have plans and policies in place, or simply do not know what to do. Similarly, even a well prepared community will be highly vulnerable to hazards if they don't have access to forecasts which gives them the lead time to take necessary actions. Therefore, an integrated approach to disaster mitigation and preparedness is critical in reducing the impacts of floods and other natural disasters.

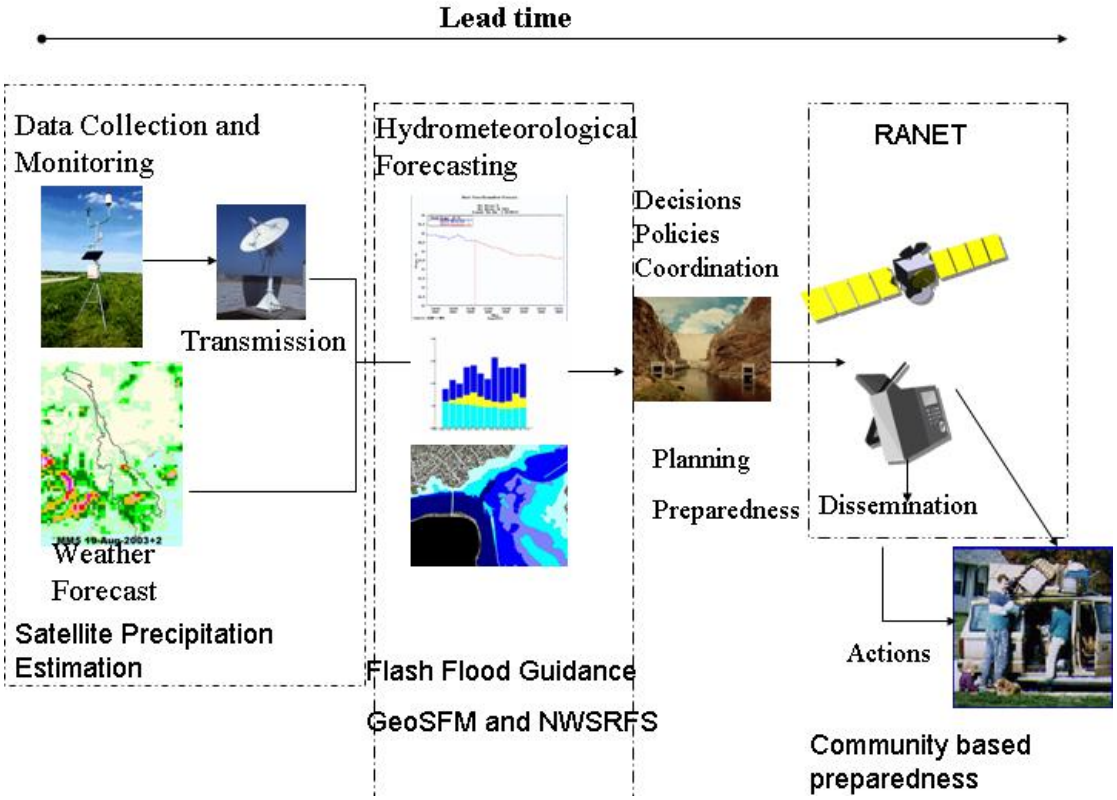

Figure 1 **An end-to-end flood mitigation process.**

In cooperation with NOAA and USGS, USAID/OFDA has been collaborating with MRC and International Centre for Integrated Mountain Development (ICIMOD) in Asia to identify and fill gaps in end-to-end flood forecasting and early warning. The programs complement current USAID/OFDA-funded community based early warning activities in the region. In this presentation and the poster sessions, AFN activities will be presented by addressing the end-to-end process of mitigation.

Data Collection and Monitoring

Monitoring extreme hydrometeorological events is the first step towards understanding what could potentially happen in the future and to choose from possible alternatives. Collection of hydrometeorological data, such as rainfall, temperature, and streamflow, is essential in simulating the natural phenomena. Ground observation networks are commonly used in collecting rainfall and other meteorological data. However, in many countries, satellite-based precipitation estimation may be the only source of rainfall data due to scarcity of hydrometeorological networks, long delays in data transmission, and absence of data sharing in many trans-boundary river basins. A combined satellite- and surface-based rainfall estimation (RFE) technique to enhance the knowledge of collecting precipitation was developed at the NOAA Climate Prediction Centre in 2001. The RFE brings value-added information to rain-gauge interpolations and is primarily intended to serve a flash flood monitoring role as a near real time rainfall dataset. The estimation complements real-time stream gage, rain gage, and independent satellite-based information.

The dataset also provides an excellent opportunity for the monitoring of seasonal moisture, especially when comparing to historical averages of anomaly and normal rainfall. Through AFN, USAID/OFDA, in partnership with Mekong River Commission and the International Centre for Integrated Mountain Development, conducted workshops on the use of RFE technology to strengthen capacity of National Meteorological and Hydrological Services and regional organizations in Asia. Under AFN, NOAA and USGS have been cooperating with MRC and ICIMOD on the use of satellite precipitation estimation to forecast and monitor flooding, flash floods, and droughts. In 2005, MRC and ICIMOD hosted training workshops on the use of RFE. AFN plans to transfer the technology to MRC and ICIMOD in 2006, which will enable regional partners to integrate local rain gage data, validate remote sensing data, improve accuracy for the region, and reduce the time lag of data transmission. In their poster session, Dr. Love and Mr. Wolvovsky from Climate Prediction Centre (NOAA/CPC) will illustrate the technology and other detailed information on the RFE (see Figure 2).

