BOBBIE ANN VALLOTTON
Evaluation of the BASINS Model for Use in Georgia:
Technical and Policy Issues in Scale, Perspective, and Boundary
(Under the Direction of TODD C. RASMUSSEN)

A review of national and local environmental laws is used to outline the major water resource management objectives in Georgia. A survey of Georgia water resources professionals is reported to identify issues and concerns. Essentials of the legislative review and interviews were drawn upon to define interrogatory criteria for evaluation of BASINS, the EPA environmental analysis system that couples spatial analysis with hydrologic modeling. Spatial data quality, model data requirements and availability, ease of importing data, and model accuracy over different scales were examined. Model use is limited due to data scarcity, precarious parameterization, and absence of predictive analysis. Recommendations for improvements include addition of a watershed model better suited to the resources of state and local personnel with predictive uncertainty capabilities, of spatial data with recent land-use and biological information, comprehensive long-term watershed monitoring, and demonstration projects in sustainable development, agriculture, and forestry.

INDEX WORDS: BASINS, spatial analysis, hydrologic modeling, water resources policy, water resources law, spatial analysis, Georgia water issues, GIS, HSPF, Hydrological Simulation Program - FORTRAN, watershed analysis, watershed management

EVALUATION OF THE EPA BASINS MODEL FOR USE IN GEORGIA:

TECHNICAL AND POLICY ISSUES IN SCALE,

PERSPECTIVE, AND BOUNDARY

by

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DEDICATION

for my mother and father

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CHAPTER 1

INTRODUCTION

1.1 Background

Clean water is essential to public health, a secure economy, and an agreeable quality of life. Rivers, lakes, wetlands, and aquifers are sources for water, sinks for waste -- such as sewage, toxic chemicals, metals, and nutrients -- as well as habitat for aquatic life. Flourishing populations, and the ensuing increases in land-disturbing activities, resource consumption, and waste generation intensify concerns over water quality and quantity. Human activities that influence water quality and quantity are governed by federal, state, and local legislation and policy. Diffuse (non-point source) pollution is affected by land planning and management, which transpires at the municipal and county levels. Local land-use is determined by local leaders in a competitive political environment with a myriad of conflicting issues.

The development of water legislation and policy reflects a relationship between policy makers and scientists. For example, scientific reports emphasizing the dominant role of non-point source pollution, followed by a series of lawsuits, created the current momentum driving total maximum daily load (TMDL) development. The scientific community contributes to policy making by explicating physical, chemical and biological processes, attempting to discern correlation, cause and effect, and even by the issues the scientists choose to address. Scientific papers often conclude with policy-laced discussions and recommendations for further research. Policy makers and institutions funding research often use scientific recommendations to direct legislation, policy, and to choose grant recipients.

Water resource managers, advisors, and consultants have a labyrinthine task of implementing law and policy, using the best available science, within a political environment of conflicting issues, with limited time and money. Water resource managers and advisors must evaluate the cumulative effects of development, industry, agriculture, forestry, and municipalities on local natural resources, while considering the economic, environmental and social implications of their recommendations. They often do not have the luxuries of controlled scientific environments, abundant funding, unlimited data, inexpensive labor, or flexible deadlines. Water resource consultants and managers use current scientific methods and tools, such as monitoring equipment, statistical analysis software, and mathematical models to implement the legislative and policy directives. The Environmental Protection Agency (EPA) (1997) reported that water quality managers lack integrated, scientifically sound methods for identification of problems and prediction of alternative management strategies.

In response to these challenges and in support of federal laws, the EPA developed the environmental analysis system, BASINS, to supply federal, state, and local agencies with data and analysis capabilities for TMDL development. BASINS is a software package that interfaces GIS and hydrologic models. GIS organizes a wide range of national environmental spatial and temporal data for analysis and for input to hydrologic models. BASINS includes: national and state databases utilities that help organize and evaluate data, and watershed level and in-stream water quality models (NPSM (HSPF), Qual2, TOXIROUTE). BASINS facilitates point and non-point source pollution studies over large areas (EPA 1998). EPA created BASINS to serve as the primary tool for total maximum daily load development.

1.2 Purpose of Research

Whittemore and Beebe (2000) note that although the prevalent perception of BASINS is one of general acceptance, there are few reports of its use. They identify the need for publication of application experiences and problems as the essence of scientific advancement and technology transfer. Whittemoore and Beebe posed the question of whether BASINS satisfies the need for a quantitative watershed assessment tool. They answered that BASINS may become the principal modeling tool for watershed assessments if the EPA improves quality assurance of data and provides adequate training and technical support.

Federal and state laws require various watershed level assessments and analysis that BASINS can support. BASINS is currently being used to support Watershed Assessments. Monitoring, modeling, and creating a growth management plan are requirements for Watershed Assessments. BASINS integrates data management and modeling requirements of watershed assessments. BASINS is also being used to support TMDL development. Establishing legally defensible TMDLs, that may have substantial impacts to landowners, demands analysis methods that are clear, objective, reliable, and reproducible. Related legal directives, such as Source Water Assessments and River Basin Management Plans have similar goals and requirements that BASINS could support. Cities, counties, and businesses need efficient and reliable analysis methods for compliance with existing and future environmental regulations.

1.3 Objectives

This thesis explores the utility of BASINS from the viewpoint of the water resource manager and analyst, who is obliged to provide scientific and managerial solutions in symphony with a mélange of conflicting interests. We examine the legal structure that managers must operate within, identify the current needs and concerns of water resource professionals (government agencies and farmers), and evaluate BASINS based on interrogatory criteria. We conclude with appropriate and inappropriate uses of BASINS. Specific objectives of this thesis are included in table 1.1.

We used currently accessible data for spatial analysis and modeling. While results that can be produced by a well-funded researcher with abundant time and financial resources are interesting, they do not address the constraints and dilemmas facing most water resource managers.

Table 1.1 Summary of Thesis Objectives.

Water Resource Legislation	• Research legislation affecting water resource management. • Present legal directives that BASINS may potentially support
Current Concerns of Water Resources Professionals	• Research water resource concerns of water resource professionals through qualitative interviews. • Identify how agency managers would like to use watershed models. • Identify concerns about watershed models. • Present potential ways that Georgia water resource professionals may use BASINS.
Description and Evaluation of BASINS	• Introduce the purpose and capabilities of BASINS. • Research the watershed level model,Non Point Source Model (HSPF) within BASINS, including its basic structure and reported uses. • Develop evaluation criteria from the legal requirements and the needs and concerns of water resource professionals. • Choose spatial analysis and modeling applications from the legal directives and concerns of the agency personnel. • Evaluate the spatial data within BASINS, including age, spatial and temporal resolution, accuracy (when available), quantity, and applicability to watershed management. • Examine and critique the current state of the BASINS system via the chosen spatial analysis and modeling applications. • Demonstrate methods of output analysis relevant to the applications.

CHAPTER 2

LEGISLATION AND POLICY OF WATER RESOURCE MANAGEMENT

2.1 Federal Legislation Affecting Watershed Management

The two major federal laws governing water quality management in the U.S. are the Clean Water Act and the Safe Drinking Water Act. The intent of the Clean Water Act is to restore the health of U.S. waterways. The Safe Drinking Water act addresses human consumption of water. They work in tandem to protect U.S. water resources from and for human activities, as well as for aquatic habitat. Other federal legislation includes the Surface Mining Control and Reclamation Act, the Resource Conservation and Recovery Act, and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, or Superfund), and the Farm Bills.

Clean Water Act

The Federal Water Pollution Control Act (33 USCA §1251-1387; FWPCA §101-607) was originally passed in 1948 and has been subsequently amended. The Federal Water Pollution Control Act became known as the Clean Water Act with the amendments of 1972 that established a national system of water quality standards and enforcement. Additional amendments in 1977 established new effluent standards and variance provisions. The objective of the Clean Water Act is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (CWA §101). The provisions of the act aimed to eliminate pollutant discharge by 1985, produce fishable and swimmable waters by 1983, prohibit toxic discharges, and develop and implement non-point source controls to support the objective of the legislation.

The Clean Water Act takes two approaches to regulating waterways, addressing point sources differently from non-point sources. The National Pollution Discharge Elimination System (NPDES) governs point sources (CWA §402). The NPDES requires permits that limit the discharge from industries and wastewater treatment plants. Permits are tailored to type of discharger and type of pollutant (conventional, nonconventional, and toxic).

Sections 303 and 401 delegates responsibility to the states for defining water quality standards that are in compliance with the Clean Water Act (McCutcheon 1993). § 303 addresses non-point source pollution and requires completion of total maximum daily loads (TMDLs) for all waters of the nation that do not meet state water quality standards after NPDES permits are in place. A TMDL is the maximum mass of a pollutant designated to enter a stream during a specified period of time. The TMDLs are established at a level that upholds state water quality standards, with a margin of safety. Streams requiring TMDLs are established through monitoring programs that identify stream segments unsuitable for a designated use, such as fishing, swimming, or drinking. The maximum allowed pollutant load is allocated among the point and non-point polluters on the stream segment. The maximum allowed pollutant load has been determined by methods ranging from stakeholder focus groups (Garcia River, California) to hydrologic modeling (Turkey Branch, Georgia).

Each state sets unique water quality standards. The states define designated uses, specific criteria that protect the designated uses, and an antidegradation policy to prevent healthy waters from deteriorating. The states use field observations, predictive models, and surveys by fish and game biologists to assess water quality (EPA 2000). The states are charged with upholding the law based on their own standards. If the state fails to administer the CWA, responsibility falls to the EPA (§ 309). Citizens have the right to sue if the CWA is violated (§ 505). § 303(d) is a highly litigated portion of the CWA. Summaries of § 303(d) and several other important segments of the CWA are provided in Table 2.1.

§ 305(b) data are used and often supplemented for identifying and ranking § 303(d) waters. The EPA combines the § 305(b) data into the National Water Quality Inventory report to Congress (available on the web at www.epa.gov/305b). The EPA and other public and private agencies are developing a Consolidated Assessment and Listing Methodology to add consistency to section 305(b) and section 303(d) reporting waters (EPA 2000). The states summarize more specific data into six general use categories forEPA reporting. § 319 of the CWA, enacted in 1987, provides money for grants to assist states with non-point source management programs. A § 319 program and grant guidance document was issued in 1996.

Table 2.1. Summary of Selected Sections of the Clean Water Act

303(d) CWA	1- Requires the states to identify waters that do not meet the applicable state water quality standards after the section 301 effluent limitations are in place. It requires the states to rank the waters according to severity of pollution and designated use. Requires the states to identify waters threatened by thermal pollution where the section 301 effluent limitations are not stringent enough "to assure protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife". States shall establish total maximum daily loads for the pollutants of the waters identified in this section. The maximum daily loads will be at a level that allows implementation of the state's water quality standards. Seasonal variations and a margin of safety will be utilized to deal with uncertainties. States shall establish total maximum daily loads for thermal pollution of the waters identified in this section. The maximum daily loads will be at a level that assures "protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife". Estimates will take into account "normal water temperature, flow rates, seasonal variations, existing sources of heat input, and the dissipative capacity of the identified waters". 2- Requires states to submit "from time to time" the identified waters and established loads of part 1 of section 303(d) to the Administrator for approval. 3- Requires states to identify and set TMDLs for all waters of the state that have not been identified in part 1 of section 303(d). 4- Standard not attained – TMDLs and effluent limitations may only be revised if the revision assures attainment of water quality standards, or if the designated use that is not being attained is removed. 5- Standard attained – revision of TMDL or effluent limitation allowed only if the revision is "subject to and consistent with the antidegradation policy established under this section".
304(e) CWA	The Administrator may establish regulations for best management practices for industry in regard to "plant site runoff, spillage or leaks, sludge or waste disposal, and drainage from raw material storage". These BMPs will be part of the requirements for effluent limitations (NPDES permits).
305(b) CWA	States must submit a biennial report including the following: 1- A description of the water quality of all navigable waters of the state taking seasonal, tidal and other variations into account and correlated to the applicable water quality standards. 2- An analysis of how well the navigable water of the state "provide for the protection and propagation of a balanced population of shellfish, fish, and wildlife". 3- An analysis of how well the requirements provide for the goals of paragraph (B) as well as for recreational activities in and on the water. 4-An estimate of the environmental, economic and social impact as well as benefits of the goals. 5-Description of nonpoint sources of pollution, the programs needed to address them and the costs of implementation.

The new national guidance promotes flexibility, the reduction of administrative oversight, interagency relationships and local inclusion through nine key elements. In response to former Vice-President Al Gore's Clean Water Action Plan, § 319 monies will only be granted to states that follow all nine key elements of the new section 319 national guidance (cleanwater.gov).

Water Quality Criteria

Section 304(a)(1) of the CWA requires the EPA to publish ambient water quality standards. National criteria guide the development of state standards (McCutcheon et al.1993). A human-health criteria protects public health and is based on carcinogenic and toxic effects of pollutants. Aquatic-health criteria protect aquatic life and are based on acute and chronic toxicity, plant toxicity and bioaccumulation. Priority pollutants are considered suspected carcinogens and are those listed in any EPA court settlement or legislation.

A water quality criterion differs from a water quality standard. A criterion is the concentration that supports a specific water use. A criterion is not enforceable by itself because it relates to pollution effects and not causes. Water quality criterion are enforced through water quality standards. Water quality standards are a either a concentration, or a discharge mass or limitation. A standard does not have to be based on a criterion (McCutcheon et al.1993). This is important when natural, localized conditions violate a criterion. Maximum contaminant levels (from the Safe Drinking Water Act) are often used as a source for setting ambient water quality standards. Each state may differ in adopted standards and some state standards may not be applied everywhere in a water body, thus violating maximum contaminant levels. For instance, states may provide for an effluent mixing zone that will exceed national criteria (McCutcheon et al. 1993).

Safe Drinking Water Act

The Safe Drinking Water Act of 1974 (42 USC §300) requires the establishment of national drinking water standards and the protection of groundwater supplies. Primary drinking water standards protect public health and are enforceable through maximum contaminant limits for constituents of concern such as metals and bacteria. Secondary standards, such as odor and appearance protect public welfare and are unenforceable (§ 300 (f)).

The Safe Drinking Water Act was amended in 1996 to encourage pollution prevention by requiring states to develop a Source Water Assessment and Protection Program (SWAP). SWAP requires the delineation of protected supply areas, listing of potential sources of contamination within the supply areas, and analysis of the susceptibility of the water system to the contaminant sources (EPA 1997).

Emergency Planning and Community Right-to-Know Act

The Emergency Planning and Community Right-to-Know Act (EPCRTKA) of 1986 (42 USCA §11001 et seq.; EPCRTKA § 301et seq.) has two main purposes. The right-to-know section requires industry and government to compile accurate information about the release of toxic chemicals and to make it available to the public. The emergency planning part requires use of the gathered data to devise emergency response plans at the local level. Section 313 requires facilities to complete toxic release forms and report the "annual quantity of the toxic chemical entering each environmental medium". The EPA is required to maintain a "national toxic chemical inventory" based on the reported data. The Toxic Release Inventory is limited to manufacturing, exempts companies that process less than 25,000 pounds of chemical per year and does not include hazardous waste facilities. The EPCRTKA is enforced through civil and criminal penalties and the right of citizens to sue (§ 325 and 326).

