White River Basin Comprehensive Study
Conceptual Model Workshops
30 July, 4 September 2002
Workshop Summary

Purposes:

The purposes for the Conceptual Model Workshops were:

1. Discuss organizing frameworks for the White River Basin Comprehensive Study,
2. Describe conceptual models and their use in comprehensive studies, and
3. Initiate development of conceptual models for the White River Basin.

The workshop agendas are shown in Attachment 1 and 2 with the workshop participants for the July Workshop listed in Attachment 3.

Background:

The White River Basin Comprehensive Study is being carried out under the Corps of Engineers' General Investigations Program. The project was authorized under Section 202 of the Water Resources Development Act (1986) as modified in 2000. The comprehensive plan will serve as a framework for environmentally sustainable development of water resources in the White River Basin. The primary objectives of the study are to comprehensively analyze the basin problems and opportunities and find possible solutions to these needs.

The White River Basin is geographically divided into two terrain types – the upper basin in the Ozark Mountains and the lower basin in the Delta. Water quality issues are prevalent in the upper basin while water quantity issues are prevalent in the lower basin. Some of the issues that will be evaluated as part of the comprehensive study include, but are not limited to, ecosystem protection and restoration, flood damage reduction, navigation and ports, watershed protection, water supply, and drought preparedness.

End Products and Overall Goals

One of the first activities at the study workshop was to identify the desired outcome or end product of the Comprehensive Study. The overall goal for this study is to protect and restore the natural system while integrating desired human uses of the basin. Sustainability of the ecological systems and water resources was the underlying principle, although it might not be explicitly addressed in this study. Establishing a framework for basin level decisions and subsequent studies was the approach proposed for attaining this overall goal. Part of this framework was the development and use of conceptual models.

Organizing Frameworks

The issues with the White River Basin are complex and interactive. Three organizing frameworks were discussed at the workshop to help evaluate and asses these complex issues:

1. Ecological risk assessment framework (EPA CFR FRL-6011-2, Vol. 63, No. 93, Thursday 14 May 1998),
2. Framework for assessing and reporting on ecological condition (SAB 2002), and
3. Economic and environmental principles and guidelines for water and related land resources implementation studies (Water Resources Council 1983).

Ecological Risk Assessment Framework

The ecological risk assessment framework provides a flexible process for organizing and analyzing data, information, assumptions and uncertainties in assessing the likelihood of adverse ecological effects. It provides a useful framework for environmental decision making by giving managers an approach for assessing environmental information with respect to social, legal, political, and economic factors in selecting a course of action. The ecological risk assessment framework has three phases: Problem Formulation; Analysis; and Risk Characterization (Figure 1).

The Problem Formulation Phase includes a preliminary assessment of existing information to determine what is available and what is needed to evaluate potential effects and risks. It includes the selection of assessment endpoints and the development of conceptual model(s) linking the assessment endpoints with the proposed management actions in the management regime and with pathways and processes from sources to effects in the scientific regime.

The Analysis Phase is the arena in which most scientists and engineers feel comfortable. This phase includes the use of empirical and dynamic models, data analysis procedures, and other analytical techniques to evaluate the effects of various management actions on the assessment endpoints. For chemical stressors, the analysis includes both exposure pathways as well as effects (dose-response) pathways. The ecological risk assessment paradigm was originally developed to consider chemical effects, but it has been expanded to include potential effects from other stressors such as hydrologic modifications, habitat alterations, and invasive species.

The Risk Characterization Phase includes two components: Risk Estimation and Risk Description. Risk estimation is the process of integrating potential effects with various management actions and assessing the associated uncertainties. Risk description uses a line of evidence or weight of evidence approach to corroborate or refute the risks estimated for the assessment endpoints and interpret the significance of the adverse effects on the assessment endpoints from various management actions. Risk description is the area in which other information (e.g., socioeconomic, regulatory, etc.) can be integrated with the ecological effects

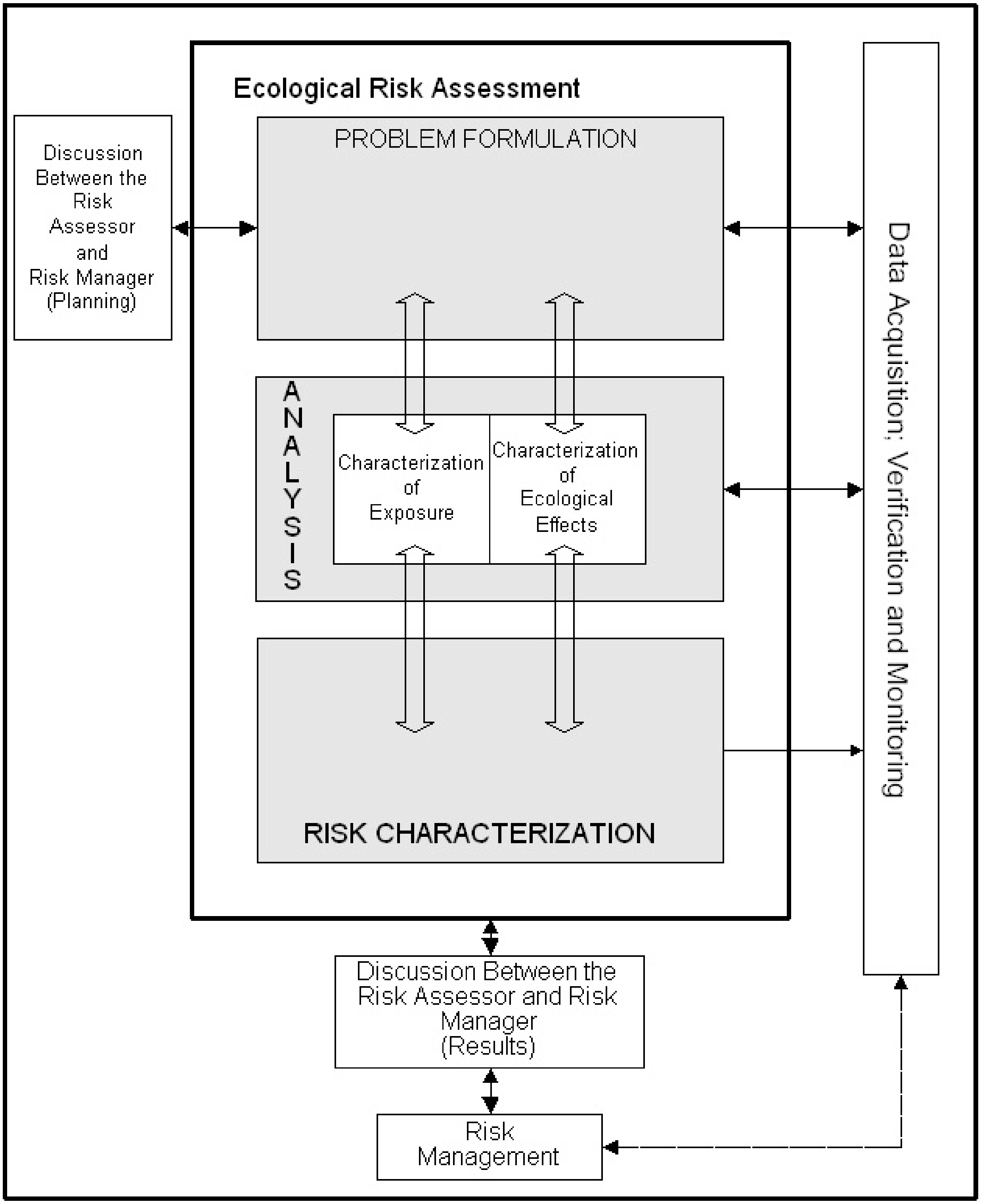

Figure 1. EPA Ecological Risk Assessment Framework (EPA 1998).

for decision makers. The final risk description can be qualitative or quantitative, but for most ecological effects the risk description will be qualitative.

