NATIONAL WEATHER SERVICE
OFFICE of HYDROLOGIC DEVELOPMENT

Operational Requirements Document

Operational Implementation of a Distributed Hydrologic Model

(DHM) Build 1 AWIPS OB8.2

Version 5.5

Revision History

Date	Version	Description	Author
April 17, 2004	1.0	Created CONOPS	SHK
April 27, 2004	2.0	Incorporated feedback from Lee and Seann	SHK
June 29, 2004	3.0	Updated Use cases	MA
October 7, 2004	4.0	Specified scope for this particular End-to-end project	SMR
October 25, 2004	5.0	Revisions based on RFC comments	MA
January 10, 2005	OSIP 1.0	Revise CONOPS For OSIP	MA & TV
January 13, 2005	OSIP 1.1	Edit Revision	SR, LC & TV
January 26, 2005	OSIP 1.2	Apply IWT Comments	TV
February 10, 2005	OSIP 2.1	Apply OSIP Review Team Comments	TV
February 22, 2005	OSIP 2.2	Add Clarification to Use AWIPS Display & Edit	SR, LC, & TV
May 24, 2005	OSIP 4.1	Special Combined ORD/CONOPS Version	TV
June 1, 2005	OSIP 4.2	Revised combined CONOPS/ORD Version	MA
08/30/2005	OSIP 5.0	Insert DHM Build 1 OB7	MA & LC
09/13/2005	OSIP 5.1	Updates and review contents	MA
09/15/2005	OSIP 5.2	Project Leader review and updates to alternatives section	MA & LC
09/15/2005	OSIP 5.3	Edit Update	TV
07/18/2006	OSIP 5.4	Update Requirements table for OB7.2	MA
01/30/2007	OSIP 5.5	Update requirements table for OB8.2	MA

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1. INTRODUCTION

The National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service (NWS) is uniquely mandated among U.S. Federal Government agencies to provide river and flash flood forecasts to the entire U.S. The lumped modeling approach to river and flash flood forecasting has been in use by NWS for the past 30 to 40 years. Lumped model forecasting was developed prior to the availability of data captured via radar and prior to the common availability of high resolution (time and space) observed precipitation, temperature and river/reservoir information that is now available with Data Collection Points (DCPs) via the Hydrometeorological Automated Data System (HADS) and various Mesonets throughout the US. While measured or observed ground truth is important in both development and operations for any model. The NWS needs to improve the accuracy of river and flash flood forecasts and advance the NWS capability to meet its mission and mandate.

The National Weather Service River Forecast System (NWSRFS) is used by River Forecast Centers (RFCs) to produce river forecasts of discharge and stage at discrete points throughout our Nation's river systems. These forecasts are currently produced using lumped hydrologic models. NWSRFS is also used to produce Flash Flood Guidance (FFG), a product that is transmitted to Weather Forecast Offices (WFOs), to assist with flash flood forecasting to protect life and property.

Distributed modeling approaches are being developed to fully exploit new data sets that describe the spatial and temporal variability of features such as rainfall, vegetation, soils, terrain, evaporation, temperature, and others. Accounting for the spatial variability of these features marks a significant advance in the NWS modeling capability. In addition, it forms a solid point from which to progress into water resource modeling according to planned NWS initiatives. With distributed hydrologic models, users have the capability to simultaneously simulate basin outlet hydrographs as well as the hydrologic response at points within the basin boundary. This capability is well suited for simulating small scale events such as flash floods.

Distributed hydrologic models offer the potential to improve the accuracy of flow forecasts at the discrete river forecasting points, and to provide information about flows on smaller streams that are susceptible to flash flooding. A Research Modeling System developed in the OHD Hydrology Laboratory (HL-RMS) has been used to show that in some RFC basins, improvements in hydrologic simulations can be obtained by using distributed models. More recently, a prototype operational system referred to as the Distributed Hydrologic Modeling System 1.0 (DHMS 1.0) was evaluated in an operational forecast setting at two RFCs. Results of this initial testing have been positive and the initial feedback is being used to define the requirements for integrating distributed modeling capabilities into NWSRFS.

The main goal of this project is to integrate distributed modeling capabilities into NWSRFS to support river flood forecasting at the River Forecast Centers. To the degree possible, the design of the system will also consider potential future applications for flash flood forecasting and water resources applications. Although the pathway and requirements for operational implementation of a distributed model for river forecasting are relatively clear, research into flash flood forecasting and water resources applications is not yet mature enough to define operational software requirements.

Using the same basic algorithms used in DHMS 1.0, research is underway to define and evaluate how distributed hydrologic modeling can be used to improve current flash flood modeling procedures. In current procedures, many WFOs use information from RFCs and the FFG to help with flash flood forecasts; however they do not use the NWSRFS because they have different operational requirements. WFOs typically use their own applications such as Site Specific and the Flash Flood Monitoring and Prediction Program (FFMP). In anticipating the eventual operational use of distributed modeling to improve flash flood forecasting known research and WFO requirements related to model element size and modularity are known and incorporated into this project. However, a complete set of operational requirements required to transfer distributed model based information or distributed model functionality into a WFO application will necessitate further research and analysis.

2. CURRENT STATE OF OPERATIONS

2.1 Description of the Current Environment

The NWSRFS is a collection of interrelated software and data stores capable of performing a wide variety of hydrologic/hydraulic functions. It is composed of three major functional systems that use the same hydrologic/hydraulic functions; Operational Forecast System, Ensemble Streamflow Prediction (ESP) System, and Calibration System.

- The Operational Forecast System uses calibrated parameter values to generate deterministic short-term river and flood forecasts and maintain model state variables.
- The Ensemble Streamflow Prediction System uses current model states and an ensemble of time series to generate an ensemble of hydrographs, providing probabilistic short or long term forecasts.
- The Calibration System generates time-series based on historical data and determines model parameters.

Although the hydrologic aspects of distributed modeling have been researched for several years, the software engineering challenges of implementing a nationally supported distributed modeling river forecasting system have only recently been considered. Implementing this system presents a big challenge because the software and system architecture of the NWSRFS was not originally designed for distributed modeling, and although there have been significant enhancements to NWSRFS over the last 20 years; the basic underlying architecture remains constant. Implementing an efficient and robust distributed modeling system will require significant changes to the current software and system architecture.

A comprehensive set of requirements for implementing a distributed model were developed for this project. By their nature, many of the requirements to effectively implement distributed modeling functionality in RFC operations are similar to requirements for using the current lumped approaches. Therefore, a big task of the software designers in this project will be to determine how to balance an integrated design approach against the fact that many of the functional requirements are supported in one form or another by existing applications such as existing NWSRFS components, XNAV, XDAT, and MPE.

2.2 User/Customer Identification & Organization

Classes of users or customers of the current system include:

- Research Scientist
- RFC Hydrologic Calibrator
- Programmer
- RFC Hydrologic Forecaster
- RFC NWSRFS Administrator
- RFC Developer
- WFO Forecaster*
- Field Support

*Although this End-to-End (E2E) project is focused on building an RFC application, general WFO forecaster requirements are considered.

2.3 Current Support Environment/Architecture

The current operational NWSRFS employed to develop river and flash flood forecasts is based on a lumped modeling approach. NWSRFS is comprised of FORTRAN, C, C++, and Java processing highly linked flat file and relational database data running on a UNIX/LINUX operation system.

3. PROPOSED SOLUTION CONCEPTS

3.1 New Capabilities and Functions

This project is the first in a series of projects that will change the NWS hydrologic modeling capability to improve upon Lumped Modeling in the following ways:

- Allow for spatially varying inputs (e.g. rainfall, soil moisture, impervious areas, etc.), spatially varying outputs (e.g. streamflow anywhere in the basin), and in some cases, more accurate point forecasts.
- Transition from assessing rainfall properties averaged over a basin to assessing rainfall on a per grid basis. For example, rather than having only one snow model per basin, it will have a snow model in each grid. This would be the same for soil moisture accounting model.

