NATIONAL WEATHER SERVICE
OFFICE of HYDROLOGIC DEVELOPMENT

CONCEPT OF OPERATIONS
And
Requirements Specification Document

Hydrologic Deterministic Verification

Phase 2

Version 3-3

Revision History

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12/21/2006	Phase 2 V3-4	Apply Post Gate 3 recommended changes – update requirements table from DOORS database	M. Andre, H. Herr

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1. INTRODUCTION

Taken form the Statement of Need (SON) document

The National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service has a need to provide enhanced verification tools to improve the operational forecasting capabilities at the River Forecast Centers (RFCs). Verification of hydrologic forecasts produced by the National Weather Service (NWS) is needed in order to recognize sources of errors in the forecasts and account for those errors, ultimately improving the accuracy of the forecasts. The RFCs have been provided verification software that runs on their Advanced Weather Interactive Processing System (AWIPS) RAX machines using the archive database.

The goal of Phase II of this project is to provide the forecasters additional tools to improve the verification of their forecasts through the enhancement of existing verification functionalities and the creation of new capabilities. The new capabilities listed below will be used with existing verification statistics and graphics currently available to the forecasters.

1. Confidence intervals on existing statistics that will provide the forecasters with a measure of how much confidence should be placed in the computed verification statistics; and

2. Ability to verify data types other than river stages, including precipitation, temperature, and stream discharge.

3. The ability to compare verification statistics over additional aspects of the forecast within a single graphic, such as forecast type source (allowing for comparing persistence to non-persistence forecasts, for example).

4. New statistical measures.

5. Ability to break down statistics based on the time of day during which the forecast was issued.

6. Ability to break down statistics by year, so that statistics may be calculated over the same time period for many different years.

7. Ability to produce graphics via the batch software without the ability to open up a display.

2. CURRENT STATE OF OPERATIONS

2.1 Description of the Current Environment

The RFC forecasters currently have access to verification software that was initially developed for Operational Build 4 (OB4), and runs on an (AWIPS) Archive (RAX) machine located at their office, using data stored in the archive database. For a description of the archive database for OB7.2 see the below link.

> ➤ http://www.nws.noaa.gov/oh/rfcdev/projects/rfcRAX_db72_docs.htm

Enhancements which provide graphical capabilities were completed for OB7.2. This software was designed for use with the National Verification Program (NVP). It generates statistics needed for that program and writes those statistics to an American Standard Code for Information Interchange (ASCII) standard file format established by the participants in the NVP which include the hydrologic forecasters at the River Forecast Centers. It is also capable of custom verification and generation of graphics summarizing verification computations.

2.2   User/Customer Identification & Organization

Primary users of the Verification Software are the River Forecast Centers (RFC's).

2.3   Current Support Environment/Architecture

The National Weather Service River Forecast System (NWSRFS) Verification System is a collection of programs that allow the hydrologic forecaster to verify river stage forecasts. The software runs at the RFCs on the Operational Baseline 7.2 (OB7.2) of the (AWIPS) Archive Database (RAX) machines.

The Verification System is comprised of the following five programs:

1. The Vfyruninfo Editor is graphical user interface used for the purpose of editing the vfyruninfo table in the archive database. This table is required by the Interactive Verification Program (IVP) in order to determine for which forecast points verification statistics are to be calculated. Furthermore, the Vfyruninfo Editor provides information about the physical elements, durations, extremums, forecast type sources, and observed sensor preferences that are to be included in the forecast-observed data pairing process.

    NOTE: Throughout this document, forecast points for which verification statistics are computed will be known as verification locations. *A verification location not only consists of a location id for the forecast point, but also the data type for one type of data to verify at that forecast point. Different data types yield different verification locations.*

2. The IVP Batch Program processes batch commands using (ASCII) text files and serves the following three functions: (1) constructs forecast and observed river stage data pairs and stores them in the vfypairs table of the archive database, (2) calculates verification statistics from previously constructed data pairs, and (3) generates plots of those statistics. All of these functions require a properly filled-in vfyruninfo table in order to execute.

3. The Verify Pairs Ingestor program provides an additional mechanism to place forecast-observed data pairs into the archive database. It extracts the data pairs from a properly formatted tabular pairs file (Verify ob3-r24 and earlier) and inserts them into the vfypairs table, but only if the data pair matches an entry in the vfyruninfo table.

4. The IVP Batch Builder is a graphical user interface that can be used to build IVP Batch Program batch files, run the IVP Batch Program, and view resulting output text and image files.

