Chapter 7. Modeling Issues

The purpose of developing a hydrologic and water quality model of the Fox River watershed is to create a tool to assist with watershed decision-making for attaining water quality standards and developing sustainable management measures. The model can provide insight to sources and impacts of nonpoint and point sources of pollution, simulate water quality conditions of alternative scenarios for future land-use practices and effluent loading to the system, and help in designing and assessing alternate management practices to reduce such impacts. A variety of water quality computer models can be customized to represent a given watershed. Many factors need to be considered in selection of the most appropriate model for the given circumstances and desired output information. This chapter includes background information on types of water quality models to provide the reader with a general understanding of water quality models, a brief discussion of previous and ongoing model studies in the watershed, a discussion of issues related to model selection, and model recommendations for the Fox River watershed. In particular, several commonly used watershed loading models and receiving water models were reviewed: Geographic Information System (GIS) Pollutant Load Application (PLOAD), Soil and Water Assessment Tool (SWAT), Hydraulic Simulation Program-Fortran (HSPF) and Enhanced Stream Water Quality Model (QUAL2E), Water Quality Analysis Simulation Program (WASP), One-dimensional Water Quality Model for Streams (CE-QUAL-RIV-1), and Dynamic Toxics Wasteland Allocation Model (DYNTOX). Appendix 7 presents detailed descriptions of these models.

7.1. Water Quality Modeling Background

Models are computer code expressing mathematical relationships that simulate physical and chemical processes occurring under the environmental settings in a watershed. Natural systems are extremely complex and can vary dramatically from one region to another. Data are needed to calibrate the mathematical expressions in the models. Often, it is the availability of data to calibrate the processes that limits or dictates the level of detail and the complexity of the processes modeled. In general, complex models that simulate more processes require more data for calibration. Computer models that simulate pollution processes related to surface water quality are normally categorized into two groups: watershed loading models and receiving water models.

Watershed loading models simulate the generation and movement of pollutants from the point of origin (source) on land surfaces to point of discharge into receiving waters. Watershed models can operate on a watershed as a whole, integrating all loads within a watershed, and allow for the subdivision of the watershed into contributing sub-basins. Loading models may include simple loading rate assessments by using regionally estimated water quality constituent coefficients for certain land-use types and estimated annual precipitation. They may also adopt complex simulation techniques that explicitly describe the processes of rainfall, runoff, sediment detachment, and transport to receiving waters (USEPA, 1997).

Transport of constituents from the land surface to the stream system is driven by precipitation events, and controlled by the watershed area, land cover (in terms of impedance to transport), sediment transport mechanisms, and slope, while the availability or loading of a constituent is a function of the parent material and land use. Precipitation and streamflow data together with area, land cover, and slope are used to calibrate the processes simulating the runoff response from the watershed for a given rainfall event. Calibration of the model for a particular area requires simultaneous measurement of precipitation and streamflow. Next, transport and delivery of various constituents are calibrated using information on land use and observed water quality data. Often, this information is not available, and processes (defined by coefficients and rate parameters) from previous studies are used initially, until field measurements are performed, wherever possible. Once these processes are established, nonpoint source loading to the stream system can be modeled for selected scenarios. Sophisticated watershed loading models also have mechanisms to simulate movement of selected constituents through the stream network. However, the in-stream flow routing may be very simplistic compared to other sophisticated hydraulic models such as UNET (one-dimensional unsteady flow through a full network of open channels) and FEQ (full equation unsteady flow) models. Watershed loading models simulate flow and concentration of selected constituents for the modeled time period at the chosen outlet point.

After constituents enter a stream network, either from point or nonpoint sources, they are subject to various transport mechanisms in the stream system. Receiving water quality models simulate in-stream hydraulics and water quality processes. Those models typically include subroutines that simulate hydraulic routing, as well as chemical and biological processes. Receiving water models can be divided into two groups in terms of hydraulics: steady-state models and dynamic models. Steady-state models only allow simulations of constant flows and associated physical, chemical, and biological transformation of water quality constituents. Dynamic models simulate time-varying and unsteady flows.