Ecological risk assessment provides a useful umbrella under which ecological information can be integrated with socioeconomic, regulatory, and similar information to assess the likelihood of adverse effects or risk from proposed management actions. Two other frameworks that are uniquely suited to guiding the acquisition and assessment of this information are the SAB (2002) and WRC (1983) frameworks.

Framework for Assessing and Reporting on Ecological Condition

A framework for assessing and reporting on ecological condition was developed by the EPA Science Advisory Board (SAB 2002). This framework was intended to serve as an organizing tool to help decision makers decide what ecological attributes were important to measure and how to aggregate these measurements into an understandable picture of ecological condition (SAB 2002). Once the goals and objectives of a study are defined (which is the purpose of the Problem Formulation Phase of Ecological Risk Assessment), there are six essential ecological attributes (EEAs), with component subcategories and elements, that can be used as a checklist to help ensure appropriate indicators (information) are collected to assess ecological condition:

1. Landscape condition,
2. Biotic condition,
3. Chemical and physical characteristics,
4. Ecological processes,
5. Hydrology and geomorphology, and
6. Natural disturbance regimes.

The first three attributes relate primarily to ecological structure and pattern while the last three relate to ecological processes and function. Examples of specific subcategories and elements under each of these EEAs are shown in Table 1. The SAB EEAs incorporate the larger scale (i.e. landscape) perspective needed to understand the observed biotic and physical and chemical responses in ecosystems. These observed responses result from underlying processes and contribute to larger scale ecological processes. With EPA's focus on watershed management, hydrologic and geomorphic indicators are critical for characterizing ecological condition. Finally, natural disturbance as well as anthropogenic stressors shape the response and condition of ecological systems. Understanding both the contribution, and interactions, of natural and anthropogenic factors is important in describing and diagnosing the causal contributions to ecological condition. The framework is not intended to be prescriptive, but rather descriptive of the kinds of information that are needed to be able to assess ecological condition.

Table 1. Essential ecological attributes and reporting categories (SAB 2002).

Landscape Condition

- Extent of ecological system/habitat types
- Landscape Composition
- Landscape Pattern and Structure

Biotic Condition

- Ecosystems and Communities
  - Community Extent
  - Community Dynamics
  - Physical Structure
- Species and Populations
  - Population Size
  - Genetic Diversity
  - Population Structure
  - Population Dynamics
  - Habitat Suitability
- Organism Condition
  - Physiological Status
  - Symptoms of Disease of Trauma
  - Signs of disease

Chemical and Physical Characteristics (Water, Air, Soil, and Sediment)

- Nutrient Concentrations
  - Nitrogen
  - Phosphorus
  - Other Nutrients
- Trace Inorganic and Organic Chemicals
  - Metals
  - Other Trace Elements
  - Organic Compounds
- Other Chemical Parameters
  - pH
  - Dissolved Oxygen
  - Salinity
  - Organic Matter
  - Other
- Physical Parameters

Ecological Processes

- Energy flow
  - Primary Production
  - Net Ecosystem Production
  - Growth Efficiency
- Material Flow
  - Organic Carbon Cycling
  - N and P Cycling
  - Other Nutrient Cycling

Hydrology/Geomorphology

- Surface and Groundwater flows
  - Pattern of Source Flows
- Hydrodynamics
  - Pattern of Groundwater flows
  - Salinity Patterns
  - Water Storage
- Dynamic Structural Characertistics
  - Channel/Shoreline Morphology, Complexity
  - Extent/Distribution of Connected Floodplain
  - Aquatic Physical Habitat Complexity
- Sediment and Material Transport
  - Sediment Supply/Movement
  - Particle Size Distribution Patterns
  - Other Material Flux

Natural Disturbance Regimes

- Frequency
- Intensity
- Extent
- Duration

These EEAs were discussed in the July workshop and specific elements for the White River Basin were proposed (Table 2). Although there are some elements that relate to current conditions within the basin, most of the attributes relate to the natural system that likely existed in the basin 300 years ago. The SAB framework is useful for assessing ecological condition, but does not incorporate socioeconomic factors that are also part of the decision-making process. The WRC Guidelines, (WRC 1983) provides a framework for incorporating socioeconomic considerations with ecological attributes in the decision-making process.

Table 2. Essential ecological attributes of the White River Basin, emphasizing the natural system.

1. Landscape Composition
   - – Geology
   - – Soil
   - – Reservoirs
   - – Streams
   - – Urban
   - – Landscape Metrics
     - • Road Density
     - • Levees
     - • Contagion
     - • Fragmentation
   - – Vegetation Types
     - * Forest
     - * Wetland
     - * Prairie
     - * Agriculture
       - • Row Crops
       - • Pasture
       - • Aquaculture
2. Hydrology
   - – Flow
     - * Magnitude
     - * Frequency
     - * Duration
     - * Interannual Variability
     - * Natural Range of Variability
   - – Groundwater Levels
   - – Infiltration/Discharge Areas
   - – Stage-Floodplain Connectivity
   - – Flooding Extent
   - – Reservoir Rule Curves
   - – Reservoir Releases
3. Geomorphology
   - – Bed forms
   - – Meanders
   - – Sinuosity
   - – Floodplain Form and Extent
4. Sediment Regime
   - – Sources
   - – Grain Size Distribution
   - – Fluxes
     - * Quantity
     - * Timing
   - – Processes
     - * Organic C Cycling
     - * Vegetation-Sediment Interactions
   - – Channel Distributions
   - – Floodplain Distribution
   - – Sediment Balance
     - * Aggradation
     - * Erosion
5. Riparian Vegetation
   - – Species – Flow/Stage Relationships
   - – HGM Relationships
6. Water Quality
   - – Nutrients
     - * Sources
     - * Loads
     - * Timing
   - – Turbidity
   - – Temperature/Transition Zone
   - – Karst Interactions
   - – Dissolved Oxygen
7. Biota
   - – Mussels
   - – Migratory Birds
   - – Macrophytes
   - – Patch Dynamics (Island Biogeography)
   - – Fish
   - – Cold water
   - – Cool water
   - – Warm water

Water Resources Council Economic and Environmental Principles and Guidelines

The Economic and Environmental Principles and Guidelines were developed over a 10-year period by the Water Resources Council (WRC 1983), a multi-federal agency committee. The WRC was intended to coordinate activities of the three major federal water resources construction agencies – Bureau of Reclamation, Corps of Engineers, and Tennessee Valley Authority. The Principles and Guidelines established standards and procedures to be used by federal agencies in formulating and evaluating alternative plans for water and related land resources studies. These Principles and Guidelines arose, in part, from the passage of the National Environmental Policy Act of 1969. The Principles and Guidelines recognize there are three important elements in any federal project:

1. contributing to national economic development;
2. protecting the nation's environment; and
3. social well-being of society.