5. The IVP is a graphical user interface that enables viewing of verification statistics via user customized graphics.

3. PROPOSED SOLUTION CONCEPTS

3.1 New Capabilities and Functions

This project will provide the forecasters enhanced functionalities for improving the verification of their forecast. These include:

- The ability to verify data types other than river stage. This includes precipitation, temperature, and stream flow. In general, any forecast data type for which the forecast and observed (or processed) values are posted to one of the following tables of the archive database can be verified: pecrsep, pedrsep, peoosep, pehpsep, pedpsep, peqpsep, pedfsep, pehfsep, and peqfsep.

  Descriptions of the types of data stored in these tables are located in the following links.

  - ➢ http://www.nws.noaa.gov/oh/rfcdev/docs/C2_datavalnames.pdf
  - ➢ http://www.nws.noaa.gov/oh/rfcdev/docs/C3_tablestruct.pdf

- The ability for the forecaster to specify observed or forecast value categories based on critical values will be expanded to include stream flow critical values. These values correspond to critical values already made available, including flood stage, action stage, moderate flood stage, major flood stage, and flood of record.

- The ability for the forecaster to specify additional statistics to view through the graphical user interface. Combined with statistics made available previously, the complete list of statistics that will be available is as follows:

  - → Errors: root mean squared error, mean error, mean absolute error, maximum error
  - → Categorical Statistics: probability of detection, false alarm ratio, critical success index, under forecast rate, over forecast rate, Average lead time to detection, and Gilbert Score (GS)
  - → Probabilistic Information: minimum, maximum, median, 25% quantile, 75% quantile
  - → Moments: forecast and observed variance, forecast and observed mean
  - → Misc Statistics: correlation, bias (%), RMSE skill score (vs. persistence), ROC area

  For a description of the statistics, see the National Weather Service River Forecast Verification Plan:

  - ➢ http://www.weather.gov/oh/rfcdev/docs/Final_Verification_Report.pdf"

- The ability for the forecaster to see confidence intervals on those statistics.

- The ability for the forecaster to produce special verification diagrams, including ROC diagrams, plots of empirical cumulative distribution functions, and plots of empirical probability density functions.

- Two additional variables that can be used for the x-axis of a graphic: forecast type source and issuance (basis) time daily interval (time of day forecast is issued).

- The ability for the forecaster to compute and display statistics based on values of particular characteristics of forecasts, including forecast type (i.e. persistence, non-persistence), analysis interval, lead time interval, issuance time daily interval, and category. Whichever characteristic is chosen, it will be referred to as the comparison variable, and its value will be displayed within the plots legend. This is in addition to already being allowed to specify the variable displayed along the x-axis and statistics displayed on the two y-axes.

3.2   Operational Policies & Constraints

The new capabilities must be designed for use, storage and execution on the existing AWIPS Archive Database (RAX) machines for OB8.2.

3.3   Operational Scenarios

The following represent the scenarios under which a hydrologic forecaster will operate the verification software that incorporates the new functionalities.

Scenario 1: Build forecast-observed pairs used for verification.

a. User determines the forecast points and river locations for which the pairs are to be generated. This determination is done outside of the verification software.
b. User specifies the verification locations corresponding to the forecast points and river locations in a batch file for pairing.
c. User specifies the time window, pairing window, and other parameters needed for pairing in the same batch file.
d. User executes the batch file via the verification software and examines screen output for any problems encountered.

Scenario 2:   Generate text verification products to use locally at the RFC or to disseminate to the public without using the IVP GUI (either via a text editor or the IVP Batch Builder).

a. User determines the forecast points and river locations for which the verification graphics will be generated, as well as the statistic(s) to be computed. This determination is done outside of the verification software.
b. User specifies the necessary verification locations to include in the product within a batch file or by referencing another batch file that defines the locations.
c. User specifies the properties of the verification group defining the data used to calculate the verification statistics in a batch file.
d. User specifies the output file name and pairs file name, if either are necessary, in the batch file.
e. User specifies the statistics to produce in a batch file.

  f. User executes the batch file via the IVP Batch Program and examines text and image products produced.

