# A view of hydroinformatics in the United States

The 4th International Conference on Hydroinformatics, hosted by the Iowa Institute of Hydraulic Research, is the first time the conference has been held in the United States (July 2000). To coincide with the conference, papers in this issue of the Journal have been selected to highlight some activities related to hydroinformatics in the United States. In selecting the papers for publication, it has been very interesting to contrast the evolution of hydroinformatics in the US with other countries and in particular with Europe.

There is a range of precise definitions for hydroinformatics. Adopting the broadest definition as being the merging of the traditional fields of computational hydraulics with information technology for managing aquatic resources, the critical need for this field is evident. For example, a hydraulic model may be the best possible simulation tool for flood risk assessment. However, if this model cannot be integrated with other assessment tools to respond to broader ecosystem and social questions, it is unlikely that the flood risk model will be adopted. Typical complex questions associated with a proposed flood management project might include: (1) altered rates of sedimentation and dredging, (2) geomorphic changes to the channel and wetlands, (3) timing, quantity and depth of flows throughout the year (hydroperiod), (4) influences on water quality during different seasons, (5) effects on the aquatic, terrestrial and avian ecosystem (particularly any rare or endangered species), (6) reduced navigation, (7) changes to infiltration and evaporation losses, (8) increases or decreases to property values, (9) land use planning issues (for example, will development occur on flood-prone lands following implementation of a 'flood protection' project, and (10) altered public access, recreation and aesthetics. In many countries, any one of these issues could potentially stall or cancel a project or management plan. The flood simulation model must be able to integrate with GIS and a range of other models whilst ensuring the model functions remain transparent, defensible and flexible. If the model cannot provide this capability, then a simpler conceptual type of model will likely be used. Recognizing a critical need for this level of complex simulation (for example, Abbott 1991; Imberger 1997), interdisciplinary groups began to emerge that expanded beyond computational hydraulics and reached out to other disciplines. In many countries, this shift has been institutionalized and directed by governmental agencies. Examples are Delft Hydraulics in the Netherlands, Danish Hydraulics Institute (recently merged with VKI) in Denmark, HR Wallingford in the UK, the German National Research Center for Information Technology, LHF in France and the Center for Water Resources in Perth, Australia. The advantages of these centers are that there is some institutional stability, strategically allocated resources and continuity of personnel.

In the US, there is no direct counterpart to these large centers and many simulation tools have started with individuals in research institutions. For example, FLUVIAL-12 was developed by Dr. Howard Chang at San Diego State University and is used extensively to simulate the dynamic and mobile river systems in southern California. Although technically sound, access to the codes by the general environmental management profession is limited and in another region, an entirely different model might be used. The great advantage of this distributed approach is that innovation and individual ideas are less likely to be stifled, but suffer from the lack of a critical mass of personnel and resources to support the codes widely. Obviously, notable exceptions exist including the growth of GIS tools such as ArcInfo and ArcView developed by the Environmental Systems Research Institute, Inc (Redlands, California) and the widespread use of the MODFLOW code through the United States Geological Survey (USGS). As a further example, probably the most frequently used hydraulic models in the world (the HEC suite of programs) are generated and supported through the Hydrologic Engineering Center (US Army Corps of Engineers) in Davis, California with only about 30 full-time employees. Most technical support, ancillary processing software and training is provided by enterprising third party commercial groups. When major codes are offered through government agencies at no distribution or acquisition fee, then there is no reliable continuing stream of funding to refine the technical elements of the program. Program development or interfaces occur primarily in response to a commercial opportunity or need that makes operation of the software faster or easier. In comparison, the major European groups can develop longterm development strategies and have technical staff sometimes in the hundreds. There are advantages and disadvantages to both systems but what is likely to happen in the next decade? A range of visions from some major strategic initiatives in the US include:

## Hydroinformatics and the National Science Foundation

The National Science Foundation (NSF) has long supported research on modeling to expand the frontiers of water science and also focuses on ways to promote sound applications of the gains in understanding in solving practical water management problems. Models have been developed that integrate hydrology with geochemistry, microbiology, ecology, mathematics, meteorology, and other disciplines. The larger goal has been to quantify the broad range of relationships that can be used in managing water to serve societal needs. Some programs work in the confines of a specific water science while others engage inter-disciplinary and inter-agency participation. These programs have become springboards for water research planning both within NSF and in league with other Federal agencies.

