A Summary of the National Weather Service Advanced Hydrologic Prediction System Demonstration in Des Moines, Iowa

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INTRODUCTION

Floods are the leading weather related hazard. Our nation's most recent and prominent events, such as "The Great Flood of 1993" in the mid-west and subsequent flooding events in the western, eastern, and upper mid-western states, remind us that major floods will occur frequently and are devastating. Preparedness for these events can lead to saving billions of federal disaster relief dollars. Floods cause an average of nearly $4 billion in damages annually, and over 75 percent of Presidential disaster declarations are in response to flooding events. It is, therefore, important to make the mitigation of this hazard a high-priority task.

Droughts, while generally not life-threatening in the United States, do have a serious impact on agriculture, ecosystems and water management, and the economy in general. With the Advanced Hydrologic Prediction System (AHPS) implemented nationwide, the National Weather Service (NWS) will have the tools to provide drought related hydrologic information to users. This improved capability builds on the traditional expertise and responsibility of the NWS flood forecasting program, and will provide the public with a full set of water resources information.

Recognizing this hydrologic forecasting requirement, the NWS has developed, implemented, and demonstrated AHPS for the Des Moines River basin in Iowa. This is the first phase towards the national implementation of AHPS. The Des Moines basin was chosen for this first phase because of the devastating impacts of the "Great Flood of 1993," which included severe flooding in the city of Des Moines, Iowa.

Our Nation's floods and droughts have forced the need for improved predictions to support flood/drought management and damage mitigation. It is imperative that AHPS products be provided to assist the mitigation of these hazards. Furthermore, the allocation of water among competing demands looms as a national problem requiring improved water quantity forecasts for sustainable development. By increasing lead times and the content of hydrologic forecasts, AHPS products will greatly improve the Nation's capability to take timely and effective actions that will significantly mitigate the impact of major floods and droughts. AHPS will also provide products to water resource managers for the optimal use of water and appropriate allocation for water supply, agriculture, navigation, hydropower, and ecosystems.

AHPS implementation began in 1995 through a significant commitment by personnel of the North Central River Forecast Center (NCRFC), Chanhassen, Minnesota; the Regional Hydrologist and other staff of the NWS Central Region Headquarters, Kansas City, Missouri; the Des Moines Weather Forecast Office (WFO), Johnston, Iowa; and the NWS Office of Hydrology, Silver Spring, Maryland. The March 1997 demonstration successfully met the implementation goals to demonstrate an operational long-term probabilistic forecast system. Furthermore, the demonstration revealed that AHPS is mature enough for implementation in other regions of the nation.

DEMONSTRATION DEVELOPMENT

In order to solicit input from the intended users of the new AHPS products, a meeting was held at the Weather Service Forecast Office (WSFO) Des Moines, October 2-3, 1996. Attendees at all or part of the 2-day meeting included NWS representatives from the Office of Hydrology, Hydrologic Research Laboratory; the National Operational Hydrologic Remote Sensing Center (NOHRSC); the North Central and Missouri Basin RFCs; WSFO Des Moines; and the Regional Hydrologist, Central Region. Other attendees represented the U.S. Geological

Survey, Rock Island Army Corps of Engineers (USACE), City of Des Moines, City of Des Moines Water Works, State of Iowa, and Iowa State Emergency Managers.

Through consultation with the users, it was decided that the following products would be issued once per week. It was also decide that these product would include the use of Quantitative Precipitation Forecasts and climate coupling. The selected products were:

- ESP probability Time Series (weekly) for flow, volume, and stage out to 60 days for 21 forecast locations in the Des Moines basin.
- 60-day Exceedance Probability Plot for flow and stage for all forecast locations.
- Flood inundation map showing 25, 50, and 75 percent probability of flooding at 60 days. Area covered by the map would be approximately downstream of Saylorville Dam to 14th Street in Des Moines, and up the Racoon River from the Des Moines River to the confluence of Walnut Creek.

In addition, it was decided that the Internet would be the primary system for issuing AHPS products to users. The WSFO Des Moines home page would provide access to the products. The NCRFC would also continue to produce all previous routine products during the AHPS demonstration. The AHPS products would be in addition to the usual hydrologic products prepared by NCRFC such as flash flood guidance, River Forecast, and Extended Streamflow Guidance products.