- Provide additional forecasts at user-defined points as needed instead of being limited during a heavy rain or flood event to forecasts issued at only pre-selected, discrete points. This will facilitate improvements in flash flood forecasting as well as providing a capability to better serve water resource and emergency managers with unique, event-driven requests.

The end goal of this project is to develop software that will support the distributed hydrologic modeling requirements of a wide range of users. By working through a formal software design process and identifying the needs for modernizing the software and system architectures currently used for river forecasting, the system that results from this project should be capable of supporting existing scientific algorithms for distributed modeling and, perhaps more importantly, be flexible enough to accommodate evolving scientific capabilities and user needs.

The project team selected a combination of a prototype and spiral methodology to define and develop distributed hydrologic modeling capabilities into NWSRFS. Spiral methodology is an accepted engineering process that allows components to be developed in pre-determined logical sequences rather than attempting to develop the entire system at one time. Each component is developed as a permanent and logically separate part of the entire system. Spiral development differs from prototype development where the component is used to understand requirements and not intended to be a permanent part of the complete system.

The initial development of the distributed hydrologic modeling project has been divided into two phases. Overlapping development paths were defined for DHMS 1.0, the prototype, and Distributed Hydrological Modeling (DHM) Build 1, the initial operational capability that will evolve to the future distributed hydrologic modeling capability. DHMS 1.0 was a short term project designed simply to enhance the current HL-RMS prototype. The goal in enhancing the HL-RMS prototype was to facilitate testing and more meaningful requirements gathering for DHM Build 1. There were no major software architecture changes for DHMS 1.0. Efforts for DHMS 1.0 focused on improving the usability and efficiency of HL-RMS. Operations and Service Improvement Process (OSIP) Stage 2 efforts for DHM Build 1 focused more on modernization of the existing software architecture and additions to the existing toolset required to incorporate distributed hydrologic modeling capabilities into the existing system to deliver a more robust and flexible framework.

The new capabilities with DHM include the ability to simulate and assess gridded model states (including soil moisture, river flows) throughout a basin, rather than just at the basin outlet. Gridded data management will be a core functionality of the new NWSRFS.

DHM Build 1 development will utilize the OSIP and associated software engineering practices to ensure that future builds can be integrated into the future and complete DHM.

Implementation at RFCs is a critical first step for flash flood forecasting because, as with the current lumped modeling approaches (FFG and Site Specific), support for high resolution hydrologic forecasting at WFOs is likely to come from the RFCs. For example, the statistical distributed modeling approach, which is being researched as an alternative to the FFG approach for ungauged locations, will have both a historical pre-processing component and an operational component. From a logistical standpoint, the pre-processing component is analogous to preparation of the FFG, which is currently done at RFCs. In addition, a calibrated, distributed model implemented at an RFC would facilitate rapid implementation of site specific models at WFOs for any point within the distributed modeling domain. This would require less work than developing separate site specific models for each point of interest, as required with the current lumped approach. Implementations of distributed hydrologic models will depend on data availability and progress in other key areas of distributed model research and development. DHM will have wider applicability as planned enhancements such as snow and frozen ground modeling, additional routing options, and alternative rainfall-runoff techniques are included. Other enhancements currently being investigated that will improve the ease of implementation include "variational streamflow" assimilation (VAR), improved a priori parameter estimation, and better calibration techniques.

DHM Build 1 is intended to utilize existing raw data and not impose new data requirements on the NWS infrastructure including the Advanced Weather Interactive Processing System (AWIPS). The existing data will be utilized on the AWIPS Workstations and the RFC Ensemble Processor (REP) computers which have already been upgraded to handle a variety of new applications including DHM Build 1. Forecast and observed grids will be generated and edited. Gridded model output may or may not be transmitted to the WFOs in DHM Build 1. However, the projected impact on the communication to transmit the model output to WFOs will be negligible until subsequent DHM Builds.

Figure 1 below depicts the conceptual DHM Build 1 and some of the potential future build capabilities mode of operation in the form of a schematic diagram.

3.1.2 DHM Build 1 Capabilities and Functions for AWIPS

Implementation of DHM capabilities will be spiral or incremental. The first stage, DHM Build 1, of operational implementation is slated for the River Forecast Centers because most of the initial scientific validation has been for RFC scale applications. This section addresses the capabilities that will be provided to the RFC with the release of AWIPS OB8.2. Section 3.1 above describes all of the functions and capabilities of the complete Distributed Hydrologic Modeling. Any capability noted in the above section not delivered in OB7.2 and OB8.2 will be deferred to future DHM Builds.

The three major pieces of DHM functionality that will be included in the AWIPS OB7.2 and OB8.2 are the capability to:

1. Display vector and grid-based (4km resolution) spatial data sets;
2. Execute grid-based SAC-SMA and Kinematic Routing algorithms;
3. Integrate lumped and Distributed Hydrologic Modeling within the existing NWSRFS modeling environment