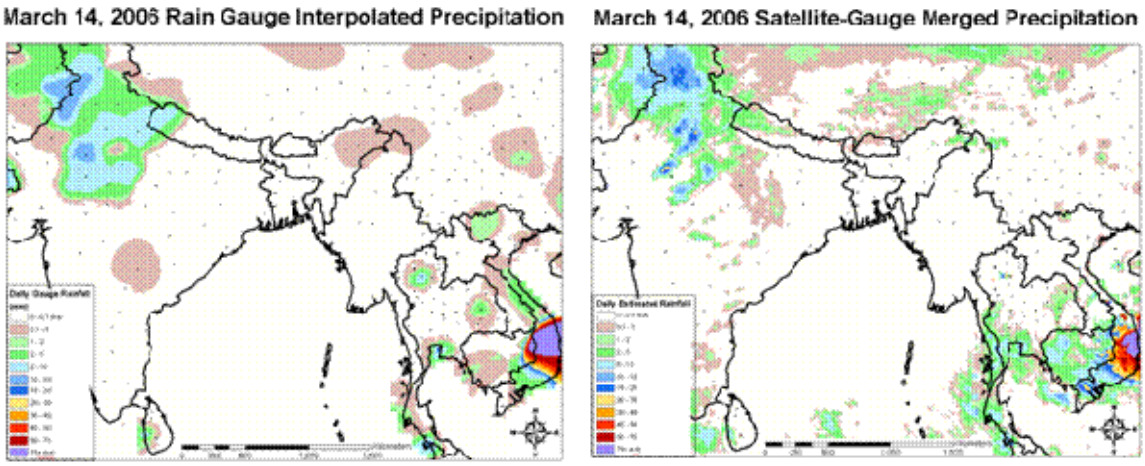

Figure 2. Rain gage versus satellite/gage merged precipitation estimates. (See poster session, T. Love and E. Wolvovsky.)

Although floods have significant impact in the region, droughts have also been prevalent in recent years throughout the region. RFE has been used in Africa and Central America to monitor potential droughts. Through his poster presentation, Dr. Husak will demonstrate the applications of RFE on potential drought monitoring in Asia. The work conducted by Dr. Husak and his colleagues demonstrate a process that uses spatially and temporally over-sampled RFE data to estimate distribution parameters for each pixel in a given interval. These distribution parameters can then be used in the development of a Standardized Precipitation Index (SPI), which measures the significance of an event by comparing it with the probability distribution. SPI is commonly used to monitor the performance of rainfall compared to a historical average of hydrological extremes such as droughts and floods.

Hydrometeorological Forecasting

Building capacities to forecast hydrometeorological parameters, such as rainfall, temperature, and river flow, is critical to providing sufficient lead time for warnings about potentially dangerous river and weather conditions. Modelling hydrological and meteorological processes is essential to response planning, not only for early warnings but also for ongoing management of water resources, agricultural planning, flood mitigation, navigation, scenario-based risk-evaluation, and environmental impact-assessments. Rainfall forecasts and potential evaporation data used in flood and river forecasting in Asia have been made available to MRC and ICIMOD through CPC.

The main causes of flooding in the Mekong, Ganges-Brahmaputra, Meghna river basins are either due to flash floods or river flooding. Due to its rapid-onset, limited warning procedures and emergency actions, the high velocity of water flows, and the associated debris flows, flash floods are the main cause of weather related deaths in many countries. Under AFN, MRC and ICIMOD also hosted flash flood guidance workshops in 2005. As an outcome of the MRC workshop, USAID/OFDA, USG partners, and MRC agreed to transfer technology for flash flood guidance, which was developed for seven Central American countries after Hurricane Mitch devastated the region. Mr. Jubach will provide a brief illustration of this Flash Flood Guidance system. He will also illustrate the capabilities of the Central America Flash Flood Guidance system and the potential implementation of a regional flash flood early warning system for the Lower Mekong River Basin.

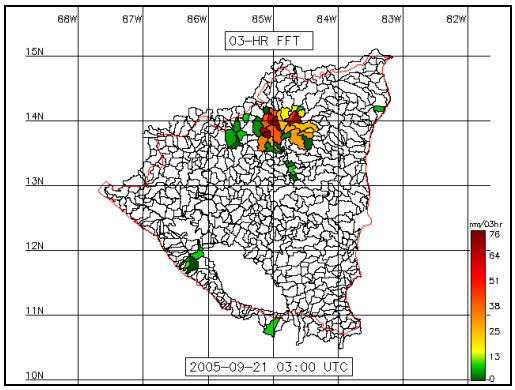

Figure 3: Example of Central America Flash Flood Guidance System product: flash flood threat. (See poster session, B. Jubach.)

