i.e. a "trash can").

Because of the bit-encoded nature of the attribute, the results of up to 20 tests can be stored in a compact manner and their results can be easily tracked. As data are ingested, the WHFS SHEFdecode application checks each value against pre-defined thresholds to determine whether the value is within gross limits (e.g. daily precipitation between 0-40 inches), or is within reasonable limits (e.g. daily precipitation between 0-5 inches). If a value is outside the gross or reasonable range, the quality code is set to indicate that it failed the test and the value is considered Bad or Questionable, respectively. The WHFS Rate-of-Change-Checker application provides a regularly-scheduled rate-of-change check that compares the numerical difference between two instantaneous values, separated by a known time duration, against a pre-defined threshold. If the threshold is exceeded, then the quality code is set to indicate the value is Questionable. Other checks can be easily added, either as a local application developed using the published knowledge of the quality code infrastructure, or as a nationally provided application.

As the WHFS applications access data, they can be instructed to access (or ignore) the data based on the quality level within which the value lies or on the results of specific tests. The WHFS applications provide comprehensive tools for the user to review and redistribute the data based on its quality. These tools can move data between the “regular” data tables and the Rejected data table. Specific interfaces exist within the HydroView and TimeSeries applications to review all data in detail; these interfaces allow the user to filter data so as to view only Questionable or Bad data, to view only Rejected Data, etc.. Upon review, the user can delete or edit the offending data using graphical or tabular-based tools. Any modified data are marked in the database as being manually edited, which by the rules of the WHFS quality control model, is assumed to indicate a Good value.

2.4 Alert/Alarm Monitoring

The WHFS applications monitor the operational data to check for conditions which indicate possible alert or alarm states in the environmental conditions being measured and reported. For each physical element, duration, and type-source, and if desired, for each specific station, the user can define a threshold value for alerts, and a threshold value for alarms. These two levels can be specified for different alert/alarm tests. The first test is performed as data are ingested by the SHEFdecode application and compares a value to alert and alarm thresholds. This is very useful for checking if a river stage has risen above a certain level. The second test runs as part of the regularly-scheduled Rate-of-Change-Checker application to compare the rate-of-change between successive values and determine if the thresholds are exceeded. A fast-rising river stage, which may still be below the threshold(s) for exceeding a value, can be detected in this manner by checking if the rate-of-change exceeds the threshold(s) for the rate-of-change.

When an alert or alarm condition is detected, the data value in question is written to a dedicated database table. The alerted/alarmed data can be viewed by the user via the HydroView application, which also allows the value in question to be viewed in the context of the full time-series of data for the station and physical element. Furthermore, the ReportAlarm application is scheduled to run regularly and check this table for entries that meet user-adjustable criteria, and creates a report summarizing the alerts and/or alarms. These criteria allow local control over the filter by which to report the information. For example, it can report only new alert/alarms, only recent alert/alarms, only observed alert/alarms, all alarms, etc. Each local office specifies how to dispense of the generated report. The process can be easily configured to interact with the AWIPS text product alert/alarm processes, which notify the user by visual or audible methods, or the process can take other actions as configured by the user.

2.5 Precipitation Data Processing

The WHFS processes many different types of physical element data, including data outside the traditional domain of hydrometeorology, such as Pressure and Wind data. One of the core data sets that are processed by the WHFS is precipitation data, which because of their importance and unique nature, have a special set of operations dedicated to their processing. Precipitation data are unusual because of their non-instantaneous duration - whereas most data are instantaneous (e.g. temperature or river level), precipitation must always have a duration (e.g. 24-hour) associated with it. Complicating this is the fact that most precipitation is reported as an instantaneous value, using an incremental counter approach, which must be converted to some known-duration accumulation, and the fact that accumulated values are not always for the same duration at which the user wishes to analyze the data. An example of this is hourly precipitation reports which the user wishes to see as 6-hour or 12-hour amounts.