Receiving water models require information on a channel's physical characteristics that influence the mixing of constituents and travel time along the stream. A river is divided into "reaches" within the model based on the channel characteristics. Reaches represent physical segments along the river. The reactions of modeled water quality constituents as they are transported along the river from reach to reach are simulated. Some substances that enter the stream network are conservative, and do not react or interact with other matter. Most constituents of interest in water quality of streams do interact. For example, nutrients such as nitrogen and phosphorus interact with algae and have an impact on dissolved oxygen (DO) levels. The chemical and physical interactions of constituents within the stream system are time dependent and have complex feedback loops. Some reactions such as the nutrient-algae interaction are dominant during low-flow events and can be modeled under the assumption of relatively steady flow conditions. During high flows, algae populations are flushed, but the delivery of constituents from the land surface peaks, and these events require dynamic, time-varying flow models. Along a stream network, timing of inflows may be a significant consideration. Steady flow models are based on the assumption that flow rate does not change during the modeled time period. In a more complex model, varying flow conditions are introduced, which is more appropriate for modeling water quality conditions associated with precipitation events. However, as the complexity of the physical and chemical processes being simulated increases, so too does the need for field monitoring for model calibration. Receiving stream models provide information on the concentration of modeled constituents within each reach for the time period modeled.

It is common practice to use model coefficients and rate parameters determined from other studies. Given that watersheds or streams are sufficiently similar, these standard values from the literature may adequately represent the watershed under study. The transferability of this information is more likely within a given watershed. Comparing model results with field observations during model calibration provides a basis for adjusting these “book values” of coefficients and parameters to represent local conditions.

Data required for watershed loading models falls into three general categories. First, data types that describe the physical setting of the watershed include watershed size, division of the watershed into homogenous sub-areas (hydrologic response units or HRUs) on the basis of imperviousness, slope, fraction of impervious areas directly connected to a channel, maximum surface storage, soil characteristics, crop and vegetative cover, curb density or street gutter length, and sewer system or natural drainage characteristics. Second, data related to defining processes include reaction rate coefficients, adsorption/desorption coefficients, growth stage of crops, daily accumulation rates of litter, traffic density and speed, potency factors for pollutants (pollutant strength on sediment), and solar radiation for some models. Finally, data are needed to define driving or forcing functions of input variables. These are ambient temperature, precipitation, atmospheric fallout, evaporation rates, etc. (USEPA, 1997).

Data for receiving water quality models can be slightly different depending on types of models. In general, dynamic water quality models that simulate time-varying flows and constituents in the stream system require more data than steady-state water quality models. River geometry; stream network; physical, chemical, and biological properties for each reach; flow; climate; inflows; and withdrawals are among the data commonly required by receiving water quality models (USEPA, 1997).

7.2. Previous Water Quality Modeling Studies for the Fox River Watershed

An analysis of pollutant loads and water quality conditions in the Fox River watershed except the southwestern portion of Kane County was conducted by Northeastern Illinois Planning Commission (NIPC, 1978). The water quality of the Fox River watershed was assessed by using a water quality model (Hydrocomp) and evaluating the effects of NIPC’s water quality management plans. The modeling results for a 13-month period from April 1976–April 1977 indicated generally good water quality in the Fox River watershed, except violations of the in-stream ammonia, phosphorous, and DO concentration levels (NIPC, 1978). With a focus on these sources of pollution, various land-use management practices and point source pollution management plans were simulated. Modeling results at Algonquin showed that the implementation of water quality management plans slightly improved the DO, and biochemical oxygen demand (BOD) concentration levels in the river, given the projected land-use scenario in 1983 (NIPC, 1978). The sources and major pollutants are listed in Table 7.1.

The Illinois State Water Survey (ISWS) has completed the initial phase of a study to develop a continuous hydrologic simulation model for the entire Illinois River basin (Singh et al., 2003). In this study, the Better Assessment Science Integrating Point and Nonpoint Sources, version 3.0 (BASINS-3.0) modeling system developed by the USEPA and its embedded model

Table 7.1. Sources and Predicted Amounts of Pollutants in Percentages at Algonquin in 1983 (NIPC, 1978)

	Pollutants (%)	
Source	*BOD*	*Ammonia*
Combined sewer overflows	2	2
Wastewater treatment plants	8	59
Stormwater runoff	18	28
Pollution from Wisconsin	72	12

HSPF, were used to simulate streamflow in the river basin. Streamflow for the nine major tributary watersheds of the basin (Fox, Des Plaines, Kankakee, Spoon, Vermilion, Mackinaw, Sangamon, La Moine, and Macoupin) was simulated using separate HSPF models for each watershed. Simulated streamflow outputs from these tributary watersheds then were added to the mainstem of the Illinois River, and a separate model also was developed for its watershed. The model constructed for the entire Illinois River basin provides a strong framework for additional model development and refinement. The model will be used to conduct analyses in support of the restoration needs assessment for the Illinois River ecosystem restoration project.