Scenario 3: Generate graphical verification products to use locally at the RFC or to disseminate to the public using the IVP GUI.

  a. User determines the forecast points and river locations for which the verification graphics will be generated. The user also determines the variable used for the X-axis (e.g. lead time, location, etc.), comparison variable used, and statistic(s) displayed on the Y-axis. This determination is done outside of the verification software.

  b. User determines which verification locations to include in the product, and defines each through a graphical user interface or uses a previous definition.

  c. User determines the properties of the verification group specifying the data used in the verification statistics to be displayed, and defines the verification group through a graphical user interface or uses a previous definition.

  d. User specifies the statistics to produce through a graphical user interface.

  e. User specifies the output file name and pairs file name, if either are necessary, through a graphical user interface.

  f. Software displays the verification graphic using default settings for graphical display.

  g. User specifies the properties of the graphical display, either by loading previously defined properties or by manually setting the properties through the graphical user interface.

  h. User creates a batch file (or batch files) to generate the verification graphic routinely. These file(s) include batch commands and actions to generate the text output file and the graphical display template.

  i. User saves verification graphic as a compressed image on a local directory.

3.4 Summary of Impacts

3.4.1 Operational Impacts

Upon delivery of the software for AWIPS OB8.2, the RFCs will gain new software capabilities that will enable them to compute additional verification statistics and analyze the statistics in a more robust manner. Furthermore, users will be able to verify input to the hydrologic models, including precipitation and temperature, while also verifying output from those models.

The RFC will require either practice or training on how to use the new and enhanced features of the verification software. These tools should facilitate better deterministic verification. Formal training, workshops, and dissemination of training materials to the RFCs will be conducted through the Office of Climate, Water and Weather Services (OCWWS) and Hydrologic Services Division (HSD).

3.4.2 Organizational Impacts

There are no organizational impacts identified at this time.

3.4.3 Impacts during Development

Development of the new tools will require interaction with the hydrologic forecasters at the RFCs in order to derive requirements and gain approval for the GUI designs and other verification functionalities. New verification concepts being defined by the NWS Hydrologic Verification team that is being formed to evaluate the next generation of verification system may impact the work that is proposed for this project. The Hydrologic Science Engineering Branch (HSEB) project team will remain in contact with the Verification team in order to stay informed on new developments and the possible introduction of requirements not previously defined.

3.4.4 Impacts during Transition

The Office of Climate, Water and Weather Services (OCWWS) representative for the RFC's shall receive adequate training on the new deterministic verification capabilities and in turn provide training to the RFCs.

3.5 Alternatives and Trade-offs Considered

Within the AWIPS structure, there is no alternative to the approach presented herein. The goal of this project is to enhance the forecaster's current forecasting capabilities to ensure that more reliable and accurate deterministic verification can be generated.

4. Requirements Development Methodology

The requirements were developed in multiple phases and concluded over the course of a few months with several meetings and interviews conducted with the field and extensive reviews of current operational procedures used in verification. Given that the goal of this project was to provide the forecaster verification tools to enable them to produce better forecasts with improved verification features, the requirements listed herein, represent the forecasters' needs for a new tool that will merge existing capabilities with new verification techniques that will operate within the current AWIPS architectural environment.

5. USE CASES

Please refer to section 3.3 of this document

6. REQUIREMENTS

The requirements listed on the requirements table represent the capabilities that have been defined previously for AWIPS release OB7.2 or earlier, as well as those that are new for OB8.2. The delivery schedule and completion status for each requirement is also provided.

APPENDICES

Appendix A – Table of Acronyms

ASCII	American Standard Code for Information Interchange
AWIPS	Advance Weather Interactive Processing System
GUI	Graphical User Interface
HSD	Hydrologic Services Division
IHFS	Integrated Hydrologic Forecast System (Database)
IVP	Interactive Verification Program
HSEB	Hydrologic Science Engineering Branch
JPEG	Joint Photographic Experts Group
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
NWSRFS	National Weather Service River Forecast System
OB	Operational Build OB4, OB5, OB7
OCWWS	Office of Climate, Water and Weather Services
PNG	Portable Network Graphics
RFC	River Forecast Centers

Appendix B – Requirements Table

**** Please note that physical element, duration, extremum, and type source all refer to the Standard Hydrologic Exchange Format (SHEF)