A 1993 Executive Order requires all federal agencies to adhere to EPCRTKA and to reduce toxic chemical releases "as expeditiously as possible" through source reduction, recycling, and proper storage and disposal. The Executive Order also encourages clean technology markets with the testing of innovative pollution prevention technologies at Federal facilities (EO No. 12856; 58FR 41981). Other federal environmental legislation affecting watershed management are included in table 2.2.

Table 2.2. Additional Federal Legislation

Surface Mining Control and Reclamation Act	30 USC 1201 et seq.
Resource Conservation and Recovery Act	
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, or Superfund)	42 USC 9601 et seq.

2.2 Georgia Legislation Affecting Watershed Management

Georgia Water Quality Control Act

Georgia administers the Federal Clean Water Act through the Georgia Water Quality Control Act (WQCA) (OCGA §12-5-30(a)). The Georgia WQCA of 1964 was enacted "to restore and maintain a reasonable degree of purity in the waters of the state and an adequate supply of such waters" (OCGA §12-5-21(a)). The Georgia Board of Natural Resources establishes permitting regulations for point sources that the Georgia Environmental Protection Division (EPD) issues and enforces. EPD manages the NPDES system through either technology-based or water-quality-based effluent limitations. Technology-based effluent limitations are based on, "...application of the best practicable control technology currently available" for existing point sources or the "best available demonstrated control technology...or other alternatives, including, where practicable, a standard permitting no discharge of pollutants" for new point sources (GA. Comp. R. & Regs. r. 391-3-6-.06(4)(d)(1) and(3)).

Discharge from publicly owned treatment plants are based on the use of secondary treatment or the equivalent (GA. Comp. R. & Regs. r. 391-3-6-.06(4)(d)(2)). Toxic effluents are prohibited in "toxic amounts" (GA. Comp. R. & Regs. r. 391-3-6-.06(4)(d)(4)) and are handled by water-quality-based effluent limitations. Water quality-based effluent limitations "specify the maximum degree of pollution permissible in accordance with the public interest in water supply; the conservation of fish, game, and aquatic life; and agricultural, industrial, and recreational uses" (O.C.G.A. §12-5-23(9)).

Table 2.3 displays Georgia's six water-use classifications with selected criteria. Some criteria apply to all waters. All waters should be free from sewage sludge, oil, scum, turbidity, odor, and color that are at *unsightly* or *objectionable* amounts that would interfere with water uses. All waters should be free from toxic, corrosive, acidic and caustic chemicals from point or non-point sources that are at levels harmful to humans, animals or aquatic life. Specific instream criteria can be found in GA. Comp. R. & Regs. r. 391-3-6-.03(5).

Non-point sources in Georgia have been managed through Best Management Practices. Best Management Practices are included in any NPDES permits held by the same person. However, operations without NPDES permits, such as farms, forestry, and industries that discharge to a treatment plant, have not been as strictly regulated. Georgia has managed non-point sources through education and incentive programs, the Erosion and Sedimentation Act (OCGA § 12-7-1 to 12-7-18), and the Georgia Surface Mining Act (OCGA12-4-70 to 12-4-84).

Georgia Safe Drinking Water Act

The Georgia Safe Drinking Water Act of 1977 (OCGA §12-5-170 to §12-5-193) is the state implementation of the Federal Safe Drinking Water Act. It requires permits (§179) for public water systems and establishes the water quality standards of the publicly distributed drinking water. EPD can enforce the law through emergency orders (§187), injuctive relief (§188), and civil (§192) and criminal (§193) penalties.

Table 2.3. Georgia Water Use Classes and Criteria. Compiled from GA. Comp. R. & Regs. r. 391-3-6-.03(6); November 23, 1998 revision.

Water Use Class	**Selected Criteria**		
Drinking Water & Fishing, Propagation of Fish, Shellfish, Game & Other Aquatic Life	**Fecal Coliform**	**May – October:**	geometric mean of 200/100ml; if non-human sources cause a natural increase, the exceedance standard is 300/100ml for lakes and 500/100ml for streams;
		November – April:	geometric mean of 1,000/100ml; max of 4,000/100ml
		"The State does not encourage swimming in surface waters since a number of factors which are beyond the control of any State….contributes to elevated….fecal coliform"	
	Dissolved Oxygen	trout streams	6.0 mg/L daily average 5.0 mg/L minimum;
		warm water species	5.0 mg/L daily average 4.0 mg/L minimum.
	Temperature	90°F maximum; Temperature of the receiving waters must not be increased more than 5°F above intake temperature. In estuarine waters, the increase must not exceed 1.5°F. Primary trout streams cannot have any temperature elevation. Secondary trout streams cannot increase more than 2°F.	
	pH	6.0 to 8.5	
	MCLs	No contaminant that exceeds the Georgia Rules for Safe Drinking Water MCLs after treatment by a public treatment plant.	
Recreation	**Fecal Coliform**	Coastal waters	geometric mean of 100ml/100ml;
		All other waters	geometric mean of 200/100ml;
		Non-human Sources	If non-human sources cause a natural increase, the exceedance standard is 300/100ml for lakes and 500/100ml for streams.
	DO, pH, Temp	Same as Drinking Water Class	
Wild River	"there shall be no alteration of natural water quality from any source"		
Scenic River	"there shall be no alteration of natural water quality from any source"		
Coastal Fishing	Site specific designations by EPD. Otherwise, all other Fish Classification criteria apply.		

***** Geometric means based on 4 sample minimum over 30 days at min. interval of 24 hours

Erosion and Sedimentation Act

The Erosion and Sedimentation Act of 1975 (OCGA § 12-7-1et seq.) established a soil erosion and sediment control program placing responsibility with local governments. The act requires best management practices for land-disturbing activities (§12-7-6). It directs local governments to adopt and enforce ordinances regarding any land disturbing activities (§12-7-4). All controls must be designed for up to a 25-year storm event (§12-7-6). A minimum buffer of 25 feet for all streams and 100 feet for trout streams must be maintained except where variances are approved (§12-7-6). The act is enforced by injunctions, emergency orders, and civil penalties not to exceed $2500 per day per violation (§12-7-13 to §12-7-16). Many groups are exempt from the Act: Agriculture, the Department of Transportation, owner contracted single family residences, forestry, surface mining, granite quarrying, and all Public Service Commission regulated utilities (OCGA §12-7-17, 2000 supp.).

Other state environmental law affecting watershed management in Georgia are included in Table 2.4.

Table 2.4. Additional Georgia Legislation. Compiled from Sutherland et al. 1990.

Ground Water Use Act	OCGA § 12-5-90 to 12-5-107
Hazardous Waste Management Act	OCGA § 12-8-60 to 12-8-83
Comprehensive Solid Waste Management Act	OCGA § 12-8-20to 12-8-40.1
Underground Storage Tank Act	OCGA § 12-3-1 et. seq
Metropolitan River Protection Act	OCGA § 12-5-440 to 12-5-457
Surface Mining Act	OCGA § 12-7-1 to 12-4-70 et seq.

EPD Programs

Georgia EPD has implemented several programs to support state and local watershed management. The Georgia Planning Act of 1989 encourages local governments to establish 20 year comprehensive plans that integrate various environmental programs into the planning landscape. Within the comprehensive plans, local governments can address the various state policies and programs in concert. EPD offers flexibility to the local governments in plan development. The local comprehensive plans can draw from information from various programs, including the federal Source Water Assessment Program and TMDL requirements, the state Watershed Assessment for Domestic Wastewater Systems, Non-point Source Management Strategies, River Basin Management Planning, and Erosion and Sedimentation Control Act. The federal and state programs are related and interdependent via the information and data that is collected, and the management plans that result. For instance, data collected for the § 303(d) and § 305(b) lists can be used for Source Water Assessments and Watershed Assessments, and data collected for Watershed Assessments can be used for Source Water Assessments. Then the EPD, the Association of County Commissioners, the Georgia Municipal Association, The Regional Development Commissions, and the Department of Community Affairs, among others must sort out jurisidictional and authoritative issues (Georgia EPD 2000).

2.3 Water Allocation Doctrines

Historically, eastern water allocation law has been based on the English common law theory of riparian rights. The early interpretation of riparian rights, the "natural flow theory," allowed people that owned property along waterways to use but not alter the quantity or quality of the water. This natural flow interpretation evolved into the "reasonable-use theory" over the last century as populations grew. According to the reasonable use doctrine, a riparian owner could divert a reasonable amount of water that did not interfere with downstream use. A downstream user could enjoin a diversion only if it caused damage (Kundell and Tetens 1998). Flow reduction was considered harm without injury. This change allowed municipalities to pump water away from the riparian areas and into cities. Competition for water from municipalities, industry, agriculture, transportation, and recreation under the reasonable-use theory results in uncertainty for all parties because all rights and quantities depend on reasonable use by other riparian owners. The reasonable-use policies consider that cumulative reasonable uses can deplete resources and damage the environment but do not "provide secure and predictable allocation" (Kundell and Tetens 1998). Surface water withdrawals are regulated under the Georgia WQCA (O.C.G.A. §12-5-31, GA. Comp. R. & Regs. r. 391-3-6-.07(3)(a) to (a)(1)).

"Regulated riparianism" is the current trend in eastern water law. "Regulated riparianism" establishes administrative water permitting programs. Trends of the administrative programs include eliminating categorical exemptions, registering water users and quantities, and establishing priority uses. Georgia removed its agriculture exemption in 1988. Alternatives to the regulatory approaches include market-based approaches, such as increasing rate structures, and stakeholder participation. For example, in 1989 the EPA Surface Water Treatment Rule required New York City to install filtration systems for protection from pathogens. New York City negotiated watershed protection strategies with the Catskill Mountains and the Delaware River Basin that would provide safe drinking water for the city and relieve the Surface Water Treatment Rule requirements. Other trends in water management include consolidation of agencies, flexibility for management in differing areas, and watershed management approaches (Kundell and Tetens 1998).

2.4 Water Quality Concerns

The 1998 National Water Quality Inventory summarizes state section 305(b) reports. The inventory covered 23% of river and stream miles, 42% of the acres of lake, 32% of estuary square miles and 5% of miles of ocean shoreline. Approximately 35% of the assessed rivers and streams were found to be impaired - not meeting its designated use as defined by State law.

Figures 2.1-2.2 present data from the 1998 National Water Quality Inventory Report to Congress. Siltation, bacteria, and nutrients are the most common pollutants of the streams that have been assessed. Agricultural production, using or occupying 41% of U.S. land, has been identified as the pollutant source for 20% of the miles of rivers assessed. Hydromodification and urban uses follow as leading causes of pollution. Excess nutrients were identified as the leading problem for lakes. Estuaries were mostly affected by pathogens, followed by organic waste, metals, and nutrients. Urban runoff and storm sewers were identified as the leading causes of contamination in estuaries probably due to the many large cities near estuaries. EPA stresses the importance of recognizing that the information is incomplete because all pollutants are not identified for every impaired segment. EPA also notes that the major pollutants may not result from the leading sources because a pollutant can accumulate from many minor sources (EPA 1998).

Sediment

Streams naturally contain organic and inorganic sediments. However, any land disturbing activity such as construction, mining, farming, and forestry can increase sediment loads in streams to harmful levels (EPA 1998). Sediment loads that exceed the natural transport capacity cause accelerated sedimentation. These excessive deposits damage aquatic life, result in heavy bed loads that clog stream channels, and provide a source of sediments for remobilization during storms. Increased turbidity reduces photosynthesis and increases macroinvertebrate drift due to a decrease in light that mimics a diel cycle (Waters 1995). Sediment deposits fill interstitial spaces of gravel and cobble substrate, altering the benthic invertebrate population. Population reductions limit the food availability for fishes. Population shifts, from orders that are available for fish consumption to burrowers that are unavailable to foraging fish, change stream fisheries. Fish are also impacted by sediment by gill abrasion, decreased visibility, and loss of reproduction habitat (Waters 1995). Many other pollutants, such as phosphorus, more readily attach to soil instead of dissolving in water and are transported to streams with eroded soil (USGS 1999). Holbeck-Pelham and Rasmussen (1997) found that the concentration of total suspended solids is highly correlated with stream discharge.

National § 305(b) summaries report that siltation contributes to 38% of the problems in assessed river and stream segments that were found to be impaired.

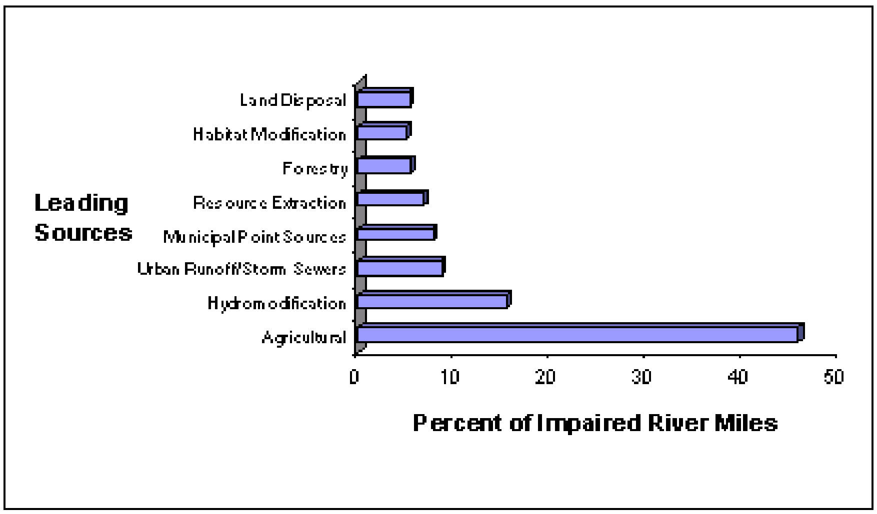

Figure 2.1 Leading Sources of Impaired River Miles (EPA 1998).

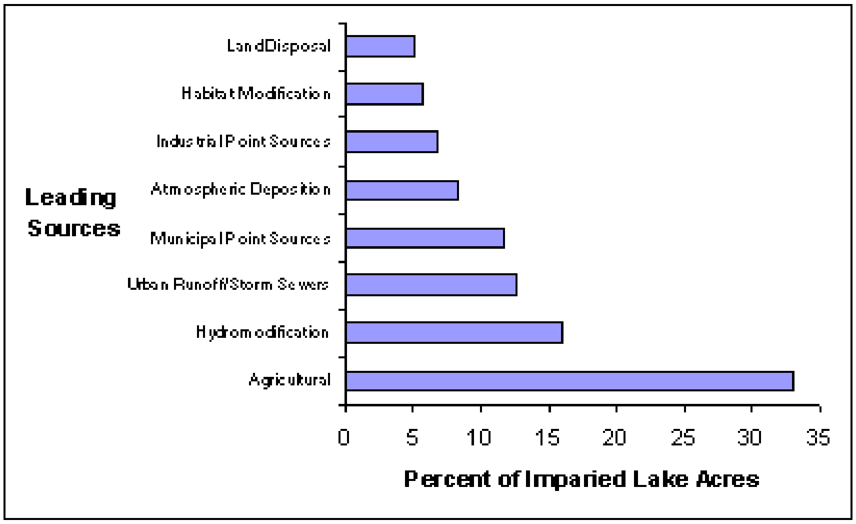

Figure 2.2. Leading Sources of Impaired Lake Acres (EPA 1998).