The USGS Geospatial Streamflow Model (GeoSFM) application began as a project of USAID's Famine Early Warning Systems Network (FEWS NET). GeoSFM was designed to utilize NOAA satellite rainfall estimates, rainfall forecast data from the U.S. Air Force, and potential evapotranspiration data combined with Geographic Information System (GIS) data to provide data and parameter estimates for streamflow forecast models. After the AFN Satellite Precipitation Workshop, MRC and other participating representatives selected the Nam Ou and Se Done river basins in Lao PDR as the test basins. These two basins were selected because they contribute large flows to the Mekong and, therefore, have a significant impact on the Mekong River main stem forecasts. The GeoSFM is a physically based catchment-scale (semi-distributed) hydrologic model consisting of a GIS-based pre-processing module and a rainfall-runoff component. The rainfall-runoff component of the GeoSFM is a physically based hydrologic model with few parameter and variable input data requirements. This component of the GeoSFM has three main sub-modules, namely: water balance, catchment routing, and distributed channel routing. Dr. Artan will present in details how these basins were calibrated using GeoSFM and technical characteristics of the model.

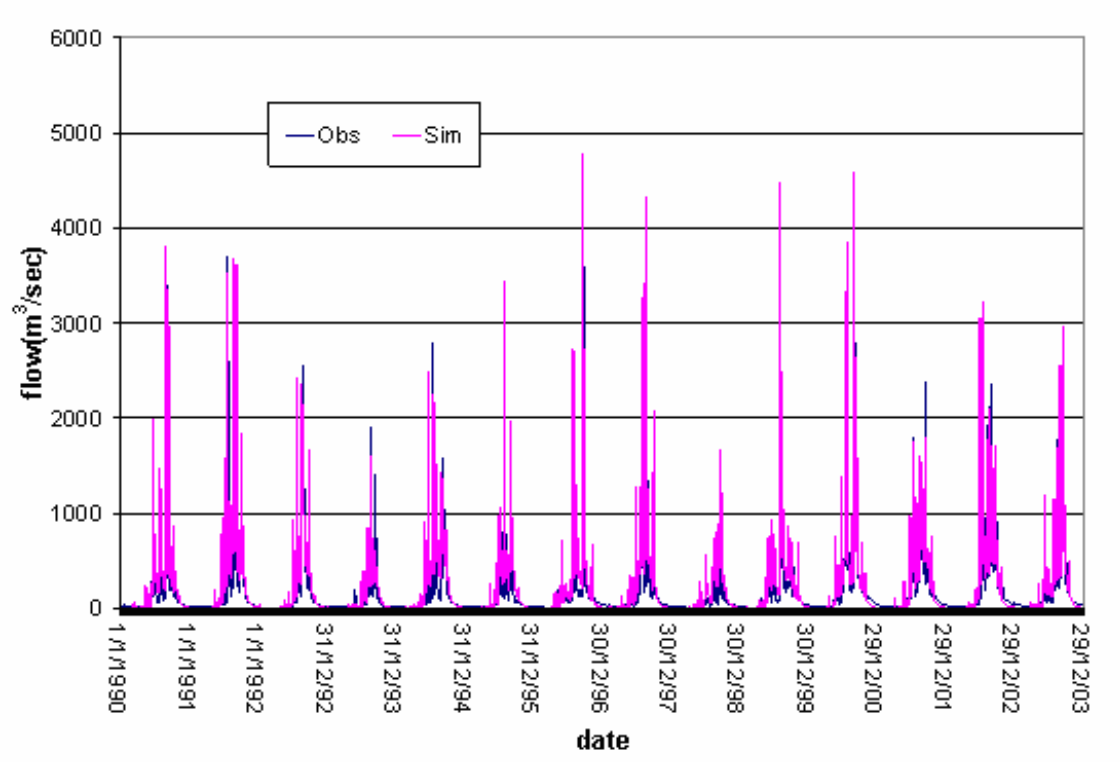

Figure 4: **Observed and simulated hydrographs from calibrated GeoSFM for the Se Done River at Souvanna Khili station. (See poster session G. Artan and G. Husak.)**

The National Weather Service River Forecast System (NWSRFS) is a fully functional operational river and flood forecasting system that is used in the U.S. to issue warnings, manage water resources, and guide navigation. The system has been implemented in a wide range of climates in both the U.S. and around the world as part of NWS technology transfer projects. NOAA, USGS, and USAID/OFDA are in the process of developing a hybrid NOAA-USGS system that would integrate independent developments from the two science agencies and apply them to the developing world. The Hybrid Flood Forecast System is well suited for application in data-sparse areas such as the Mekong River Basin. Dr. Day will illustrate the technical advantages of the system as illustrated in Figure 5.