Three examples may be useful. A large recent initiative at NSF has been in ‘‘Biocomplexity’’, focused on interdisciplinary work to quantify and understand relationships between physical heterogeneity and ecological diversity and their dynamics. A recent NSF-sponsored workshop, by a group called WEB (Water, Earth and Bios) has concluded that advances in hydrologic science are obstructed by not having consistently organized data collected over time to support cross-disciplinary work and is moving toward recommendations for addressing the situation. Thirdly, NSF is beginning support for SAHARA (Sustainability of Semi-Arid Hydrology and Riparian Areas), a Science and Technology Center at the University of Arizona to make practical applications of advances in hydrologic science to water management applications in a part of the country where water shortage is becoming increasingly critical.

In the lead in this journal, ‘‘Introducing Hydroinformatics’’ Michael Abbot presents the dificult task of persuading ‘‘one another in more equitable ways’’ in a world where water approaches the ‘‘level of the religious’’. He concludes with words that strongly echo the experience of the hydrology program at NSF in that the ‘‘aim of ‘building community’ remains as a beacon towards which we must constantly steer’’. Even though we seldom use the word ‘‘hydroinformatics’’, this is what water research at NSF is all about.

by Douglas L. James, Program Director, Hydrologic Sciences
National Science Foundation, Arlington, Virginia. April 2000.

## Hydroinformatics in the Columbia Basin
## Ecosystem Diagnosis & Treatment Model (EDT)

The EDT method is a landscape-based approach for relating events and actions affecting animal populations and their habitat to the long-term performance of species of interest. The EDT method incorporates a conceptual framework, a procedure, and a set of informatics tools. The framework provides the theoretical foundation, the procedure prescribes the steps in planning and analyzing ecosystem information in support of decision-making, and the tools are the databases and model components used to organze, analyze, and summarize information. Development of EDT was funded largely through the Northwest Power Planning Council (NPPC) Fish and Wildlife Program and in response to the need for a clear and explicitly stated framework to serve as the rational, scientific basis for the program. EDT addresses cumulative effects of a range of environmental parameters distributed spatially throughout the ecosystem. It is a tool for tracking the operating assumptions upon which adaptive management action plans can be built. EDT can be used to:

- develop working hypotheses regarding action priorities; for example, diagnose salmon performance problems and identify treatment alternatives;
- develop and document working hypotheses—the conditions required to achieve specified objectives—for detailed and comprehensive action alternatives;
- assess potential benefits and risks associated with incorrect operating assumptions—in other words, analyze consequences under alternate hypotheses;
- identify key uncertainties to guide research, monitoring and evaluation.

EDT is an expert system and, as such, differs from statistical models in both purpose and design—a key distinction. Expert systems seek to be comprehensive and explanatory. They generate hypotheses rather than test them, and they formulate operating assumptions upon which actions can be based and risks understood. C. S. Holling states the distinction in another way *". . . reductionist science, i.e. the science of parts, was essential to provide bricks for an edifice, but not the strategic design of the edifice. Such strategic design is needed for appropriate diagnosis and policy, and it has to emerge from a science of integration. A science of integration combines research and application, is interdisciplinary and faces the realization that knowledge of the system we deal with is always incomplete".*

EDT is a tool for building hypotheses. It depends upon the results of statistical analyses to formulate new hypotheses, which in turn can be tested through statistical models. It is a framework for integrating results from statistical analyses with knowledge and opionions from all relevant scientific disciplines. Expert systems like EDT consist of data linked to conclusions through a set of rules. EDT was conceived to be flexible so that new knowledge, information, and data can be incorporated, thus allowing the expert system to remain current. At the heart of EDT is the structure that defines how data and rules are linked. This temporal-spatial-conceptual architecture of data and rules is the Framework as defined and explained in the Multi-species Framework process. The data and rules themselves are more ephemeral and replaceable.