Pathogens

Pathogens are transported into streams from point and non-point sources, usually adsorbed to, or by the same processes as, sediment. Pathogen sources include sewage overflows and leaks, treatment plant malfunctions, inadequate septic systems, animal operations, and wildlife. Bacteria have been a concern for decades. *Coliform* bacteria have been used as the primary indicator for human feces contamination. *Fecal coliform* bacteria, originating from the intestines of warm-blooded animals, is a sub-group of total coliform bacteria, and indicates that there may be additional contamination. Protozoa (Protoctista) of concern include *Cryptosporidium*, *Giardia lamblia*, and *Entamoeba histolytica*, all causing some form of gastroenteritis. Between 1965 and1984 there were 28,000 reported cases of giardiasis in the United States. *E. hystolytica* causes 28 deaths per year on average in the U.S.. *Cryptosporidium* is of increasing concern in the U.S. (McCutcheon et al. 1993).

Cryptosporidium parvum is an enteric parasite communicated by the ingestion of oocysts found in animal and human feces. *C. parvum* is highly resistant to chlorination, and at only 4 to 6 µm, is small enough to pass through commonly used filters. *C. parvum* causes a gastrointestinal disease called Cryptosporidiosis that currently has no cure and can be chronic or fatal to people with threatened immune systems (Guerrant 1997). Over twenty million Americans live in communities with unfiltered drinking water of surface water origin; these areas include major cities, such as New York, San Francisco, and Boston that have many immunocompromised people.

Giardia or *Cryptosporidium* were the leading causes of 129 drinking and recreational waterborne disease outbreaks in the U.S. between 1991 and 1994. In 1993, over 400,000 persons were affected by *Cryptosporidium* in Milwaukee in the largest waterborne outbreak in U.S. history, with a 52% infection rate (Guerrant 1997). Surface water, well water, and spring water were the drinking water sources associated with the outbreaks. *Cryptosporidium* oocysts have been found in small amounts in 65% to 95% of the tested public surface water supplies (Juranek 1995). Every waterborne outbreak of cryptosporidiosis occurred where the drinking water treatment met state and federal standards (Juranek 1995). People drinking water from surface water supplies that are downstream from wastewater treatment facilities or confined animal agriculture are considered to be at a higher risk of exposure (CDC 1997). A *Cryptosporidium* outbreak in Carrollton, Georgia, in 1987 infected 13,000 people (Adler et al. 1993). A 1985 *Giardia* outbreak in Pittsfield, Massachusetts, affected 3,800 people (Adler et al. 1993).

A mid-1980s survey of 66 water treatment plants in fourteen states and one Canadian province detected either *Giardia*, *Cryptosporidium*, or both in 98% of samples. There were significant correlations between *Giardia* and *Cryptosporidium* densities and turbidity, total and fecal coliform, and waters receiving industry or wastewater effluents. *Giardia* or *Cryptosporidium* were found in 39% of the filtered drinking water. Microscopic investigations into the cysts and oocysts suggested that most were nonviable; no outbreaks were reported in any of the studied systems. Parasite positive systems had average plant effluent turbidity of 0.19 nephelometric turbidity units (NTU) and 78% of the positive systems met the Surface Water Treatment Rule of 0.5 NTU. Treatment facilities with higher parasite counts in the raw source water had a higher probability of occurance of *Giardia* or *Cryptosporidium* in the treated water (Le Chevallier and Norton 1995). A survey of the same sites in the early 1990s found 69.8% of the samples to be positive for *Giardia* or *Cryptosporidium* or both (*Giardia* - 45%; *Cryptosporidium* - 51.5%). The authors suggest cyclic variations in cyst and oocyst populations to be the reason for the decline. LeChevallier and Norton (1995) state that the results suggest that *Giardia* or *Cryptosporidium* will be detected at most facilities if sampled enough. They also state that *Giardia* or *Cryptosporidium* will be found in the treated water if it is present in the raw water because filtration will remove only 99 to 99.7% of cysts and oocysts (LeChevallier and Norton 1995). Also, water utility operators must balance pathogen concentrations with maximum residual disinfectant levels which may cause increases in cancer. Fewer source water pathogens reduce the cost of treatment, the risks of disinfectant exposure, and the probability of outbreaks. The state section 305(b) reports indicate that wastewater plant malfunctions, urban runoff, combined sewer overflows, and inadequate septic systems cause most of the bacteria elevations in recreational areas (EPA 2000).

Nutrients

Nutrients are necessary elements of the ecosystem. However, overabundance of nutrients, such as phosporus and nitrogen may encourage algal blooms that deplete dissolved oxygen upon death and decay, leading to fish kills. Nutrient enhanced waters may also cause odors and excessive weed growth that interfere with recreation (EPA 2000). Unlike phosphorus, nitrate-nitrogen is directly toxic to humans and other mammals (Carpenter et al. 1998). Cyanobacteria blooms can cause fish kills, odors, and trihalomethane formation during water chlorination. When cyanobacteria blooms die, water-soluble toxins are released that can kill livestock and threaten human health (Carpenter et al. 1998).

Toxic dinoflagellates (*Pyrrhophyta*) including *Pfiesteria spp.* have been indicated in finfish and shellfish kills, flounder *walks*, human and livestock epidermal lesions, and human nervous system dysfunction. Approximately 75% of the *Pfiesteria*-like toxic outbreaks have occurred in nutrient enriched water (Burkholder et al. 1997). *Pfiesteria*-like dinoflagellates have been detected from Delaware to Alabama. Burkholder et al. (1997) reports that lab and field data suggest that *P. piscicida* can be “stimulated” due to anthropogenic nutrient loading. Excess algae growth has also been linked to *Vibrio cholerae* proliferation (Epstein 2000).

Nutrient sources in urban areas include wastewater treatment plants, industrial discharges from fertilizer and fossil fuel plants, golf course and lawn fertilizers, and automobile emissions. Nutrients also result from agricultural and silvicultural runoff from fertilizer and manure applications, concentrated animal feeding operations (EPA 2000; USGS 1999; McCutcheon 1992). The USGS (1999) compared concentrations of total nitrogen and total phosphorus across agriculture, urban and undeveloped land uses. Total nitrogen and phosphorus concentrations were highest in agriculture and urban areas.

Other Contaminants

Other important contaminants include oxygen-depleting organic wastes, metals, pesticides, other toxic chemicals, thermal pollution, and habitat modification. Concerned about endocrine disruptors is increasing (Smaglik 1998; Raloff 1998; Stan and Heberer 1997). Prescription drugs are excreted in human waste in the original or biologically active form (Raloff 1998). Chemists at an agricultural research agency in Switzerland have found cholesterol-lowering drugs (clofibric acid), blood lipid regulating drugs (phenazone and fenofibrate), and analgesics (ibuprofen and diclofenac) in many waters, ranging from groundwater beneath wastewater treatment plants to rural mountain lakes. A German chemist found the same drugs along with antiseptics, drugs for epilepsy, and beta-blocker heart drugs in “nearly all streams and rivers in Germany” (Raloff 1998).

2.5 Identification of Contaminant Sources

Point Sources

Point source pollution originates from a concentrated area or pipe, such as a wastewater treatment facility or industrial plant. The Georgia Water Quality Control Act defines a point source as "any discernible, confined, or discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged" (OCGA §12-5-22(8)).

Federal, state and local investments in municipal sewage treatment exceeded $128 billion between 1972 and 1989, resulting in a 46% decrease in organic waste releases. However, there are inadequate waste systems that leak pollutants, and many cities have combined sewer and drainage systems that release between 3 and 11 billion pounds of raw solids and between 1 and 3 billion pounds of organic matter every year according to the Natural Resources Defense Council (Adler et al. 1993). Industrial pollution controls have eliminated annual discharges of over 1 billion pounds of toxic pollutants and even higher volumes of conventional pollutants (organic wastes) (Adler et al. 1993). These are conservative estimates because the Toxic Release Inventory does not include all dischargers. EPA (1991) reports that the nation has successfully focused on point source discharges in the past; however, there are many challenges regarding non-point source pollution.

Non-point Sources

Non-point source pollution originates from the land and air surrounding a waterbody. Runoff from roads and parking areas contribute organic chemicals and oils to the waterways. Croplands often have high levels of nutrients and pesticides that runoff during storm events. Construction sites with bare land erode during rain events, sending sediment into streams. The Clean Water Act lists agriculture, silviculture, mining, construction, subsurface waste disposal, saltwater intrusion, and hydraulic changes due to engineered structures as non-point sources (33 USCA §1314; CWA §304). EPA reports erosion and nutrient washoff as the two main sources of non-point source pollution in surface waters (EPA 1998).

USGS Studies

The National Water Quality Assessment Program, administered by the USGS, works to understand the spatial and temporal patterns of water quality including the impact of human activities. The studies use standardized methods that allow comparisons across the nation. To date, the USGS has studied 50 major river basins and aquifer systems across the United States. Mixtures of nutrients and pesticides are commonly found in watersheds with significant urban and agricultural land use. At least one pesticide was detected in most surface water and fish samples and over half of shallow wells from urban and agriculture lands. The concentrations were most always below the EPA drinking water standards but over half of the concentrations exceeded aquatic life protection guidelines. Most urban streams had concentrations exceeding an aquatic guideline in 10 to 40 percent of samples. The USGS findings indicate seasonal patterns related to time and amount of chemical application, storm magnitude, and management practices (USGS 1999).

Physiography also effects contamination. Soils, slopes, vegetation and land use practices are factors related to contamination. Land with steep slopes, clayey soils and sparse vegetation are more likely to cause surface water contamination. Flat areas with highly permeable subsurface media are have increased potential for ground water contamination. Areas underlain by impermeable soils have less ground water contamination, but more surface water contamination. Management practices that slow runoff improve stream quality but threaten ground water quality from increased infiltration. The Southeast, with soils and hydrology that favor denitrification, has lower nitrogen concentrations in streams (USGS 1999).

Stream quality responds within one to two years to management changes. Groundwater quality responds over years or decades due to slower travel times (USGS 1999). Lower percentages of phosphorus than nitrogen reach the streams due to the tendency of phosphorus to sorb to soil. However, phosphorus is typically the limiting nutrient in freshwater streams, and thus is more likely to reach levels that cause excessive plant growth (over 60 to 100 µg/L). Nitrogen is normally the limiting nutrient for estuaries (USGS 1999).

Agricultural areas have the highest levels of surface water contamination from nitrogen and herbicides (atrazine, metolachlor, alachlor, cyanazine). Urban areas, comprising of less than 5% of the United States land, have the highest concentrations of phosphorus and insecticides (diazinon, carbaryl, chlorpyrifos, malathion, DDT, dieldrin, chlordane). Insecticides, used for lawn insects, mosquitoes and termites, are typically more toxic to aquatic life than herbicides.

Organochlorine insecticides (DDT, chlordane, aldrin, dieldrin) are frequently detected at elevated levels in fish and bed sediment of urban streams, exceeding aquatic life guidelines for sediment at 40% of the sites, and for fish at 20% of the sites. The most commonly found herbicides in urban areas are atrazine, simazine and prometon, used for weed control. Phosphorus concentrations often exceeded the EPA goal of 100 µg/L to control algae growth in urban streams due to wastewater effluent (USGS 1999). Phosphorus concentrations were highest in semiarid western and southwestern cities where wastewater effluent is a significant portion of streamflow and in the East.

Nitrogen levels have been stable since the 1970s due to a combination of technology improvements and population growth. The dominant form of nitrogen in urban streams has changed from ammonia to nitrate due to conversion during treatment. Nitrate is less toxic to fish, but contributes to algae growth, as does ammonia. River basins with mixed land uses had moderate nutrient and pesticide concentrations due to dilution from undeveloped areas (USGS 1999). Nitrate contamination was most frequently detected in shallow (less than 100 feet below surface) groundwater beneath urban and agricultural lands. Aquifer concentrations were usually lower than shallow ground water due to the variety of lands recharging major aquifers, including undeveloped lands. Aquifers overlain by geology that allows rapid vertical movement of water had more contamination. The four aquifers with nitrate levels that exceeded the EPA drinking water standard were shallow, sand and gravel aquifers in agricultural areas (USGS 1999).

Risk of pesticide exposure to humans is unclear. There are not standards for all pesticides, nor are there standards for mixtures, breakdown products and seasonal pulses. Long-term effects on immune, nervous, and reproductive systems are unknown. Some of the commonly detected pesticides are suspected endocrine disruptors that interfere with hormone levels and reproduction (USGS 1999).

Georgia Studies

The USGS found that urban and suburban areas have had the most important effect on stream health in Georgia due to intense land use, impervious surfaces, population density, industry and transportation. Concentrations of nutrients, pesticides, and organic compounds increase as the percent of urban land increases. Although not as high as urban watersheds, the USGS found increased nutrient concentrations in watersheds dominated by animal feeding operations. The survey also found erosion, sedimentation, and nutrients to be the major concern in timber harvested watersheds (Frick et. al. 1998).

The Georgia Environmental Protection Division (EPD) indicated that metals, pathogens and low dissolved oxygen were the main contaminants of rivers in Georgia. Lakes were mostly impaired by metals, acidity, and pathogens. Estuaries were mostly impaired by pathogens and low dissolved oxygen. Urban runoff, combined sewer overflows and industrial and other nonpoint sources were the common sources. In 1998, the EPD reported that non-point source pollution was the cause of impairment for 85% of streams and 99% of lakes that were monitored and found to need improvement. The EPD reported that inorganic compounds were found in highest concentrations in urban and suburban streams, that urban, suburban and poultry production had the most nutrient pollution, and that fish were found to thrive the most in streams draining forested land. EPD stated that "the most influential factor in water quality is land use" (EPD 1998). They also indicated that most of the land use sources are not under EPD's authority and that water quality problems need local action to correct the land use sources (EPD 1998).

2.6 Emerging Alternatives

Watershed Approach

EPA (1991) called for "non-conventional, cost-effective ways to address the remaining problems," and also stated that a "holistic, locally tailored approach...must become...a routine process for protecting and restoring water quality." A watershed protection project establishes goals and objectives for the watershed; provides a structured communication system for government agencies; private landowners; industry representatives, and other interested parties; identifies the greatest threats to water quality; and encompasses most of the land in the watershed (EPA 1991).

Quantity Issues

Four major water quantity issues currently challenge water resource managers in Georgia. The *waterwars* of the Apalachicola-Chattahoochee-Flint River Basin and the Alabama-Coosa-Talapoosa River Basin will result in water apportionment agreements between Georgia, Alabama and Florida. Excessive consumption of water from the Upper Floridan Aquifer is forcing Georgia to examine groundwater programs. The Ground Water Use Act of 1972 was passed in response to the concern of saltwater intrusion due to over pumping of the coastal aquifers. Concerns have been raised about the 7Q10 standard for instream flow requirements. (The 7Q10 flow is a statistical estimate of the lowest average stream flow for seven consecutive days with an average frequency of once every ten years; it is approximately 10% of normal flow.) The 7Q10 standard is the minimum flow considered for a permit. The Wildlife Resources Division (WRD) of the Georgia DNR reports that the 7Q10 flow is not an acceptable standard for baseflow conditions for aquatic life, having been associated with catastrophic reductions in available aquatic life habitat. The WRD recommendation includes minimum stream flows ranging from 30% to 60% depending on stream category and season (Kundell and Tetens 1998).