The Kane County Department of Environmental Management and USGS developed hydrologic and hydraulic models to improve and update floodplain delineation in Blackberry Creek watershed (Soong and Straub, 2003; Soong, 2001). They also intended to use these models for the analyses of future watershed conditions according to the 2020 Land Resource Management Plan, including detention requirements, flood mitigation, and wetland protection alternatives developed by the county. For the floodplain delineation, HSPF was used to generate continuous streamflow record at Blackberry Creek, and the U.S. Army Corps of Engineer’s model HEC-RAS was used for flood profile analysis. In addition, a two-dimensional finite-element surface-water modeling system (FESWMS) model was adopted to analyze the occurrence and conditions of flood diversion at Jericho Lake in the watershed (Soong and Straub, 2003).

Using the HSPF model, Duncker et al. (1995) studied the rainfall-runoff relations for five watersheds (6.3–59.6 square miles) and three single-land-use watersheds (38.2–305 acres) in Lake County, Illinois. Rainfall data collected for 1990–1993 were used for model calibration and verification. They noted significant differences between the best model parameters for the single-land-use watersheds and those for larger watersheds. Model parameters were refined through regional calibration and verified for other watersheds not included in the calibration. The models satisfactorily simulated the long-term, annual, and monthly water balances.

Researchers in the Department of Landscape Architecture at the University of Illinois at Urbana-Champaign are conducting a study using the HSPF model to examine the effect of land-use changes and best management practices for the mitigation of nonpoint source pollutions in the Blackberry Creek watershed. That study simulates hydrology and sediment and water quality constituents (dissolved nitrite plus nitrate and orthophosphate). That study delineates 25 sub-watersheds within the Blackberry Creek watershed based on 30-meter resolution digital elevation model (DEM) and reach files (RF-3) using 1970–1995 meteorological data collected at Chicago Midway Airport and Rockford Airport, both in Illinois. Surface water–daily streamflow data from 1960 to 2001 at Blackberry Creek near Yorkville (USGS gaging station # 05551700) were used for the water budget calibration. Water quality data collected from the monitoring station at Yorkville (IEPA station DTD02) were used for calibration of sediment and nutrients. Sustainable land-use plans and landscape design patterns will be developed based on the modeling results (S. Kang, personal communication, August 11, 2003).

7.3. Considerations in Model Selection

Appropriate model selection depends on the types of water quality problems, potential sources and timing of their occurrence, desired spatial and temporal scales of model results, data availability, model complexity, uncertainty, and available resources. These issues are discussed in the following sections.

7.3.1. Constituents and Sources

Table 5.22 shows the critical times and conditions for various water quality constituents of concern from analysis of the Fox River water quality data. Critical times and conditions identified for the constituents range from hourly to seasonal time scales. In addition, rain events carry large loads and result in higher concentrations of nitrate/nitrite in receiving rivers and streams. Those critical times/conditions correspond to the environmental conditions when natural (pollution) processes pose the most stress for water quality and health of ecosystems. They can be related to environmental factors (e.g., temperature and light availability), hydraulics (low vs. high flow and dams), and overland pollution processes (e.g., runoff). They represent challenges for selecting appropriate computer models to assist with watershed management and planning. Models selected for addressing water quality issues within the Fox River watershed should simulate pollution processes properly and resulting water quality at proper time scales and flow conditions. Water quality constituents simulated should include DO, nitrogen, phosphorus, fecal coliform, algae, and suspended sediment.