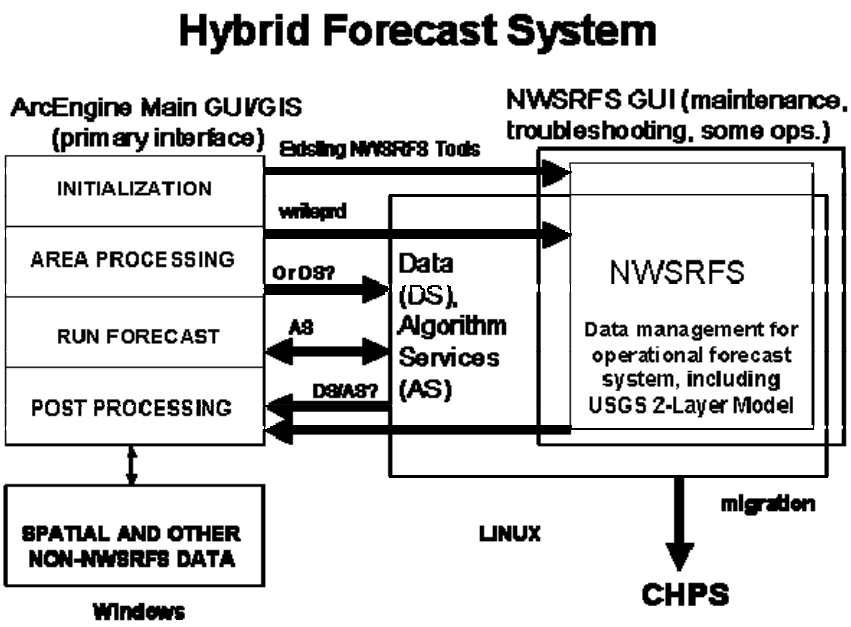

Figure 5: Hybrid NWSRFS and GeoSFM system. (See poster session, J. Day.)

Planning, Preparedness, Decision Making, and Coordination

For successful flood mitigation, decision makers must implement necessary measures such as planning for extreme events, developing policies for disaster management, warning affected populations, and providing coordinated and effective responses to disasters.

Dissemination of Information to People at Risk

State of the art technology and perfect forecasts alone can not save lives and property unless forecasts and warnings reach the populations at risk with sufficient lead time to take appropriate measures to reduce the impact of disasters. MRC and NOAA hold a workshop on implementing the Radio and Internet (RANET) technology in the lower Mekong River basin in 2005. RANET, used globally to improve dissemination of information to people in remote areas, is an international collaboration to improve access to weather, climate, and related development information for populations in remote and resource poor areas. The technology assists in day-to-day resource decisions and preparation against natural hazards. RANET identifies appropriate, low-cost communications technologies—primarily based on radio and internet standards—that can be used to augment existing communication systems in developing countries. A key tenant of the RANET program is local ownership and management. RANET depends on four critical components (see Figure 6) to move information from capital cities to rural communities. As a result of the workshop, NOAA and MRC received pilot project proposals from riparian countries. MRC riparian countries participated in the global RANET workshop recently and plan to implement pilot projects in 2006.