The interstate water conflict, the coastal aquifer overdraft and the minimum instream requirements propel intrastate water allocation issues into the debate. As water supply diminishes and water demand appreciates, the reasonable use approach will fail due to a lack of excess water. Emerging alternatives include a market approach, and a public process approach. The market approach bases water apportionment on the highest market value. A public process of water allocation would include river basin and watershed management planning. Kundell and Tetens (1998) assert the need for more monitoring, better resource analysis, and expanded capabilities in information management to support decision making.

Litigation in Georgia

In Sierra Club v. Hankinson, 939 F.Supp. 865 (N.D. Ga. 1996), a federal judge found that the EPA and Georgia had failed to comply with the Total Maximum Daily Load requirements of the Clean Water Act. Only two inadequate Total Maximum Daily Loads had been developed in the 16 years since the first TMDLs were due (1313 U.S.C.A. Notes of Decisions 1999). The EPA was required to develop TMDLs in Georgia within five years. The Georgia Center for Law in the Public Interest, now called Georgia Legal Watch, committed itself to follow the progress of TMDL development in Georgia, and to make sure all of the court orders are completed. BASINS was released by the EPA in 1996 to assist federal, state and local agencies with TMDL development.

2.7 Summary

Federal and state legislation requires Source Water Assessments (Safe Drinking Water Act), Watershed Assessments for Domestic Wastewater Systems (Georgia EPD Policy), TMDLs (Clean Water Act), and publicly accessible data (Emergency Planning and Community Right To Know Act). Neither federal nor state legislation specifies tools or methodologies for conducting the required analyses. In response to the TMDL requirements of the CWA, EPA developed BASINS to support TMDL development. BASINS has the potential to support various other watershed level analyses. In chapter 4 we will present the structure and processes of the watershed model (NPSM) within BASINS. In chapter 5 we will evaluate the current capabilities of BASINS with respect to the legal requirements and the needs of water resources scientists and managers.

CHAPTER 3

DEFINING GEORGIA WATER RESOURCES CONCERNS

Water resource scientists and managers were consulted for their professional views on the current water resources concerns in Georgia. The opinions documented are those of the interviewees, not the agencies. Twenty interviewees were identified by referral from water resources professionals, agency listings, and interviewees themselves. Agency or group interviewed and number of interviews are included in table 3.1.

Table 3.1. Agencies Interviewed.

Agency or Group Interviewed	**Number of People Interviewed**
Agricultural Research Service	2
Crop and Soil Science, University of Georgia	1
Georgia Environmental Protection Division	2
Georgia Farmers	3
Georgia Legal Watch	2
Georgia Soil and Water Conservation Commission	1
Institute of Government	1
School of Environmental Design, University of Georgia	1
Natural Resources Conservation Service	2
Oconee River Land Trust	1
Pollution Prevention Assistance Division	1
U.S. Environmental Protection Agency	1
U.S. Geological Survey	2

Interviews were conducted to define the objectives and needs of Georgia. The approach was qualitative with time for in-depth discussion. The purpose of this segment of the research was to identify key issues in watershed management, not to gain a representative random sample of Georgia public opinion.

Conducting a representative survey was entirely outside the scope of this project; however, the key objectives identified may be useful in guiding future avenues of research. The sample was purposive; there was a specific purpose for the people included in the interviews. Three general questions were asked over about one hour. The general questions were followed by more specific questions depending on the area of expertise, interest of the interviewee, and the direction of the conversation. The interviewee had the opportunity for in-depth explanation. Specific questions were derived from the following general ones:

1. What do you think the critical concerns and needs are in Georgia water resources management?

a)Are we limited more by scientific knowledge or by implementation? b)Are laws or education/incentives more effective?

c) What do you think about TMDLs?

d) What policy changes are needed?

e) What are the sources of water quality concerns?

f) What issues do you see regarding data, e.g. comparability, sharing, monitoring needs, etc.?

g) What role can models play?

2. How do you see a tool like BASINS being used?

3. What would you want to know about BASINS before you would feel comfortable using it to make decisions?

Comments are summarized and presented in bulleted form for easier reading and to preserve authenticity.

3.1 Policy

Policy Issues

- Economic interests, political pressures and tax driven development are major factors threatening water quality.
- Land trusts have eased development pressure by purchasing development rights.
- The federal and state agencies can provide technical support but cannot provide momentum.
- All parties need to be at the planning table from the start. For example, a local watershed plan, in Georgia, called for no new agriculture and required farmers to approach the zoning board before pesticide applications. The outcome was a result of the absence of farmers in the planning process.
- Public meetings are often not effective. Only a few people show up and they are not the people that need to be involved. Sending posters, brochures, and other media to meetings such as Kiwanis, county fairs, and the Cattleman's Association is effective and efficient because people are already there.

- Drinking water supply issues are becoming more serious, leading to the building and planning of water reservoirs. Concerns over silt, nutrient and bacteria pollution in the reservoir inspire an awareness of watershed health. It is difficult to make counties work together. Watersheds do not end at county borders.
- The Georgia Environmental Protection Division (EPD) governs the quality of the air and water in Georgia. The EPD faces many dilemmas. EPD informs industry that they need to increase effluent treatment. Industry responds that they will have to move to Mexico and destroy 500 U.S. jobs. The politicians arrive. Once stakeholders construct their house on the lake, they demand clean water and tighter restrictions for farmers and industry. Local governments want to grow and develop and accuse the EPD of being unrealistic. Many environmental groups feel that EPD is not enforcing existing laws, and threaten to sue if the EPD does not comply with their wishes.
- More education, incentives and development of regional council structures are needed. The local governments could shift enforcement to an authority or council. An authority has the distance from elected officials to make unpopular decisions. Local legislations instead of the state legislation will have to create these authorities and councils because the state will not shift power to a regional authority or council. Florida's Water Management Authorities have been successful. They have the ability to tax (ad velorem) which gives them the resources to make a difference. Georgia's topography does not lend itself to mater management districts

with long narrow river basins in the north running perpendicular to the coastal plain groundwater. However, Georgia may benefit from some type of regional management.

- We have not reached a crisis point yet. Political will is weak. People do not relate drinking water to expelled water. People are not yet ready to pay the price.
- There is current interest in the state legislature to decrease the 100 foot buffer on trout streams to 50 feet for the second home market.
- An informal survey by the Georgia Soil and Water Conservation Commission found that most landowners were willing to give up land for a 40 foot buffer at a cost-share rate of 78%.
- Would like to see state tax benefits for landowners that have land in greenspace easements and grant programs for land trust groups to support stewardship costs.
- More money is needed and it should be used in a coordinated way. Currently, much of the 319 money is going to small, scattered projects with no coordination by geography, pollutant, or programs.
- The Natural Resources Conservation Service Environmental Quality Incentives Program requests 3 to 4 million each year and receives 1 million dollars per year. A watershed group applied for a 4 million cost-share grant and received 103,000. The money that is available does not go very far.
- Policy should be changed to prioritize the way we look at streams; we need to look at streams by the magnitude of impairment.

- Development and manufacturing are done the least expensive way for the short term while externalizing costs. Long term costs are to public health and the environment. Prevention is easier than extraction.
- How can we get the people to understand, especially when there are serious health ramifications? Excessive amounts of money combined with politicians that are focused on the next election reduces the incentive to think about finite resources. Short term vision makes it hard to make the best decisions. Instead we should be thinking three to four generations ahead. Educating school children may be effective.
- Site specific solutions are necessary; a general width buffer requirement fails to take varying scenarios into account. Site specific solutions require human resources and money.

Laws and Education

- Education with incentives has been effective. Laws have proven to be less effective. For instance, Atlanta continues to illegally dump raw sewage into the Chattahoochee River from the combined sewer overflows. Permits are regularly violated.
- Development requires more laws due to its transient nature. The developer does not have the relationship with the land that the farmer does; the developer moves on after the sale. The farmer depends on the land for his livelihood, thus making education and incentives more effective.

- More laws could be useful at the local level. Local ordinances need to relate growth and development to water quality. EPD is trying to get local leaders to equate land to water quality and plan accordingly. More local enforcement is needed through added personnel. Currently the EPD requires local growth plans before they will issue new wastewater treatment plant permits. The growth plans often have an impact on land use zoning. Local government leaders that try to control land zoning often do not get reelected. It is difficult to tell people how to use their land. The most effective solution to this dilemma is to create stakeholders groups and work with citizens from the beginning so they understand the issue. Then, in the end, most citizens are satisfied because they understand the complexity of management and were present through the decision making process.
- Would like to see better enforcement of local laws. State law currently requires at least a 25 foot buffer on all streams; agriculture silviculture, and DOT are exempt. The Georgia River Network found that 96% of all variances requested were granted.

TMDLs

- Decisions are being made without enough scientific information. TMDLs are a good approach because they focus on impaired segments instead of generalizing across the state. However, we do not have enough knowledge to set good TMDLs. We need more monitoring.

- Even when we have adequate scientific knowledge to set appropriate standards, we will have to increase mitigation strategies. Why not go ahead and deal with the sources we know? There is no need to have a specific numeric goal to increase implementation of BMPs. We need more money in cost-share programs for mitigation techniques. Fencing livestock out of streams, riparian buffers with selective harvesting, and storing waste for several weeks prior to application for fecal coliform and hormone reduction are recognized techniques for bacteria and nutrient reduction. However, we do not know how much these techniques reduce pollution which affects TMDL allocations.
- A TMDL on one stretch of water is not useful, but if the whole watershed is managed properly TMDLs are taken care of.
- Money is being wasted on TMDL development without adequate science. A comprehensive plan would be more appropriate than a TMDL number.
- Watershed assessments, with NPDES permits linked to growth, would meet the goals of the TMDL. Money is being spent on watersheds that violate the inappropriately low fecal standard but do not have problems.
- TMDLs should be done but are not successful yet. We are having to do TMDLs without an idea of what is reasonable. We do not know background levels, sources, and often we don't know if there is really a problem. We are not sure of the effect of impoundments on water quality.
- Most TMDLs in Georgia are for fecal coliform. The fecal standard is 200 counts/100 mL in the summer and 1000 counts/100 mL in the winter. The fecal standard is unreasonable since these values are common in pristine

> watersheds. We do not know baselines or expectations from pristine areas.

Summary

Respondents discussed a range of policy concerns, from issues of tax-driven development, to scientific knowledge vacancies in TMDL development, to a paucity of federal money for demonstration projects. Most topics were derived from the relationship between land-use and water quality. For example, development increases the amount of impervious area in a watershed and converts streams into engineered stormwater conveyances. TMDL implementation involves identifying sources of pollutants and allocating pollution among users in a watershed. Demonstration projects can show methods of sustainable development, agriculture, and forestry. These examples, along with most of the issues raised, were various reflections of land-use management concerns.

Respondents viewed land-use management and planning as a leading and growing threat, as well as a potential anodyne, to water quality in Georgia. They recognized the dilemmas that develop as economic health is poised against environmental health in a political landscape. Communities can govern land use management through local zoning and land management ordinances, deciding what, where, and how development occurs. Many interviewees recognized that local government leaders often meet resistance to land management ordinances from developers and landowners, bidding land use planning interests against strategies for re-election. Many interviewees felt that most local leaders have not yet developed the vibrant political will, regarding water resources, that is necessary to invoke change. Respondents felt that the role of scientific and regulatory agencies in local watershed planning should be to supply information and technical tools that support state and local decision making.

Interviewees believed that Total Maximum Daily Loads (TMDLs) are a good attempt at site specific solutions and at accounting for non-point sources. However, the division of the watershed into arbitrary segments and the lack of scientific knowledge about hydrologic processes caused many respondents to question the wisdom of the TMDL program. Interviewees felt that the investment of limited time and financial resources into comprehensive watershed management approaches that address the political, economic, financial, transportation, as well as the scientific landscape of the watershed may be more beneficial.

One of the farmers summed up the issues well when he said, “The management plan is key. When you have a regulation here and a rule there, you don’t have a plan. You have a mess.”

Respondents suggested a range of policy solutions, from economic incentives to enhanced local ordinances with improved enforcement. Respondents felt that economic incentives were appropriate for agriculture and forestry, since farmers have a relationship with and a stake in the land, but laws with enforcement were needed to address the transient nature of development. State agency respondents believed that landowners are willing to support Best Management Practices if the costs are distributed among the beneficiaries.

Interviewees saw the future of watershed management in coordinated planning, alternatives to the conventional reductionist approach to resource management, and citizen driven decisions.

3.2 Science

Science vs. Implementation

- Science needs to tell us more about where and how to monitor, about BMP effectiveness and land use contributions. We need to know the effect an on-farm Nutrient Management Plan will have on the watershed. We do not have that data now.
- In many areas, implementation is having to precede science. Scientists need more money and are slow to redirect research. Lawsuits by environmental groups are pressuring the state to act, forcing issues that we do not have the science to support.
- In a study on four watersheds in conservation tillage practices with no application of manure or poultry litter for at least thirty years, a large storm produced huge fecal coliform counts. This data was taken as a baseline event for a poultry litter application experiment. If the researchers had not gotten this baseline data, they would never have known the extent of the fecal coliform baseline numbers and would have blamed the high counts on the poultry litter.
- The science behind choosing minimum in-stream flows is in development. We know ways to mitigate the effects of forestry and development on water quality, but implementation is limited; the science is robust enough

to protect water resources. Source Water Protection is also implementation limited; we know what to do. The science is too limited for good TMDLs. There is not enough scientific evidence know where to set the NTU standard.

Pollutant Source Identification

- The 25th anniversary of the Clean Water Act in 1999 celebrated the success of the NPDES program in cleaning up point sources and stressed the continued non-point source problems. Improvement is definite, but not complete. Many streams are damaged by leaky sewers and combined sewer overflows. The water quality of Peachtree Creek in Atlanta is many times worse than the effluent from an Atlanta wastewater treatment plant. Peachtree Creek is an example of bad land use planning. Todd Rasmussen (Hydrology Professor, University of Georgia) found high levels of fecal coliform in urban streams that were not from wastewater treatment plants. What were the sources?
- The success of the point source program is directly related to the dollars spent. Since 1972, over 100 billion has been spent on PSP and under 2 billion has been spent on non-point source pollution. The Clean Water Action Plan budget requested 200 million for the EPA and 200 million for Farm Bill programs. The EPA money was funded for FY1999 for 319 programs that are open to anyone. The Farm Bill money was not funded. Both monies were intended for use for Best Management Practices.

- Sediment is the dominant pollutant. The question remains of whether it is newly eroding sediment or mobile bedload sediment. Sediment is not on 303(d) lists because there is no numerical standard. Sediment is evaluated through biological indicators. Most biologically impaired listings are due to sediment. If we could reduce sediment pollution we would be reducing a lot of other pollution as well since many pollutants are transported to the streams adsorbed to sediment or by the same processes as sediment. For example, negatively charged clay has an affinity for metals and ortho phosphates.
- Discovering the sources of pollution require more data and more monitoring to relate land management with edge of field water quality and impacts to the stream.
- Microbial data is noisy with many unknowns. There is not enough science to justify extensive intervention. The fecal coliform indicator will need to be replaced with pathological indicators linking the organisms to the sources.
- The small actions of everyone have a large combined impact. The little things each individual does- fertilize lawns, insecticides on houses, disposing of oil, etc. - multiplied by the 4.5 million people in Atlanta, for example, matters. The state has little control over land use. Consistency and enforcement of local ordinances is needed.