Two primary sets of procedures in the Principles and Guidelines relate to National Economic Development (NED) and Environmental Quality (EQ), with Social Well-Being (SWB) considered as part of integrating NED and EQ.

The NED and EQ procedures address:

National Economic Development	**Environmental Quality**
- M&I Water Supply	- Interdisciplinary
- Agriculture	- Public Involvement
- Flood Damage	- Process
- Power (Hydroelectric)	* Define resources
- Transportation	* Development evaluation framework
* Inland	* Inventory resource
* Deep Draft	* Forecast
- Recreation	* Assess effects
- Commercial Fishing	* Appraise
- Other Direct Benefits	* Judge net EQ
- Unemployed/Underemployed Labor Resources	

The WRC (1983) Principles and Guidelines were developed during an era of active dam construction and reservoir development, which is no longer occurring. The overarching purposes of these guidelines, however, are still applicable – contributing to *sustainable* economic development and *sustaining* ecological systems. Without sustainable ecological goods and services, sustainable economic development isn't possible.

Integrated Approach

Combining elements from all three frameworks might provide an integrated approach for sustainable water resources within regional hydrologic landscapes (Figure 2). The risk assessment framework provides the overall umbrella in which potential adverse effects or likely risk can be assessed for various proposed management plans or actions. The SAB framework provides information for assessing the ecological elements needed as part of the EQ analysis and the Principles and Guidelines provide information on the socioeconomic aspects of the study that should be considered. Both the NED and the EQ reflect the applicable laws and regulations regarding water resources.

One of the next steps in the process is to determine what should be included in the comprehensive study. Developing a conceptual model(s) of the White River Basin, including both the natural system and the desired human uses of the system, could contribute significantly to establishing priorities on what studies need to be conducted, where in the basin they should be conducted, what information is critical in making decisions, how might these studies might be phased based on their contribution to reducing uncertainty in decisions, and which elements are tangential to the process.

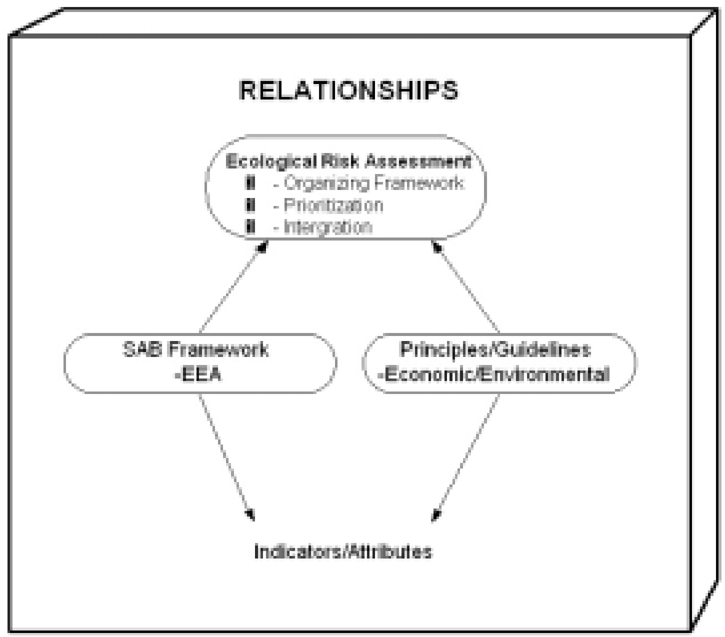

Figure 2. Integrated framework considering elements from EPA (1998, SAB (2002), and WRC (1983) frameworks.

Conceptual Models

Conceptual models have been defined as qualitative representations of the relationships among variables (EPA 1998). Conceptual models of ecological systems have been used to describe the relationship among patterns at a landscape scale, or among structure or processes at an ecosystem level.

There are at least five benefits associated with developing conceptual models (EPA 1998):

1. Conceptual models highlight what is known and not known and can be used to plan future work.
2. The process of developing a conceptual model is a powerful learning tool.
3. Conceptual models are easily modified as knowledge increases.

4. Conceptual models can be powerful communication tools. They provide an explicit expression of the assumptions and understanding of the system for others to evaluate, and
5. Conceptual models provide a framework for prediction and are a template for generating additional risk hypotheses.

Two additional benefits of conceptual models emerged from their use by the AR Game and Fish Commission (AGFC) Eagle Mortality Task Force. A conceptual model was developed to help 1) identify those factors that would affect decisions about the project, and 2) to prioritize the studies that were needed to provide additional information.

There are multiple approaches for developing conceptual models, such as starting with the major economic and ecological characteristics or factors in the basin, focusing on the issues and stressors, identifying the major state variables and fluxes among them, developing an input-output matrix of linkages among variables, or any combination of the above.

Natural System Conceptual Model

The group chose to start developing the conceptual model by identifying the critical elements and linkages among these elements for the natural system in the basin. Understanding the natural system and its interactions should help assess which uses are compatible with the natural system, which are not, and management actions that might be implemented to move closer to the overall goal. Understanding the natural system requires some understanding of the historical changes that have occurred, identifying reference conditions and comparing these reference conditions with existing conditions. It was not the intent of the group to return to pre-settlement conditions, but rather determine what was realistically achievable in the basin using historical conditions to help characterize which areas have experienced the greatest change. These conceptual models were developed for the entire basin. While greater specificity and detail could be added to any of these compartments, the rule of Occam's razor was used to develop these conceptual models. This rule states that simplicity is preferred to complexity; no more detail is added than is needed to solve the problem or resolve the issue.

The natural system reflects the interaction of geology (in its broadest context of uplifts, soils, and physiography) and climate as the primary forcing functions in the basin (Figure 4). Geology and climate interact with plant communities to form the land cover. As indicated by its central position in the conceptual model, land cover is pivotal in affecting many of the other system attributes. Land cover and geology influence infiltration and groundwater recharge while climate and land cover influence runoff (Figure 4). The character of the riparian vegetation and riparian habitat reflect the interaction of landcover, groundwater, and runoff. Land cover, runoff, and geology (i.e., basin slope, relief, etc.) influence the geomorphic characteristics of the basin. Flow dynamics in the basin are influenced by groundwater contributions, runoff, and riparian vegetation (Figure 4). While land cover is pivotal in the terrestrial system, flow is pivotal in the aquatic ecosystem. Flow and geomorphology influence the sediment regime and instream habitat, which in turn affects the biotic communities in the White River. Geology, riparian habitat and flow influence the water quality regime, which also affects the stream biotic communities.