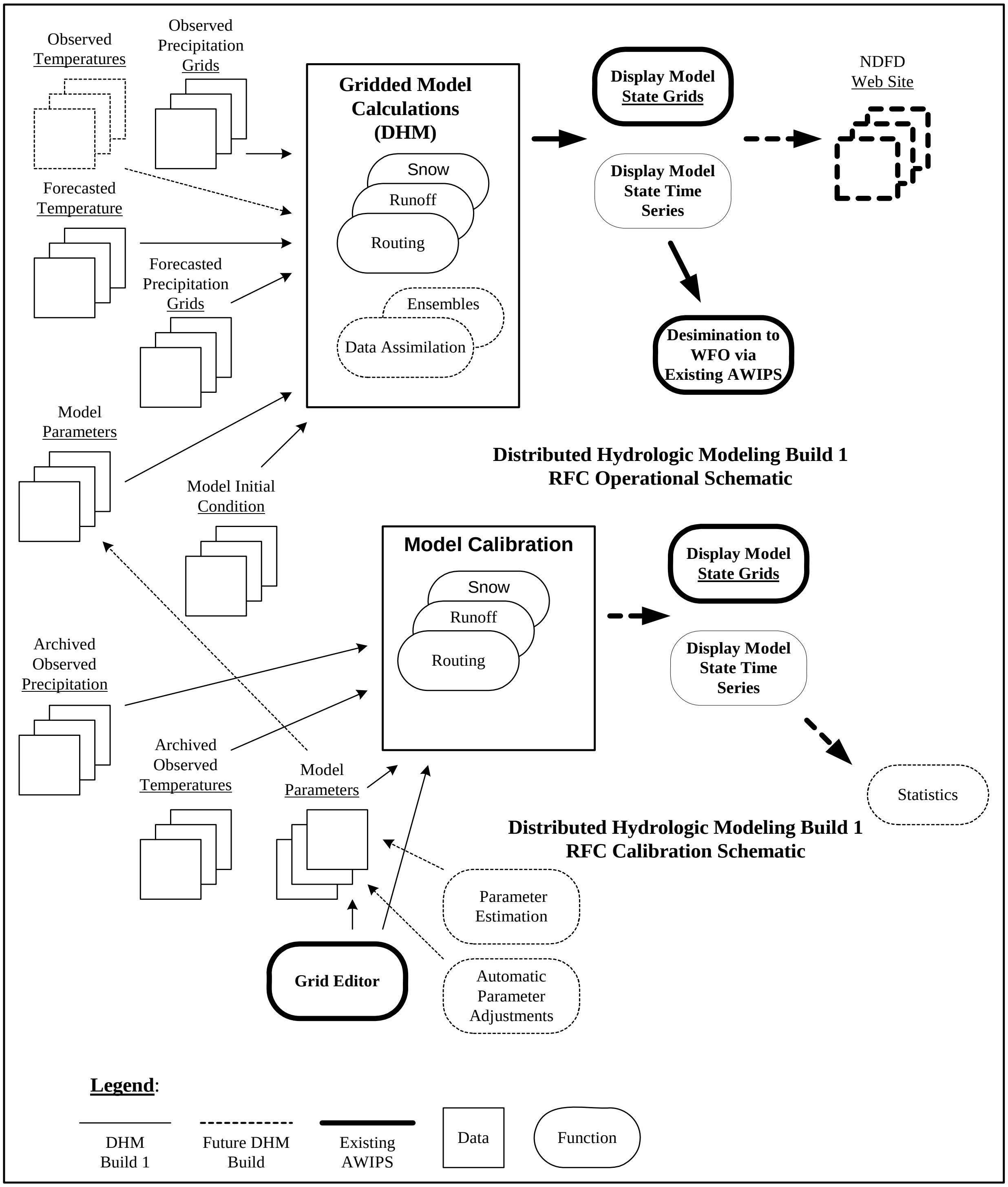

Figure 1 – Conceptual Distributed Hydrologic Modeling Operational & Calibration Schematic Diagram

Two-Dimensional Digital Data Display (D2D) will be used to display DHM vector and grid-based (4km resolution) spatial data. D2D is an existing graphical user interface (GUI) used by the RFCs and WFOs. At the field offices D2D is used to display meteorological observations and weather model data. Because D2D is already part of the suite of software used at the RFCs during normal day-to-day operations, using D2D to analyze DHM-based vector and grid-based spatial data sets should be manageable.

Grid-based versions of SAC-SMA and Kinematic routing are the modules/operations included in DHM Build 1. To date these grid-based operations are the only ones tested under operational scenarios. For the past year the West Gulf River Forecast Center (WGRFC) and Arkansas- Red Basin River Forecast Center (ABRFC) have explored using these two modules/operations to generate a hydrograph for basins currently modeled using a lumped approach. A comparison of lumped-based soil moisture accounting and routing algorithms to DHM shows that in some cases DHM can provide measurable benefits. Because the DHM modules/operations will be limited to the Sacramento Soil Moisture Accounting Model SAC-SMA and Kinematic routing, any areas where the SAC-SMA is not appropriate will not be capable of switching to DHM.

The third area of functionality included in DHM Build 1 is the integration of lumped and distributed modeling. A prototype version of DHM at the RFCs has been in an off-line mode, where DHM is executed outside of existing NWSRFS computations. Preliminary tests of DHM at the RFCs concluded the use of two separate systems (one for DHM and another for lumped modeling) was not acceptable. In Build 1, DHM will be an integrated part of NWSRFS. DHM Build 1 will use existing NWSRFS routines to setup a basin for modeling. This will require adding a new operation (modeling algorithm) to the list of existing NWSRFS operations. In addition, DHM Build 1 is being deployed with the Interactive Forecast Program (IFP) GUI as the tool to view model forecast time series. IFP is an RFC tool already used in normal day-to-day operations.

Enhancing the AWIPS D2D application to display DHM grid-based data for AWIPS OB7 will be completed by the Software Engineering Center and the Meteorological Laboratory SEC/MDL. The Grid Raster computation engine will be developed in-house by the Hydrologic Software Engineering Branch (HSEB) at OHD. In-house development using a combination of components and algorithms from the HL-RMS prototype, existing tools in the NWSRFS (XDMS, OFS) and OHD-developed new features will allow for software development with a known system and architecture, and ensure that the RFC‘s needs are met and future DHM development and enhancements can be supported.

Figure 2 below is the conceptual design for the integration of the DHM Build 1 into AWIPS and NWSRFS for OB7.2 and OB8.2

3.2 Operational Policies & Constraints

The new Distributed Modeling capabilities must still run on the AWIPS, the core operational system used at the NWS. DHM will comply with all AWIPS architecture requirements. DHM Build 1 will have minimal impact on the AWIPS architecture. Subsequent DHM Builds will probably impact the AWIPS infrastructure. DHM modules/operations will be limited to the Sacramento Soil SAC-SMA and Kinematic routing, any areas where the SAC-SMA is not appropriate will not be capable of switching to DHM.

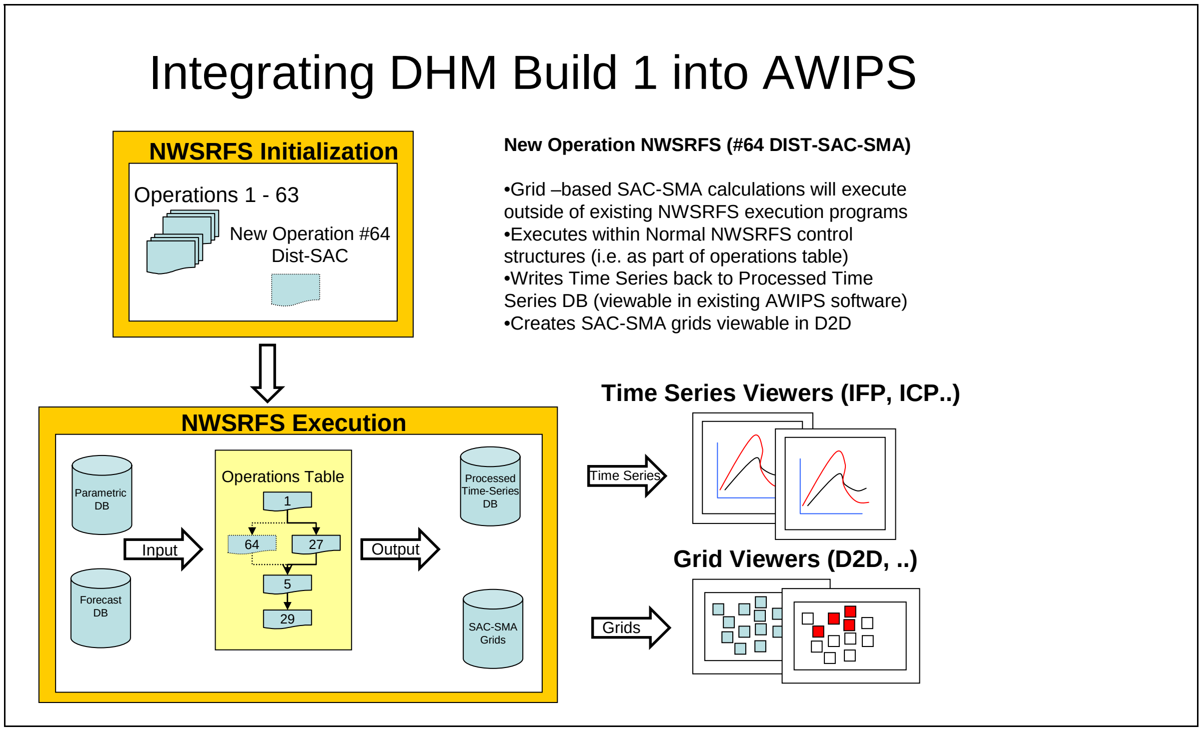

Figure 2 – Conceptual Integration Design for DHM Build 1 into AWIPS NWSRFS.

The impact of subsequent builds will be determined during concept development of those builds.

3.2.1 Scientific Constraints

The development of the DHM for AWIPS OB7 and OB8 releases will cover only rainfall-runoff modeling and will not include snow modeling capabilities.