7.3.2. Spatial and Temporal Features

The spatial resolution of watershed loading models is typically more a product of data availability than model capability. Watershed loading models simulate runoff characteristics at outlet points from defined sub-watersheds. Within a given watershed, the more sub-watersheds selected, the greater number of locations or points for calculation of runoff characteristics. However, the accuracy (or uncertainty) of the results can only be validated by available monitoring data. The spatial resolution of system variables, such as topography, land cover, and availability of climatic data also must be taken into consideration.

In general, the size of watersheds differ according to gaging stations, channel characteristics, or area of interest. Flow records at gaging stations allow model calibration and validation. Therefore, flow outlet points of watersheds should be determined based on the locations and number of gaging stations. Channel characteristics, such as cross section, slope, and length, affect the behavior of water, sediment, and water quality constituents. The watershed should correspond to the appropriate channel size and area of particular interest. The size of specific areas with critical water quality issues that require detailed modeling may be an important factor for determining spatial resolution of the modeling work.

Temporal scales of modeling studies can be on the order of years, days, or hours. Some models simulate only responses of a watershed to storm events, while others are designed for continuous simulation to assess long-term responses. The availability of climatic data, such as temperature and rainfall, will affect the time step used in a watershed loading model. In areas where only daily rainfall data are available, modeling hourly runoff requires assumptions about the rainfall distribution that introduce uncertainty into the model results. Of the models reviewed in this report, the HSPF model can be used to simulate both storm events and continuous simulation, and the SWAT model is for continuous simulations only. Within a large watershed, it is possible to use different time steps and temporal scales to model various tributaries. Tributaries with highly urbanized land use and more detailed precipitation data may be modeled for a shorter time scale to assess storm contributions, while better results for predominantly agricultural tributary watersheds may use a daily time step. The results of these models (loadings from the tributaries) are inputs to the mainstem of the river, and results can be aggregated (summed over a day) or disaggregated (daily loads proportioned over 24 hours) for simulations of water quality in the mainstem.

Receiving stream models for rivers such as the Fox River require information on the spatial features such as width, depth, length, and channel geometry for different segments of the river. It is often reasonable to assume that there is little variation of concentration across the width and depth of the stream compared to variation of concentration in the longitudinal direction. For this reason, one-dimensional models (QUAL2E, DYNTOX, CE-QUAL-RIV-1, and HSPF) are appropriate to simulate most riverine water quality issues (USEPA, 1997).

The variability of flow in a river, as well as time variations in inflow (discharges) and outflow (withdrawals) must be considered when determining the temporal scale of a receiving stream model. In addition, chemical and physical interactions of constituents within the riverine system are time dependent and may have complex feedback loops. For example, nitrogen may be in the form of ammonia nitrogen, nitrite, nitrate, and organics. Depending on factors such as DO and pH, nitrogen transforms at different rates as it travels in different reaches of the river. Furthermore, hydraulic features such as dams may dramatically affect various in-stream processes, and kinetics of the processes must be taken into consideration for model selection. For example, as water passes over a dam, aeration occurs when DO is below saturation concentration, but deaeration occurs when DO is above saturation concentration, with a deleterious net effect. The DO concentration in the water is affected by water level differences, air and water temperatures, dam height, dam shape, and water quality. The instantaneous change of DO at a dam site may have a more lasting effect on water quality than any other single physical factor (Butts and Evans, 1978b). In a study of dams in the northeastern Illinois conducted for NIPC by ISWS staff (Butts and Evans, 1978b), individual dam calibration factors were developed for those dams in selected watersheds, including the Fox River. The findings of the study were incorporated in the QUAL2E model code. The HSPF model does not include subroutines for physically based simulation of dams. The QUAL2E model, operated in a quasi-dynamic mode, simulates temporal variations in water quality conditions under steady flow conditions in which the flow does not change, and discharges and withdrawals are constant for a given simulation. This is a reasonable approximation for low-flow conditions. Various steady flow and discharge/withdrawal conditions can be explored with different input datasets. A set of similar models could be calibrated to represent low-flow conditions in different seasons. Simulation of time-varying flow, such as storm conditions, can be accomplished using models such as the HSPF.