The specific goals of the demonstration were reiterated to be as follows:

- Use Quantitative Precipitation Forecasts (QPF) in the short-term forecasts.
- Use climate coupling and Ensemble Streamflow Prediction (ESP) techniques in long-range hydrologic products.
- Provide probability information in hydrologic products.
- Demonstrate a flood inundation mapping capability.

Lastly, the methods for evaluating the forecasts were determined. Verification of the AHPS demonstration would be based on a comparison of observed crests with Spring Flood Outlooks based on ESP procedures. Also included would be a summary of user evaluations as to the quality and usefulness of ESP-type products.

DEMONSTRATION DESCRIPTION

Computation of Forecasts

Forecasts distributed during the AHPS demonstration in Des Moines, Iowa, were computed using the ESP technique. To forecast with the ESP technique, an ensemble of possible streamflow hydrographs are calculated by initializing hydrologic models with the current states of the hydrologic system and then forcing those models with historical precipitation and temperature time series. A distribution is then fit to a sample taken from this ensemble of streamflow hydrographs. The fitted distribution describes the likelihood of an event occurring. It is from this fitted distribution that forecast products are derived. An empirical distribution was used as the underlying distribution for all the AHPS demonstration forecasts.

For the demonstration, a method was developed to integrate long-range meteorological fore-casts into the streamflow forecasts. This method consists of shifting the historical precipitation and temperature time series by daily λ values prior to using them as input to the hydrologic models. The daily λ's were calculated from the 2- to 6-

day Hydrometeorological Prediction Center precipitation and temperature forecasts, the 7- to 11-day Climate Prediction Center (CPC) precipitation and temperature forecasts, the 1-month climate outlook from CPC, and the seasonal climate outlooks from CPC. WSFO preceded the 24-hour QPFs that were also blended into the ESP forecasts.

Description of Forecast Products

The NCRFC provided AHPS forecast products for 20 locations during the demonstration and also the 5-day deterministic forecasts for all 20 locations. (See figure 1 for a map of the forecast point locations.) Examples of the 5 day forecast product is presented in figure 2, the Probability Interval plots with weekly intervals in figures 3-5, and Exceedance Probability plots for the 60-day forecast period in figures 6-7. The NOHRSC was responsible for providing the Inundation Map an example of which is presented in figure 8.

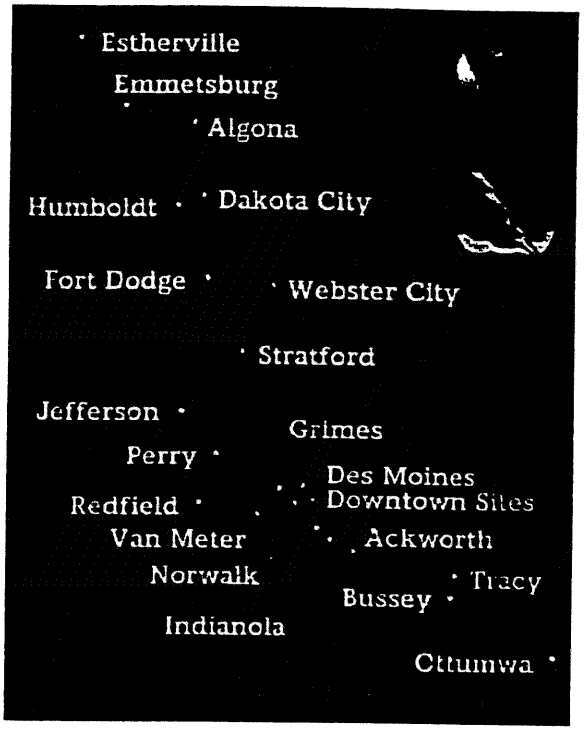

Figure 1

Probability Interval Plots for Maximum Flow, Maximum Stage, and Volume. These plots show the probability that the variable of interest at a point on a river will exceed a particular value in a 7-day period. The vertical axis shows flow measured in cubic feet per second and the horizontal axis shows time. Each vertical bar represents the probabilities for a 7-day period. The three probability levels are: greater than 75 percent, 75-50 percent, and 50-25 percent. The variable of interest can be either the Maximum Flow at a point, the Maximum Stage at a point, or the Volume passing a point. Examples of these products may be found in figures 3, 4, and 5.