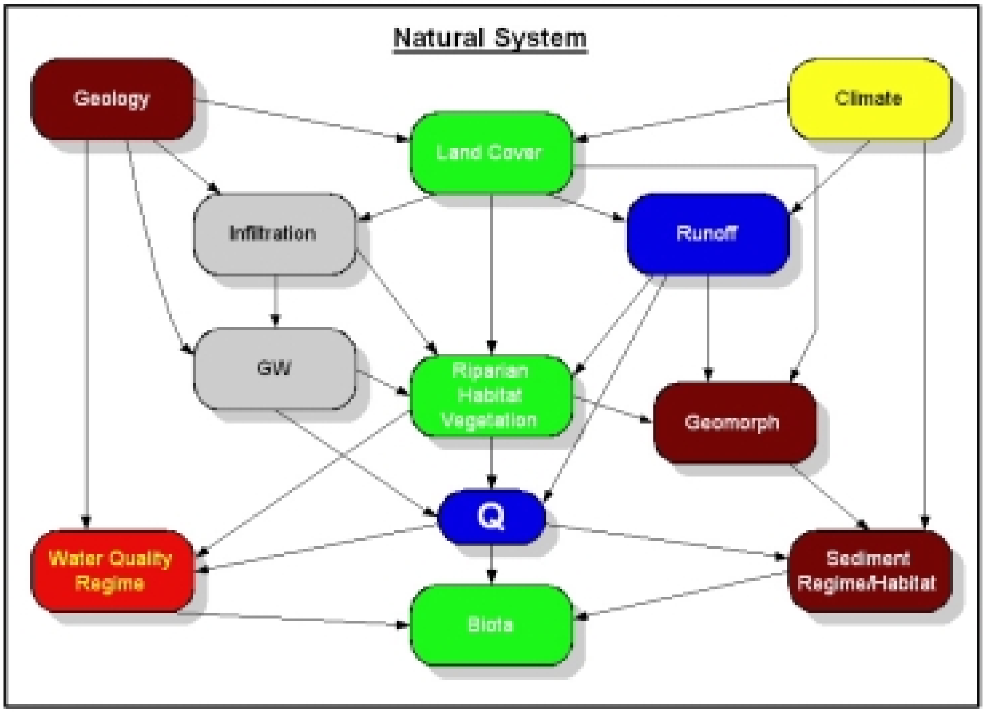

Figure 4. Conceptual model of the White River Basins before European settlement.

So, what does the conceptual model tell us? First, land cover and flow are pivotal in affecting what happens in the basin and its responses. Second, the land and river are tightly coupled. What happens in the watershed affects what happens in the river. Third, groundwater and surface water both interact and both are influenced by what happens in the watershed – affecting one (surface or groundwater) affects the other. These three observations are not new, but they are critically important for evaluating alternative management practices. One of the purposes of conceptual models is to document what is known or suspected in a visual format.

What is more difficult to show in a conceptual model are temporal changes or dynamics. The White River has always been a dynamic system with large flow fluctuations and a continually migrating and moving stream channel, particularly in the lower basin, with oxbows and meander cutoffs. It continues to be a dynamic system so management practices that are applicable today might not be appropriate in the future.

The natural system conceptual model provides a foundation for assessing changes that have occurred in the White River basin over time. While the same essential ecological attributes are represented in the current system, human activities have modified these essential ecological attributes, their relative importance in affecting watershed and aquatic components and their interactions within the White River. These differences are discussed in the next section.

Current System Conceptual Models

Two major changes have occurred in the White River Basin – land use change and the construction of the dams and associated reservoirs on the White River. The two pivotal factors affecting the natural system – land cover (land use) and flow – then, have been significantly changed. Geology, physiography, and location of the dams divide the White River into an upper and lower basin. While there are similarities in some of the desired uses within these two basins, there are also differences. The issues in the upper basin are primarily associated with the reservoirs along the upper White River system. The issues in the lower basin relate primarily to water quantity, including both surface water and groundwater. The July workshop participants identified some of the desired uses of water in the White River Basin (Table 3) and some of the issues associated with reservoir use in the Upper Basin (Table 4) and water use and control in the Lower Basin (Table 5). While the issues in the Upper Basin were identified primarily for the reservoir ecosystems, some of the topics such as re-allocation of water supply and minimum flow re-allocation are also important issues for the Lower Basin.

The July workshop identified some of the human/economic uses and issues in the White River Basin (Table 3). The participants also identified issues associated with the reservoirs in the upper basin (Table 4) and streams, primarily in the lower basins (Table 5). The human and economic uses relate directly to some of the categories to be addressed in assessing National Economic Development. Monetary values can be derived for each of these uses or activities, either through direct market valuation techniques or through non-market valuation procedures such as travel cost models, hedonic, or contingent valuation economic approaches.

Table 3. Human/Economic Uses/Issues.

Agriculture Community	**Commercial**
*Irrigation	*Fishing
*Water Supply	*Shelling
*GW	*Gravel-mining
*Floodplain Encroachment	
*Flood Control	**Recreation**
*Navigation	*Boating/Skiing
*WQ	*Fishing
	*Waterfowl – Hunting
Urban Community	*Birdwatching
*M&I Water Supply	*Tourism, Guides, etc.
*Navigation	
*Flood Control	
*Recreation	

The September workshop participants reviewed these desired uses, issues and initial conceptual models of the natural system. Following discussion of the desired outcome of the Comprehensive White River Basin Study, the desired uses, issues, and potential management practices and programs within the Basin, three geographic areas were identified for developing additional conceptual models.

Table 4. Reservoir Issues	
Adjacent Landuse	Hydroelectric
*Shoreline Development	Minimum flow re-allocation
*Shoreline Clearing	Municipal water supply
	Lake level management
WQ	Aging infrastructure
Re-allocation of water supply	Regulating plan (Black River – Clearwater Lake)
*Mitigation of water (firm yield) to hydroelectric	Threatened and Endangered Species

Table 5. Instream Issues	
Irrigation withdrawal	Cultural/Archeological Issues
Cultural/Archeological Issues	F&W Species of Special concern (Including plants
Dredging & Snagging	Temperature & transition zone
Minimum flow – trouting & boating	Hydropower – low head issue (Batesville)
Flooding	Navigation
Levees	Shoreline Development
Channel instabilities	Lake Tanneycomo – powersite dam

These three geographic areas were:

1. Upper Basin – White River Reservoirs
2. Lower Basin – White, Black, and Little Red River Mainstem
3. Lower Basin – Non-White River Mainstem Systems

In the upper basin, many of the concerns are associated with reservoir quality and the contribution of the reservoir systems to the regional economy. In the lower basin, one of the greatest concerns is the water quantity, both for groundwater and surface water systems. There are also concerns about flow regulation and associated ecological effects within the White River mainstem. The concerns for the lower basin non-mainstem river systems, such as the Cache River, are related to ecological restoration, both of smaller watersheds and riparian habitat. General conceptual models were developed for each of these three situations. In addition, a specific conceptual model was developed within each of these three geographic areas to illustrate how conceptual models might be used to guide the evaluation of specific environmental issues.