3.2.2 Technical Constraints

The possibilities of using the Forecast System Laboratory Graphical Forecast Editor (GFE) for the DHM grid editing functionalities did not materialized due to FSL's established calendar and other AWIPS OB7.2 commitments. As a result the development of the DHM Build 1 Grid display functionalities for OB7.2 will be limited to the use of the Data-to-Display (D2D) NWSRFS/AWIPS component. The grid editing and data manipulation functionalities of DHM Build 1 will be considered in future development plans for DHM

3.2.3 Policy Constraints

The development and operational implementation of the DHM Build 1 follow the current and established AWIPS and NWSRFS policies.

3.2.4 Financial and/or Schedule Constraints

The DHM Build 1 shall be implemented within the established scheduled release of the AWIPS OB7.2 and OB8.2

3.3 Operational Scenarios

The modes of operation for Distributed Modeling are the same as those for NWSRFS. The grid data will be accessible through AWIPS D2D application for use by the River Forecasting Centers. The system that will support Distributed Hydrologic Modeling is comprised of C, FORTRAN, C++, and Java processing highly linked flat file and relational database data running on a LINUX operation system.

The following are the specific identified user classes that will use DHM:

- Research Scientist
- RFC Hydrologic Calibrator
- Programmer
- RFC Hydrologic Forecaster
- Field Support
- WFO Forecaster (a potential user for future versions of the software – not formally addressed in DHM Build 1)

The scenarios that each user class will be as follows:

4.1 Research Scientist

- Sets up model
- Analyzes model input and output time series data
- Trains forecasters on how to use the system
- Writes documentation
- Examines various simulation scenarios (e.g. lumped vs. distributed and different time-steps)
- Develops methods and codes to estimate and adjust model parameters
- Develops methods and codes to define model geometry
- Manages current and previous model run files
- Makes adjustments to parameters or states using multiplicative and additive factors
- Develops spatially variable estimates for rainfall runoff, routing, and snow parameters from physical characteristics of the land surface (a-priori)
- Collects data and puts it into database
- Defines/maintains geographic data
- Analyzes model input and output spatial data
- Runs the model
- Defines model element topological relationships and geographic characteristics
- Develops methods and codes to analyze inputs and outputs
- Develops new models

4.2 RFC Hydrologic Forecaster (runs IFP, issues forecasts)

- Runs the model
- Analyzes model input and output time series data

- Analyzes model input and output spatial data
- Specifies modifications (mods) to distributed model parameter states during real-time forecast operations
- Sets up model

4.3 RFC Hydrologic Calibrator

- Sets up model
- Analyzes model input and output time series data
- Manages current and previous model run files
- Makes adjustments to parameters or states using multiplicative and additive factors
- Develops spatially variable estimates for rainfall runoff, routing, and snow parameters from physical characteristics of the land surface (a-priori)
- Collects data and puts it into database
- Analyzes model input and output spatial data
- Runs the model
- Defines model element topological relationships and geographic characteristics

4.4 Computer Programmer

- Analyzes model input and output time series data
- Uses text and graphical output to compare effects of code changes
- Debugs problems in existing modeling procedures
- Implements new models (design, code, test for AWIPS)
- Trains forecasters on how to use the system
- Writes documentation
- Analyzes model input and output spatial data
- Runs the model
- Sets up model
- Troubleshoots system problems (hardware and software configuration)
- Installs new software and configures hardware based on specifications

4.5 RFC Field Support

- Analyzes model input and output time series data
- Analyzes model input and output spatial data
- Runs the model
- Sets up model
- Troubleshoots system problems (hardware and software configuration)
- Installs new software and configures hardware based on specifications

5. USE CASES – DHM Build 1

Use cases are derived from the User Classes and are defined in the HOSIP Stage 2 (Validation) and Stage 3 (Research & Analysis). The use cases are detailed steps that a user or class of users will undertake in order to accomplish a specific task or function.

The use cases described in the tables below are a representation of how the system will be used by different users of the DHM software in the first build that will be delivered to the RFC's for AWIPS OB7. Distributed Hydrologic Modeling (DHM) is an enhancement to the existing National Weather Service River Forecast System (NWSRFS).

Use Case: 1	**Runs the model**
Date created:	09/08/05
Actor:	RFC Hydrologic Forecaster
Description:	In forecast mode DHM will be integrated into the existing NWSRFS control structure (i.e. the user does not choose to specifically run DHM, but an area is predefined to use DHM through the operations table). A forecast model run is initiated in batch mode by OFS-FCST and in interactive mode by IFP. Independent DHM crons are not required.
Preconditions:	Need input and initial model states are required as well as required storage capability and CPU to run DHM on the RFC's machines
Postconditions:	Output Grids will be available for fielding
Priority:	High Priority – Necessary for Initial Implementation
Frequency of use:	Daily or as often as every hour

Normal course:	1. Choose the area to model
	2. In IFP, select the carryover group, then select a segment
	3. In OFS, select a carryover group, forecast group, or segment
	4. Choose the time period to model
	5. Model start time
	    a. In IFP, Carryover date
	    b. In OFS, STARTRUN
	6. Model end time
	    a. In IFP, End of Run
	    b. In OFS, ENDRUN
	7. Start of forecast period
	    a. In IFP, Last day of observed data
	    b. In OFS, LSTCMPDY – Last computational day
	Run the Model,
	OFS and IFP execute the operations table, the place where a description of which modules to execute (e.g. SAC-SMA, Unit Hydrograph) and their order is given, on a per segment basis. For DHM, the operations table for a segment has to already have been predefined (using FCINIT) to use DHM.

Alternative course:	Steps (calibration mode):
	1. Choose the area to model
	    a. Specify the outlets to model
	2. Choose the time period to model
	    a. Specify the Start and End time
	3. Run the Model,
	Initiate a model run by specifying the input deck name. All the model settings are taken from the input deck

Exceptions:	None Noted

Assumptions:	User familiarity with the existing river forecasting operations workflow
Notes and Issues:	When fully integrated, DHM runs in calibration mode will execute by running mcp3. The user will have the option to specify a distributed Sacramento and/or distributed Kinematic routing module through the mcp3 input deck. This level of integration is not planned for OB7. A GUI for setting model options and initiating DHM runs is planned for AWIPS OB7. Steps in calibration mode 1. User chooses the area to model • Specifies the outlet to model 2. Chooses the time period to model • Specifies the Start and End time 3. Run the Model • Initiates a model run by specifying the input deck name. All the model settings are taken from the input deck

Use Case: 2	**Analyzes Model input and output time series data (forecast and calibration mode)**
Date created:	09/08/05
Actor:	Research Scientist, RFC Hydrologic Forecaster
Description:	DHM will use existing software to analyze input and output time series data
Preconditions:	User must have previously ran Model
Postconditions:	User must be satisfied with results and should also have knowledge on how to edit model data
Priority:	High
Frequency of use:	Daily or as often as every hour
Normal course:	Forecast Mode: Use existing procedures to get IFP to display input/output time series data (e.g. a PLOT-TUL or PLOTTS operation has been previously defined to show the desired data)
Alternative course:	Calibration Mode: Use existing procedures to get ICP to display input/output time series data (e.g. a PLOTTS operation has been previously defined to show the desired data), or use XDMS.
Exceptions:	
Assumptions:	User must have familiarity with the existing river forecasting operations workflow
Notes and Issues:	

Use Case: 3	**Analyzes model input and output spatial data**
Date created:	09/08/05

Actor:	Research Scientist, RFC Hydrologic Forecaster
Description:	Grid based input/output data is a key difference between DHM and lumped modeling. For OB7, DHM will include a grid-based version of the SAC-SMA and Kinematic overland and channel routing models. The grid-based model inputs (e.g. precipitation), model parameters, and model outputs will be viewable using existing applications. Two-Dimensional Data Display (D2D) will be used to display a predefined set of grids in forecast mode. It's not expected RFC forecasters will use D2D in calibration mode. Although not impossible, displaying calibration grids through D2D will require some manual steps. Users will be able to view grids in calibration mode via XDMS.
Preconditions:	User must have previously ran the Model
Postconditions:	User must be satisfied with results and should also have knowledge on how to edit model data
Priority:	High
Frequency of use:	Daily as often as every hour
Normal course:	Steps (forecast mode): 1. To view model input, parameter or output data select the Hydro Menu in D2D, then select the DHM submenu 2. Select the DHM submenu should return a list of input, parameters, and output available for viewing (Values at 12Z? Latest Value?) 3. To view Map Background layers; select the Map Background menu and select the appropriate layer from the list of map background layers
Alternative course:	Steps (calibration mode): 1. Manual steps for displaying calibration grids in D2D have not been fully determined 2. Use existing steps for viewing DHM grids in XDMS (see User's manual)
Exceptions:	
Assumptions:	User familiarity with the existing river forecasting operations workflow
Notes and Issues:	It's not expected that RFC forecasters will use D2D in calibration mode. Although not impossible, displaying calibration grids through D2D will require some manual steps. Users will be able to view grids in calibration mode via XDMS.