60-day Exceedance Plot for Maximum Flow and Maximum Stage. These plots show the probability distribution for the Maximum Flow or Maximum Stage over the identified 60-day period. The vertical axis shows the flow values measured in cubic feet per second, and the horizontal axis shows the probabilities. The triangles indicate sample points, and the line through the points represents the distribution that has been fit to those sample points. A point on the line indicates the probability that a specific flow will be exceeded some time during the identified 60-day period. Examples of these products may be found in figures 6 and 7.

Inundation Map for Maximum Stage. The AHPS Flood Inundation Map is intended only to demonstrate the capability of generating real-time inundation maps derived from NWS hydrologic forecasts. The inundation map depicts the probabilities that specific areas around Des Moines will be flooded during the identified 60-day period. Any given area is assigned one probability range for the specific 60-day period: a greater than 75 percent chance of flooding; a 50-75 percent chance of flooding; a 25-50 percent chance of flooding; or a less than 25 percent chance of flooding. The map does not give information about flood depth above the ground, river stage, or flood return interval and is not related to any hypothetical 25-, 50-, or 75-year return-interval flood. The inundation map is based on the best digital elevation model (DEM) data available. If a DEM of greater resolution and accuracy were available, it could be used with the demonstration software and procedures to produce a more accurate flood inundation map based on the NWS hydrologic forecasts. An example inundation map may be found in figure 8.