7.3.3. Model Complexity

In general, models with greater complexity do not automatically generate more accurate predictions. Because complex models often require a large number of unobservable parameters for which values must be assigned, they may make it easier to obtain a spurious match between model predictions and observations. Adding more complexity to the analysis implies that more time, funding, expertise, and data will be required. Thus, it is generally a good idea not to have any more temporal and spatial details than is necessary to address the problem at hand. However, if foreseeable model applications cover a wide range of complexity, it is advantageous to adopt a more complex model to address various scientific and engineering applications than to continuously switch models from one phase of a project to another or from one project to another (Nix, 1990). Table 7.2 shows the range of model complexity of the models reviewed herein.

7.3.4. Types of Model Uncertainty

Model applications for decision-making have been hampered by uncertainties associated with model predictions. Increasingly, resource managers are requiring analysis of uncertainties associated with modeling results so they can consider the implications of the uncertainty in their decision-making.

Beck (1987) stated that four problem areas are associated with uncertainty in water quality mathematical models. They are: 1) uncertainty about the relationships among the variables characterizing the dynamic behavior of systems, which is uncertainty about model

Table 7.2. Range of Model Complexity (USEPA, 1997)

Model	*Range of complexity*
PLOAD	Low
SWAT	Medium
HSPF	High
CE-QUAL-RIV-1	High
QUAL2E	Medium
WASP 6	Medium
DYNTOX	Low

structure, 2) uncertainty about the value of the parameters appearing in the identified structure of the model for the system's behavior, 3) uncertainty associated with predictions of the future behavior of the system, and 4) the design of experiments, or monitoring programs, for the specific purpose of reducing the critical uncertainties associated with a model. The sources of uncertainty most usually accounted for are uncertainty in the initial state of the system, uncertainty in the model parameter estimates, uncertainty in the observed input disturbances and output responses, and uncertainty arising from unobserved input disturbances of the system (Beck, 1987, p. 1396).

Various sensitivity analysis methods have been used to identify model parameters that significantly affect model prediction uncertainty and the water quality constituents for which model-prediction uncertainty is unacceptable (Melching and Yoon, 1996). Uncertainty analysis helps to determine the robustness of a mathematical model or analysis that tests a plausible range of estimates of key independent variables to determine if such variations make meaningful changes to the results of the analysis (Morgan and Henrion, 1990). Among many models, only the QUAL2E has uncertainty analysis sub-routines incorporated. Melching and Yoon (1996), Masliev and Somlyody (1994), Morgan and Henrion, (1990) performed uncertainty analysis for other models has been performed using sensitivity analysis (SA), first-order reliability analysis (FORA), Monte Carlo simulation (MCS), and Latin hypercube sampling (LHS).

7.3.5. Data Needs and Model Experience

The capability of any model to accurately address water conditions is directly related to the accuracy of input data and the level of expertise required to manage the model. For complex models, a large portion of the error in model prediction can result from the lack of sufficient data. To have reasonable predictions, large quantities of data are required, such as channel geometry, slopes, land-use perviousness factors, reaction rate coefficients, soil properties (including texture, permeability, and erodibility), and monitoring data for discharge, river stage, reaeration, water quality, precipitation, temperature, evapotranspiration, etc. Much of the needed data are not readily available from standard monitoring practices. For this project, all available data and analyses for the Fox River have been compiled in phase I. Additional input data will be needed to develop a detailed hydrologic and water quality simulation model for the Fox River watershed.

Selection of a model or a combination of models is an important decision, not only because of the time and resources a modeling effort involves, but also due to the technical expertise needed to develop and maintain the model. Preferably only those models should be selected that have been widely used and tested under varying physiographic conditions, which are periodically updated by their developers to keep up with the changing technology, and for which vast user support is available through well-developed user's manuals and Internet-based discussion groups. Generally, federally supported models are expected to have continued technical and developmental support. The ISWS has experience with the BASINS-HSPF, SWAT, and QUAL2E models that have continued technical, developmental support from USEPA. The use of such models will save time and costs, and provide appropriate problem-solving capacity. These models are part of the public domain and are available at no cost to any user.