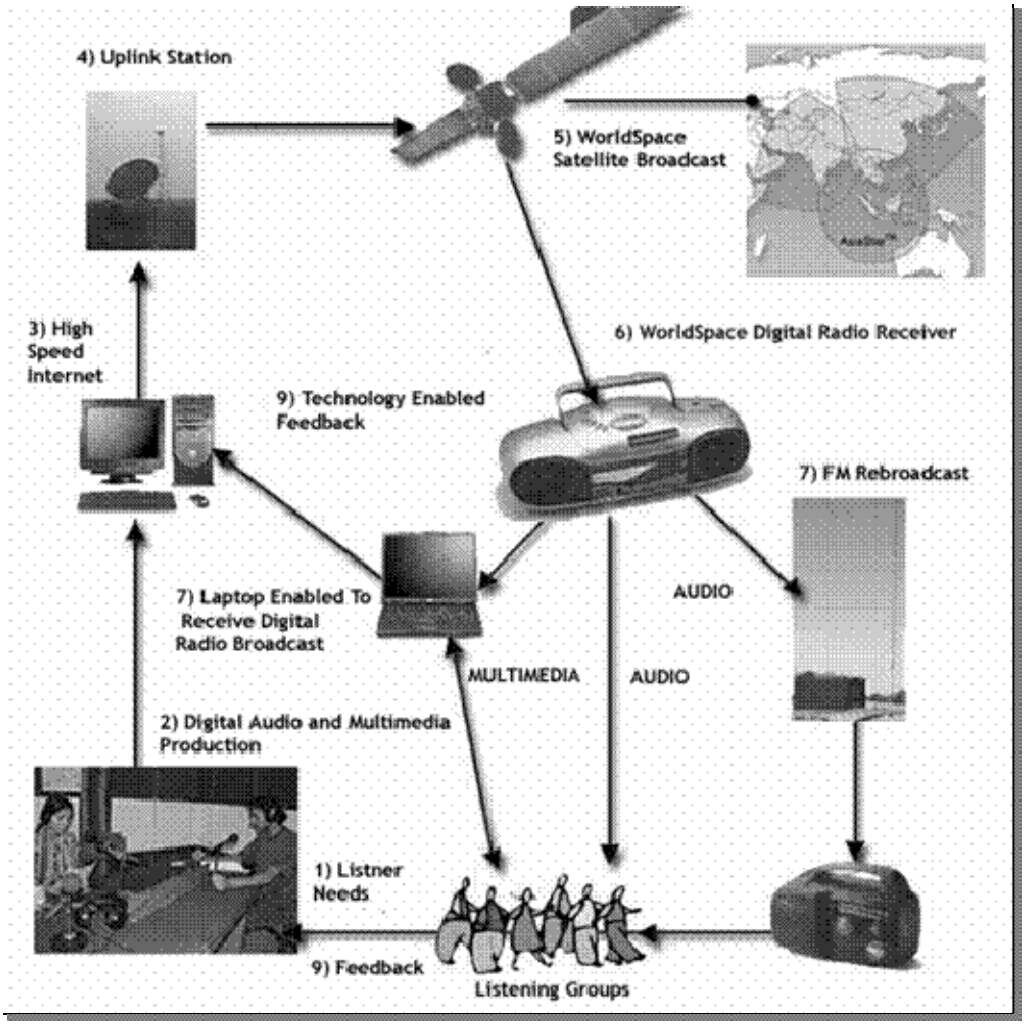

Figure 6 RANET Components.

Actions Taken by Population at Risk to Lessen the Impacts of Potential Hazards

USAID/OFDA has been supporting community-based preparedness and early warning projects in the region to raise community awareness and capacity to reduce vulnerability to extreme floods. USAID/OFDA and MRC have been implementing a community-based flood preparedness project in Cambodia in partnership with American Red Cross, Action Contra la Faim, and the Cambodian Red Cross. Another example is the community-based flood information system that has been implemented in Bangladesh by Riverside Technology, Inc., the Center for Environment and Geographic Information Services (CEGIS), and the Bangladesh Disaster Preparedness Center (BDPC). (See poster session by Dr. Martin et al.)

CHINA COUNTRY REPORT: NATIONAL FLOOD FORECASTING SYSTEM IN CHINA

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Abstract

This paper focuses on the key technologies for structure of flood forecasting model-base and flood forecasting schemes, and the coupling mechanism of model calibration with optimization algorithms as well as the interactive operational forecasting which fully exerts forecaster's knowledge and experience, enhances the efficiency of forecasting analysis and improves quality of forecasting production. Meanwhile, a technical system of the universal flood forecasting i.e. National Flood Forecasting System (NFFS) is built.

Key Words: Flood Forecasting, Forecasting Scheme, Parameter Calibration, Interactive Forecasting

1. INTRODUCTION

The Bureau of Hydrology (BOH) is a non-profit agency affiliated to Ministry of Water Resources (MWR) with administrative function. BOH takes the following responsibilities: managing hydrological sector all over China; organizing and providing guidance to monitor and analyze water quantity and quality of surface water and ground water as well as assessing water resources; collecting, processing and forecasting precipitation information and water regime for state key flood control areas and important large-sized reservoirs and providing decision-making support to State Flood Control and Drought Relief Headquarters. The division of hydrological information and forecasting (DHIF) supports this mission not only by providing flood forecasting and warning for the protection of life and property and but also basic hydrological information for improvement of economy and environment. The hydrological experts of DHIF have been designing, developing, testing and implementing a hydrological forecasting system i.e. the National Flood Forecasting System (NFFS). In future, NFFS will be developed and applied in hydrological forecasting sectors of BOH in 31 provinces and 7 large river authorities as well as 244 local hydrological centres in China. It will improve significantly the modernization level of hydrological information and forecasting in whole country and provided a great deal of flood forecasting achievements with long lead time and high accuracy to the flood control and decision-making sectors in recent years.

2. BACKGROUND

After late 1980s, with the popularity and evolution of computer technology, varied flood forecasting software were developed respectively by hydrological information and forecasting sectors in different levels. However, owing to lack of uniform management, these locally developed software programs introduced three major problems into flood forecasting. First, this independent software was developed according to specifically requirement and objectives. With the hydroclimatic variation in China from humid to arid conditions, there is no flood forecasting system which include all the features needed to model the flow in rivers in the varied hydrometeorologic regimes. Second, this software had a rigid program structure which made it difficult to add new modules as additional features were developed. The hydrological modelling structure required that all basins use the same models in a fixed sequence. Third, the software was dependent on the individual who did the initial development. When that person changed jobs or retired, much of the knowledge of how to run the programs, or how to maintain or enhance the programs was lost. Hence, by 1998 there is no a uniform flood forecasting system to be developed and applied in China.

3. NATIONAL FLOOD FORECASTING SYSTEM

In late 1990s, with the implementation of National Flood Control Command System project, the uniform standard real-time database has been built in hydrological information centres of national, provincial and local BOH. It supports the technique basis for NFFS. In 1998, the BOF of MWR began a project to design the structure of NFFS. A major objective of the project was to develop a system structure which looked toward the future of flood forecasting. The basic design requirement for NFFS is (1) to found standard advanced software and hardware configuration based on the uniform standard real-time database and client/server environment, (2) to adopt modular structure to easily add new models and procedures to keep up with technological changes, (3) to let the user control the selection of models and the sequence of use, (4) to have a model calibration system which combined manually and automatically calibration method, (5) to allow the user to flexibly control real-time processing and use graphical and tabular interface for interactive forecasting, (6) to efficiently process large amounts of data to produce forecasts at hundreds or thousands of locations, (7) to have integrated powerful flood forecasting management function.