Data and Monitoring

- There is wide recognition for a need for more monitoring data, especially current data. Money is spent on conservation practices without us knowing for sure if they achieve what they are supposed to.
- Data limits scientific knowledge. Scientific knowledge effects decision making. Data is the interface between research and management. Data can direct research and management. Research can direct management. Management can direct research.
- Data collection is expensive and time consuming, often with complicated methods. We need to recognize what information is useful before we gather data.
- EPA and USGS studies have overestimated agriculture contributions because they have not taken management into account. EPA has used fecal pollutant concentrations "as excreted" in fresh waste. Management has a huge impact on fate and transport.
- Congress and the NSF do not fund many monitoring projects. The EPA 319 program will fund monitoring projects that involve conservation practices.
- There are few incentives for people to share data. We spend a lot of time collecting data but do not use what is already collected. This is an inefficient use of resources. One reason for this is that standards are dispersed. Federal, state, and local agencies all use different standards and different scales. Quality controlled and quality assured datasets require effort and money to collect. People do not want to give their hard

work away for nothing. Rewards for data sharing could help. Promotion boards could consider database development and sharing. Tenure committees could consider data sharing as an indicator of impact and success. Also the issue of protecting data quality if many will be using it.

- There is variability in collection methods even when using the same protocol. Lab protocols, field methods, hold times, and time of sampling differ. For example, the EPD uses a broth method for fecal coliform to produce a most probable number. The USGS uses a filtration method with a hold time less than 4 hours. It is not valid to lump this data together and statistically analyze. Data with differing confidence limits and detection limits (10 ppm or100 ppm) cannot be lumped together. We can learn from existing data, but cannot mix data to reach any meaningful conclusions. Each project has short term goals without a vision for the region, state, or country. There are national efforts to collect more transferrable water quality data. Many professionals would like to see the federal and state agencies work more on data management.
- There are sleeping problems that will arise in the future. Pharmaceuticals and endocrine disruptors are predicted to be a big problem in the coming decades. Endocrine disruptors effect the fetus in the 4 to 9 week gestation period of the sexual system development. The reproduction of the second generation will have to be studied.
- Sampling is not being done well. Agencies do not have the money or human resources to sample well. Lack of monitoring data limits the

success of TMDL development. Even if a TMDL is in place, if there is no monitoring, how can we sense violations?

- Reference values are needed because samples could be at the end of a storm event. Most streams would fail if sampling is done during high flow. If we get one high number from a site we know nothing. Forested sites fail after rain events. Often we cannot detect the difference between a pristine and impacted site unless the animals are in the creek, or it is a huge event. Sampling a pristine site and an impacted site at the same time gives statistical power (t-test). More studies on small watersheds are needed to link problems to the sources.
- Critical conditions for point source pollution are at baseflow due to less water with higher concentrations. Critical conditions for non-point source pollution are at stormflow because NPSP enters as runoff. Current routine sampling observes baseflow but does not capture stormflow. More monitoring stations and data at each station are needed.

Summary

The interviewees believed that scientific understanding can promote better decision-making, and indicated that many water resources issues cannot be addressed well due to a lack of scientific knowledge. For example, the effectiveness of Best Management Practices and Nutrient Management Plans are not clear, and the science of pollutant source identification and in-stream flow minimums are in development. Many respondents emphasized the need for long-term monitoring, and commented that national standardized methods would allow data comparability among agencies.

3.3 Sectors

- Most impaired streams are around major cities. For instance, Flat Creek in Gainesville, Georgia, consistently violates water quality criteria. The fecal coliform count increases along the Oconee River as it passes through Athens, Georgia. Athens doubles the phosphorus in the Oconee River. The turbidity keeps it from eutrophying until it reaches Lake Sinclair.
- For urban pollution, the state of the art far exceeds the state of the practice due to human resistance to change. The culture of engineering is one of convention, not innovation. Designers are not allowed to implement stormwater infiltration, porous pavement or cluster development. Demonstration projects would educate and promote the advantages of innovative designs, but require money.
- Planning is a public, not scientific process. Public commitment is a necessary and continuous process.
- Urban sprawl is a major concern. Lands that were previously not suitable for farming and were in the CRP are now being sold for development due to rising property taxes. Urban sprawl probably cannot be regulated since land use is decided at the local level, but development can be improved through conservation development such as clustering.

- Impact fees would tie the real costs of development to the property instead of being paid by the community. Developers would pay the city for processing applications. This money could pay for new streets, water and sewer lines, and electrical lines. The impact fees could help pay for local enforcement officers and local ordinances. Developing subdivisions would be slightly more expensive, resulting in less urban sprawl.
- Demand for more wastewater treatment plants are growing as the population rises. Gwinnett County is constructing a new wastewater treatment plant that will discharge directly into Lake Lanier, the drinking water source for much of Atlanta. This is the "tip of the iceberg." More will follow.
- Urban infrastructure lacks proper maintenance of permanent engineering sewage structures to temporary silt fences.

Agriculture

- Agriculture differs from development. The farmer has to take care of the land because it is his livelihood. The developer moves on to another project after the sale.
- Well managed agriculture lands benefit the entire community. We need creative ways to put a value on the environmental services of agricultural and forest land. Some expenses need to be transferred to the benefactors.
- Agricultural agencies work better with EPA and EPD in Georgia than other states. For example, the agencies work together on non-point source

assessments. The Natural Resource Conservation Service and Georgia Soil and Water Conservation Commission develop the agricultural part of EPD's River Basin Planning Program. The agricultural sector submits the most applications for 319 programs. EPD supports a voluntary approach to Best Management Practices. If a complaint is filed, EPD will investigate and give the Georgia Soil and Water Conservation Service the opportunity to arbitrate. If an agreement is not reached, the case returns to EPD for fines and Best Management Practices requirements. The Suwanee River Basin Interagency Alliance resulted from an Natural Resource Conservation Service study.

- Misconceptions about agriculture result from people's lack of familiarity with farms along with sensational journalism. Most people, including policy makers, dwell in cities or suburbs and have no experience with agriculture. The inexperience combined with dramatic journalism results in misunderstandings.
- Some policies affecting agriculture are based on opinions/misconceptions instead of science. Environmental law firms have effective political maneuvering. Agriculture has less representation in the Georgia General Assembly than in the past.
- Pollution reduction is not limited by technology, but is restrained by lack of money. BMPs are designed for 25-year, 24-hour storm events for an acceptable benefit to cost ratio.
- Erosion is partially a cultural problem, again plagued by humans' resistance to change. No-till agriculture is not clean and pretty.

- Conservation practices often need money for commencement. Producers continue to use conservation practices once they get started. For instance, no till agriculture requires different equipment from conventional till agriculture, requiring serious money for equipment purchases.
- Demonstration projects of successful NPSP strategies and their cost-effectiveness would be helpful.
- Many farmers find the excessive paperwork and extra conditions of some of the government programs wasteful. For instance, when applying to qualify for a waste management upgrade program, the farmer may be required to set aside areas for wildlife.
- Many farmers desire the regulations to be based on science and not emotion. Emotion based regulations are subject to change each year, wasting time and money for the farmer. The farmer desires scientifically based, solid, stable, practical regulations.
- Nutrient Management Plan is key. If your Nutrient Management Plan is right, then it all works together and you are handling and applying nutrients properly. If there are rules and regulations here and there, we end up with bits and pieces. Then you don't have a plan. You have a mess.
- 100 to 150 foot buffers will filter most pollutants from normal operations, but nothing will contain a catastrophic event.
- Regulations should be scientifically based. If regulations say a 200 foot buffer is needed, and prove it, then that is what it should be.

- If you have a high concentration of chickens and urban growth and you are cutting natural buffers for development, something has to give.
- Urban wastewater plants can direct discharge in emergency situations. Just think of Atlanta. Agriculture cannot direct discharge ever. Some people are trying to pass jail sentences for breaches even if they are accidental. In North Carolina floods, the wastewater treatment plants also flooded and breached during the hurricanes.

Summary

Human resistance to change was a theme that echoed throughout many of the interviews. Respondents felt that adherence to the status quo of design development, along with degrading urban infrastructures were leading causes of impaired urban streams. Several interviewees held concerns for current development patterns that result in inefficient use of urban infrastructure, and felt that development could be improved through innovative techniques.

Several respondents articulated that well-managed agricultural and forest lands benefit the entire community by providing food and forest products, clean air and water, and green space. Many interviewees suggested that the implementation costs of Best Management Practices should be paid by all beneficiaries, not only the farmer. One interviewed farmer stressed the need for regulations that are stable and scientifically based, not politically driven. A view held by many respondents was that agricultural and forestry non-point source pollution should be managed through economic incentives in the form of cost-share programs and pollution trading.

3.4 Modeling

Modeling Issues

- Models are one tool; they do not provide the only answers to complex questions. Project results should be presented with the model as one tool. We should not only present model results, but we should report the project results.
- Model quality is dependent upon the assumptions of the model and the data put into them. Need to know the quality of input data in order to know the quality of the output data. For example, if the input data is only from baseflow, then knowledge about storm flow cannot be assumed.
- Models are useful to determine what has the highest variance and uncertainty. For example, we have extensive ion monitoring. Are there big variations in calcium? No. Is this needed? Fecal coliform has lots of variance and uncertainty.
- Parameter sensitivity can guide allocation of monitoring funds.
- Need to have ability to take management into account for fate and transport.
- Few models account for the benefit of organic matter in manure.
- Impoundments are not included in the modeling. There are thousands of impoundments in the Upper Oconee Watershed.
- We do not know the decay rates for fecal pathogens; do not know the effects of temperature and moisture on decay rates.
- Is modeling worth the time and money, if in the output says we need bacteria reduction? Does modeling tell us anything new? If one model run

indicates a 35% needed reduction and another model run indicates a 55% needed reduction, will we do anything different?

- If there are two farms in different geographical location, and one farm is next to a large stream, and the other farm is next to a small stream, is it equitable to require different BMPs for the two farms because the model ouptut different answers? Only have one BMP manual.
- State agencies need something that is user friendly, simple and quick.
- Helps people visualize the impacts of their decisions.
- Indicates trends. Can contrast practices if they are different enough.
- Compare relative differences, but not absolute numbers.
- Ability to look across a climatic historical record and at risks of catastrophic events.
- Trust models more for nitrogen and sediment than phosphorus and pathogens

BASINS Uses

- Watershed characterization - create maps/info. of what is going on where in the watershed
- Use as management tool in decision making process for city planners, Regional Development Centers
- Locate areas with development pressures of interest to Land Trusts
- Educate public on the connection between land use and water quality
- Identify priority watersheds for preservation, enhancement, restoration
- Strategic implementation of conservation practices

- Identifying contributing areas
- Development planning - stormwater and erosion
- Locate where greenspace is needed for planners and Land Trusts
- Inform the public of choices
- Help Land Trusts inform landowners of issues
- Best Management Practices scenario testing - benefits of buffers, filter strips, vegetative properties (requires good data and good understanding of Best Management Practices/reduction relationship)
- Allocation of resources - allocation of resources is often based on political boundaries, political pull and guesswork
- Supporting initiatives by showing where problems are
- Permitting process - to support requests
- Local groups do watershed assessments
- Analyze dramatic changes in the land use of watersheds
- Nutrient Management - location in watershed, distance from water
- Disribution of agriculture water supplies for irrigation
- Application rates
- Simulate potential changes for planning
- Teaching tool to show people the potentials of land use changes. Graphics are especially good to illicit change.
- Anything that does not look at absolute numbers
- Assists with locating environmental factors related to pollutants

BASINS Concerns

- The unknown; the black box approach.
- Paramaterization is problematic. The parameters are not based on standard soil properties.
- Need more data to understand relationship between land use and loading. There is not much data for build up and wash off curves. How do we know the fecal coliform concentration of runoff for each land use?
- User friendliness.
- Can it be applied across watersheds? Assumptions, limitations, error.
- Many people are using the default values in HSPF.
- Even if the amount of cropland in the watershed is known, you do not know if manure is applied as fresh manure, day old manure, week old dried manure, poultry litter, etc. What is the fecal coliform concentration at elapsed times after application?
- We do not understand the natural cycles of streams yet. Our concepts and standards have come from data that we have extrapolated too far from.
- Where do you get the parameters from?
- Can run variable reasonable scenarios and get different answers. Can get whatever you want and it can be defensible.
- Modeling is an art, not a science. Experience is required to know what is going on and to know the appropriate uses and manipulations of the models.

- We do not have the experimental data to model the effect of buffer strips or impoundments on nutrients and pathogens. For instance, if we have two streams, one with a dam and one without, the dam will be an important buffer. BASINS will model them as the same.
- Need to know the assumptions and deficiencies of the models. Local planners cannot be expected to do this. They need to be supplied with this information along with the modeling package.
- BASINS data is not current. Lake Oconee is not in the BASINS data. Some roads are not in BASINS; Highway 316 is absent.
- There is a time lag for processing weather data.
- Data is too coarse for many uses. GSWCC works in a smaller area than BASINS can support. Georgia Legal Watch would like to use BASINS for small streams, but cannot due to data resolution.
- If comparing urban to forestry to agriculture, the data must be comparable.
- HSPF requires calibration. Most local groups will not be able to do the intensive calibration required by HSPF.
- How hard is it to add local data to BASINS. (Comparability issues.)
- Data points have been found to be in wrong locations. Some NPDES points are in wrong place.

Summary

Respondents emphasized that models are simplifications of reality, with assumptions, and approximations. Interviewees accentuated the point that models should not be viewed as the sole provider of answers to complex questions. State agency participants identified their need for simple, quick, user-friendly models that help people visualize the impact of various decisions. There was no consensus regarding the effect that modeling has on decision-making, such as whether varied model output will result in unique policy strategies. A state agency participant asked a meaningful question, “if a model calls for a 50% or a 75% reduction in fecal coliform loading, will we do anything differently?”

Respondents viewed BASINS as potentially useful for watershed management through characterization and education, but not for the generation of absolute values. Primary concerns over BASINS included issues of user-friendliness, data quality and comparability, parameterization, and the lack of experimental data.

3.5 Summary and Discussion of Interviews

Abundant conflicting interests, intense economic and political pressures, and prosaic political will inadvertently conspire to degrade water resources. These themes resonated throughout the interviews, as respondents ebbed and flowed from subjects of policy and community involvement to issues of insufficient scientific understanding. One of the farmers summed up the issues well when he said, “…if you have a high concentration of chickens, and urban growth, and you are cutting your buffers, something has to give…”. These issues, including public, economic, and environmental health culminate at the community level, placing local leaders and citizens at the helm of water resources issues. The citizens will decide what will ‘give’ in local planning commission meetings across the United States where they will have to make decisions regarding land-use and management. Decision making will be enhanced if current scientific understanding is felicitously conveyed to the local leaders and stakeholders.   Joshua Ledbetter, of Rockefeller University said:

The scientific mind can bring much to the political process. But science and politics are a hard match. Truth is the imperative of science; it is not always the first goal of political affairs…A vital responsibility of the expert advisor is to clarify technical issues so that the essential policy questions become accessible to the judgement of the community at large… (Robert Wood Johnson Foundation 1995).