Upper Basin Conceptual Model

Land use changes that have occurred in the upper basin are the primary contributors to issues associated with White River reservoir water quality (Figure 5). Agriculture, urban/suburban development, shoreline encroachment, and similar activities are contributing to reservoir quantity and quality issues. The influences of land use on all other activities is illustrated in the conceptual model for the upper basin (Figure 5). While climate and geology are still important forcing functions on the system, land use and associated changes dominate the effects on other system components and processes.

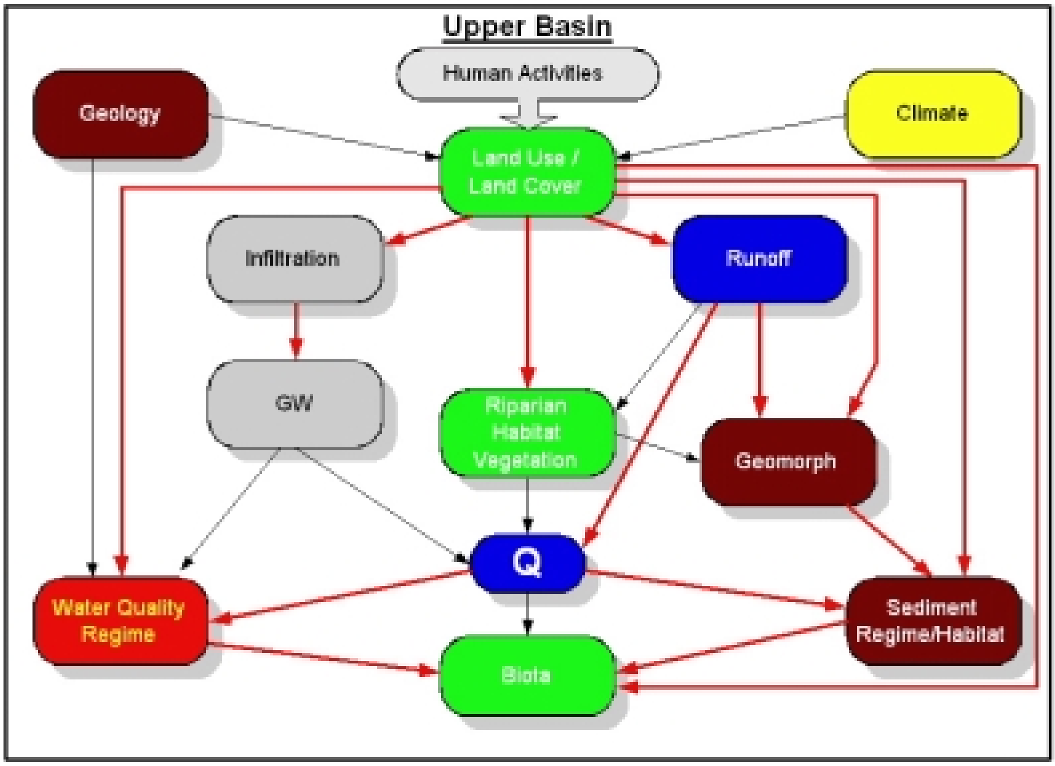

Figure 5. Conceptual model of the existing Upper White River Basin illustrating the influence of human activities and land use changes.

increased growth and development of urban/suburban areas and the increase in confined animal operations have both raised concerns about potential effects on reservoir water quality.

An example of how a conceptual model can be used to highlight the primary factors contributing to potential water quality issues is shown in Figure 6. Reservoir eutrophication, primarily from phosphorus loading, is a concern because eutrophication leads to decreased water clarity, nuisance algal blooms, drinking water, and other water quality problems. Phosphorus is the limiting nutrient in the White River reservoirs. In addition, because phosphorus from nonpoint sources is transported primarily in particulate form, controlling phosphorus loads can also contribute to controlling sediment loads.

The conceptual model (Figure 6) identifies the key steps in assessing and controlling phosphorus loading. The first step is to determine the phosphorus assimilative capacity of the reservoirs (i.e., how much phosphorus loading can occur before water quality problems develop). The next step is to determine the total phosphorus loading to the reservoirs from both point and nonpoint sources. Point sources can be controlled through the NPDES program if the total phosphorus load exceeds the assimilative capacity of the reservoirs. For nonpoint sources, it is important to determine the natural background phosphorus loads so the anthropogenic load can be estimated. Best Management Practices (BMPs) can be used to reduce the nonpoint source anthropogenic loads, if needed. These BMPs can be implemented through voluntary programs or economic incentives. This conceptual model describes the general approach for conducting a phosphorus

TMDL or for developing a watershed management plan to control phosphorus loading to the reservoirs.

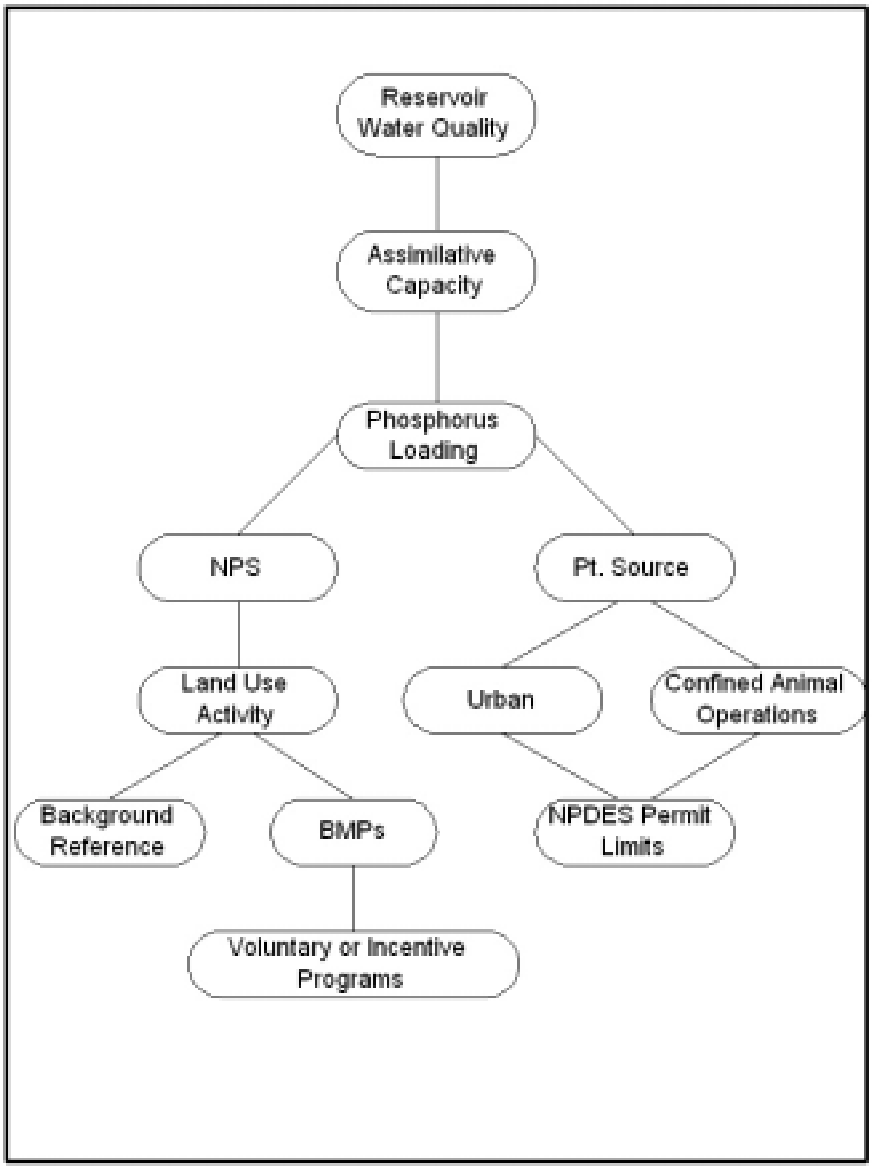

Figure 6. Conceptual model for reservoir water quality in the Upper White River Basin.