At present, the major parts of NFFS is shown as following:

(1) Software and hardware configuration of NFFS

The software and hardware configuration of NFFS includes computer hardware platform, computer operating system above Windows 95/98 and standard real-time database as well as client/server environment. The NFFS software can be installed in client computer. There are two supporting database i.e. IDBS and FDBS which be constructed in server (see Fig1). IDBS is the real-time database. FDBS is forecasting database to store the model code, parameter, state, flood forecasting scheme, forecasting result, historical hydrometeorologic data, basin geography information system (GIS) and user information. NFFS is developed based on GIS which have a powerful capacity to display and manage river, topography, basin boundary, gauging station distribution, Thiessen polygon boundary, real-time and forecasting information query for forecasting location.

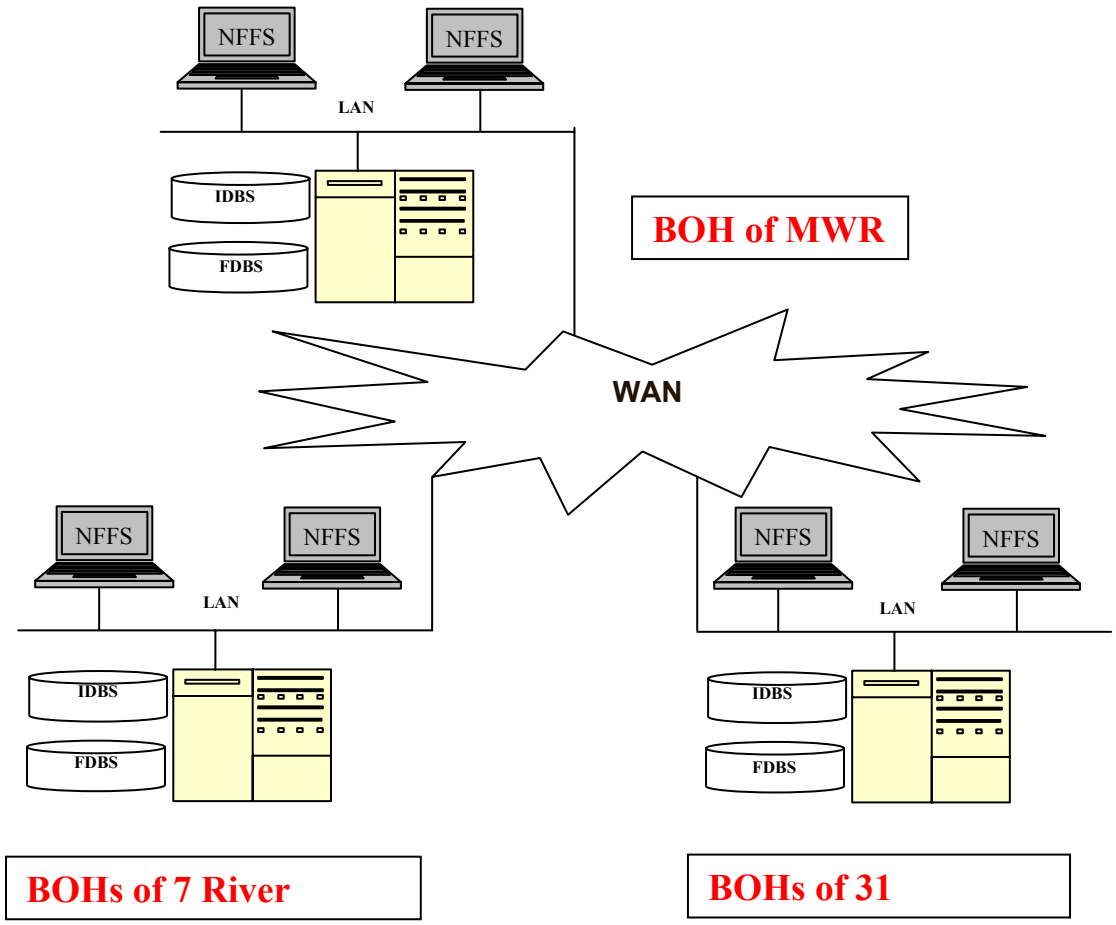


Fig 1. NFFS's Environmental Structure

(2) Flood forecasting models and methods

NFFS adopts complete modular structure so that modules can be independent of system and components could be developed by a number of individuals. The user can easily add new models and methods based on standard I/O files form and flexibly select a set of models and methods to build a forecasting scheme for any basin. At present, hydrological models in NFFS can be selected from the following list:

Soil	Xinanjiang Soil Moisture Accounting	SMS_3
	Sacramento Soil Moisture Accounting	SAC
	Rain-Runoff correlation Method	P_RZHJR
Channel	Lag and K Routing	LAG_3
	Muskingum Routing	MSK
	Unit Hydrograph	UH_B
	Diffusion Wave Model	KSB
Utility	Empirical Model	P######

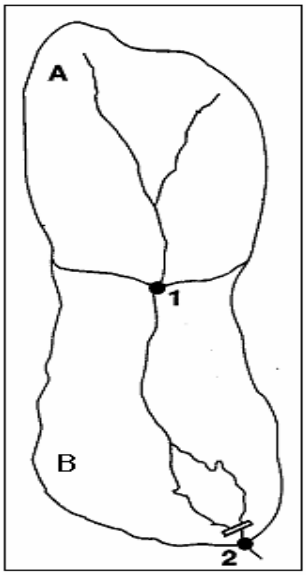
Reservoir regulation	Independently controlled reservoir regulation under various modes of operation	RES_SNGL

These hydrological models were compiled to dynamic link libraries with 32 bit as outer function.