7.4. Model Recommendations for the Fox River Watershed

Given the size of the Fox River watershed and the diversity of land use in the watershed, no one model will serve as an adequate tool to generate information about all watershed processes. Furthermore, while considerable data have been collected for the watershed, considerable additional data are needed to calibrate water quality models of sufficient spatial and temporal resolution to represent all areas of interest in the watershed. It is recommended to establish a flexible, modular framework that can be refined as data become available for the study area. The model framework should be designed to reflect the level of detail desired in the future, not constrained by currently available data. The watershed may be represented by an integrated suite of models, including both watershed load and receiving water models. It is recommended that watershed load models initially be developed for major tributaries to the Fox River in the study area. The Fox River should be represented by a receiving water model to simulate the movement and transformation of pollutants within the river. Tributary watershed models may be updated and refined as data become available. At some future date, it may be desirable to develop receiving water models for the tributaries. The complexity and detail of each tributary model can vary, yet still provide "input" to the Fox River receiving stream model. Additional watershed loading from areas draining directly to the Fox River also must be simulated.

The USEPA's BASINS modeling system (USEPA, 2003a, 2003b, and 2001a) integrates a GIS, national watershed and meteorological data, and state-of-the-art environmental assessment and modeling tools into one package. The modeling system includes a suite of models that can be used to perform an integrated analysis of point and nonpoint sources. Specifically, BASINS includes assessment tools (TARGET, ASSESS, and DATA MINING) for evaluating water quality and point source loadings at large or small scales; utilities including local data import and management of local water quality observation data; two watershed delineation tools; utilities for classifying DEMs, land use, soils, and water quality data; an in-stream (receiving) water quality model (QUAL2E); a simplified GIS-based nonpoint source annual loading model (PLOAD); two watershed loading and transport models (HSPF and SWAT); a postprocessor (GenScn) of model data and scenario generator to visualize, analyze, and compare results from HSPF and SWAT; and mapping, graphing, and reporting formats for documentation. The BASINS modeling framework provides the state-of-art integration of GIS tools with water quality modeling. Nationally derived environmental and GIS databases have been prepared for use with BASINS for nationwide assessments, but these do not have high-resolution data. It is necessary to prepare datasets with updated, higher resolution information on streamflow, precipitation networks, land use, soils, stream geometry, etc. Datasets for the Fox River watershed are identified on Fox River Watershed Investigation Web site (http://ilrdss.sws.uiuc.edu/fox).

Various model options offered within the BASINS framework illustrate the point that different modeling approaches are needed to meet objectives of various modeling applications. Modeling routines offered in nonpoint source watershed loading models may allow for detailed specifications related to agricultural practices such as planting and harvesting or emphasize the hydrologic processes and the urban landscape. Both the HSPF and the SWAT models have some mechanism for stream routing, but the hydraulics are not well developed. A unique river such as the Fox requires more detailed hydraulics, as offered in the QUAL2E receiving water model, to simulate features such as the many dams.

7.4.1. Watershed Loading Modeling

Given the mixed land uses within the study area (from Stratton Dam to the confluence of the Fox River with the Illinois River) and anticipated growth of population and urbanization, the HSPF model within the BASINS modeling framework is recommended for the watershed loading modeling of pollutant loads. The HSPF model allows modeling of pollution processes that occur in both pervious and impervious lands, with a variety of options for modeling urbanized landscapes. The fairly complex model can accommodate the level of spatial and temporal detail to address issues in the Fox River watershed. The model can simulate the constituents of interest and has the flexibility to use hourly or daily time steps. It can be used to model storm events or long-term continuous simulations. The HSPF model has been used extensively by researchers and has a solid history of successful applications. The major tributary watersheds are shown in Figure 2.2. Thirteen tributaries listed are within the study area below Stratton Dam. Individual watershed loading models should be customized for each of these watersheds as well as selected additional watersheds of smaller tributaries that drain directly to the Fox River. It is expected that the number of modeled tributary watersheds will be between 13 and 25. The 12-digit Hydrologic Unit code (HUC12) boundaries shown in Figure 2.2 provide insight to the number of sub-watersheds that eventually may be delineated for detailed assessments of areas of special interest.

In addition to developing the HSPF models, insight could be gained by also calibrating a SWAT model for two selected tributaries for a comparative study of results generated by the HSPF and SWAT models. The SWAT model was designed for modeling of agriculturally dominated watersheds with crop management practice options and plant growth capability. The comparison will allow identification of strengths/weaknesses and sensitive parameters in both models. The results will be taken into account when formulating management measures and implementation plans in later phases of study. The modeling comparison will provide information to determine if the SWAT model should be used for watersheds not expected to experience significant urban growth.