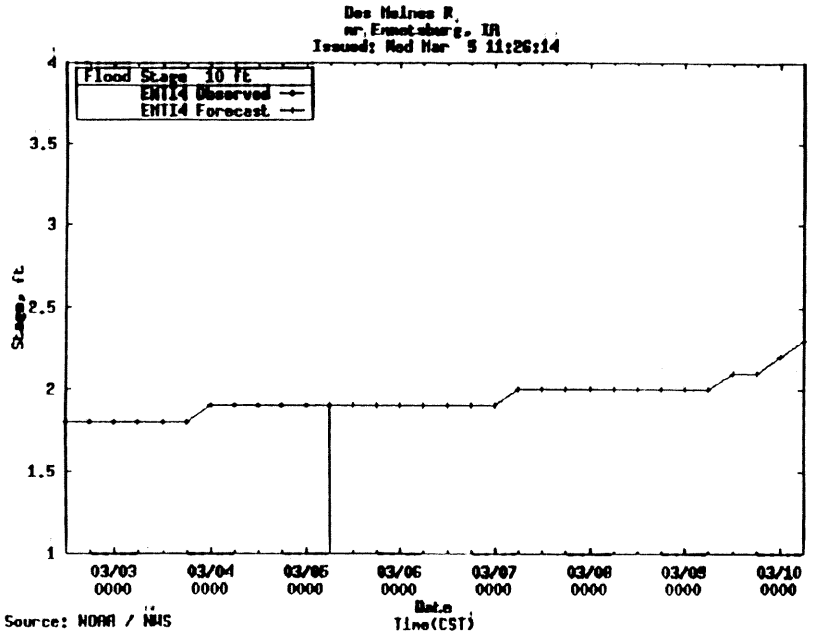

figure 2

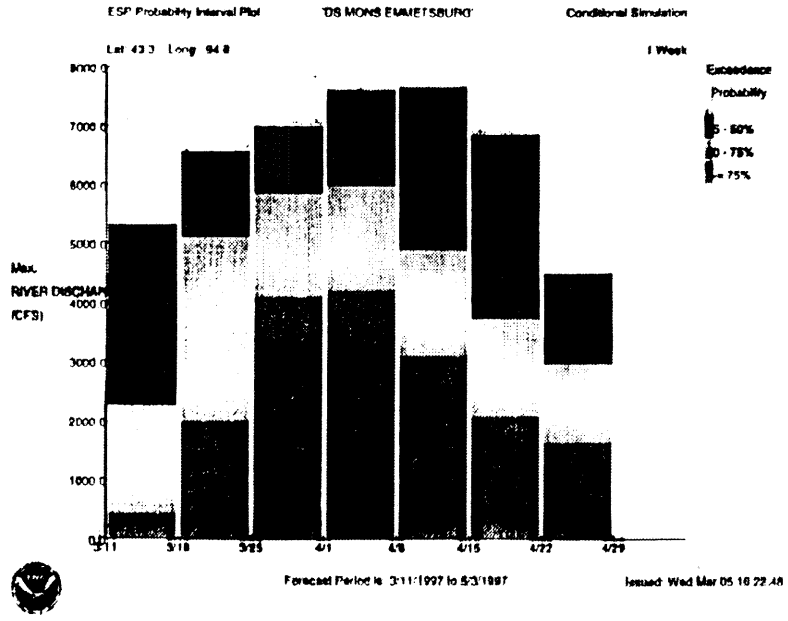

figure 3

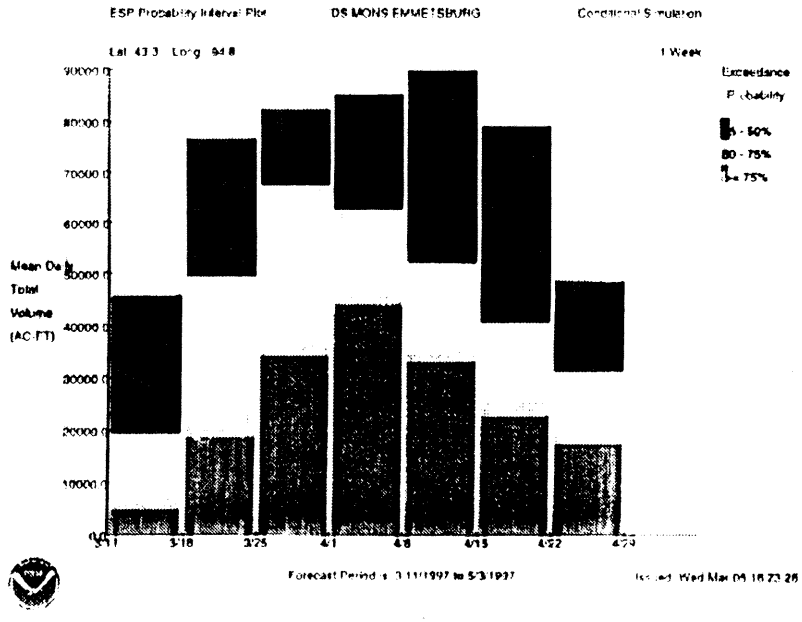

figure 4

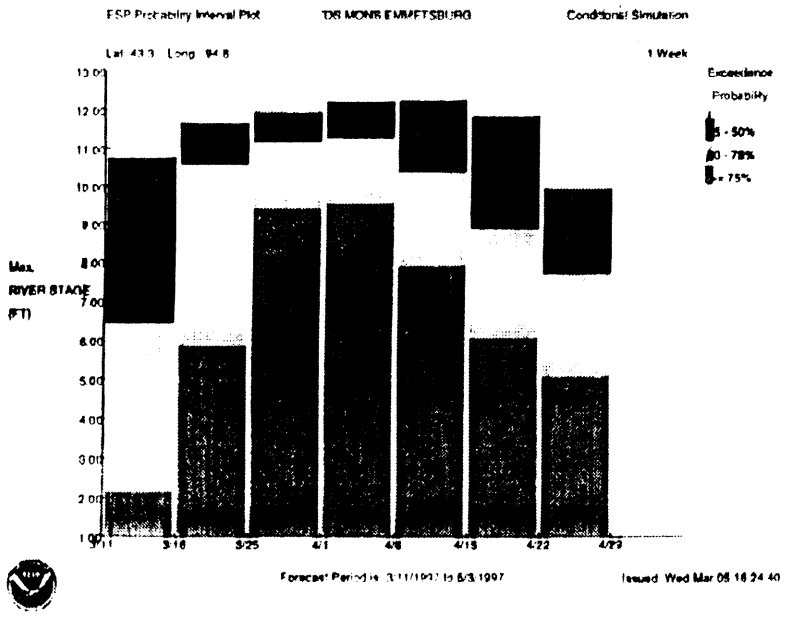

figure 5

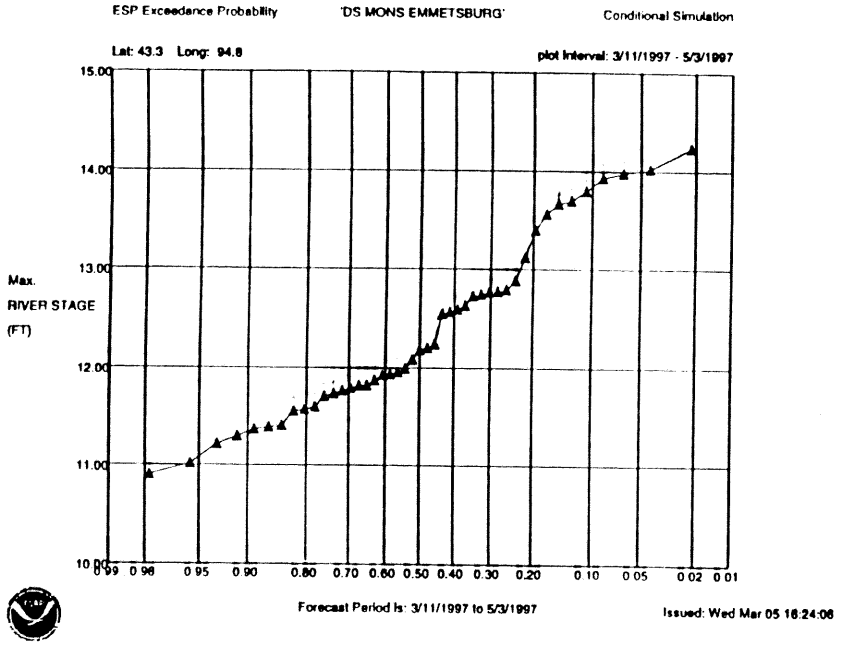

figure 6

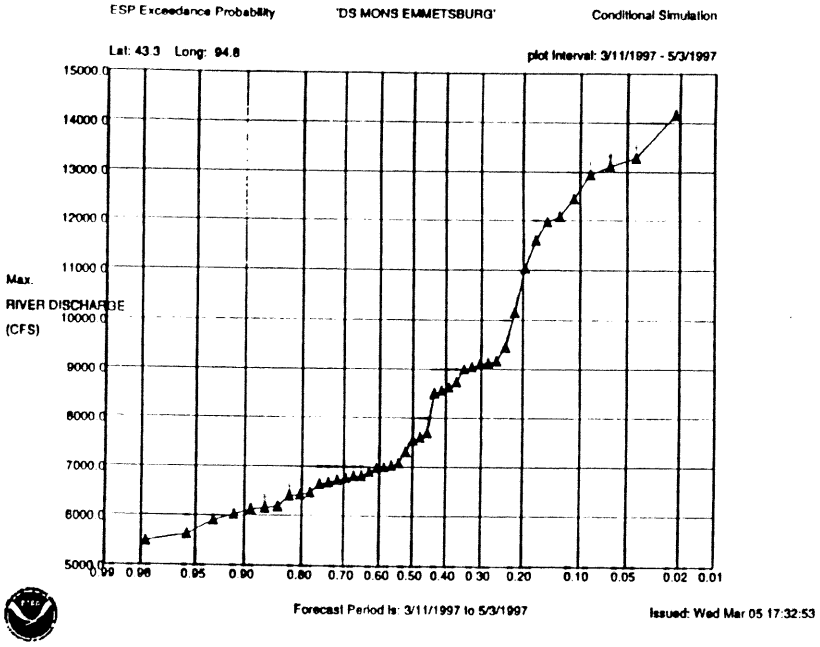

figure 7

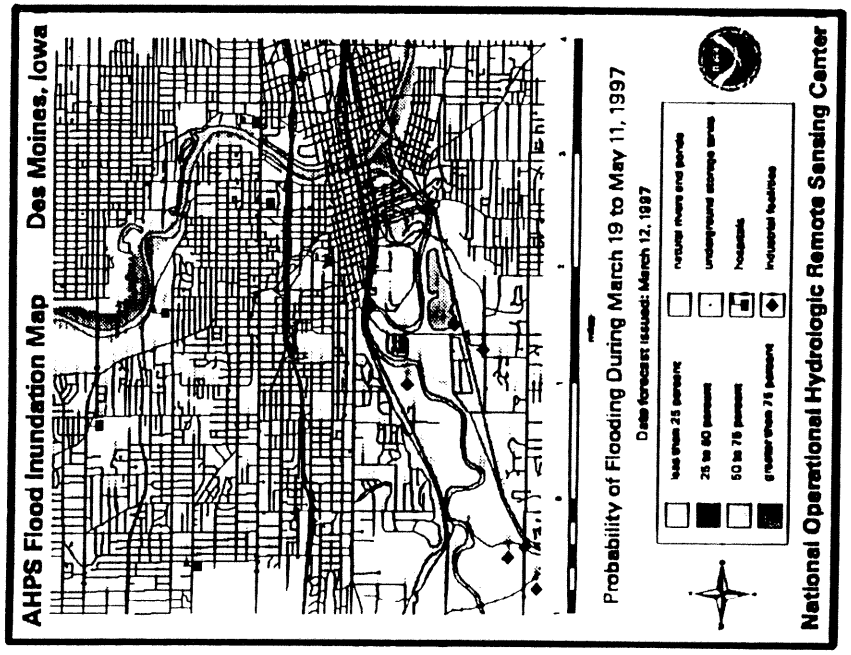

figure 8

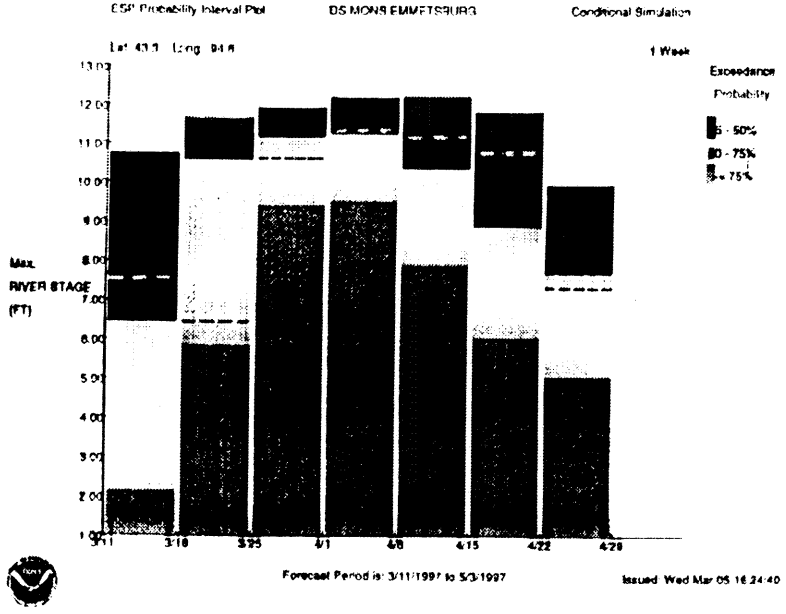

figure 9

AHPS PRODUCT EVALUATION

Hydrologic conditions during the demonstration

Snow conditions at the beginning of March were 8-13 inches of snow for the Upper Des Moines river basin, with unusually high water equivalents of 3- 6 inches; central and southeast Iowa had 2-4 inches of snow, with less than 2 inches of water equivalent. Average temperatures across the Des Moines river basin ranged from around 30 degrees in the northwestern sections in Minnesota to the lower 40s in southeastern Iowa. This was between 2-4 degrees below normal in the northwest to around 4 degrees above normal in the southeast. Precipitation amounts ranged from 0.5-1 inch in the Minnesota sections to 1-2 inches in Iowa. This was 50-75 percent of normal. Most of the precipitation fell the first week of March when Des Moines received almost an inch and a quarter of precipitation.