Scientific information is conveyed through technical and decision-support tools, which are also used by the local planners to implement legal and policy directives. The technical tools being produced by federal agencies must meet the needs of the users, including user-friendliness and defensibility. For example, hydrologic models, that are being used for watershed assessments and TMDL development, must have realistic data and parameterization requirements, and should be legally and scientifically defensible. Some of the legal directives, including TMDLs, will be challenged in court when they cause considerable impact upon landowners. The technical tools provided should stand up to the legal and scientific challenges.

Regardless of the technical tools that are utilized, public support is necessary for successful implementation of local ordinances, including watershed management plans. Scientists must be able to communicate the knowledge gained from data and analysis, as well as, the limitations of the data and analysis, in order to maintain the trust of the public. One respondent made a simple, and often overlooked point; “In the end, planning is a public process, not a scientific one.” Diminishing the gulf between policy, science, and the public requires the input of people with technical knowledge, as well as, political insight.

CHAPTER 4

WATERSHED MODELING

4.1 Watershed Models

The EPA document, *Compendium of Tools for Watershed Assessment and TMDL Development* (1997) discusses reasons for watershed modeling and reviews available models based on their theoretical basis, range of application, and required inputs, but does not address calibration or application design issues. According to EPA (1997), models can be used to assist with targeting watersheds; developing objectives; defining solutions; developing plans for management implementations; tracking progress toward achieving objectives and; addressing the interrelation of multiple watershed stressors. Table 4.1 includes several commonly used non-point source models.

Tsihrintzis et al. (1996) also summarized the capabilities of several watershed models. The hydrology of agricultural lands can be simulated with HSPF, ARM, NPS, and CREAMS. PRZM primarily models forested and natural lands. HSPF has the most comprehensive capabilities, simulating urban and agricultural lands, surface and subsurface flows, sediment, pesticides, and nutrients (Tsihrintzis et. al. 1996). SWMM is primarily an urban land use model and is deficient in agricultural land simulations. Donigian and Huber (1991) stated that conceptual, or mechanistic, models such as HSPF, CREAMS, and

SWMM, are data intensive but produce superior hydrologic simulations leading to improved predictions.

Table 4.1 Non-point Source Models

Model Name	Common Title	Source / Supporting Agency
Hydrological Simulation Program - Fortran	HSPF	EPA
Agricultural Nonpoint Source	AGNPS	ARS
Areal, Nonpoint Source, Watershed Environmental Response Simulation	ANSWERS	VPISU (Biological Engineering Systems)
Chemicals, Runoff, and Erosion from Agricultural Management Systems	CREAMS	ARS
Ground Water Loading Effects of Agricultural Management Systems	GLEAMS	ARS
Soil and Water Assessment Tool	SWAT	ARS
Pesticide Root Zone Model	PRZM	
Storm Water Management Model	SWMM	Various private and EPA

4.2 BASINS

BASINS is a package of spatial data interfaced with a suite of hydrologic models. A watershed level point and non-point source pollution model, NPSM (HSPF), and in-stream water quality model (Qual2) are included in BASINS. BASINS 3.0 will include SWAT, a raster based watershed level model, as an alternative to NPSM(HSPF). BASINS was developed by the EPA Office of Water, primarily to support TMDL development. BASINS integrates many separate and time-consuming tasks of Watershed Assessments - preparing and summarizing data, creating maps and tables, and applying models. According to EPA (1998), the time needed for analysis is reduced, more questions can be answered, and data needs are better identified when using BASINS. EPA

(1998) stated that BASINS supports the identification and prioritization of water-quality limited waters, the characterization of point and non-point sources and the evaluation of their magnitude and significance, the fate and transport processes of the point and non-point sources, the relative values of potential control strategies, and the visualization and communication of environmental conditions to the public.

EPA appears to have a strong commitment to BASINS. The EPA provides BASINS free of charge on the EPA web site (www.epa.gov/ost/basins). The EPA provides technical assistance, and is continually working to improve and update the system. BASINS 3.0, currently in beta release, has raster capabilities that enhance watershed delineation and includes the Agricultural Research Service developed SWAT model and the USGS GenScn model. Table 4.2 includes several of the datasets included within BASINS along with the corresponding metadata.

4.3 Hydrologic Simulation Program – Fortran (HSPF)

HSPF Overview

The current watershed model in BASINS is NPSM, which essentially is HSPF with a graphical interface and the capability to import spatial data. HSPF originated in the 1960s as the Stanford Watershed Model (Crawford and Linsley 1966) and has been modified through the years. HSPF is a continuous, lumped-parameter, quasi-physically based watershed model that simulates water quantity and quality. HSPF includes routines for fluid, sediments, pesticides, tracers, and other water quality constituents on pervious cover, impervious surfaces, and within stream reaches. HSPF can also model in-stream nutrient fate and transport, biochemical oxygen demand, dissolved oxygen, pH, phytoplankton, zooplankton, and benthic algae (EPA 1997).

Discrete constituents, such as water, sediment, and chemicals are passed through a fixed environment that represents the watershed. The watershed is divided into segments that are assumed to have homogeneous properties (Bicknell et al. 1992). HSPF can be applied to watersheds of all sizes and land uses using fitted parameters.

EPA (1997) recommended use of HSPF as a team effort by highly trained personnel due to its comprehensive nature. EPA (1997) stated that if detailed models are “properly applied and calibrated,” they can make “relatively accurate predictions of variable flows and water quality at any point in a watershed.” They also stated that the additional accuracy gained by using a model like HSPF may not justify the required effort and resources, and that the use of detailed models is more cost-effective for complex situations.

Inputs to HSPF include precipitation, watershed boundaries, land-use information, and stream reach data. HSPF partitions the precipitation falling over the watershed into rainfall on the stream reach, surface flow, interflow and baseflow. Hydrologic processes such as infiltration, evapotranspiration, surface flow, and baseflow are simplified into a series of flows and storages. Equations with fitted parameters control the inflows and outflows from each storage.

Table 4.2. Several Datasets Included within BASINS.

Data	Data in BASINS	MetaData
Meteorological	NOAA data used by SWRBB (preccursor to SWAT) model	Geographic locations made into point coverages in ARC/INFO. Theissen polygons generated from point coverage. No quality assurance procedures conducted by EPA.
Land Use	GIRAS LU/LC	1:250,000 scale quads of LULC
Hydrography	Reach File 1	*Hydrography*: Prepared by EPA from 1:500,000 NOAA aeronautical charts with corrections from aerial photography and satellite imagery for BASINS. Optically scanned with finer resolution than feature line width. *Flow data*: Mean annual flow and 7Q10 low flow estimates at downstream ends of over 60,000 reaches combined with an estimate of travel-time velocity for the same reaches under each flow regime. All RF1 flow data are estimates of flow at places other than USGS gages. 4112 USGS gages with flow data plus another 4000 without useful flow data were used for all RF1 reaches flow and drainage area estimates.
	Reach File 3	Unvalidated reach data from a series of EPA hydrographic databases that provide connectivity regardless of topology. The metadata advises conservative use of RF3.
Elevation Data	DEM	Produced from 1 degree DEMs from the Defense Mapping Agency converted to shapefiles and resampled to 300m cells. Elevation in meters or feet.
Permit Compliance System	PCS	Developed to track permit compliance of the NPDES and includes data on over 75,000 facilities. Facilities with no coordinates are not included. Coordinates are assigned to facility station, not discharge pipe. Zeros or blanks in the coverage are given lat/long values from another facility with the FINDS identifier.
Industrial Discharges	IFD	Automated database of industrial dischargers created for the EPA. Includes the PCS, NPDES, POTW, Toxicity Information System, Organic Chemical Producer’s database, and Waste National Priority List sites. Includes facility information, pipe location, flow, and facilities that discharge to a POTW

Table 4.3. Several Datasets Included within BASINS (continued).

Data	**Data in BASINS**	**MetaData**
Soils Data	STATSGO	Soil association maps developed by the National Cooperative Soil Survey from more detailed maps. Soil surveys, LANDSAT images, and data on geology, topography, vegetation, and climate were used when detailed maps are not available. Detailed maps are sampled and the data is expanded statistically to generalize the entire area. The original map data are collected in 1 X 2 degree topo quad units and are merged as statewide coverages. Designed for regional, state and multi-state management.
Drinking Water Supplies	DWS	State collected data compiled by EPA to monitor public drinking water supply, study patterns of contamination and new contamination.
Water Quality	STORET	Water quality data for 47 physical and chemical parameters. The data are compiled from many different organizations including government agencies, universities, contractors, individuals and water labs. The data providers are responsible for the data quality. The attribute table includes an agency code.

The fitted parameters do not directly represent a physical characteristic, such as infiltration rate, soil bulk density, or soil depth, but are representations of several physical processes combined. The parameters must be estimated from observed data through calibration.

The capability of HSPF to predict the effects of land use changes on water quantity and quality lies in the ability to fit unique parameters for each land use type. The term *land use type* can be used interchangeably with *soil-cover type* in this discussion of HSPF. In order to assign parameters for each land use type, the user must:

- Locate watersheds with the same soils, topography, and climate of the study area that are dominated by a single land-use type, for each land use type modeled;
- Collect precipitation and runoff data in each watershed for an adequate time period (five years is often suggested as the minimum); and
- Calibrate HSPF for each land-use type

Then the user can predict future land use change scenarios by assigning the calibrated parameters for each land-use type.

Water Budget Processes

The algorithms for the water budget of the pervious land segment module are based on the LANDS subprogram of the Stanford Watershed Model IV (Crawford and Linsley 1966) and are also used in HSP (Hydrocomp 1976), ARM, and NPS (Donigian and Crawford 1976 a,b; Bicknell et al. 1992). The following sections include descriptions of some of the water budget algorithms in HSPF. Refer to the HSPF users manual for in-depth descriptions (Bicknell et al. 1992). Figures 4.1 and 4.2 illustrate the general structure of HSPF processes.

<u>Precipitation</u>

Precipitation and evaporation data must be recorded or gathered from established weather stations. The precipitation that is not intercepted is available for surface runoff, surface detention, or infiltration. The infiltration algorithms calculate continuously varying infiltration rates as a function of soil moisture over time (see Philip 1957). Spatial variation is accounted for using a linear probability density function that divides the available precipitation into potential runoff (surface detention, surface flowand interflow) and infiltration. (Bicknell et al. 1992).

Infiltration

The infiltration algorithms represent infiltration as a function of time and soil moisture, and as it varies over the land segment. The soil moisture equations originate from Philip (1957). Fixed infiltration characteristics, such as soil permeability and land slope, vary spatially across the watershed. Areal variation is accounted for using a linear probability density function. Figure 4.3 illustrates the infiltration/interflow/surface runoff functions of the water budget processes in HSPF. The variables that determine the location of lines I and II are calculated by the following relationships:

IBAR = (INFILT/(LZS/LZSN)**INFEXP)*INFFAC

IMAX = INFILD*IBAR

IMIN = IBAR – (IMAX – IBAR)

RATIO = INTFW*(2.0**(LZS/LZSN))

IBAR = mean infiltration capacity over the land segment (in/interval)

INFILT = infiltration parameter (in/interval)

LZS = lower zone storage (in)

LZSN = parameter for lower zone nominal storage (in)

INFEXP = exponent parameter greater that one

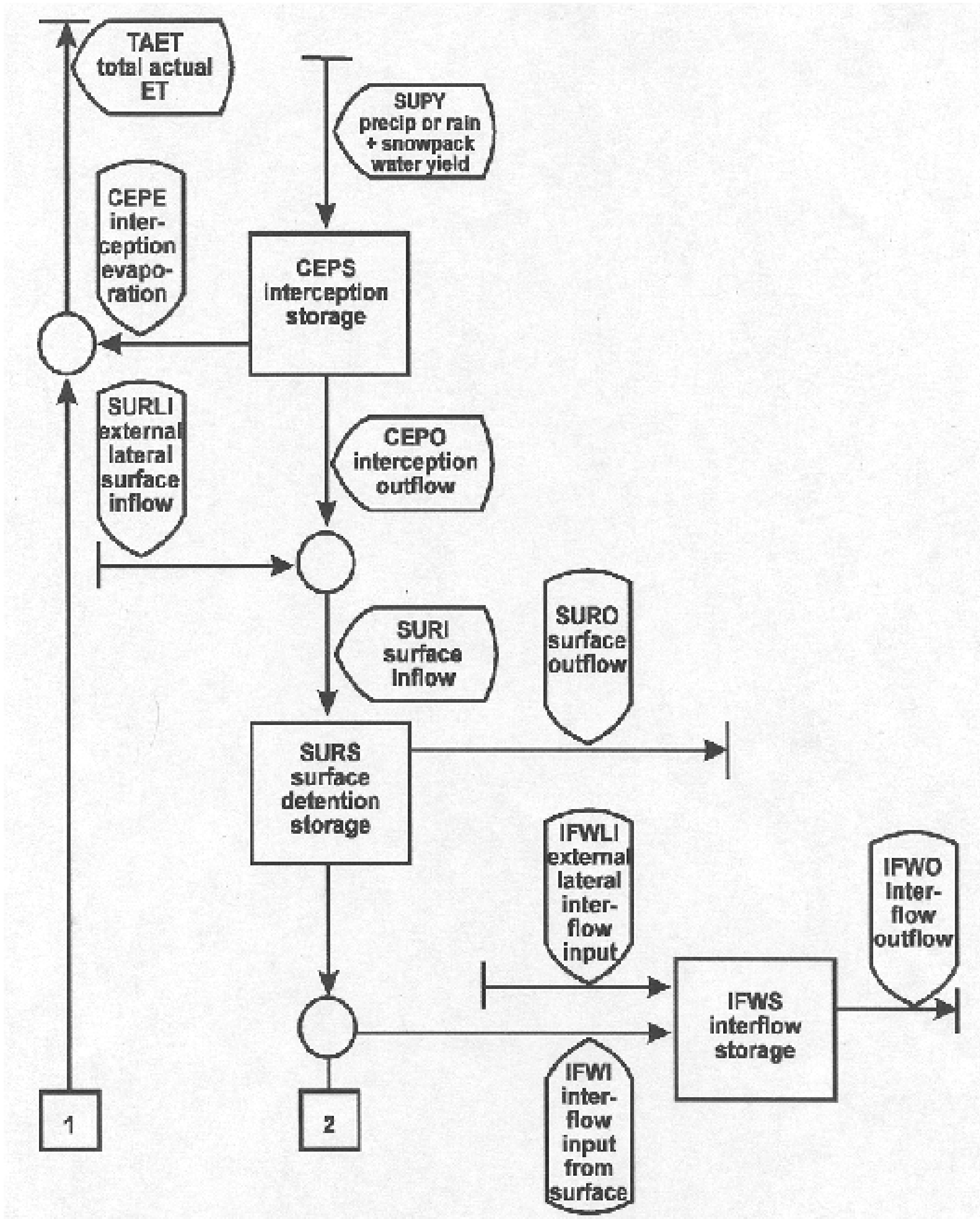

Figure 4.1. HSPF Structure (Bicknell et al. 1992).