Within the HydroView application, there is an interface which allows the user to display converted and time-distributed precipitation data to any ending time or duration. This same feature is used by the RiverPro application to express these values in external products. Lastly, this feature is the sole purpose of the Stage 2 Pre-Processing application. The Stage 2 application then uses these data to create a grid of hourly gage-based values using objective analysis techniques. Stage 2 also processes the on-the-hour DPA products, which contain hourly gridded precipitation radar estimates, and merges the data with the just-mentioned gage-based grids to produce a gage-radar grid, which is intended to represent the best gridded estimate of precipitation fields. The Stage 2 Pre-Processing and Stage 2 programs are scheduled to run twice an hour in sequence.

The HydroView application provides the tools to view the gage-based and gage-radar precipitation grids for a single hour or for multiple hours. In addition to these Stage 2 grids, HydroView displays the DPA products, as either hourly or multi-hourly accumulations. The gridded data can be displayed as grids, or they can be use to compute average values for hydrologic basins, counties, or NWS forecast zones and then displayed.

2.6 Data Viewing and Analysis

The primary WHFS applications for viewing hydrologic data are the HydroView application, which focuses on the geographic display of data, and the TimeSeries application, which presents the data for a given station as a graphical or tabular time series. The TimeSeries application can be executed separately from HydroView, or can be invoked by HydroView for the station currently being reviewed, thereby providing a powerful, fast way to view the data in synoptic form and, as needed, as a detailed time series.

The HydroView application provides information to the user in the geographic display which contains annotated data, or in the numerous windows which can be displayed via the HydroView menu options. The geographic display allows the user to overlay displays of rivers, basins, zones, counties, cities, and highways, and to zoom and pan the displayed data. Operational data overlays are available and are categorized as either point, areal, or gridded data displays.

Point data for any station observations can be overlaid on the geographic display. This includes the primary hydrometeorological elements such as river stage, precipitation, snow, and temperature, and many Furthermore, forecast data for river stage and discharge can be annotated on the map. The stations can be filtered according to their "source", thereby allowing data from different data networks to be analyzed. For each station, an icon can be used to denote its location; for river stations, the icon is color-coded corresponding to their relation to action and flood levels. This feature allows the user to quickly determine those stations which are near or exceeding flood stage. Furthermore, special controls for displaying the precipitation data are available. The geographic data being displayed can be viewed in a tabular fashion, thereby providing a synoptic report tool.

Areal data consisting of Flash Flood Guidance (FFG) and Mean Areal Precipitation (MAP) amounts can be displayed for counties, zones, and basins. The MAP data can be derived from the DPA (a.k.a. Stage 1) product, the Stage II gage-only grid, and the Stage II gage-radar grid (Shedd, 1993). These data sets can also be displayed in gridded form. Comparisons between the FFG and MAP precipitation data are performed as part of the Area-Wide component of the HydroView program, which allows the user to monitor precipitation events which may result in flash flooding.

HydroView can display information for the currently selected station in graphical and tabular form. A parameter-time plot of any of the operational data for the station is available to allow detailed time-series review of the observed and forecast data for a station. The same information can be viewed in tabular form. For both forms, data can be edited, deleted, or inserted.

Other displays, independent of the geographical or time-series displays, are available in HydroView. For a given station, various displays of reference data are provided. Specifically, for river stations, a river staff gage display, a flood impact listing, a rating curve, and a history of floods for the station can be displayed. For the entire set of stations, a listing of data sources, and a listing of contacts associated with the station can be displayed. Operational data interfaces in HydroView include two methods for viewing the profile of a river, which shows the river levels along a river reach in a graphical fashion. A listing of the reporting status of every station, which includes all the latest observations, and a listing of all the hydrologic text products in the database, are provided to monitor the data values and products. As mentioned earlier, HydroView includes interfaces for viewing the precipitation data, the alert and alarm data, the Questionable/Bad data, and the Rejected data.