In NFFS, there are 9 variety of standard I/O files including model parameter file, model initial state file, water level and discharge input in same interval time file, observed water level and discharge input file, point rainfall input file, areal rainfall input file, net rainfall I/O file, model terminal state file, water level and discharge output in same interval time file. These 9 files can be stored in one file according to fixed sequence of use as module interface parameter. If any I/O of conceptual model or empirical model can be programmed based on above description, it will be a general standard forecasting model.

(3) Forecasting scheme

The flood forecasting schemes embody that a set of models and methods selected considering the features of related rivers. The user can found and manage easily forecasting schemes for consecutive forecasting from upstream to downstream by friendly human-machine interface in NFFS. The processing include inputting basin code, lead time of forecasting scheme, basin boundary, code of gauging stations selected, weights of precipitation stations, parameter, state, interval time, warming time of models selected, rating curve, warning threshold and illumination (see Fig. 2).



SMS_3	Area A
LAG_K	Area A to Point 1
MSK	Point 1 to Point 2
SMS_3	Area B
LAG_K	Area B to Point 2
ADD/SUB (Runoff)	Area A + B
ADJUST-Q	Point 2
STAGE-Q	Point 2 (Q→H)

Fig 2. The Process of Forecasting Scheme Foundation

(4) Model calibration

Calibration of model parameters can be completed well by error-trial and automatic calibration methods based on human-machine interface in NFFS. The Simplex and Rosenbroke optimization methods were adopted in calibration module of NFFS. The independent calibration module is only related to parameters optimized and objective function selected so that the module can be easily updated (see Fig 3.).

Two objective functions i.e. coefficient of determination and water balance can be selected. Threshold of objective function can be selected according requirement of user.

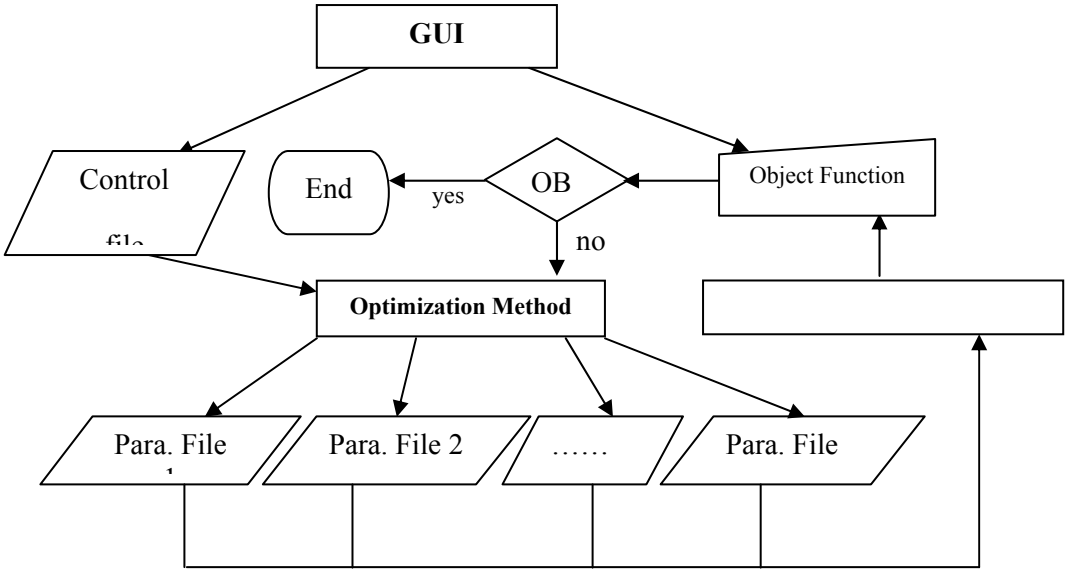


Fig 3. The Process of Parameter Optimization Calibration

(5) Real-time operational forecasting

In NFFS, there are interactive forecasting and automatic timing forecasting. The automatic timing forecasting means NFFS can automatically accomplish forecasting by forecasting scheme and sequence selected, even every hour. Interactive forecasting can provide the information to forecaster for the correction of data and simulated results. The interactive forecasting module can deal with rainfall input, rainfall in lead time, runoff input, model parameter, model state, rating curve, results and adjustment optimization by graphical interface (see Fig.4). Forecasting error statistic module can analyze all forecasting results for any forecasting location to compare the accuracy of forecasting schemes and assess capacity of forecaster.