Reqt ID No.	Complete Deterministic CONOPS	Requirements Type	AWIPS Build	Priority Level	Qualification Type	Reqts Status
1	Functional Requirements					
1.1	User shall be able to specify all aspects of a pairing run of the software via a batch file	Pairing	OB4	High	Test	Complete
1.1.1	User shall be able to specify if observed data to pair with forecasts is drawn from observed tables or processed tables	Pairing	OB8.2	High	Test	
1.1.2	User shall be able to specify verification locations for which forecasts are to be paired with observations	Pairing	OB4	High	Test	Complete
1.1.2.1	User shall be able to specify the location ids for forecasts that are to be paired	Pairing	OB4	High	Test	Complete
1.1.2.2	User shall be able to specify the Standard Hydrologic Exchange Format (SHEF) physical elements for forecasts that are to be paired	Pairing	OB8.2	High	Test	
1.1.2.2.1	Acceptable physical elements shall include, but are not restricted to, HG, HT, HP, PP, TA, QT, and QI	Pairing	OB8.2	High	Test	
1.1.2.3	User shall be able to specify the SHEF duration code for forecasts that are to be paired	Pairing	OB8.2	High	Test	
1.1.2.3.1	Valid durations shall include, but are not restricted to I, D, H, and Q	Pairing	OB8.2	High	Test	
1.1.2.4	User shall be able to specify the extremums for forecasts that are to be paired	Pairing	OB8.2	High	Test	
1.1.2.4.1	Valid extremums shall include, but are not restricted to Z, X, N, D, F, R, and H	Pairing	OB8.2	High	Test	
1.1.2.5	User shall be able to specify any combination of duration and extremum, so long as the forecast and observed/processed data to use in pairing is stored in one of the tables the software has access to	Pairing	OB8.2	High	Test	
1.1.2.5.1	Observed tables shall include the pecrsep, pedrsep and peoosep tables	Pairing	OB8.2	High	Test	
1.1.2.5.2	Processed tables shall include the pehpsep, pedpsep, and peqpsep tables	Pairing	OB8.2	High	Test	
1.1.2.5.3	Forecast tables shall include pedfsep, pehfsep, and peqfsep	Pairing	OB8.2	High	Test	
1.1.2.6	User shall be able to specify the SHEF type sources for forecasts that are to be paired for each combination of location id, physical element, duration and extremum	Pairing	OB8.2	High	Test	

1.1.3	User shall be able to specify the pairing window used to construct pairs	Pairing	OB4	High	Test	Complete
1.1.3.1	An observed value shall not be paired with a forecast value if the difference between its obstime and the forecast validtime exceeds the paring window	Pairing	OB4	High	Test	Complete
1.1.4	User shall be able to specify the time interval (start time and end time) over which pairing is to be executed	Pairing	OB4	High	Test	Complete
1.1.4.1	User shall be able to specify interval by fixed-dates	Pairing	OB4	High	Test	Complete
1.1.4.2	User shall be able to specify the interval relative to the current system time	Pairing	OB4	High	Test	Complete
1.1.4.3	User shall be able to specify the start time and end time to the second	Pairing	OB4	High	Test	Complete
1.1.5	User shall be able to specify if persistence data pairs are to be generated	Pairing	OB5	High	Test	Complete
1.1.5.1	A persistence data pair shall be constructed relative to a generated forecast data pair, but with the forecast replaced by the most recent observed value as of the basis time of the forecast such that the observed's value obstime is within the pairing window of the forecast basistime	Pairing	OB5	High	Test	Complete
1.1.6	User shall be able to initiate the pairing algorithm within the batch file	Pairing	OB4	High	Test	Complete
1.1.6.1	For each forecast value to be paired (based on user settings), a best observed value shall be selected based on the following criteria, in order of importance: • SHEF Qual Code: a single character code describing the quality of the data (for example, 'G'ood, 'B'ad, 'Q'uestionable, etc.) • Sensor preference list: a list of observed type sources in order of desirability • Observation time: proximity of observed obstime to forecast validtime	Pairing	OB4	High	Test	Complete
1.1.6.1.1	The SHEF Qual Codes in order of preference are 'G', 'M', 'P', 'V', 'S', 'Z', 'T', 'F', and 'Q'	Pairing	OB4	High	Test	Complete
1.1.6.1.2	An observed value with a SHEF Qual Code of 'B', 'R', or 'E' shall never be paired with a forecast value	Pairing	OB8.2	High	Test	
1.1.6.1.3	A forecast value with a sensor preference list shall be paired only if a corresponding observed value with a SHEF type source is listed for that forecast value	Pairing	OB8.2	High	Test	
1.1.7	Constructed pairs shall be stored in the vfypairs table of the archive database	Pairing	OB4	High	Test	Complete