2.7 Hydrologic Modeling

The WHFS includes a hydrologic model for providing quantitative forecasts of river conditions for headwater basins (Erb, 2002). This modeling system generates a time-series of forecast stage and discharge for small, fast-response basins which will supplement the RFC forecasts for the RFC-modeled basins, or provide forecast information for basins which are not currently modeled. This model uses precipitation data as the primary input, and using the RFC-provided FFG to represent initial soil moisture conditions and various geomorphologic properties of the basin, determines the runoff from the precipitation. This runoff will then be converted to stream discharge using a unit hydrograph transformation, and then the river stage will be determined from the stream rating curve. The resulting data are stored in the database and can be used by other WHFS applications, such as the RiverPro product formatter which will include the data in generated public products.

The WHFS contains the results of a catalog of dambreak scenarios. The Dam Catalog feature is available in both the HydroView and HydroBase applications and allows the user to query and update a large set of data that includes static reference data and forecast failure scenario data for dams across the United States. The failure scenario data has been computed using reference data from the catalog regarding the physical characteristics of the dam and reservoir. This data was used by a specialized version of the NWS Simplified Dam Break Model.

2.8 Report Generation

A set of WHFS operations allow the user to generate reports for single stations or all stations in the database. These reports can be viewed, printed, or saved to a text file for future reference. The text report function available in the HydroBase and HydroView application produces a River Station report in either the Form E-19 or Form E19-A, and a Cooperative Station report Form B-44A. Multiple-station text reports include a Station List report, a Station Classification report, and a Service Backup report. While these text reports contain generally static data, there are other reports containing operational data. The Flood Event report is similar to the NWS Form E-3, using flood report data identified by the daily runs of the FloodSequencer application.

The TimeSeries application produces a detailed list of time series data in a Time Series Table report. The HydroView application produces a Synoptic Data report via its point control function, and a Station Precipitation report via the point precipitation interface. Lastly, the RiverPro product generation application can be configured to generate reports of operational data by creating products for internal use only and saving the products as a text file.

2.9 Product Generation

RiverPro is an automated formatter for the hydrometeorological products (Office of Hydrologic Development, 2000). Initially, it was designed for generating the following products: River Statement, Flood Statement, and Flood Warning. However, as new application features have been added, and new data have been made available in the database, it can now create other hydrologic products and products outside the hydrology program.

RiverPro can create routine products according to pre-defined instructions or event-specific products using pre-defined instructions which can be interactively adjusted as necessary. It can create products in a completely automated fashion by using a combination of these pre-defined instructions and the current hydrometeorological conditions. The format and wording of the products are controlled by a set of template files which can be configured to meet each office's needs.

RiverPro adheres to NWS policy regarding the content of the product. This includes the ability to create products in a conventional "product-section" form, a "segmented" form, or a form suitable for voice presentation. The voice-ready products are distributed on co-located or neighboring NOAA Weather Radio (NWR) transmission towers. All dissemination of the products is performed using standard AWIPS communications protocols and mechanisms.

RiverPro, like other WHFS applications, recognizes the assigned responsibilities for each data station, where each station is assigned a responsible office, and for service backup purposes, each station has a primary backup office and a secondary backup office. In the rare event that an office is unable to operate due to a power outage or system malfunction, RiverPro can generate products for the neighboring offices.

Another WHFS product generation function is the TimeSeries application, which can format SHEF-encoded data products. This feature allows existing data, either as-is or corrected for quality-control purposes, and locally-entered data to be packaged into a text product and transmitted to other NWS destinations.

3. FUTURE CAPABILITIES

Since its initial deployment in 1996, the WHFS and its associated IHFS database have steadily evolved to include major new functional components which cover most of the components for the national requirements of the WFO Hydrology Program. Development of new applications and enhancement of existing applications is still ongoing and will be for some time, as requirements change and new methodologies become available.