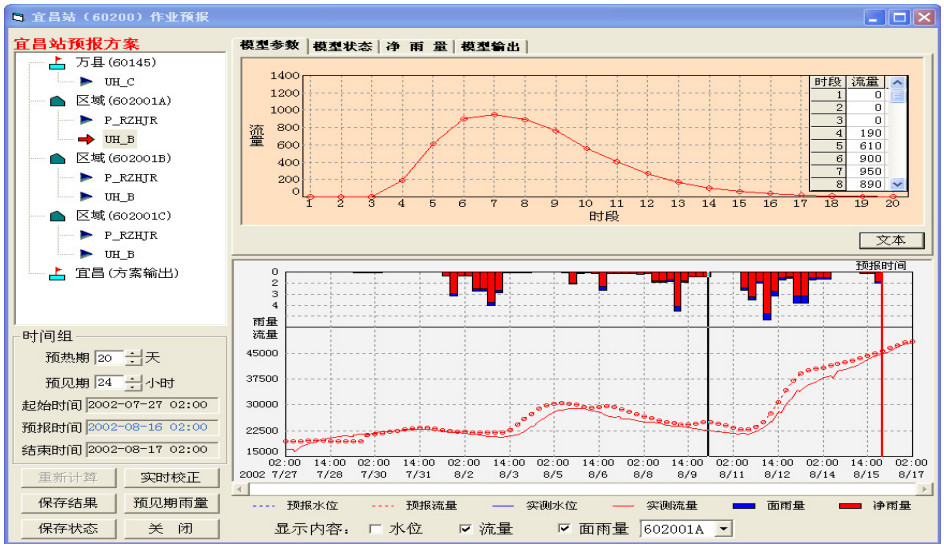


Fig 4. Interface of real time operational forecasting

(6) Utility modules

In NFFS, a number of data processing modules were developed, including model parameter file production module, model state file production module, three-dimension map display and query module, automatic generation of catchment boundary module (see Fig.5), Thiessen polygon area calculation module, point rainfall in same interval time calculation module, rainfall distribution module, water lever and discharge conversion module, forecasting error adjustment module and forecasting scheme I/O module etc.

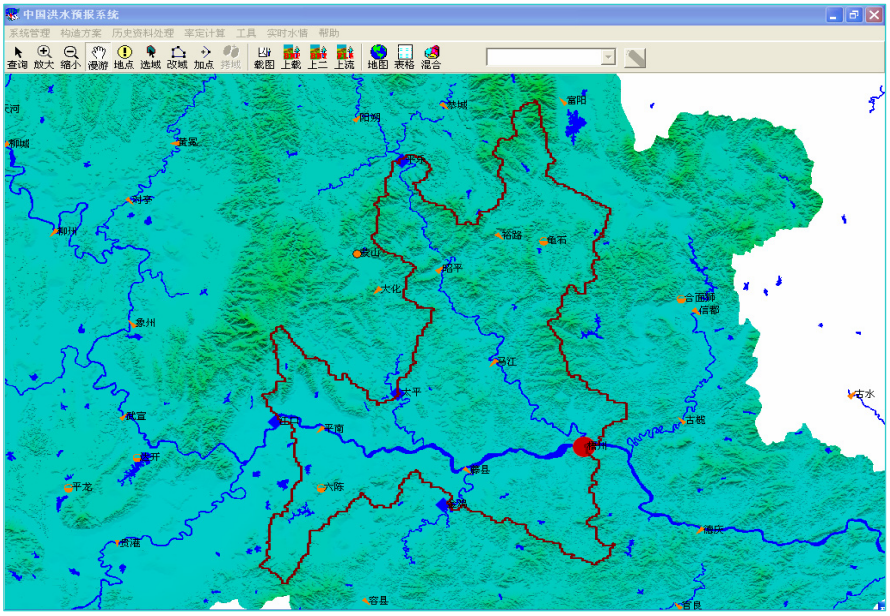


Fig 5. The module of automatic generation of catchment boundary

(7) System management

NFFS has powerful system management function including user management, forecasting model management, forecasting scheme management, hydrological station management.

User management includes administrator, general user. Administrator can add, delete and modify forecasting model, distribute forecasting scheme, manage automatic timing forecasting, user information; General user can construct, delete, modify, calibrate and operate its own forecasting scheme. Hydrological station management includes system station management and scheme station management. System station management can add, delete, modify the feature of hydrological station in electronic map by SA; Scheme station management can add, delete modify the precipitation station used in scheme by general user.

4. SUMMARY

The main conclusions are summarized as follows:

(1)The paper studies a set of unified standard data interface and management system to found flood forecasting model-base which possesses the basic characteristics of software reuse, independence, unification and expansion.

(2)The paper presents the management system of forecasting scheme, indicates the structure of flood forecasting scheme which can be finished easily and quickly based on man-machine interface.

(3)The paper shows the standard data interface between coupling mechanism of model parameters calibration with optimization algorithms.

(4)The paper demonstrates all kinds of man-machine interactive interface in the process of manual flood forecasting so that it is helpful to quicken the speed of forecasting analysis and to promote the quality of forecasting production.

Based on the key technology frames mentioned in this paper, the National Flood Forecasting System has been developed and applied successfully to 22 kinds of hydrologic sectors in both Ministry of Water Resources and provinces.

5. ACKNOWLEDGMENTS

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