Use Case: 4	**Specifies modifications (mods) to distributed model parameter and initial states**
Date created:	09/08/05
Actor:	RFC Hydrologic Forecaster (runs IFP, issues forecasts)
Description:	DHM software will allow users to modify distributed model parameters and initial model states. Distributed SAC-SMA and Kinematic routing use spatially varying model parameters and initial state variables that can be modified by specifying a basin wide multiplier or constant value. Enhancing IFP with an interface for specifying DHM mods in forecast mode.

Preconditions:	Previous analysis of time-series spatial data and knowledge of current River Forecasting operations and workflow
Postconditions:	More accurate model results that reflects current river state
Priority:	High
Frequency of use:	Daily or as often as every hour
Normal course:	1. For a given segment, specify a basin wide constant value or multiplier for individual SAC-SMA or Kinematic routing parameters a. In IFP, use the modifications GUI to specify the constant value or multiplier b. In OFS, use the MOD command to specify the constant value or multiplier 2. For a given segment, specify a basin wide constant value or multiplier for individual SAC-SMA or Kinematic routing initial states 3. When specifying a basin wide constant or multiplier for a parameter the change is in effect for the duration of the run (e.g. OFS, STARTRUN to ENDRUN). Care must be taken to update the initial states to reflect new parameter values (i.e. carryover transfer) 4. When specifying a basin wide constant or multiplier for an initial state the change is applied to the carryover state variables. Care must be taken to make sure the updated state value is within the range of acceptable values (i.e. less than or equal to the maximum value for the state variable) a. In IFP, use the modifications GUI to specify the constant value or multiplier b. In OFS, use the MOD command to specify the constant value or multiplier 5. Re-run the model to determine the effects to the outlet hydrograph 6. If satisfied with the changes write the parameter value multipliers to the DHM DB. For basin wide initial state variable multipliers or initial state constant values as long as output grids are saved for dates greater than the carryover date, future runs will contain the effects of the specified multiplier or constant value for initial states
Alternative course:	Developing a GUI for specifying mods in calibration mode is planned for OB7.
Exceptions:	
Assumptions:	
Notes and Issues:	Additional user training will be required

Use Case: 5	**Sets up the models (SAC-SMA and Kinematic routing)**
Date created:	09/07/05
Actor:	RFC Hydrological Forecaster
Description:	Before using DHM, users must go through steps to setup the model over a basin. We are not planning to provide any new features for setting up a model. Users will be expected to use existing software (XDMS, OFS, etc.). We plan to improve on the existing process by providing scripts and

	minor enhancements to XDMS to automate the some of the model setup.
Preconditions:	Users should know how to use the existing software (XDMS and OFS)
Postconditions:	Ready to run the Model
Priority:	High
Frequency of use:	Daily or as often as every hour
Normal course:	Steps to set up a model in DHM Build 1 over a basin/segment: 1. Define a new discharge outlet or select an existing outlet 2. Adjust the basin area associated with the outlet (optional) 3. If it's a new outlet point, define the basin in OFS. 4. Calibrate the SAC and Kinematic routing parameters 5. Generate parameter grids 6. Define initial state and parameter adjustments (multipliers or constants) 7. Define the Distributed SAC and Kinematic routing operations within an OFS segment using OFS-FCINIT 8. Define DHM time series as input to existing lumped operations to combine lumped and distributed modeling (optional) 9. Make sure the segment is included in a new/existing forecast group Make sure the segment is included in a new/existing carryover group
Alternative course:	
Exceptions:	
Assumptions:	
Notes and Issues:	Training will be needed. The process should improve by next DHM Build

Use Case: 6	**Trains forecasters how to use the system**
Date created:	09/07/05
Actor:	OCWWS RFC Support
Description:	As part of DHM for AWIPS OB7.2 the RFCs will be provided with documentation detailing the steps required to use DHM in calibration and forecast modes. Where appropriate, the existing documentation will be edited to reflect enhancements to the software and write new documentation for new software. A plan is in the works to provide training materials, including step-by-step instructions, exercises, data, and expected results to help the RFCs become familiar with DHM.
Preconditions:	OCWWS RFC Support must be trained in the software
Postconditions:	RFC Support will have obtained necessary training to support the software
Priority:	High
Frequency of use:	As required or on demand by the field
Normal course:	Training provided through yearly workshop
Alternative course:	Individual training

Exceptions:	
Assumptions:	
Notes and Issues:	

Use Case: 7	**Troubleshoots system problems (hardware and software configuration)**
Date created:	09/07/05
Actor:	Computer Programmer
Description:	As part of the development of DHM for AWIPS OB7, OHD is writing system and programmer level documentation to provide a clearer understanding of the underlying software. A suite of tools for testing the DHM software is being built. The tools will include test data, scripts, procedures and notes for diagnosing errors. All tools will be built using existing AWIPS software to allow debugging in the field or at OHD.
Preconditions:	Understanding and knowledge of software and access to available documentation
Postconditions:	Ability to provide requested fixes and enhancements
Priority:	High
Frequency of use:	As requested
Normal course:	Enhancement and request for fixes by RFC shall be reported to the OCWWS RFC Support Team. Request for enhancements and fixes will be reported to the appropriate organization for software modification.
Alternative course:	
Exceptions:	
Assumptions:	
Notes and Issues:	

6. Support Environment/Architecture –

6.1 Summary of Impacts DHM Build 1

The basic structure of river and flash flood forecasting will be enhanced to include an alternative approach, distributed hydrologic modeling. As this change is large, efforts within OHD to perform the software engineering, training, and other tactical elements of designing, developing and deploying distributed modeling will be significant.

6.1.1 Operational Impacts

There will be operational impacts after implementing Distributed Modeling Build 1 capabilities at the River Forecasting Centers. The new NWSRFS will provide RFCs with the capability to choose between lumped and distributed hydrologic calculations. For the RFCs to make informed choices, significant efforts will need to be devoted to training

NWSRFS users at RFCs on how to setup basins, calibrate, implement and use associated tools related to Distributed Hydrologic Modeling. It will require significant time and effort to setup and calibrate basins within each RFC before being able to issue comprehensive forecasts using DHM. Basins can be phased in by calibrating problematic areas first. Training will also be necessary for those at the Hydrologic Support Division responsible for supporting the RFCs with using NWSRFS.

In addition, the amount of disk space required to store the data for the DHM could, potentially, exceed an RFC capacity depending on the actual configuration of the RFC workstations. Even though RFCs normally actively manage the amount of data on their Archive Database (not the RAX) by storing information on CD's, the normal partition fills up at least twice per year. Hence, in the current environment, the RFCs may not have the space even to maintain a continuous archive of the locations defined for the DHM. In an operational environment, the DHM model would be run once per hour and will require 500 megabytes of disk space to run efficiently on the River Ensemble Processor. With hourly flow output, DHM yields 5760 flow outputs per site per day. In comparison lumped model is run 4 times a day with 6 hour output and yields 160 flow outputs per site per day. So as more forecast points are added to the distributed model the current disk capacity will fill up very quickly.