These conditions led to a few minor flood events within the Des Moines river basin during the month of March, with the majority of forecast points remaining below flood stage. Nine locations experienced minor above-flood stage conditions; however, at least three of these were largely due to ice affects (Algona, Jefferson, and Perry). It should be noted that an early melt occurred just prior to the beginning of the AHPS demonstration period. The benign hydrometeorologic conditions during the demonstration period, and the short period involved, minimized the amount of data analysis that was possible.

Evaluation

Analyzing the daily 5-day deterministic forecasts indicates diminishing skill after day 3 of the forecast period and significant variations in forecast values on days 4 and 5 of the forecast period. This can be primarily related to the fact that only 1 day of QPF was available.

To evaluate the Probability Interval plots, the observed data were overlaid on the plots for verification. The 60-day probability interval plots were examined by comparing observed hydrographs for the 60-day period to the interval plots issued on March 5. See figure 9 for an example. It was found that most of the observed maximum stages for each week were distributed almost equally in the 25-50 percent and 50-75 percent intervals; this is what would logically be expected. However, the number of observed stages in the greater than 75 percent interval was zero, while the number in the less than 25 percent interval was 11. This was probably a result of below-normal precipitation during the demonstration period. The observed stages for each interval for the 12 sites were as follows.

Interval	No. of weekly maximum stages
less than 25%	11
25%-50%	36
50%-75%	37
greater than 75%	0

The 60-day exceedance probabilities for a given observed data value were determined directly from the ESP output. Examining the 60-day products indicates that, in some cases, the observed data had exceedance probabilities in excess of 70 percent, with some observations having probabilities greater than 98 percent.