EDT computes future capacity, productivity and diversity of salmon in the Columbia Basin as a function of: a) the bank of genetic resources embodied by the animals alive today and b) the environment available to them. The current version of the EDT expert system, while incorporating genetic fitness factors, has a primarily environmental focus. EDT constructs "survival landscapes" that describe the patterns of survival conditions for salmon over time and space. EDT assesses the *quality* of the habitat in regard to the biological template of specific species, such as chinook salmon. The specific purpose of the application of EDT in the Multi-species Framework analysis was to compare a set of comprehensive visions for the Columbia Basin in terms of the prospective performance of salmon populations in each of ten ecological provinces (a total area in excess of 58 million hectares). The first stage in this analysis focused on chinook salmon. Based on available environmental descriptions of some 7,500 spatial habitat units for the Columbia River basin as well as information on hatchery production, harvest, and hydro operations, EDT projected productivity, capacity and diversity for 73 natural and 50 hatchery populations of chinook salmon under 10 different scenarios. These scenarios included the current, historic, no-action conditions as well as seven alternative futures for the Columbia River Basin. the analysis represents the long-term average performance and survival potential for chinook salmon.

by Peter Paquet & Chip McConnaha
NORTHWEST Power Planning Council, Oregon. April 2000.

## Hydroinformatics and Future Directions for HEC Software

The mission of the US Army Corps of Engineers Hydrologic Engineering Center (HEC) is to support the Corps in its water resources management responsibilities. This is accomplished by increasing the Corps technical capability in hydrologic engineering and water resources planning and management and providing leadership in improving the state-of-the-art in hydrologic engineering and water resources planning. By means of programs in research, training, and technical assistance, HEC maintains awareness of the problems and needs of the Corps and the nation. A commitment is also made to keep abreast of the latest developments throughout the profession, and to make use of this information in a manner best suited to the needs of the Corps. One of the main products of HEC is software for use by Corps offices engaged in water resources management activities. The current family of HEC programs is the result of 30 years of program development activities. The software is widely used by other U.S. federal, state, and local government agencies, private consultants, and international institutions. The software is available through the worldwide web and is in the public domain.

In recent years, HEC has been actively modernizing and replacing several of its major software packages by taking advantage of advances in engineering and planning technology, and developing new source code using contemporary engineering and computer science standards on desktop computing environments. This successor software (Nexgen) is designed for interactive use as single station programs or for use in multi-tasking, multi-user network environments. The river analysis (HEC-RAS), hydrologic modeling (HEC-HMS), and flood damage analysis (HEC-FDA) software packages have been released, with main development for reservoir systems analysis planned for 2000.

The HEC software makes use of a common data management system (HEC-DSS) that is publicly available. This approach provides a mechanism for facilitating integration with other Corps and non-Corps software. HEC also has adopted a standardized format for data exchange with GIS systems.

The current philosophy of providing the successor software for both the U.S Army Corps of Engineers and as public domain software to the profession at large will be continued. Concepts of object-oriented software design offer significant potential benefit in future software development, improvement, and maintenance. New codes adopt published hardware and software standards where available, and de facto standards otherwise, to maintain software platform portability. The technical difficulties of migrating HEC software development from a batch Fortran era to that of a multi-platform, object-oriented, GUI-based culture has not been trivial, but is paying substantial dividends now, and will continue to do so in the long run.

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In this issue, a very limited but representative range of activities from the field of hydroinformatics is presented. Dr. Goldberg, a pioneer in the application of genetic algorithms in engineering, provides a review and future directions of this field in helping understand complex natural systems. Drs Hamlet and Lettenmaier provide an overview of climate change modeling, and their recent research shows significant potential consequences in managing water resource systems for irrigation, flood management and water supply. If these projections of climate change prove to be correct, many re-operation studies may be required in the Western states in the next decade. Dr. Tuthill et al. provide an example of the level of technology being employed in one state to adjudicate water rights and ensure that scarce water is distributed in a fair, legal and defensible manner. The consequences of this adjudication program is vital to regional agriculture and the state's economy. The increasing role of decision support software that can be operated in a group environment of stakeholders is illustrated by Dr. Jankowski. Finally, one of the most prominent and complex projects in the United States – the management and restoration of the Florida Everglades is profiled by Dr. Loucks.

Clearly, the rapid development of tools to simulate aquatic ecosystems or integrated hydrologic, ecologic and economic models indicate that we are just at the beginning of a new era of computational ability. It will be interesting to observe whether the distributed development of these tools in Universities or small commercial businesses prevalent in the United States prove to be more effective in fostering innovation than the more traditional centralized research institutions.

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