1.2	User shall be able to specify the aspects of a verification run through either a graphical user interface (GUI) or batch file	Computing Verification Statistics	OB4	High	Test	Complete
1.2.1	User shall be able to select forecast observed pairs stored in the RAX archive database for computing verification statistics and generating graphics	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.1.1	User shall have the ability to select the location ids required for pairs to verify	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.1.1.1	Available location ids (those for which pairs can exist) shall be provided allowing multiple selections from the GUI	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.1.2	User shall be able to select the SHEF physical elements for data to verify	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.1.2.1	Available physical elements shall be provided allowing multiple selections from the GUI	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.1.2.2	Available physical elements shall include any valid physical element for which forecast-observed pairs can be constructed	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.3	User shall have the ability to select the SHEF duration required for pairs to verify	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.3.1	The available duration shall be provided allowing multiple selections from the GUI	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.3.2	Available duration shall include any valid duration code for which forecast-observed pairs can be constructed	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.4	Use shall have the ability to select the SHEF extremums required for pairs to verify	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.4.1	Available extremums shall be provided allowing multiple selections from the GUI	Computing Verification Statistics	OB8.2	High	Test	

1.2.1.4.2	Available extremums shall include any valid extremum for which forecast-observed pairs can be constructed	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.5	User shall have the ability to select analysis time interval for pairs to verify	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.1.5.1	The validtime of a forecast shall be checked to see if the forecast-observed pair is within the analysis time interval in order to determine if that pair is to be included in the calculation of verification statistics	Computing Verification Statistics	OB4	High	Test	Complete
1.2.1.5.2	User shall have the ability to specify the start date and time of the period for the verify pairs on which analysis will be performed	Computing Verification Statistics	OB4	High	Test	Complete
1.2.1.5.3	User shall have the ability to specify the end date and time of the period for the verify pairs on which analysis will be performed	Computing Verification Statistics	OB4	High	Test	Complete
1.2.1.5.4	User shall have the ability to specify the start and end of the period to the nearest second	Computing Verification Statistics	OB4	High	Test	Complete
1.2.1.6	User shall have the ability to select the SHEF forecast type sources (TS) required for pairs to verify	Computing Verification Statistics	OB4	High	Test	Complete
1.2.1.6.1	Available SHEF type sources shall be provided allowing multiple selections from the GUI	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.1.7	User shall have the ability to specify the lead time interval for pairs to verify	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.1.7.1	The difference between the validtime and basistime of a forecast shall be checked to see if the forecast-observed pair is within the lead time interval and subinterval in order to determine if that pair is to be included in the calculation of verification statistics	Computing Verification Statistics	OB4	High	Test	Complete
1.2.1.7.2	User shall have the ability to specify the lower bound on the lead times to verify	Computing Verification Statistics	OB4	High	Test	Complete

1.2.1.7.3	User shall have the ability to specify the upper bound on the lead times to verify	Computing Verification Statistics	OB4	High	Test	Complete
1.2.1.7.4	User shall have the ability to specify the lower bound and upper bound on the lead times to the nearest hour	Computing Verification Statistics	OB4	High	Test	Complete
1.2.1.8	User shall have the ability to specify an issuance time-of-day interval for pairs to verify	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.8.1	The basistime of a forecast shall be checked to see if the forecast-observed pair is within the issuance time-of-day interval in order to determine if that pair is to be included in the calculation of verification statistics	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.8.2	User shall have the ability to specify the lower bound (time of day) on the basistime	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.8.3	User shall have the ability to specify the upper bound (time of day) on the basistime	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.8.4	User shall have the ability to specify the lower and upper bounds on the basistime to the nearest hour	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.9	User shall have the ability to select the required river response time for pairs to verify	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.1.9.1	Available response times shall be provided allowing for multiple selections from the GUI	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.1.9.1.1	Available response times shall include: • NONE • SLOW • MEDIUM • FAST	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.1.10	User shall have the ability to select whether or not persistence forecasts will be verified	Computing Verification Statistics	OB7.2	High	Test	Complete

1.2.1.11	User shall have the ability to specify pairs to verify based on if the verification location is an active forecast point.	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.12	User shall have the ability to specify pairs to verify based on if the observation in the pair came from an observed table or processed table	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.13	Forecast-observed pairs shall be acquired from the vfypairs table of the archive database	Computing Verification Statistics	OB4	High	Test	Complete
1.2.1.14	User shall not be able to specify observed pairs for a single statistics calculation that are different data types, as determined by their physical elements (i.e. stage, flow, precipitation, temperature)	Computing Verification Statistics	OB8.2	High	Test	
1.2.1.15	The batch program will exit with an appropriate message if any parameter of the verification run is improperly specified	Computing Verification Statistics	OB4	High	Test	Complete
1.2.2	User shall have the ability to set parameters for computing the verification statistics	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.2.1	User shall have the ability to specify categories for each verification location for computing the verification statistics	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.2.1.1	User shall have the ability to specify categories relative to critical values loaded from the rivercrit table of the archive database	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.2.1.1.1	The categories shall be set relative to the following river stages/flows: • flood stage/flow • action stage/flow • moderate flood stage/flow • major flood stage/flow • flood of record/flow	Computing Verification Statistics	OB8.2	High	Test	
1.2.2.1.1.2	Categories shall not be set relative to critical values of a different data type than the pair's data type	Computing Verification Statistics	OB8.2	High	Test	
1.2.2.1.2	User shall have the ability to specify categories using fixed numbers (not relative to other values)	Computing Verification Statistics	OB7.2	High	Test	Complete