Lower Basin, Non-Mainstem Conceptual Model

The lower basin, non-mainstem rivers are similar in many respects to the upper basin in that land use is a dominant factor controlling and influencing both the quantity and quality of water in the system (Figure 7). Land use has also significantly altered both the geomorphic and sediment regimes in these streams through loss of riparian habitat and vegetation. Many rivers have also been snagged or dredged, which has also contributed to loss of riparian habitat and unstable streams. In addition, withdrawal of groundwater has lowered aquifers, reducing available water to support base flow in streams

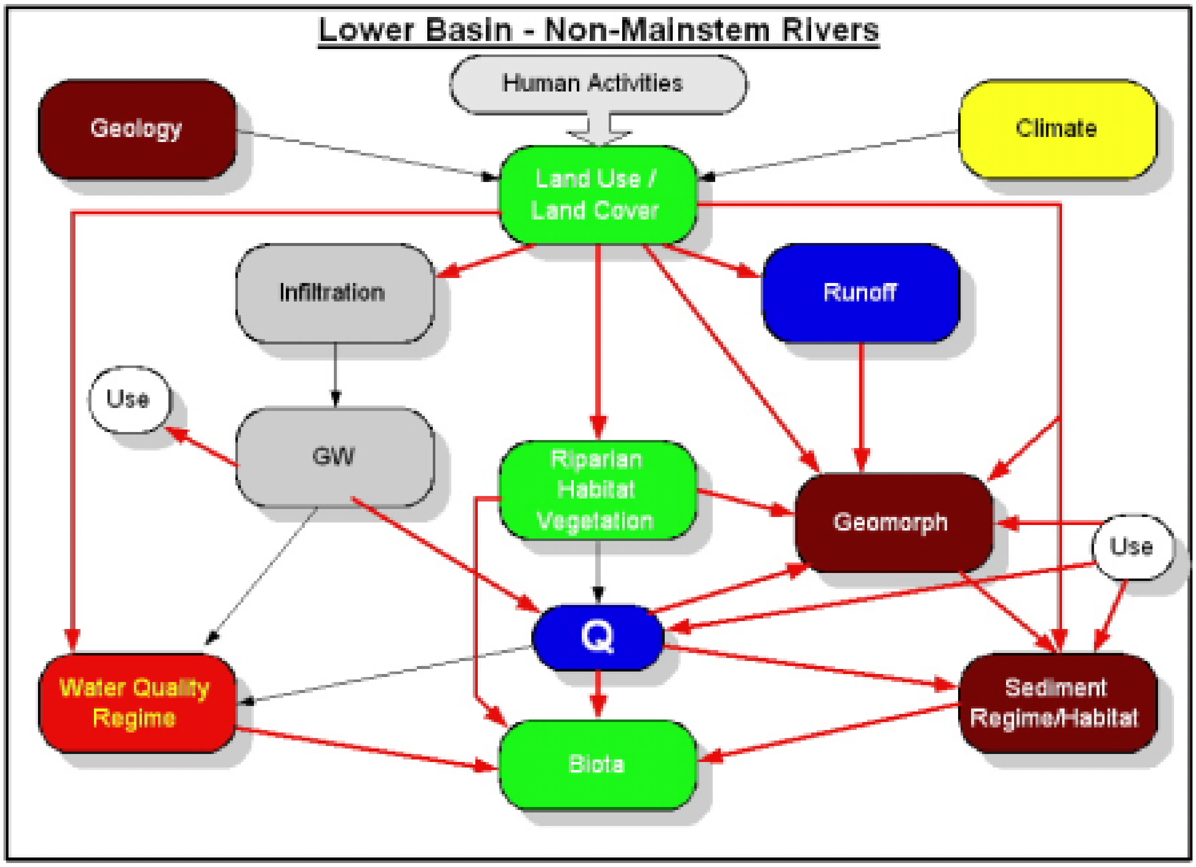

Figure 7. Conceptual model of non-mainstem rivers in the Lower White River Basins. Human activities and land use change are dominant factors in the lower basin along with groundwater use.

Loss of bottomland hardwoods, riparian habitat, and vegetation in the lower basin, non-mainstem rivers is one of the major issues associated with these river systems. Timbering, loss of riparian habitat. and land use changes have contributed to geomorphic and sediment regime changes affecting biotic conditions in these rivers.

A conceptual model can be used to identify the primary factors to be considered in restoration of these habitats (Figure 8). Watershed restoration, whether *in toto* or for specific river segments, starts with an assessment of the existing conditions within the lower basin. From this information, reference watersheds or riparian systems can be identified. By developing a set of targeting criteria, existing watersheds can be screened to identify a set of candidate watersheds for restoration. Watershed or riparian restoration could occur through a combination of voluntary efforts and economic incentives. While additional detail will be required for the restoration plan, the critical steps and information needed for restoration can be identified in the conceptual model.