6.1.3 Organizational Impacts

The complete impact of including distributed hydrologic modeling capabilities within NWSRFS is not currently known. In its simplest usage, distributed hydrologic modeling is providing another hydrograph trace at basin outlets; however, there are many other data sets produced by a distributed model that may provide new, useful information to the forecaster. DHM may lessen the gap between RFC and WFOs with regard to site specific modeling by potentially providing more real-time operational assistance during flash flood events.

6.1.4 Impacts During Development

The integration of DHM capabilities into NWSRFS is intended to be a seamless transition. The recent appointment of a new contractor, (Raytheon) tasked to handle the AWIPS evolution may impact scheduled work that had previously been assigned to the former AWIPS contractor. As such, the development work may be hindered by new developers' unfamiliarity with the D2D software and will require additional time to get acclimated to the task. Scheduled coordination and meetings between the maintainers of AWIPS, OHD and SEC will be necessary to help mitigate problems and issues that arise in order to keep the project on track.

6.1.5 Impacts During Transition

There are minimal anticipated impacts to the current system during transition other than a particular RFC's ability to store the data required for DHM.

7. Alternatives and Trade-offs Considered

The alternatives analysis that meets the NWS needs to improve river and flash flood forecasting was previously accomplished and is summarized as follows:

1 Status Quo – This approach was to continue the Lumped Modeling. The approach was eliminated because of the inherent problems with Lumped Modeling. Forecast improvement, both from forecast accuracy and downstream implications of flood events, cannot be met without replacing Lumped Modeling. Financially, it would seem that doing nothing is better. However, that must be weighed against the significant loss of life property that could and has resulted from an inability to "distribute" forecasts.

2 Implement Distributed Modeling in the NWSRFS – This approach was selected as the alternative to staying with Lumped Modeling. OHD conducted an extensive Distributed Modeling Intercomparison Project (DMIP) to look at alternative techniques that could be used. The results of the research was documented in a research paper, published, and vetted throughout the research community. Ten different approaches were studied. OHD selected the approach that produced the most advantageous results with the most economically favorable profile, i.e., the approach that could be economically achieved and met forecast improvement and geographical forecasting objectives of field forecasters. Forecasting using a Grid Raster was selected.

3 Steps 1 and 2 above were done outside the current DHM project. The DHM project was entered into the OSIP process due to the desirability to utilize, and therefore modify, existing AWIPS components. OHD then commissioned the development of a "Grid Raster" prototype that was used to validate previous decisions as well as to define the conceptual scope and operational requirements. The prototype was fielded in the ABRFC and the WGRFC. Based on the outcomes of the prototype operation, the project team determined that a spiral development methodology should be used to field DHM in a series of attainable builds. The "Grid Raster" build was designated as Build 1.

4 In the current OSIP stage for DHM Build 1, the project team preformed a make/buy analysis to determine if any existing distributed modeling approaches could be used to meet the requirements defined when the prototype was in operation. Investigation identified two possibilities, the Object Modeling System (OMS), developed at NRCS/ARS, and the Geographic Information System - Remote Sensing (GIS-RS), developed at NOHRSC. Costs and benefits of developing Build 1 from scratch were compared to modifying OMS and GIS-RS. The project team selected to develop DHM Build 1 from scratch utilizing existing prototype code where applicable.

The OSIP Stage 3 alternative analysis results are summarized below.

Object Modeling Systems NRCS/ARS	
Pros	***Cons***
More modern technology (uses java/netbeans)	No current functionality specific to raster-based

	modeling
Used at more than one government agency (USGS and ARS are using it to do hydrology)	USGS/PRMS (similar to HLRMS) work is in early stages
Better known by research community	ARS is primary customer; work with USGS and other collaborators is not top priority
Well funded and supported by ARS/USDA (actively being developed)	HSEB is less familiar with Java than C
	In a state of transition
Geographical Information System-Remote Sensing	
Pros	***Cons***
More mature system used to do raster-based operational snow modeling	Older technology (C and Xmotif)
Easier collaboration, developed and supported at an NWS office (NOHRSC)	Job-control through Perl scripting, Perl not easily maintainable
RFCs have some familiarity of GISRS through IHABBS	GISRS fine tuned for NOHRSC purposes, customizing requires considerable knowledge of existing architecture
Relational DB centric - Will Use Postgres by 09/05	No system documentation
Existing GUIS and APIS to analyze raster data	10,000.00 lines of code, which does not include Application Program Interfaces (API's)
Existing interfaces with D2D	Poor performance. Slow run-time for SAC-SMA model – 30-40 seconds for 1 day and 50 minutes for 5-day run
In-House Development using components of the HL-RMS	
Pros	***Cons***
In-house development of the DHM will take advantage of existing algorithms from the HL-RMS prototype and familiarity with existing tools in the NWSRFS (XDMS, OFS).	New code will have to be written to handle generic raster-based modeling functionality that may already exist in an existing system
Ability to create software that is developed to meet the specific needs of the user.	Will require the HL software developers to have a robust knowledge of existing code and take advantage of that code to facilitate development
Will provide RFC more useful software that will make future enhancements much easier	
Familiarity with the software architecture and flexibility and facilitation for integration of new science modules.	
Greater interaction between the DHM scientists responsible for scientific modules and DHM software developers that will implement them.	

7.1 Disadvantages & Limitations

Due to the increased computational and data processing requirements, operational impacts on system performance must be assessed. Initial indications are that a single, deterministic distributed model run has modest and acceptable computational requirements; however, this issue may need revisiting as future enhancements such as the consideration of distributed ensemble forecasts are considered. The implementation of a Distributed Hydrologic Model at the RFC's will involve extensive manual calibration as no automatic schemes have yet been devised or determined.

8. Requirements Development Methodology

The requirements presented in the Appendix provide the DHM capabilities developed using use cases with the assistance of the West Gulf River Forecast Center (WGRFC) and Arkansas-Red Basin River Forecast Center (ABRFC). The development team also employed the use of a prototype to elicit the requirements. The elicited requirements were verified by the ABRFC and WGRFC. Lastly, the DHM will be developed using the spiral systems development methodology. The elicited requirements represent the first iteration of the DHM Build 1. They also contain the necessary components for future DHM Builds.

9. REQUIREMENTS

The Requirements Specification for DHM Build 1 are contained in the Requirements Tables in Appendix B.

APPENDICES

Appendix A – Table of Acronyms

ABRFC	Arkansas-Red Basin River Forecast Center
AWIPS	Advance Weather Interactive Prediction System
CONOPS	Concept of Operations
DCP	Data Collection Platform
DHM	Distributed Hydrologic Modeling
DHMS	Distributed Hydrologic Modeling System
DMIP	Distributed Modeling Intercomparison Project
DMS	Distributed Modeling System
D2D	Data to-Display
FFG	Flash Flood Guidance
FFMPP	Flash Flood Monitoring Prediction Program
HL-RMS	Hydrology Laboratory Research Modeling System
HSEB	Hydrology Software Engineering Branch
HSMB	Hydrology Science and Modeling Branch
IFP	Interactive Forecast Preparation
GUI	Graphical User Interchange
MDL	Meteorology Design Laboratory
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
NWSRFS	National Weather Service River Forecast System
OB7	Operational Build 7
OCWWS	Office of Climate, Water and Weather Services
OFS	Operational Forecast System
OHD	Office of Hydrology Development
ORD	Operational Requirements Document