1.2.2.1.3	User shall have the ability to specify whether to categorize the forecast-observed pairs for computing verification statistics based on the forecast value and/or the observed value	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.2.2	User shall have the ability to specify if statistics should be calculated separately for each forecast type source	Computing Verification Statistics	OB8.2	High	Test	
1.2.2.3	User shall have the ability to specify if statistics should be calculated separately for each verification location	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.2.4	User shall have the ability to specify the analysis subintervals, which breakdown the overall analysis time interval into evenly spaced subintervals for statistics calculation	Computing Verification Statistics	OB4	High	Test	Complete
1.2.2.4.1	Analysis subintervals parameters shall be defined in terms of: • Years (fixed analysis period for each year over several years • Months • Weeks • Days • Hours	Computing Verification Statistics	OB8.2	High	Test	
1.2.2.5	User shall have the ability to specify the time step for the lead time subintervals, breaking down the overall lead time interval into evenly spaced subintervals for statistics calculation	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.2.6	User shall have the ability to specify the basistime subintervals, breaking down the overall basistime interval into user-specified subintervals for statistics calculation	Computing Verification Statistics	OB8.2	High	Test	
1.2.3	User shall have the ability to select verification statistics to compute	Computing Verification Statistics	OB7.2	High	Test	Complete

1.2.3.1	Verification statistics that may be computed include: • Errors: RMSE, ME, MAE, MaxErr • Categorical Stats: POD, FAR, CSI, under forecast rate, over forecast rate, Gilbert score, average lead time to detection • Probabilistic Info: min, max, median, 25% quantile, 75% quantile • Moments: forecast variance, observed variance, forecast mean, observed mean • Misc Statistics: correlation coefficient, bias (%), RMSE skill score (vs. persistence), and ROC area	Computing Verification Statistics	OB8.2	High	Test	
1.2.3.2	Available statistics shall be provided, allowing for multiple selections from the GUI	Computing Verification Statistics	OB7.2	High	Test	Complete
1.2.3.3	User shall have the ability to specify whether or not confidence intervals will be computed for all calculated statistics	Computing Verification Statistics	OB8.2	High	Test	
1.2.3.3.1	User shall the ability to specify the significance level for the confidence intervals	Computing Verification Statistics	OB8.2	High	Test	
1.3	Users be able to generate graphs within a GUI or via a batch file	Generating Graphics	OB7.2	High	Test	Complete
1.3.1	User shall have the ability to select the type of graphs	Generating Graphics	OB7.2	High	Test	Complete
1.3.1.1	Graph types shall include: • scatter plot • line plot • bar plot	Generating Graphics	OB7.2	High	Test	Complete
1.3.2	User shall be able to manipulate the display of graphs	Generating Graphics	OB7.2	High	Test	Complete

1.3.2.1	User shall be able to modify the following aspects of a graph: • chart size • plot title text, font, color, and size • all axis label text, fonts, colors, and sizes • all axis tick mark fonts, colors, and sizes • x-axis tick mark label text • All axis ranges • legend label text, font, and size • legend component text • plot shapes and line/bar/shape colors • shape size for scatter plots and line plots	Generating Graphics	OB8.2	High	Test	
1.3.2.2	User shall be able to modify the properties of the graphics by selecting fonts, colors, tick marks etc. from a supplied lists in the GUI	Generating Graphics	OB7.2	High	Test	Complete
1.3.2.3	User shall be able to make modifications to the graphs via the GUI	Generating Graphics	OB7.2	High	Test	Complete
1.3.2.4	User shall be able to choose whether or not default settings are used for a modifiable setting	Generating Graphics	OB7.2	High	Test	Complete
1.3.3	User shall have the ability to select the variables to display on the X-axis of the graphic	Generating Graphics	OB7.2	High	Test	Complete
1.3.3.1	Variables that can be displayed on the X-axis shall include: • location • analysis time subinterval • lead time subinterval • forecast value category • observed value category • forecast type source • basistime subinterval	Generating Graphics	OB8.2	High	Test	
1.3.4	User shall have the ability to select a comparison variable, such that the generated graphic can be used to compare verification results over values of that variable	Generating Graphics	OB8.2	High	Test	