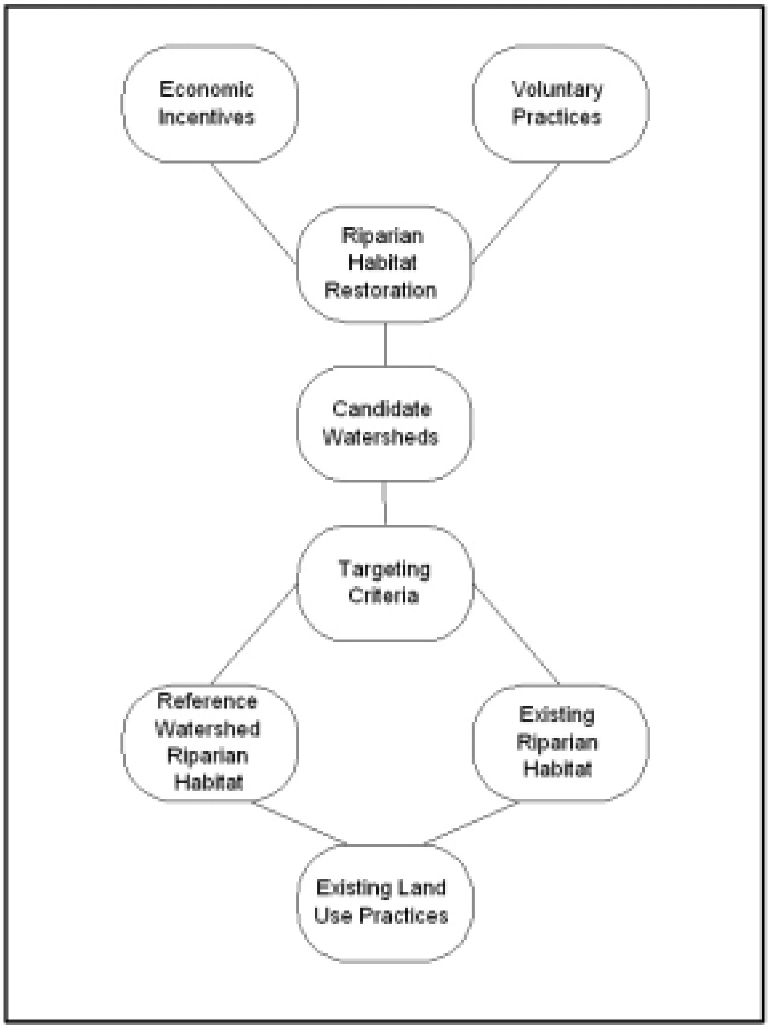

Figure 8. Conceptual model of riparian habitat restoration in the lower basin, non-mainstem White River system.

Lower Basin, Mainstem White River

The mainstem White River in the lower basin is dominated by reservoir operation (Figure 9). Reservoir operation controls the magnitude, frequency and duration of flow in the White River. The regulated flow permits other river uses such as navigation to be achieved, but these uses also contribute to altered geomorphic and sediment regimes.

By far, one of the greatest issues in the lower White River Basin is water quantity and the interaction between groundwater withdrawals, existing and potential surface water withdrawals. A conceptual model describing an approach for determining the volume of sustainable water is shown in Figure 10. At a minimum, three estimates of surface water quantity are needed: 1) the time-varying flows (minimum and seasonal flows) to sustain aquatic ecosystems; 2) consumptive uses; and 3) recycling and reuse estimates. Information on consumptive use and reuse and recycling of surface water have been estimated as have estimates of recharge rates and their intra- and interannual variability. However, the ecological requirements for aquatic communities are not available. Minimum flows have been established for coldwater fishes, but minimum flows, and desired ranges of hydrologic variability, have not been estimated for the aquatic ecosystems. This information, therefore, becomes a high priority if sustainable water quantity estimates are to be developed. With an estimate of how much water is available and can be sustained, legislation or regulations can be established, if needed, to prioritize water allocation among competing sources if the demand exceeds the available supply. Adaptive management and economic incentives can also be used to reallocate water based on opportunities for increased supply or alternative demand management approaches. In this case, developing the conceptual model not only helps identify the critical elements, but also priority study areas.

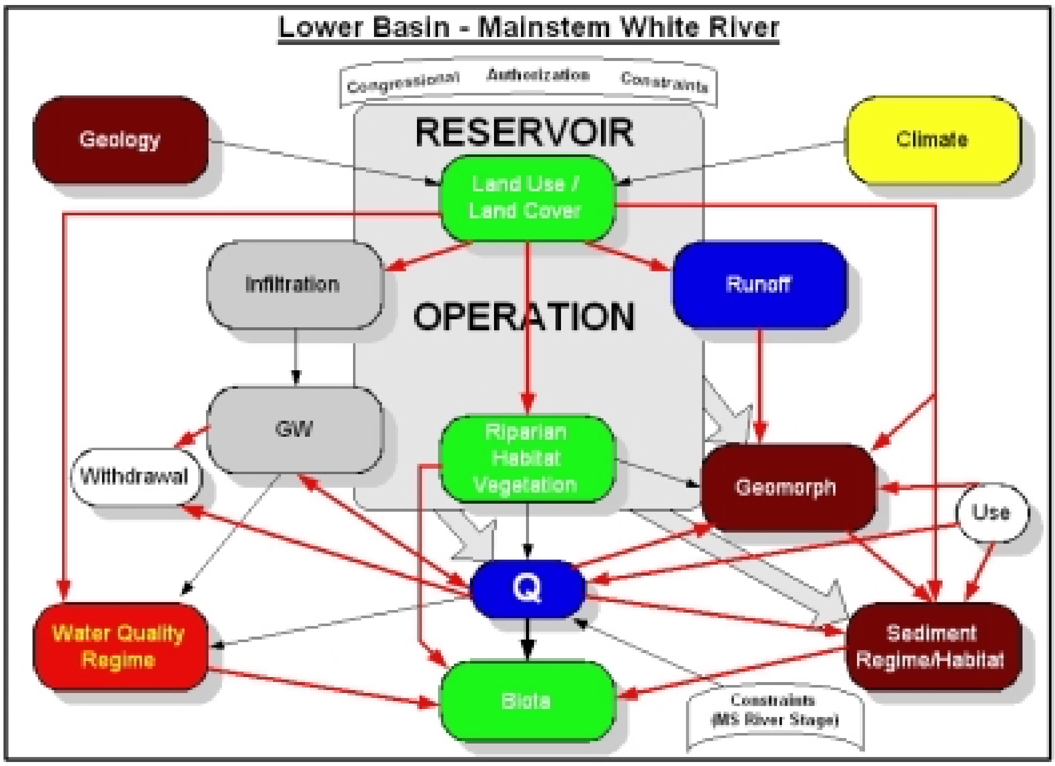

Figure 9. Conceptual model of the Lower mainstem White River Basin. Upstream reservoirs are the dominant influence on the White River. The reservoir operation is constrained by authorized purposes. Water withdrawal is a major issue in the lower basin.

An additional conceptual model was developed for a tailwater fisheries below Bull Shoals and Norfolk Reservoirs. The downstream fisheries in the White River is both an economic and ecological issue. There is a world-class trout fishery in the White River downstream from Bull Shoals and Norfolk Reservoirs, which contributes significant recreational revenue to the regional economy. A conceptual model of the primary factors contributing to the tailwater fisheries was developed at the September workshop (Figure 11). Temperature, dissolved oxygen,