OSIP	Operations and Service Improvement Process
RFC	River Forecast Centers
SAC-SMA	Sacramento Soil Moisture Accounting Model
SEC	Software Engineering Center
WFO	Weather Forecast Offices
WGRFC	West Gulf River Forecast Center

Appendix B – Requirements Table

ID	Requirements for DMS	Priority	Verification Type	AWIPS Build	Requirements Status	Requirements Type
	REQUIREMENTS for SPATIAL DATA EDIT/DISPLAY					
1.1	The standard overlays shall include county boundaries	High	Test	OB7.2	Complete	Spatial Data Edit/Display
1.2	The standard overlays shall include forecast group boundaries	High	Test	OB7.2	Complete	Spatial Data Edit/Display
1.4	The standard overlays shall include the basin boundaries	High	Test	OB7.2	Complete	Spatial Data Edit/Display
1.5	The standard overlays shall include the RFC Area Boundary	High	Test	OB7.2	Complete	Spatial Data Edit/Display
1.6	The standard overlays shall include fine-scale Rivers	High	Test	OB7.2	Complete	Spatial Data Edit/Display
1.7	The standard overlays shall include coarse-scale rivers	High	Test	OB7.2	Complete	Spatial Data Edit/Display
1.8	The standard overlays shall include state boundaries	High	Test	OB7.2	Complete	Spatial Data Edit/Display
1.9	The standard overlays shall include town locations	High	Test	OB7.2	Complete	Spatial Data Edit/Display
1.1	The standard overlays shall include highways and roads	High	Test	OB7.2	Complete	Spatial Data Edit/Display
1.12	The standard overlay shall include the vector representation of flow directions	High	Test	OB7.2	Complete	Spatial Data Edit/Display
1.13	The standard overlays shall include flow accumulations	High	Test	OB7.2	Deferred	Spatial Data Edit/Display
1.15	The standard overlays shall include hydro forecast points	High	Test	OB7.2	Deferred	Spatial Data Edit/Display
1.16	The standard overlays shall include hydro informational points	High	Test	OB7.2	Deferred	Spatial Data Edit/Display
1.17	The standard overlays shall include dam locations	High	Test	OB7.2	Deferred	Spatial Data Edit/Display

1.2	The standard overlays shall include Precipitation Stations	High	Test	OB7.2	Deferred	Spatial Data Edit/Display
1.21	The standard overlays shall include Temperature Stations	High	Test	OB7.2	Deferred	Spatial Data Edit/Display
1.25	The standard overlays shall include CWAs	High	Test	OB7.2	Complete	Spatial Data Edit/Display
1.27	The standard overlay shall include a DEM layer	High	Test	OB7.2	Complete	Spatial Data Edit/Display
12	The DHM Software shall allow the user to display precipitation grids	High	Test	OB7.2	Complete	Spatial Data Edit/Display
12.1	The DHM Software shall allow the user to display NEXRAD-based hourly or sub-hourly precipitation grids produced at the RFC's	High	Test	OB7.2	Complete	Spatial Data Edit/Display
12.2	The DHM Software shall allow the user to display synoptic six-hour total precipitation grids for the current day	High	Test	OB7.2	Complete	Spatial Data Edit/Display
12.3	The DHM Software shall allow the user to display the current day's 12Z 24 hour total precipitation grid	High	Test	OB7.2	Deferred	Spatial Data Edit/Display
12.4	The DHM Software shall allow the user to display 24-hour total precipitation grids	High	Test	OB7.2	Deferred	Spatial Data Edit/Display
13.2	The DHM Software shall allow the user to display SMA model parameter grids	High	Test	OB7.2	Deferred	Spatial Data Edit/Display
13.2.1	The DHM Software shall allow the user to display original (a priori) SMA model parameter grids	High	Test	OB7.2	Deferred	Spatial Data Edit/Display
13.2.2	The DHM Software shall allow the user to display adjusted SMA model parameter grids	High	Test	OB7.2	Deferred	Spatial Data Edit/Display
13.3	The DHM Software shall allow the user to display Routing model parameter grids	High	Test	OB7.2	Deferred	Spatial Data Edit/Display
13.3.1	The DHM Software shall allow the user to display original (a priori) routing model parameter grids	High	Test	OB7.2	Deferred	Spatial Data Edit/Display
13.3.2	The DHM Software shall allow the user to display adjusted routing model parameter grids	High	Test	OB7.2	Deferred	Spatial Data Edit/Display
14	The DHM Software shall allow the user to display model state grids	High	Test	OB7.2	Complete	Spatial Data Edit/Display
14.2	The DHM Software shall allow the user to display initial model states grids as “Absolute“ values	High	Test	OB7.2	Complete	Spatial Data Edit/Display

14.3	The DHM Software shall allow the user to display initial SMA model state grids as 'percent full' values	High	Test	OB7.2	Complete	Spatial Data Edit/Display
14.5	The DHM Software shall allow the user to display model output grids by date as 'Absolute' values	High	Test	OB7.2	Complete	Spatial Data Edit/Display
14.6	The DHM Software shall allow the user to display model SMA State grids by date as 'percent full' values	High	Test	OB7.2	Complete	Spatial Data Edit/Display
45	The DHM Software shall process grid based modifications (i.e. user defined requests to edit a grid by adding, subtracting, multiplying, or distributing over a user-selected region)	High	Test	OB8.2	Multiplier Only	Spatial Data Edit/Display
45.1	The DHM Software shall process grid based modifications by decoding a user defined grid-based modification	High	Test	OB8.2		Spatial Data Edit/Display
45.2	The DHM Software shall process grid based modifications by applying a user defined grid based modification at run-time	High	Test	OB8.2		Spatial Data Edit/Display
46	The DHM Software shall support all current Mods plus grid-based mods through IFP or an IFP-like interface	High	Test	OB8.2		Spatial Data Edit/Display
	REQUIREMENTS FOR SIMULATION FUNCTIONALITY					
83.1	The DHM Software shall offer the user a way to specify simulation start and end dates	High	Test	OB7.2	Complete	Raster Computation
83.6.6	The DHM Software shall allow the user to choose whether initial SMA State grids shall be output	High	Test	OB7.2	Complete	Raster Computation
83.6.8	The DHM Software shall allow the user to choose whether initial routing state grids shall be output	High	Test	OB7.2	Complete	Raster Computation
83.7	The DHM Software shall allow the user to specify the number of days before the forecast time to start the simulation	High	Test	OB7.2	Complete	Raster Computation
83.8	The DHM Software shall allow the user to specify the number of hours of QPF	High	Test	OB7.2	Complete	Raster Computation
83.8.2	The DHM Software shall allow the user to compare model runs (for a given basin) using different amounts of QPF.	High	Test	OB7.2	Complete	Raster Computation
84.1	The DHM Software shall allow the user to specify lumped and distributed SMA calculations for each basin (only SAC)	High	Test	OB7.2	Complete	Raster Computation
84.1.1	The DHM Software shall calculate distributed SMA (on SAC) for each basin	High	Test	OB7.2	Complete	Raster Computation
84.3	The DHM Software shall allow the user to specify lumped (unit hydrograph) and distributed local routing for each basin	High	Test	OB7.2	Complete	Raster Computation