1.3.4.1	Variables that can be used as the comparison variable shall include: • location • analysis subinterval • lead time subinterval • forecast value category • observed value category • forecast type source • basistime subinterval	Computing Verification Statistics	OB8.2	High	Test	
1.3.4.2	The comparison variable values shall be reflected in the shapes and colors used, as shall be shown in the legend	Generating Graphics	OB8.2	High	Test	
1.3.5	User shall be able to specify which statistics are displayed against the primary (or left-hand) y-axis and which statistics shall be displayed against the secondary (or right-hand) y-axis	Generating Graphics	OB7.2	High	Test	Complete
1.3.5.1	Multiple statistics shall be allowed for display against a single y-axis only if they have the same unit of measure	Generating Graphics	OB7.2	High	Test	Complete
1.3.5.2	User shall be able to display confidence intervals on the graphic, if desired	Generating Graphics	OB8.2	High	Test	
1.3.6	User shall have the ability to specify special graphic products to be constructed	Generating Graphics	OB8.2	High	Test	
1.3.6.1	Special graphic products include the following: • ROC diagram • Plot of estimated cumulative distribution functions • Plot of estimated probability density functions	Generating Graphics	OB8.2	High	Test	
1.4	From the GUI user shall have the ability to save all parameters necessary for reproduction of a graphic via the batch software	Building Batch File from GUI	OB7.2	High	Test	Complete
1.4.1	User shall be able to save parameters defining data to verify	Building Batch File from GUI	OB7.2	High	Test	Complete
1.4.1.1	Parameters defining the data to verify shall be saved in ASCII file format and syntax as valid input for the concurrent version of IVP Batch Program	Building Batch File from GUI	OB7.2	High	Test	Complete
1.4.2	User shall be able to save parameters defining verification graphic, given data to verify	Building Batch File from GUI	OB7.2	High	Test	Complete
1.4.3	User shall be able to use the verification batch software to reproduce graphic displayed via the GUI using saved parameters of data to verify and graphics to produce	Building Batch File from GUI	OB7.2	High	Test	Complete

2	TECHNICAL REQUIREMENTS	Technical Requirements				
2.1	The new verification functionalities shall be developed using new and existing verification programs and software	Technical Requirements	OB8.2	High	Inspect	
2.1.1	The new Verification GUI shall be developed making use of the software components of the following programs from the NWSRFS Verification system • IVP Batch Program • Vfyruninfo Editor • IVP Batch Builder • IVP GUI • Pairs Ingestor	Technical Requirements	OB8.2	High	Inspect	
2.2	All text output shall be written in ASCII format	Technical Requirements	OB7.2	High	Test	Complete
2.3	All images shall be saved in either JPEG or PNG compressed format	Technical Requirements	OB7.2	High	Test	Complete
3	SECURITY AND PRIVACY REQUIREMENTS	Security & Privacy Requirements				
3.1	The new graphical display software shall comply with AWIPS security requirements	Security & Privacy Requirements	OB7.2	High	Inspect	Complete
4	INPUT REQUIREMENTS	Input Requirements				
4.1	The new software shall use the archive database as a source of forecast-observed pairs for verification	Input Requirements	OB7.2	High	Inspect/Test	Complete
5	OUTPUT REQUIREMENTS	Output Requirements				
5.1	User shall have the ability to view and/or export data comprising every graphic displayed	Output Requirements	OB7.2	High	Test	Complete
5.1.1	Use shall be able to specify output files produced by verification software in both GUI and batch mode	Output Requirements	OB7.2	High	Test	Complete
5.1.2	In batch mode, user shall be able to specify an output file to which groups of statistics shall be saved, with corresponding confidence intervals, in an ASCII tabular format	Output Requirements	OB8.2	High	Test	