User Response

In order to evaluate the AHPS products from a user perspective, surveys were given to emergency management and other critical customer groups along the Des Moines basin. The following external customers returned an AHPS survey: West Des Moines Fire and Civil Preparedness; USACE; Des Moines Water Works; USACE, Rock Island; Emmet County EMD; Kossuth County EMD; Wright County EMD; Marion County EMD; Calhoun County EMD; Madison County EMD; Polk County EMD; Clarke County EMD; and an unknown.

Survey Results.

Question 1 - *How often did you access the AHPS products?*

multiple times per day	2
daily	0
every few days	2
weekly	0
less often than weekly	5 -- (due to lack of flood threat)
never	4 -- (due to lack of flood threat)

Question 2 - *For the following, please rate 1 to 10 with 1 being "unsatisfactory", 5 being "satisfactory" and 10 being "outstanding".*

	External Mean Responses
Ease of access to AHPS products	7
Understandability of AHPS products	7
Quality of AHPS products	7
Display of AHPS products	7
Timeliness of AHPS products	8
Usefulness of AHPS products	8

Question 3 - *Please rate the following WSFO Des Moines Home page products:*

	Not Useful	Useful	Essential
Current stages	0	1	7
5-day forecasts	0	2	6
Probability time series			
Stage	0	1	6
Flow	0	1	6
Volume	0	2	4
60-day Exceedance probabilities			
Stage	0	5	3
Flow	1	4	3
Site information	0	5	2
Site map	0	3	3
Gauge information	0	0	7
Inundation map	1	2	4
Help products	0	4	2

Question 4 - *What do you like best about AHPS?*

- The information was right before you and then you could plan your strategies.
- Rainfall potentials.
- Accuracy, timeliness, uncertainty, length of future forecast, ease of graphics.
- Timely information.

Question 5 - *What do you like least about AHPS?*

- No Internet access.
- Did not use since flooding was not a problem during the demonstration.
- Occasional trouble accessing.
- First time user - I found it confusing.
- Download slow.

- Timeliness of access.

These users rated AHPS products as 7 or 8 (on a scale of 1 to 10). They evaluated most AHPS products as "essential" to their operations. These users stated that what they especially liked about AHPS was "the information was right before you and then you could plan your strategies."
At a later time a more rigorous verification and comparison with other procedures could be made. However, even a cursory review of the types of products made available to the public, and an examination of Figures 2-8, shows the obvious advantages of AHPS because of the wealth of additional probabilistic information available through AHPS techniques. The user response before, during, and after the demonstration clearly showed the usefulness and applicability of ESP probability type hydrologic products.

SUMMARY

It should be remembered that the primary purpose of this demonstration was to show that all the necessary operations required for AHPS could be developed, implemented, and operated in an operational real-time environment. From that perspective, the AHPS demonstration was a total success.

The ESPADP software was developed and implemented at NCRFC. The Sacramento soil moisture accounting model had to be calibrated and running at NCRFC for the Des Moines basin. The capability to utilize QPF and climate information in long-range hydrologic forecasting was demonstrated. All of the necessary software and data necessary for inundation mapping had to be acquired by the NOHRSC and tailored for the Des Moines basin. Staff at WSFO Des Moines and NCRFC had to design a home page for disseminating the AHPS products, become familiar with the products, and work with the local users of the products. All of these many varied and critical requirements were accomplished on schedule.

All of the required AHPS products began flowing from NCRFC and NOHRSC to WSFO Des Moines and then to the public on schedule on March 5, 1997, and continued through March 26, as planned.

While the lack of significant flooding activity in the Des Moines basin during the demonstration was disappointing, it was not a problem for the overall project. In the early implementation stages of AHPS, the primary goals were to implement the AHPS at NCRFC, generate the forecast products as required, produce the inundation maps, and transfer all of this information to WSFO Des Moines. At WSFO Des Moines, the AHPS products were placed on the Internet home page, along with significant amounts of additional hydrologic information (E-19 information such as site history, location, maps, historical flood data, stage damage information, etc.) for access by outside users. All of this was accomplished and successfully demonstrated during this project.

This critical demonstration showed that all of the necessary pieces of AHPS are viable. The positive user response provides a critical impetus for the NWS to continue in its efforts to implement the AHPS across the nation.