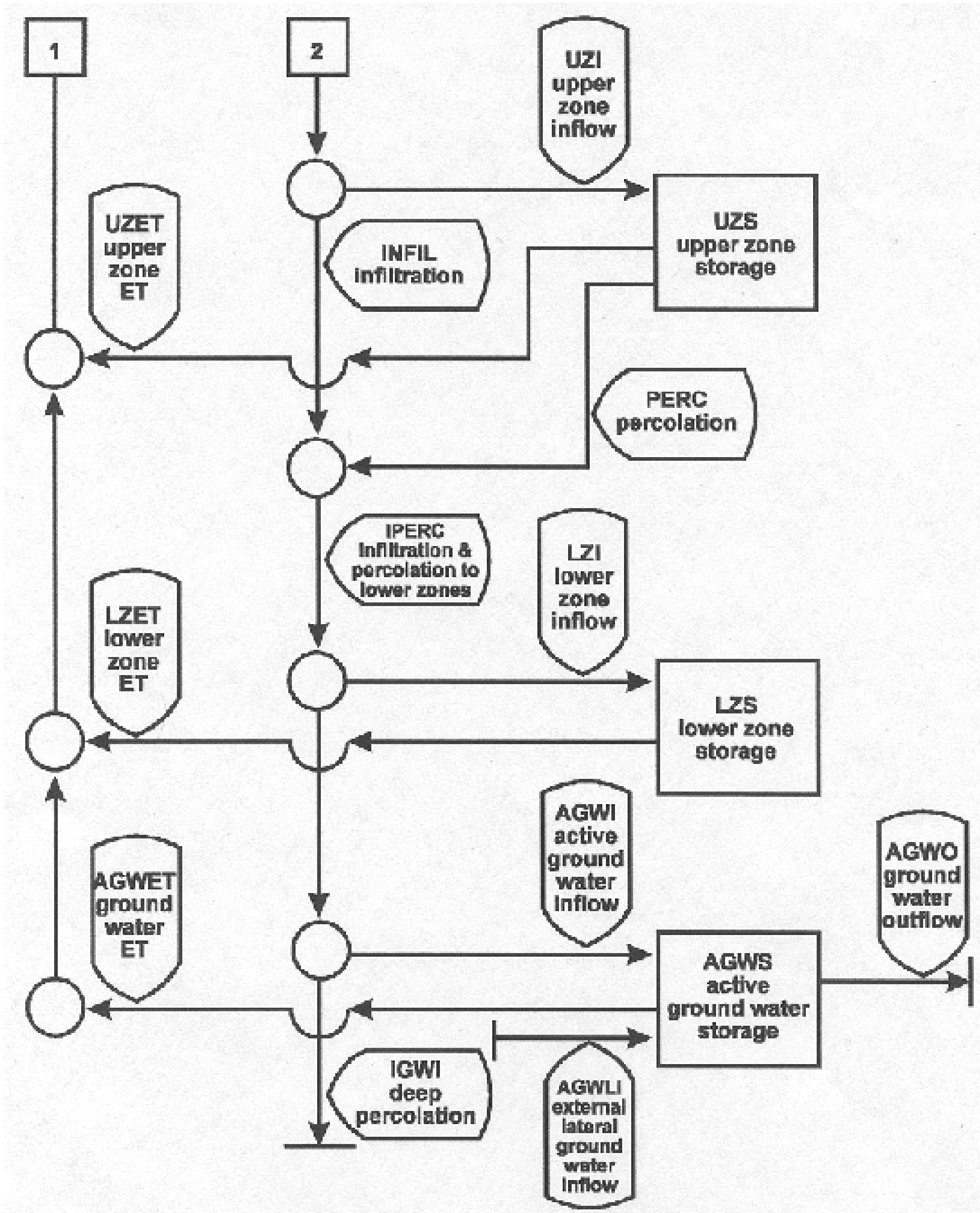

Figure 4.2. HSPF Structure (Bicknell et al. 1992).

IMAX = maximum infiltration capacity (in/interval)

INFILD = parameter giving the ratio of maximum to mean infiltration capacity over the land segment

IMIN = minimum infiltration capacity (in/interval)

RATIO = ratio of ordinates of line II to line I

INTFW = interflow inflow parameter

Surface flow, Interflow and Baseflow

Hillslope processes in HSPF are divided into overland flow, interflow, baseflow, and inactive groundwater. Overland flow is treated as turbulent flow and is simulated using Manning's equation plus a function that relates outflow depth to detention storage (Bicknell et al. 1992). Overland flow rate is decided by the following equations:

For SURSM < SURSE (overland flow rate is increasing)

SURO = DELT60*SRC*(SURSM*(1.0 + 0.6(SURSM/SURSE)**3)**1.67

For SURSM >= SURSE (at equilibrium or receding)

SURO = DELT60*SRC*(SURSM*1.6)**1.67

SURO = surface outflow (in/interval)

DELT60 = DELT/60.0 (hr/interval)

SRC = routing variable

SURSM = mean surface detention storage over the time interval (in)

SURSE = equilibrium surface detention storage (in) for current supply rate

SURSE = DEC*SSUPR**0.6

DEC = calculated routing variable

SSUPR = rate of moisture supply to the overland flow surface

DEC = 0.00982*(NSUR*LSUR/SQRT(SLSUR))**0.6

SRC = 1020.0*(SQRT(SLSUR)/(NSUR*LSUR))

NSUR = Manning's n for overland flow plane

LSUR = length of overland flow plane (ft)

SLSUR = slope of overland flow plane (ft/ft)

Interflow inflow originates from surface flow or upslope later flows. The interflow outflow calculation uses a linear function related to storage. Interflow discharge is related to interflow inflow, interflow storage, and an interflow recession parameter. The interflow recession parameter is the ratio of the current interflow outflow rate to the value one day earlier, and can vary monthly. Interflow discharge is calculated from the following equations:

IFWO = (IFWK1*INFLO) + (IFWK2*IFWS)

IFWO = interflow outflow (in/interval)

INFLO = inflow into interflow storage (in/interval)

IFWS = interflow storage at interval start (in)

IFWK1 = 1.0 – (IFWK2/KIFW)

IFWK2 = 1.0 – (EXP(-KIFW)

KIFW = -ln(IRC)*DELT60/24.0

IRC = interflow recession parameter (per day)

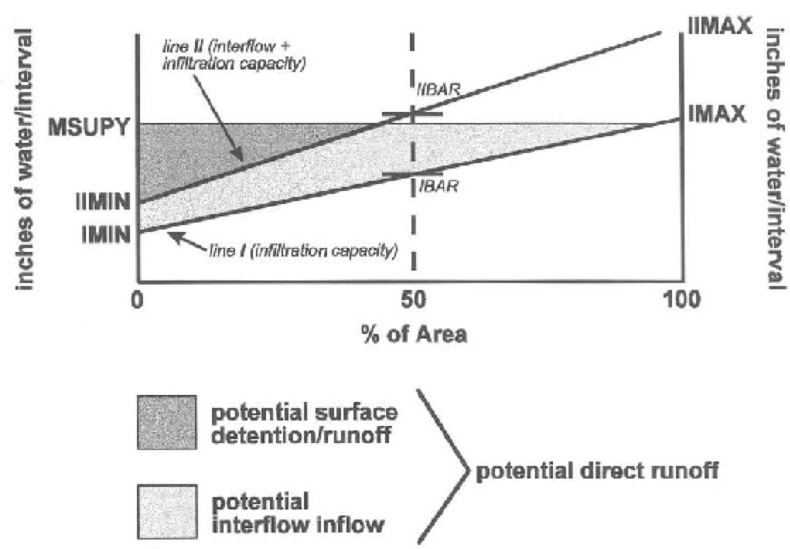

Figure 4.3. Determination of Infiltration and Interflow Inflow (Bicknell et al. 1992)

DELT60 = number of hours per interval

24.0 = number of hours per day

EXP = exponential function

Water in the upper zone either percolates or is available for ET. The infiltration plus percolation from the upper zone that does not remain in the lower zone plus any external lateral inflow enters either active or inactive groundwater. The user sets the DEEPFR parameter, which is the fraction of the groundwater inflow that is inactive. The remaining groundwater inflow becomes inflow to active groundwater storage. Active groundwater outflow assumes that aquifer discharge is proportional to the product of the energy gradient of flow and the cross-sectional area. Groundwater outflow is estimated by:

AGWO = KGW*(1.0 + KVARY*GWVS)*AGWS

AGWO = active groundwater outflow (in/interal)

KGW = groundwater outflow recession parameter (1/interval)

KVARY = parameter that can make active groundwater storage to outflow relation nonlinear (1/in)

GWVS = index to groundwater slope (in)

AGWS = active groundwater storage at interval start (in)

Evapotranspiration

Potential evapotranspiration is customarily estimated using evaporation pan records with an adjustment factor for area and cover. Actual evapotranspiration (ET) is estimated by HSPF by supplying moisture from five sources. Active groundwater outflow can be the first source for evapotranspiration, designated by a user defined fraction. This simulates ET from riparian vegetation withdrawing groundwater as it enters the stream as baseflow. If that fraction does not meet the ET demand, the next source is interception storage. There is no user designated fraction for interception, but ET draws on the entire storage. If ET is still not satisfied, water is drawn from the upper zones storage, then the active groundwater again, and the lower zone storage last. Evapotranspiration from the lower zone storage is based on transpiration. Vegetation type, root depth, cover density, stage of plant growth, and soil moisture properties are lumped into the LZETP parameter. The LZETP parameter can vary monthly unlike the other ET parameters. A linear probability density function arbitrarily assigns variations over the land segment.

CHAPTER 5

EVALUATION OF BASINS THROUGH SELECTED APPLICATIONS: EXPERIMENTS IN SCALE, PERSPECTIVE, AND BOUNDARY

BASINS was applied in various scenarios to test its utility from the viewpoint of the water resource manager. The evaluation was designed from the standpoint of a typical BASINS user. The author has training in hydrology, watershed issues, and GIS, but no training in engineering or modeling. The author did not take a training course, but relied upon the BASINS manual and training notebook, on-line help, and scientific literature.

BASINS was evaluated based on criteria presented in question format. Specific questions were developed from the interviews with the water resource professionals (Chapter 3) and from the legislation (Chapter 2). The interviews with the water resource professionals revealed the demands they place on watershed models and the expectations they have for model application and performance.

To respond to all of the interrogatory criteria, methods include descriptions, examinations and analyses. The spatial analysis capabilities of BASINS were found to be useful for various management scenarios. Watershed level modeling with BASINS was found to have extensive and unrealistic data demands, precarious parameterization, and un-defined prediction uncertainties.

Questions selected from the interviews with water resource professionals and the water resource legislation are presented in table 5.1.

Table 5.1. Interrogatory Criteria Used to Evaluate BASINS.

1 – What input data are required for watershed modeling?
2 – What are the calibration requirements?
3 – Is the model user-friendly?
4 – What spatial data layers are available in BASINS?
5 - What is the quality of the spatial data?
6 – Can local data be imported into and utilized within the BASINS system?
7 – How is BASINS being used in the scientific literature?
8 - How is BASINS being used for TMDLs?
9 – Can BASINS be applied across a range of watershed scales?
10 – How well can BASINS support selected potential uses?

5.1 What input data are required for watershed modeling?

The required input data for NPSM (HSPF) falls into three general categories: climate and watershed information; stream reach data; and fitted parameters.

Climate and Watershed Information

Weather, land use, elevation, and soils data are used to calculate the hydrological processes occurring over a user-defined watershed. Specific data requirements depend upon the constituents being modeled and the presence or absence of snow in the water budget. Data can be divided into an hourly or daily time-step. All weather data included in BASINS is in an hourly time step.

Stream Reach Data

The necessary stream reach data are included within BASINS Reach File 1 attribute table, but are absent from BASINS Reach File 3 attribute table. Table 5.1 organizes required input data for modeling with NPSM (HSPF). The first column includes data about stream reach length and connectivity. The second column includes channel geometry data that is used to calculate the function table.

The function table defines the depth-volume-area-discharge relationship of each stream reach. The depth-discharge relationship is important for flow simulations. The volume information is used to calculate pollutant loads from concentrations. Area is used to determine physical, chemical, and biological reactions at the air/water interface, including volatilization rates. Although the data required for stream reaches is highly detailed, EPA (2000) reports that HSPF flow rate predictions do not appear to be sensitive to channel cross-sections.

Fitted Parameters

HSPF requires many fitted parameters that are adjusted during calibration. Calibration is discussed in the following section. Table 5.2 includes a few of the fitted parameters. Donigian (1983a) discovered that UZSN, INFILT, INTFW, and LZSN may vary between watersheds in the same region. The EPA

(2000) reports that LZSN, INFILT, AGWRC, DEEPFR, INTFW, IRC, MON-INTERCEP, and MON-LZETPARM are sensitive parameters, and that all other parameters had little influence on flow rate predictions. An in-depth description of parameters and their ranges can be found in BASINS Technical Note 6 on the BASINS web site, www.epa.gov/ost/basins.

Table 5.2. Stream Reach Data Necessary for Watershed Modeling in BASINS.

DATA REQUIRED - REACH	DATA REQUIRED - FUNCTION TABLE
Cataloging Unit	Reach ID
Reach segment	Segment Length
Mile point	Mean Depth
Length	Mean Width
Type	Manning's Coefficient
Level	Slope
Divergence	Cross-section (default is trapezoid)
Name	Slope of upper floodplain
Segment length	Slope of lower floodplain
Reach ID	Floodplain width
Downstream segment	Channel depth
Upstream right segment	Floodplain sideslope change at depth
Upstream left segment	Maximum depth
Complementary segment	No. of exits (only 1 allowed in BASINS 2.01)
Change in elevation	---------
Average elevation	---------

5.2 What are the calibration requirements?

EPA (2000) stated that calibration is essential when using HSPF for predicting what-if scenarios, and that "confidence in predictions depends directly on the confidence in how accurately the model calibration represents the watershed." Four to five years of observed data are considered adequate for calibration (Larson et al. 1982; Maidment, personal communication). Observed time-series measurements necessary for calibration include weather, flow, and water-quality data.

Table 5.3. Selected HSPF Parameters.

HSPF Parameter	**Parameter Description**
LZSN[1]	lower zone nominal storage
INFILT[1]	soil infiltration capacity
AGWRC	groundwater recession rate
UZSN	upper zone nominal storage
IRC	interflow recession parameter
INTFW	interflow inflow parameter
DEEPFR[2]	groundwater inflow fraction entering inactive storage
UZS[1]	upper zone storage
LZS	lower zone storage
CEPS[3]	interception storage
SURS	surface overland flow storage
IFWS	interflow
AGWS	active groundwater storage
GWVS	index relating active ground water inflow to groundwater table slope

1-varies with soil properties
2-varies with subsurface characteristics
3-depends on land cover

Traditional calibration techniques include varying parameters over a range of values, comparing predictions to observations, and adjusting parameters until the predictions fit the observations. Automated calibration programs have been developed. PEST is an automated, model-independent, parameter estimation program that optimizes an objective function, allowing the user to set bounds on estimations (Doherty 2000). Regardless of the method chosen for calibration, flow must be calibrated first, then followed with calibration of selected water quality constituents.

Many applications of HSPF involve predicting water quantity and quality effects of future land-use changes. The capability of HSPF to predict effects of land-use changes on water quantity and quality relies upon the ability to fit parameters for each land-use type. To assign parameters for each land use type, the user must:

- locate watersheds with the same soils, topography and climate of the study area that are dominated by a single land use type, for each land use type that will be modeled;
- collect precipitation and runoff data in each of these watersheds for an adequate time period (five years is often suggested as the minimum); calibrate HSPF for each land use type;
- With the appropriate calibration data, the user can predict future land-use change scenarios by assigning parameters unique to each land use type.