Some of the changes planned for the WHFS are replacement of the Stage 2 Precipitation Processing operations with the Multi-Sensor Precipitation Estimator (MPE). The MPE supports the mosaicking of data from multiple radars, and improves accuracy by utilizing climatological normal precipitation to adjust precipitation and by using a bias correction algorithm. The MPE will provide, for the first time, a user interface for adjusting these gridded estimates of precipitation.

The Site-Specific headwater model will make use of the new MPE grids. Significant improvements are also expected for this hydrologic model, not just its user interface but possibly in the incorporation of new rainfall-runoff models. The Dam Catalog and its associated interfaces and operations are planned for a major overhaul, with more informative graphical displays, and with the new ability to re-run the hydraulic model for estimating the dam break flows under different scenarios. More quality control checks are planned, including a spatial consistency check for comparing values from two stations for the same time. The infrastructure underlying the data storage is being examined for modifications, particularly with respect to using the Gridded Binary (GRIB) and Network Common Data Form (netCDF) data formats that are widely used in the AWIPS data infrastructure.

The RiverPro product formatter will be enhanced to use the Valid Time Event Coding (VTEC) feature. New features will be added to the formatter to further enhance its ability to create even more product types, and to use any data in any portion of the product.

4. OPERATIONAL SUPPORT

The WHFS is a complex, large-scale operational system that operates 24 hours of every day at over 120 WFOs and 13 RFCs. The success of a system of this magnitude depends on a dedicated support operation to provide technical assistance and systems support. In recognition of this specific need, the NWS has in place a four-person team that provides 24-hour phone support desk for the WHFS and its associated system environment. In addition to the support team which focuses on WHFS issues, the NWS maintains a 24-hour support desk as part of the AWIPS Network Control Facility (NCF) operations. The NCF team focuses on the system aspects of the AWIPS systems.

In addition to phone support, the WHFS Field Support Group maintains a comprehensive web page (http://www.nws.noaa.gov/oh/hod_whfs/) to provide formal documentation on all aspects of the WHFS. This web page includes User's Manuals, Reference Manuals, System Manuals, Release Notes, What's New documents, What's Wrong documents, customization instructions, installation instructions, tutorials, etc. The Field Support Group works with the NWS Training Center to conduct residence training courses, and tele-training, in addition to attending NWS Regional meetings and other relevant forums to make presentations on the WHFS activities.

The requirements of the WHFS are continually evolving in order to meet the needs of NWS customers, which include both the NWS offices themselves and the general public served by the offices. The WHFS Development Group and the Field Support Group work together with NWS field and regional offices to identify and prioritize the requirements. This allows for the proper planning of additions and changes to the WHFS to ensure that it continues to meet the needs of the NWS Hydrology program.

5. SUMMARY

The WHFS system provides the NWS hydrology program with a comprehensive set of applications for performing its mission. At the center of the WHFS is the IHFS relational database which contains essentially all the data. The integrated applications provide data ingest for the operational data, and data management functions control the entire system. Quality control and alert/alarm monitoring operations are performed as the data are ingested and at regular intervals. Because of its importance and unique nature, the precipitation data are processed in a special manner. Numerous interfaces are available for the analysis and display of the data, in geographic, tabular, and time-series form. Hydrologic model operations allow for the generation of local hydrologic forecasts, which can then be used along with other available observed and forecast data by the automated product formatting capability for issuance of public hydrologic and other products.

A dedicated support operation provides the critical operational support of the system, and provides the necessary training for proper field use. The WHFS operates within the AWIPS system in a complementary fashion, making use of AWIPS data ingest and data dissemination operations. The WHFS provides the required national-level functionality for the WFO hydrology program and for the critical infrastructure for the RFC hydrology program. New requirements and requests for enhanced functionality are being addressed through ongoing development activities to ensure that the WHFS continues to be the comprehensive, centerpiece tool in the NWS hydrology program..

6. REFERENCES

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