INTRODUCTION TO MODELS

Kenneth G. Renard[1]

Computer simulation models that implement mathematical expressions of physical processes are powerful tools for both research and practice. The advances in computer modeling have closely paralleled the development of computers in general and specifically in personal computers. As computers have decreased in price and physical size, yet increased in problem-solving capacity and speed, our ability as engineers and scientists to emulate prototype systems has progressed until we can now postulate models that are more complex than our ability to make prototype measurements with which to validate model components.

The US Congress recognized the potential of models in successful planning of water resources. They then instructed the Office of Technology Assessment (OTA) to (1) assess the nation's ability to use models efficiently and effectively in analyzing and solving water resource problems and (2) make recommendations for improving the use of available technologies. The OTA Report (1982) stated:

> "Mathematical models are among the most sophisticated tools available for analyzing water resource issues. They can use the capabilities of today's digital computers to perform and integrate millions of calculations within seconds in order to understand and project the consequences of alternative management, planning, or policy-level activities. Models not only assist in decision making--they provide information that people must interpret in light of existing laws, political and institutional structures, and informed professional and scientific judgment. Nonetheless, models can significantly improve the informational background on which decisions are based, and substantially reduce the cost of managing water resources."

An excellent introduction to the subject of model classification by Woolhiser and Brakensiek (1982) points out that although criteria used in model classification vary (the criteria vary with special interests or the needs of a particular discipline), models can generally be classified as either "formal" or "material" as suggested 40 years ago by Rosenblueth and Wiener (1945). A formal (intellectual) model is a symbolic, usually mathematical, representation of an idealized situation that has an important structural property of the real system. This is the most common model type used in natural resource problem solving. A material model is a physical representation of a complex system having a simpler structure than the real system, yet preserving the most important properties of the prototype. The iconic model (a look-alike) is a simplified version of a prototype system which uses the same materials as a prototype (e.g., a hydraulic model uses a fluid although not necessarily the same as the prototype fluid). Rainfall simulators, lysimeters, and experimental watersheds are other examples of iconic models. In an analog model, the model quantities measured are of a different substance than in the real system. One of the most common analog models is one which measures the flow of electric current to represent the flow of water. Material models were dominant in water resource problem solving up to a decade or so ago, but they have been largely replaced by mathematical models. The results of experiments with rainfall simulators, lysimeters, plots and experimental watersheds provide most of the validation tests for mathematical models.

A theoretical model includes both a set of general laws, or theoretical principles, and a set of statements of empirical circumstances. On the other hand, an empirical model

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omits general laws (e.g., law of physics), and is, rather, a representation of real-life data (the Universal Soil Loss Equation (USLE) being a well known example). Thus, in an empirical model such as a regression relationship, two variables may appear to be physically related (and thus a theoretical model) when, in fact, they are not.

Other model classifications involve such things as the analytical tools used. For example, models may be stochastic, system (also called "magic" or "black box") models, or analytical component models (using the physics of a process(es) to produce a required output). This later model, also referred to as a causal model is increasingly the more common model concept and should provide the greatest flexibility to evaluate management alternatives. In practice, many models actually involve combinations of these modeling techniques.

Finally, model development generally consists of: (1) problem definition, (2) system identification, (3) decisions on model type, (4) mathematical formulation, (5) decisions on computing methods, (6) programming, (7) parameter estimation, (8) validation, and (9) experimentation.

Some pitfalls associated with physically-based hydrologic models enumerated by Ferreira and Smith (1988) are discussed.

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