CONTINUING EDUCATION FOR CHANGING HYDROLOGIC FORECASTING REQUIREMENTS

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We are in an era of rapid change in hydrologic forecasting methodology brought about by major technological advances. Implementation of this new technology is in progress now and will result in major improvements in our Nation's capabilities to forecast weather, river stages, floods, and water supplies. These advances in technology are affecting the way all government and private water agencies do business and in turn will dictate important changes in continuing education designed to meet the operational and the research and development workforce requirements of the future. Elements of new technology which already exist, are currently undergoing implementation, or are planned for implementation will affect all aspects of the forecast system, ranging from data acquisition and processing to hydrometeorological analysis and modeling. While these new advances are generic to many of the water agencies and users, my subsequent comments are based on those pertaining to the hydrologic service of the National Weather Service (NWS) and its cooperators.

Improvements in hydrologic forecasting procedures are being effected for all scales (forecast lead times) ranging from flash flood conditions to extended streamflow predictions for water management applications. A significant element for improvement of forecasts at all scales is improved hydrometeorological data information and its management. The forecast systems of the future will incorporate a high degree of data automation from in situ, as well as remote sensors, such as weather radars and satellites. Effective use of these data will depend on enhanced and distributed data processing facilities, standardized data transmission formats and communication protocols, automated quality control and data processing, objective multivariate data analysis procedures, and efficient data base management procedures. Thus, continuing education must cover those specialized aspects of data systems in their component parts and in their integrated design relationships as they affect more comprehensive and timely data gathering -- essential elements of a complete forecast system.

The use of weather and climate forecasts is another important aspect of incorporating hydrometeorological information into the hydrologic forecast system. Since the uncertainty of weather and climate forecasts is still large, even at the current state of the art for many hydrometeorological conditions, these uncertainties must be considered objectively as part of the methodology applied in the hydrologic forecast system. Development and application of such objective procedures will require that the hydrologist be versed in mathematical and statistical/probabilistic techniques. Since the most effective utilization of available hydrometeorological information will require objective techniques for weighting, integrating, and updating the data and modeling components of the forecast system, an overall goal for continuing education should be to provide the hydrologist with an adequate background in

various estimation theory procedures. Implementation of these procedures will become increasingly important as the volume and characteristics of the hydrometeorological information increases and as we move toward more automated systems.

Equally important to the acquisition and application of hydrometeorological data and information, which feeds the hydrologic forecast system, is the development and implementation of a suitable variety of hydrologic models. The complexity of the modeling portion of the system may vary greatly, depending on use, available data, and associated calibration difficulties. Generally, the modeling subsystem will increase in complexity as the application moves from a simple headwater situation to multiple watersheds with varied physiographic conditions and complex river mechanics and reservoir considerations. The models should replicate the physical processes of the watersheds and river systems which they represent to the maximum degree feasible. The degree of physical realism that can, or should, be modeled will depend on many factors, including the modeler's knowledge of the physics, data availability, computer resources, the accuracy sought for the particular application, and overall feasibility of model implementation. A challenge for continuing education is to not only provide training on hydrologic modeling principles but to provide the hydrologist with: 1) an overall perspective of practical limitations in the use of a particular modeling approach for given applications and conditions and 2) an overall understanding of the model's relationship to the other parts of the forecast system, especially the hydrometeorological data and information which drive the model.

Other aspects of hydrologic modeling which should be considered in concert with development of a model are the requirements for model calibration and model design features which will facilitate: 1) linkage to other components of the modeling system; e.g., the dynamic coupling of a rainfall-runoff model with a precipitation model, 2) automatic updating of model states, and 3) incorporation of remotely sensed information. Again, the intended model application will govern the relative importance of various model design characteristics. For example, efficiency of calibration may not be a big issue if the use of the model is restricted to a few areas for planning or design purposes, but it certainly becomes a significant issue if the model is to be implemented as part of a national forecast system. Continuing education for the hydrologist should provide sufficient breadth of understanding so that he/she can think in an integrated system sense appropriate to the application. This aspect of continuing education is becoming increasingly important as our world is undergoing explosive orientation toward hardware and software systems.

The aspects of hydrologic forecasting and associated continuing education raised above indicate that various mechanisms and levels of training should exist to ensure that our Nation's hydrologists remain prepared to meet the challenges of the future. These challenges must be shared and met by the educator, the researcher, and the operational hydrologist in order to meet a number of training objectives. Some specific training objectives to consider

include:

- firm grounding in fundamental principles of hydrologic response but with increased emphasis on coupling meteorologic phenomena. Essentially, training is required in both hydrologic and meteorologic sciences.

- familiarity with modern hardware and communication systems and associated software systems.

- understanding of the basic principles and specific technologies used for hydrometeorologic observations, especially remote sensing technologies such as weather radar and satellites.

- understanding of probability, statistics, and estimation theory which will be increasingly applied to data quality control, data analysis, model calibration, and model updating.

Meeting these training objectives will require not only continuing traditional educational mechanisms but also new training mechanisms. Some specific educational mechanisms which are appropriate to consider include:

- strengthening ties between operational water agencies and the university community so that university curriculum planning can be updated as a result of advances in science, technology, and operational procedures.

- collocated university/government operational training facilities.

- agency sponsored training at national and/or regional training centers.

- careful consideration of training needs along with new system acquisitions so that the full cost of system implementation, including training costs, is allowed for.

- increased use of on-site training and more sophisticated training technologies such as video instruction and computer-aided instruction.

- coordination of university research projects through cooperative research arrangements with sponsoring and operational agencies.

- technology transfer programs designed to include educational documentation for national and international use.

<u>Summary</u>

The hardware and software systems applied to hydrologic forecasting, the mathematical models producing forecasts, and the sources of data used by

forecast systems are all simultaneously in a period of rapid change. The mix of skills required of the Nation's hydrologic forecasters and water managers is likewise undergoing rapid change. These changes create a strong challenge to develop innovative and cost-effective training mechanisms so that potential improvements in the Nation's capability to forecast weather, river stages, floods, and water supplies can actually be realized.