5.1.4	User shall be able to specify a pairs file to which forecast-observed pairs will be output in ASCII tabular format	Output Requirements	OB4	High	Test	Complete
5.1.3	User shall be able to specify an output file to which data comprising a graphic will be output in an ASCII tabular format	Output Requirements	OB7.2	High	Test	Complete
5.1.4	User shall be able to specify a template file to which parameters defining how aspects of a graphic differ from defaults will be output in an ASCII tabular format	Output Requirements	OB7.2	High	Test	Complete
5.1.5	User shall be able to specify an image file to which a user customized graphical product will be saved in a compressed format; either JPEG or PNG	Output Requirements	OB7.2	High	Test	Complete
5.2	Sufficient information shall be provided for all ASCII output and pairs files to indicate all parameters defined by the user for calculation of the statistics	Output Requirements	OB7.2	High	Test	Complete
5.3	All ASCII tabular output files shall use a 'I' (pipe) as the delimiter	Output Requirements	OB4	High	Test	Complete
5.4	Output sent to the terminal screen shall summarize the progress and status of actions taken by the verification software	Output Requirements	OB4	High	Test	Complete
5.4.1	User shall be able to control the level of detail of the screen output	Output Requirements	OB4	High	Test	Complete
6	**LOGISTICS REQUIREMENTS**	**Logistics Requirements**				
6.1	The new software shall be deployed through the normal AWIPS release process	Logistics Requirements	OB7.2	High	Inspect	Complete
7	**PROCESSING & PERFORMANCE REQUIREMENTS**	**Processing & Performance Requirements**				
7.1	The new features of the verification software shall not alter the performance of existing functionalities and programs that are part of the current NWSRFS Verification System	Processing & Performance Requirements	OB8.2	High	Inspect	
7.2	The processing of the statistics and confidence intervals shall not alter the performance of existing functionalities programs that are part of the current NWSRFS Verification System	Processing & Performance Requirements	OB8.2	High	Inspect	
7.2.1	The confidence intervals and statistics generated by the verification batch software shall not use an inordinate amount of disk space of the RAX database	Processing & Performance Requirements	OB8.2	High	Inspect	

7.2.1.1	The processing of the confidence intervals and statistics shall use no more than 10% of CPU time	Processing & Performance Requirements	OB8.2	High	Inspect	
7.3	Any restrictions on the number of data that can be processed at one time shall be documented and any methods used to increase that amount shall be outlined	Processing & Performance Requirements	OB7.2	High	Inspect	Complete
8	**INTERFACE REQUIREMENTS**	**Interface Requirements**				
8.1	**System/Component Interface Requirements**	**Interface Requirements**				
8.1.1	The new software shall use data in the RAX archive database	Interface Requirements	OB7.2	High	Test	Complete
8.2	**DATA MIGRATION REQUIREMENTS**	**Data Migration Requirements**				
8.2.1	Any changes to the tables in the archive database shall be documented and procedures will be written describing how to migrate the archive database data to account for these changes	Data Migration Requirements	OB8.2	High	Inspect	
9	**TRAINING REQUIREMENTS**	**Training Requirements**				
9.1	The RFC's shall receive training and training materials on how to use the new deterministic verification software tool	Training Requirements	OB8.2	High	Demo	On-going
9.2	Development of training guide and user manual for the hydrologic verification software shall be completed by representatives from OHD	Training Requirements	OB8.2	High	Demo	On-going
9.3	User training, workshops and dissemination of user documentation for the hydrologic verification software shall be coordinated through OCWWS/HSD	Training Requirements	OB8.2	High	Demo	On-going
10	**DOCUMENTATION REQUIREMENTS**	**Documentations Requirements**				
10.1	Documentation on the usage and functionalities of the new deterministic verification shall be provided	Documentations Requirements	OB8.2	High	Demo	
10.1.1	The User manual for the new verification tool shall be developed by OHD in accordance to AWIPS documentation standards	Documentations Requirements	OB8.2	High	Demo	

10.1.2	The User manual for the new verification tool shall include examples and instructions on how to use the new GUI	Documentations Requirements	OB8.2	High	Demo	
11	**CONSTRAINTS**	**Constraints**				
11.1	The new deterministic verification tools shall be developed for the AWIPS release of OB7.2	Constraints	OB7.2	High	Inspect	Complete
11.1.1	The new deterministic verification tools shall be updated for the AWIPS release of OB8.2	Constraints	OB8.2	High	Inspect	
11.2	The graphical component of the new verification tool shall execute on the AWIPS Archive Database (RAX) machines	Constraints	OB8.2	High	Inspect	
11.3	Verification products produced with the new verification tool shall be stored in the AWIPS RAX archive database machines	Constraints	OB7.2	High	Inspect	Complete
11.4	The system supporting the new deterministic tools shall execute on the LINUX Red Hat operating system	Constraints	OB7.2	High	Inspect	Complete
11.5	The new deterministic verification tool shall be operational at all River Forecast Centers	Constraints	OB7.2	High	Inspect	Complete
11.6	The development of new deterministic tools shall conform to the AWIPS Operational Documentation standards	Constraints	OB7.2	High	Inspect	Complete
11.7	The Verification software shall use Chart Director(Http://www.advsofteng.com/) to render chart graphics	Constraints	OB8.2	High	Inspect	