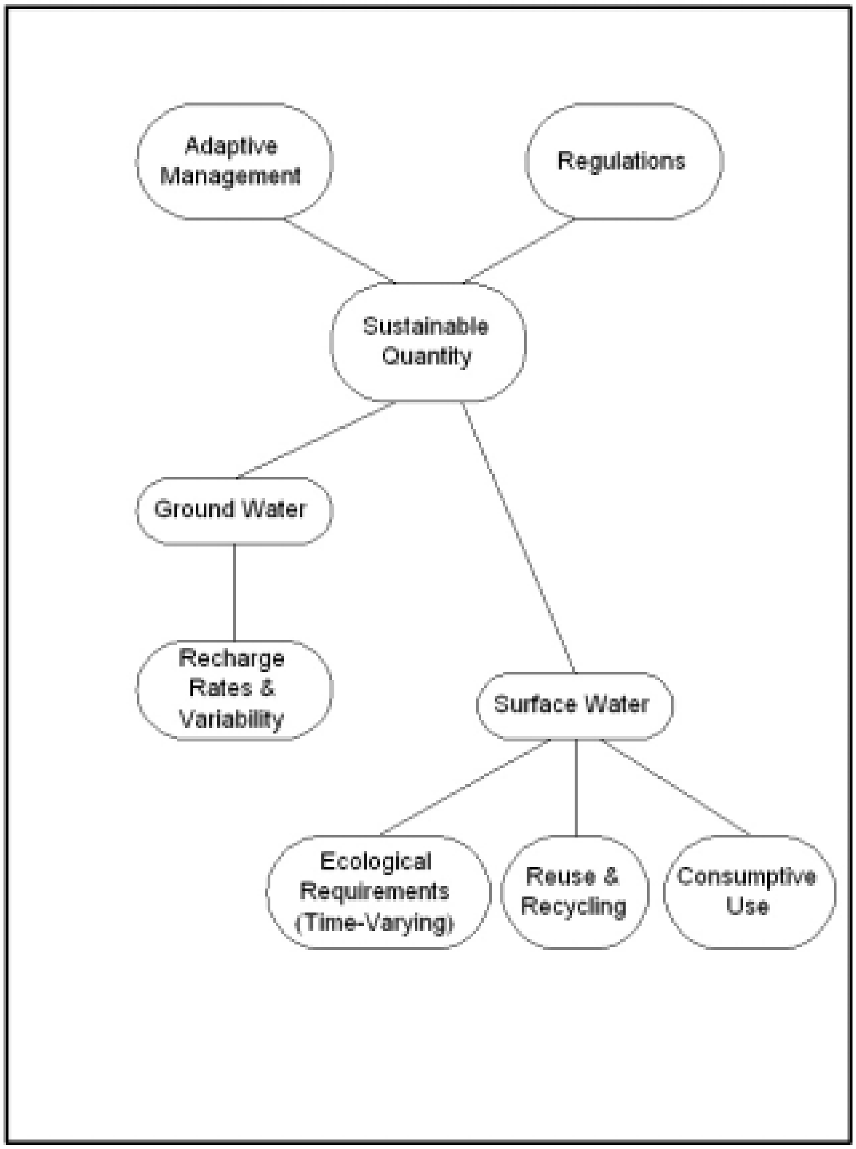

Figure 10. Conceptual model for sustainable water quantity in the lower White River Basin.

and instream habitat are the primary physical, chemical factors affecting the tailwater fisheries. These are a function of the flow releases from the upstream reservoirs. The flow regime includes both minimum low flows as well as seasonal flows that mimic historical flow dynamics. Downstream releases are controlled through reservoir operation, which is constrained by congressionally authorized project purposes, allocated storage, and minimizing downstream flood damage.

The tailwater fishery is also influenced by fishing pressure and stocking. Fishing pressure, in turn, influences the stocking required to maintain an adequate tailwater fishery. Public access is directly related to fishing pressure. In this example, the conceptual model helps identify the interactions needed between Arkansas Game and Fish Commission fisheries biologists, Corps of Engineers reservoir management personnel and Southwest Power Authority personnel to sustain and enhance the tailwater fishery.

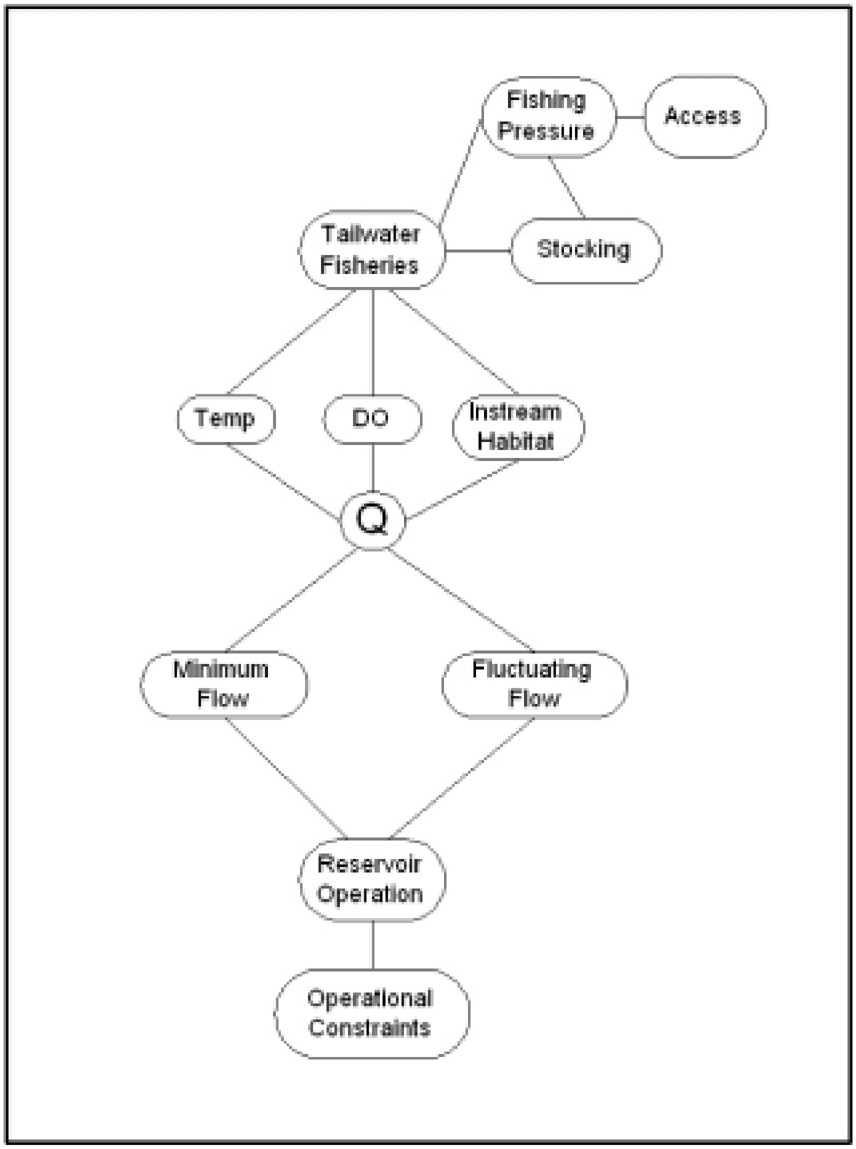

Figure 11. Conceptual model for tailwater fisheries in the mainstem of the White River System.

Conclusion

Conceptual models have been developed for the natural system, upper basin, lower basin non-mainstem and lower basin mainstem White River Basin. These conceptual models contribute to:

- identifying pivotal factors controlling ecological responses in the White River basin,
- contrasting the natural system with the current conditions in both the upper and lower basins,
- documenting the major factors controlling reservoir water quality changes,

- illustrating the process for watershed or riparian habitat restoration for non-mainstem rivers in the lower basin,
- identifying priority studies to estimate sustainable water quantity in the lower basin, and
- highlighting areas of needed coordination to sustain the world class trout fishery in the White River tailwater.

Conceptual models can help guide the information needs and priority studies in the White River Basin Comprehensive Study.

Attachment 3
Participants at July Workshop.

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