The HSPF model is continuously improved by the USEPA. A newer version, WinHSPF (a Windows interface of the HSPF) was released recently. The BASINS-3.0 model contains version 12.0 of the HSPF. Detailed users’ manuals for the model, its Windows interface, postprocessor (GenScn), and optimization program (HSPEXP) are freely available. The USEPA provides interactive users support via the Internet through a Listserve, and through several training programs conducted on a regular basis. The U.S. Department of Agriculture Agricultural Research Service (USDA-ARS) is continually improving the SWAT model. Detailed users’ manuals for the model and its theoretical documentation are available. The SWAT modeling group provides interactive user support via the Internet through a Listserve, and through several training programs conducted on a regular basis.

7.4.2. Receiving Water Quality Modeling

Information generated by watershed loading models provides inputs to receiving water models for simulation of in-stream processes and water quality. It is recommended that a receiving water quality model be developed for the Fox River mainstem. The river should be divided into segments to account for heterogeneity in hydraulic characteristics such as flow, river depth, and slope. Reaches should be established with consideration of changes in channel hydraulics (e.g., velocity, time of travel, and dams); outlets from tributaries that are expected to have a significant impact on water quality (determined from the watershed model); effluent outfalls; and locations suitable for calibration, given available data and segments of the river that are of particular interest. Channel geometry may be determined from several sources, including cross-section surveys from flood insurance studies conducted for the Federal Emergency Management Agency, the FEQ unsteady–flow model of the Fox River (Knapp and Ortel, 1992), gaging station cross sections, and other sources. Point discharges regulated under National Pollution Discharge Elimination System (NPDES) permits with average annual flow of 0.1 million gallons per day or greater should be included to study the impacts of those point sources (approximately 70 sites).

The steady-state model QUAL2E is recommended for simulation of water quality under low-flow conditions in which flow does not change, and discharges and withdrawals are constant. The assumption of steady-state streamflow is appropriate for relatively stable, low flows. Low flows for modeling can be selected to correspond to statistical probabilities of occurrence, such as the 90 percent annual chance of exceedence flow (the flow exceeded 90 percent of the time) using the Illinois Streamflow Assessment Model (ILSAM) model developed by Vern Knapp, ISWS (Knapp and Meyers, 1999). The ILSAM model can be used to define flows in terms of annual and monthly flow exceedence probability. Like other streams and rivers in northeastern Illinois, low head dams are a major feature in the Fox River and have profound effects on in-stream hydraulics and water quality (Santucci and Gephard, 2003). Model variables and rate parameters defining processes, such as reaeration, sediment oxygen demand, and algae growth rates, may be selected from data collected along the Fox River as available and then from studies of similar rivers. Another feature of the QUAL2E model is its incorporated module for uncertainty analysis that allows quantification of uncertainties associated with model predictions. The uncertainty module should be applied to the water quality simulations and the model results reported with associated uncertainty to the Fox River Study Group. The QUAL2E model has been an industry standard for years, and many engineers have expertise with its application. This will facilitate the model's use by others as needed.

Large loads of some pollutants, such as suspended sediments and nitrogen, occur during and immediately after rain events. Sediment-bound chemical constituents such as phosphorus could be released to the water column from sediment deposited in the river channel and pose a threat to water quality later. Simulation of time-varying flows can be accomplished using a flow dynamic model such as the HSPF model (RCHRES module). The model allows simulation of sediment transport and deposition and is appropriate for studying effects of pollutant loads on short- and long-term water quality. The HSPF model could be used for the Fox River for high-flow conditions in conjunction with QUAL2E applications for low-flow conditions.

Calibration of receiving water models can be done at a higher spatial resolution than the watershed loading models when monitoring data are available. For example, additional calibration locations can be chosen for detailed investigation of particular water quality conditions in river reaches of concern (e.g., in-stream pools) to improve model reliability. An assessment of the model accuracy and precision, and sensitivity to various coefficients and parameters should be conducted. The initial model could be used to identify data gaps, such as inputs to the system for which there are no field observations but the potential for significant impacts. Simulations can be conducted to evaluate a limited set of scenarios of changing conditions and could be used to assist with the identification of future monitoring locations.