84.4	The DHM Software shall allow the user to specify lumped and distributed main channel routing for each basin	High	Test	OB7.2	Complete	Raster Computation
84.4.1	The DHM Software shall calculate distributed main channel routing for each basin	High	Test	OB7.2	Complete	Raster Computation
85	The DHM Software shall include options to specify runs that allow logical combinations of independent lumped and distributed operations	High	Test	OB7.2	Complete	Raster Computation
85.1	The DHM Software shall allow information to be passed between lumped and distributed operations through time series	High	Test	OB7.2	Complete	Raster Computation
85.1.1	The system's distributed routing module shall be able to ingest QINE time series from upstream.	High	Test	OB7.2	Complete	Raster Computation
85.1.2	The DHM Software shall allow the user to specify an option to generate total SQIN as a combination of lumped routed SQIN and distributed local SQIN	High	Test	OB7.2	Complete	Raster Computation
85.1.3	The DHM Software shall allow the user to specify an option to generate total SQIN as a combination of distributed routed SQIN and distributed local SQIN (all distributed)	High	Test	OB7.2	Complete	Raster Computation
85.1.3.1	The DHM Software shall calculate total SQIN as a combination of distributed routed SQIN and distributed local SQIN (all distributed)	High	Test	OB7.2	Complete	Raster Computation
85.2	Distributed Modeling Operations shall pass input and output through grids	High	Test	OB7.2	Complete	Raster Computation
86.2	The DHM Software shall allow the user to output gridded SMA State data sets for the computational domain and specified time steps	High	Test	OB8.2		Raster Computation
86.3	The DHM Software shall allow the user to output gridded runoff states for the computational domain and specified time steps	High	Test	OB7.2	Deferred	Raster Computation
86.5	The DHM Software shall allow the user to output gridded routed flow states for the computational domain and specified time steps	High	Test	OB8.2		Raster Computation
87	Carryover states shall be saved at the last time step in calibration mode	High	Test	OB7.2	Deferred	Raster Computation
88	Carryover states shall be saved at a minimum of once per day in forecast mode	High	Test	OB7.2	Complete	Raster Computation
89	The DHM Software shall allow the user to specify model information for each basin in the computational domain	High	Test	OB8.2		Raster Computation
89.1	The DHM Software shall allow the user to specify model parameters for each basin in the computational domain	High	Test	OB8.2		Raster Computation

89.2	The DHM Software shall allow the user to specify initial model states for each basin in the computational domain	High	Test	OB8.2		Raster Computation
89.2.1	The DHM Software shall allow the user to specify initial model states for each basin in the computational domain as a fixed value	High	Test	OB8.2		Raster Computation
89.2.2	The DHM Software shall allow the user to specify initial model states for each basin in the computational domain as a % of an existing state grid	High	Test	OB8.2		Raster Computation
89.3	The DHM Software shall allow the user to specify constant adjustment factors for parameters in each basin in the computational domain	High	Test	OB8.2		Raster Computation
89.4	The DHM Software shall allow the user to specify constant adjustment factors for initial states in each basin in the computational domain	High	Test	OB8.2		Raster Computation
96	The DHM Software shall allow the user to define a forecast group as a group run (i.e. running the model for a group of 2 or more basins)	High	Test	OB7.2	Complete	Raster Computation
97	The DHM Software shall allow the user to define a carryover group run (i.e. running the model for a group of 2 or more forecast groups)	High	Test	OB7.2	Complete	Raster Computation
107	The DHM Software shall allow the user to run the model in batch mode	High	Test	OB7.2	Complete	Raster Computation
107.1	The batch mode run shall consist of modeling one or more segment(s)	High	Test	OB7.2	Complete	Raster Computation
107.1.1	The segment shall contain 0,1, or more lumped operation(s)	High	Test	OB7.2	Complete	Raster Computation
107.1.2	The segment shall contain 0,1, or more distributed operation(s)	High	Test	OB7.2	Complete	Raster Computation
107.2	The batch mode shall consist of modeling one or more forecast group(s)	High	Test	OB7.2	Complete	Raster Computation
107.2.1	The forecast group shall contain one or more segment(s)	High	Test	OB7.2	Complete	Raster Computation
107.2.1.1	The segment shall contain 0,1, or more lumped operation(s)	High	Test	OB7.2	Complete	Raster Computation
107.2.1.2	The segment shall contain 0,1, or more distributed operation(s)	High	Test	OB7.2	Complete	Raster Computation
107.3	The batch mode run shall consist of modeling one or more carryover group(s)	High	Test	OB7.2	Complete	Raster Computation
107.3.1	The carryover group shall contain one or more forecast group(s)	High	Test	OB7.2	Complete	Raster Computation

107.3.1.1	The forecast group shall contain one or more segment(s)	High	Test	OB7.2	Complete	Raster Computation
107.3.1.1.1	The segment shall contain 0,1, or more lumped operation(s)	High	Test	OB7.2	Complete	Raster Computation
107.3.1.1.2	The segment shall contain 0,1, or more distributed operation(s)	High	Test	OB7.2	Complete	Raster Computation
117	The DHM Software shall allow the user to run the model from a cron	High	Test	OB7.2	Complete	Raster Computation
117.1	The DHM Software shall allow the user to use relative dating	High	Test	OB7.2	Complete	Raster Computation
117.2	The DHM Software shall allow the user to specify state grids generated X hours ago as current carryover	High	Test	OB7.2	Complete	Raster Computation
	REQUIREMENTS FOR MISCELLANEOUS					
119	The DHM Software shall allow the user to display a topology diagram for segments	High	Test	OB7.2	Complete	Miscellaneous
119.1	The DHM Software shall allow the user to display a topology diagram to show the upstream to downstream connectivity of segments in a forecast group	High	Test	OB7.2	Complete	Miscellaneous
119.2	The DHM Software shall allow the user to display a topology diagram to show the upstream to downstream connectivity of segments in a carryover group	High	Test	OB7.2	Complete	Miscellaneous
119.3	The system topology diagram shall distinguish the active segment from all other segments in the upstream to downstream topology diagram	High	Test	OB7.2	Complete	Miscellaneous
120.1	The GUI mode run shall consist of modeling one or more segment(s)	High		OB7.2	Complete	Miscellaneous
120.1.1	The segment shall contain 0,1, or more lumped operation(s)	High	Test	OB7.2	Complete	Miscellaneous
120.1.2	The segment shall contain 0,1, or more distributed operation(s)	High	Test	OB7.2	Complete	Miscellaneous
120.2	The GUI mode run shall consist of modeling one or more forecast group(s)	High	Test	OB7.2	Complete	Miscellaneous
120.2.1	The forecast group shall contain one or more segment(s)	High	Test	OB7.2	Complete	Miscellaneous
120.2.1.1	The segment shall contain 0,1, or more lumped operation(s)		Test	OB7.2	Complete	Miscellaneous
120.2.1.2	The segment shall contain 0,1, or more distributed operation(s)	High	Test	OB7.2	Complete	Miscellaneous
141	The DHM Software shall display data in Metric and English units	High	Test	OB7.2	Complete	Miscellaneous

141.1	The DHM Software shall allow the user to define either English or Metric as the default	High	Test	OB7.2	Complete	Miscellaneous
197.2	The DHM Software shall have automatic file maintenance to delete old state grids	High	Test	OB7.2	Complete	Miscellaneous
	INPUT REQUIREMENTS					
213	DHM shall utilize existing precipitation raw data as input to the model computations.	High	Demo	OB7.2	Complete	Input Requirements
	PROCESSING & PERFORMANCE REQUIREMENTS					
214	The DHM Software shall utilize existing raw input data and not require any new data	High	Demo	OB7.2	Complete	Processing & Performance Requirements
214.1	The DHM Software shall generate forecast and observed grids at RFC's using existing processing resources, specifically, the RFC Ensemble Processors (REP) and AWIPS workstations and not utilize the AWIPS Hubs (DX)	High	Demo	OB7.2	Complete	Processing & Performance Requirements
214.2	The DHM Software shall edit forecast and observed grids at the RFC's using existing processing resources, specifically, the REP and AWIPS workstations and not utilize the AWIPS Hubs (DX)	High	Demo	OB7.2	Complete	Processing & Performance Requirements
214.5	The DHM Software shall utilize no more than 500 megabytes of disk space of River Ensemble Processor(REP) per hourly run	High	Test	OB7.2	Complete	Processing & Performance Requirements