5.3 Is the model user-friendly?

In chapter 3, interviewees stressed the importance of simple, quick, and user-friendly watershed level modeling and analysis. With increasing responsibilities and decreasing budgets, agency scientists do not have the resources to use a complex, time-consuming, and data-demanding model. Agency scientists and other water resource managers need analysis methods that are straightforward, and have clear instructions and adequate support. User-friendliness was evaluated by applying the model in several scenarios.

Recurring problems included unrealistic data requirements, disorganized guidance, and reliance upon “best professional judgment” for calibration decisions. For instance, the BASINS manual explains the graphical user interface, directing the user where to point and click on the computer screen. The HSPF manual explains the HSPF model structure and routines. The HSPF Application Guide from the 1980s discusses intelligent use of the model when run from DOS with manually input data. The BASINS training notebook includes a more in-depth discussion than the BASINS manual, but remains limited.

The BASINS website, with case studies and listserve postings, was essential to the application of BASINS. However, searching the listserve archives involves sorting through an entire month of correspondence. Search results do not return a list of individual postings, but the month of the postings. The melange of scattered sources combine into thousands of pages of documentation. The desire for improved guidance is evident in the BASINS listserve postings.

Several participants have asked for submissions of TMDL case studies using BASINS to create a guidance resource for users. A TMDL case study list was not compiled due to lack of response from other listserve participants. One listserve respondent replied that they are using BASINS for TMDL development, but are not ready to release the results. The respondent indicated that they have barely touched the complexity of BASINS, and do not have the computer capacity for the data requirements.

HSPF was computationally efficient, processing the data quickly, and with few errors. Challenges of BASINS/HSPF application are not in model execution, but in objective use of the model.

5.4 What spatial data layers are available in BASINS and what is the quality of the spatial information?

The spatial and temporal data within BASINS were examined for scale, resolution, and age. Modeling and decision-making implications of the data quality were considered. Table 4.2 includes many of the data as well as the corresponding metadata. Details of the spatial analysis evaluation are included in the following subsections. Each subsection includes a description of the data scale, age, and source. Limitations and issues of concern are also discussed within each subsection.

Land-Use/Cover

The land-use/land cover data was captured at a 1:250,000 scale by the USGS and converted to ARC/INFO by EPA. The land-use/land cover was captured from 1977 to the early 1980s and organized in Anderson Level II classification. The TIGER urban areas data were captured in 1990. The age of the land-use data is the most limiting factor in regard to hydrologic modeling. Land-use data from the 1980s was useful for certain applications, but limits the utility of BASINS. For example, analysis and modeling of developing areas relies upon current land-use data.

Land-use history is a hydrologically important aspect of land-use that is not captured in a single land-use layer. A field that has not been tilled for thirty years will differ in hydrologic response from a field that has been fallow for only two years. A series of land-use coverages through time would illustrate changes and trends.

Reach Files

Reach File 1 was created by EPA in 1982 from 1:500,000 scale NOAA aeronautical charts. Reach File 1 includes 700,000 miles of streams and open waters. EPA quality assurance methods included visually checking linkages, and checking flow data. Reach File 1 flow data and channel geometry were obtained in the late 1970s from USGS gaging stations considered to have the longest period of record for natural flow data (Ed Partington, personal communication). Reach File 1 flow data are estimates of mean and 7Q10 flow at non-USGS station locations. EPA estimated flows for 60,000 reaches using streamflow data from less than 2,000 reaches. Drainage areas under 500 mi^2 rarely had USGS gages, thus are not well represented. An additional 4,000 gages were used for drainage area assignment. All Reach File 1 flows were produced from data from 4,112 USGS gages. The flow estimates are for the downstream ends of gaged and ungaged reaches, not at USGS gage sites. Average velocities were estimated using streamflow, measured time-of-travel, when available, and watershed characteristics. EPA advised that flow estimations are not designed to produce accurate results on start reaches, ungaged tributaries, estuaries, or ungaged coastal streams. Local variations in accuracy exist due to irregular density and irregular periods of record for the USGS gages (Reach File 1 metadata).

Reach File 3 is an alpha layer of a series of hydrographic databases from the EPA produced to establish hydrologic ordering. Reach File 3 - Alpha is unvalidated and EPA recommended conservative use of the data. Reach File 3 is being updated and made available as the National Hydrography Dataset.

Water Quality

The Water Quality layer in BASINS originated from EPA STORET database. STORET is a compilation of water quality data from federal, state and interstate agencies, universities, contractors, individuals and water labs. The vast array of methods used to collect water quality constrains comparability. Watershed screening would be a suitable use for the data; however, scientific or regulatory applications, such as total maximum daily load development, would not be a responsible use of these assorted data.

Drinking Water Facilities

The Drinking Water layer has an accuracy code in the attribute table. The accuracy codes were assigned based on agreement between state and county FIPS codes. An accuracy code of 1 means that the facility is within the correct county. An accuracy code of 2 indicates that the facility is within the state, but outside of the correct county. The Drinking Water attribute table for the Upper Oconee Hydrologic Accounting Unit was queried for accuracy codes equal to 1. All but one drinking water facility had an accuracy code of 1.

Precipitation Data

Precipitation data included in BASINS is measured at an hourly time step. Disaggregation software, such as METCMP, was not used according to Sayedul Choudhury (Tetra Tech, BASINS Listserver 1999). The weather stations included in the BASINS package are inadequate for modeling local watersheds. Due to spatially variable precipitation with discrete and scattered phenomena, a record of localized storm events are important for modeling. For instance, an intense storm at a weather station may not occur over the area being modeled.

Hydrologic Accounting Units

Spatial data in BASINS is grouped into 8-digit USGS watersheds, called Hydrologic Accounting Units. BASINS is advantageous to water resource managers because data layers are organized by watersheds, over which political boundaries can be defined.

Most Hydrologic Accounting Units were digitized at a 1:250,000 scale. Some Hydrologic Accounting Units were digitized at a 1:100,000 or a 1:2 million scale. The boundaries created at such small scale may limit its use with larger scale data that may be imported, such as 1:24,000 hydrography data. Discordant boundaries between the two scales may cause problems upon application. For instance, a 1 mi^2 tributary watershed could potentially lie on or outside of a 1:2 million scale boundary line, resulting in complications when delineating the watershed.

Digital Elevation Model

The BASINS DEM is a 300 meter polygonal re-sample of the 1-degree USGS DEMs. The metric length of 1-degree varies depending on location due the curvature of lines of longitude. The vector format excludes the possibility of automated watershed delineation. The finer resolution and raster format of the USGS 30 meter DEMs are better suited for watershed analyses. The BASINS

DEM is suitable for large river basin screening analyses. BASINS 3.0 will have raster capabilities, thus easing the import of USGS 30 meter DEMS.

5.5 Can local data be imported into and utilized within the BASINS system?

Watershed Delineations

Watersheds can be delineated by method of choice and imported into BASINS. For this evaluation, watersheds were delineated using ArcView by a method from the web site of David Maidment, University of Texas at Austin. In general:

- Stream coverages were converted to grid and burned (intersected and merged through application of an ArcView Avenue script) into a 30-meter DEM.
- The elevation values of the DEM were raised by an arbitrary amount.
- The stream coverage and raised DEM were merged using an Avenue script. The stream elevations are maintained while the surrounding elevations are raised, keeping the flow that reaches the streams from flowing back out of the streams.
- The DEM sinks were filled and the watershed was delineated using the ArcView hydrologic extensions.
- Watershed coverages were converted into shapefiles with ARC/INFO and imported into BASINS.

The utility of the imported watersheds within BASINS was constrained by the resolution of the Reach File 3 data. Each watershed must have either a

Reach File 1 or a Reach File 3 associated with it for recognition by NPSM. The watersheds delineated from 30-meter DEMs in ArcView and ARC/INFO were at a finer resolution than Reach File 3. The user could manage this problem by manually creating a new reach in the NPSM stream reach tables, or by extending the length of the available Reach File 3.

Water Quality Data

Water quality data can be added to BASINS. The appended data must follow a specific format that differs from the original data. The appended format can be found in the BASINS manual. Data can be downloaded from STORET and processed into the required format. Imported the land use and water quality data cannot be used by the BASINS scripts to generate characterization reports. BASINS 3.0 is supposed to allow graphical and statistical interpretations of user imported data (Jack Kittle, AQUA TERRA, BASINS Listserver).

Land-Use Data

Land-use data can also be imported. Land-use types should be limited to six to eight optimum, and ten to twelve maximum (Donigian AQUA TERRA, BASINS Listerver). Land-use types should be grouped by hydrologic response, not cover type. Each additional category increases the workload exponentially (Roger Lehman, WESTON, BASINS Listserver). Tony Donigian seconded Lehman's comments, adding that in his thirty years of experience with HSPF it has become clear that the many parameters for each land use type cannot be distinguished. Waterbodies are modeled in the RCHRES module of HSPF, and not included in the land use modules (PERLND and IMPLND).

Distance units must be kept consistent when importing land-use data. In BASINS, conversion factors for land use are in meters, so the imported land use must be projected in meters (Ed Partington, EPA, BASINS Team, BASINS Listserver).

5.6 How is BASINS being used in the scientific literature?

This section summarizes application of HSPF as documented in academic research papers, EPA case studies for TMDL development, and TMDL submittals. Applications of HSPF can also be found in reports generated by consulting firms; however, these industry documents are often inaccessible.

Literature

Tsihrintzis et al. (1996) used HSPF for a planning study to evaluate effects and alternatives for a wellfield protection area in Florida. They simulated runoff, recharge, sediment, nutrient, and pesticide transport. They applied the model to current conditions, for chemical application reduction, for sewage sludge application, and for future urbanization. Their results showed decreased contaminant concentrations for the two application alternatives and for the future urbanization scenario.

Laroche et al. (1996) used HSPF to evaluate alternatives of pesticide management. Laroche et al. (1996) used HSPF to predict streamflow and atrazine transport in a 78-hectare agricultural watershed in Quebec. PEST

(Doherty 1994), a parameter estimation program employing the Gauss-Marquardt-Levenberg algorithm, was used to optimize the parameters. Flow was calibrated from June 1991 to January 1993 and evaluated from February to November 1993. Pesticide transport was calibrated from February to November 1993, but not evaluated due to limited data. Laroche et al. (1996) used the instantaneous, single-value Freundlich isotherm equation for transport. They explored the effects of increasing area and application rates of atrazine. Application occurred during June of each year. The 2 µg/L aquatic life standard was increasingly exceeded as application area and rate increased. The standard was exceeded 4, 149 and 245 days/year for application rates of 1.5, 4.5 and 9.0 kg/ha, respectively, on 90% of the watershed.

Ng and Marsalek (1989) used HSPF to evaluate future effects of urbanization on a developing watershed in Newfoundland. The soils developed from clastic sediments including coarse siltstone, slate, sandstone, and acid volcanic rocks. Till underlies 90% of the study area. They calibrated HSPF with 29 months of data and postponed verification due to limited data. They consulted Donigian and Davis (1978) for initial parameter assignment. Ng and Marsalek (1989) adjusted parameters to match their data and to agree with the hydrologic setting of glacial till with low infiltration and quick hydrologic response. They ran HSPF for three future scenarios of 50%, 100%, and 200% increases in impervious areas. Simulations indicated that streamflow increased by only 1% when the impervious area was tripled. The small effect of urbanization on streamflow volume was unusual due to poorly drained soils over solid bedrock and low evapotranspiration rates. Eighty percent of precipitation became streamflow. Simulated peak flows were more sensitive to urbanization and increased approximately 20% when the impervious area was doubled. They concluded that HSPF provided good simulations for low and high flows, and snowmelt in the unusual setting and that modeling was effective for planning. They also noted the extensive nature of model calibration and suggested that extended calibration datasets would improve the modeling. In agreement with Donigian et al. (1984), Ng and Marsalek (1989) reported that 30 to 50% of the project resources went to calibration. More spatially-distributed precipitation data and more stream cross-sectional data were also noted as possible improvements to their modeling.

Bicknell et al. (1985) demonstrated how HSPF could be used to model flow, sediment, pesticides, and nitrogen for BMP planning in a 7,240-km^2 watershed in central Iowa. Limited calibration was performed because it was a demonstration project and not intended for planning decisions. They used parameter values from a previous, data-intensive study on a nearby, smaller watershed. They adjusted parameters to imitate conservation tillage and leaving crop residue on the field after harvest. Soil moisture retention, interception, Manning's resistance coefficient, and land cover parameters were increased and sediment production from tillage was decreased. The infiltration, bulk density, soil temperature, and chemical-application volumes were not altered. They experienced the limitations of using a single rainfall record for varying precipitation conditions over a large area. Flow was overestimated by 53% to 190% during a storm event that was more intense at the weather station than over the entire area. Flow was underestimated during a storm event when precipitation was lighter at the weather station than in other sections of the study area. Flow, runoff, erosion, and ammonia concentration declined when simulated under conservation tillage practices. Sediment loading was less affected by conservation tillage practices due to a greater dependence on channel scour than surface erosion. Nitrate loading was less affected due to its independent mobility.

Laroche et al. (1996) found that HSPF simulated streamflow well, with observed and simulated peaks at the same location and with similar times and magnitude. Laroche et al. (1996), Chew et al. (1991), Moore et al. (1988) and Donigian et al. (1983a) found that HSPF underestimated runoff volume between 3% to 20%. Laroche et al. (1996) concluded that a calibrated HSPF was sufficient to simulate streamflow on a small agricultural watershed. Laroche et al. (1996) found that HSPF produced atrazine concentrations with similar ranges and simultaneous peaks between observed and simulated values. They found that HSPF overestimated the total mass of atrazine leaving the watershed when using optimized parameters. They found that optimized parameters made small improvement and suggested that HSPF be used for pesticide modeling with minimal calibration at the low observed concentrations. Table 5.4 lists several parameter values from the studies.

EPA Case Study

EPA (2000) prepared the Fecal Coliform TMDL Modeling Report for the 192 mi^2 Cottonwood Creek Watershed in Idaho. NPSM (HSPF) was used to simulate the hydrology and fecal coliform loads. EPA used a spreadsheet to calculate parameters related to bacteria and then calibrated to observed data.

Table 5.4. Selected Parameter Values and Recommended Ranges.

Parameter	LZSN	INFILT	AGWRC	UZSN	IRC	INTFW	DEEPFR
Ng & Marsalek (1989)	30	0.5	0.98	10	0.5	7	0
****Laroche (1996)**	361	5.83	0.99	19.27	0	9.83	--
***Donigian et al. (1983a)**	216	2.35		15.65	0.6	1	--
***Moore et al. (1988)**	125	0.1-0.5	0.98	5	0.1	1	--
***Kuark Leite (1990)**	120	0.5	--	1.0-6.0	--	1	--
***Chew et al. (1991)**	127	1.6-3.6	--	0.4-1.1	--	0.75	--

** Laroche used parameters that were optimized using PEST
* Laroche (1996)

EPA ran the model with point and non-point source reductions to determine the load reductions needed to uphold state water quality standards. Reductions ranged from 23% to 88%. They also ran HSPF for various scenarios for source impact identification. EPA concluded that the wastewater treatment plant was not a significant source of fecal coliform, and that cattle in the streams, pastures with cattle, manure application, and faulty septic systems were significant sources of fecal coliform.

EPA used few of the data packaged in BASINS. They imported data from the Idaho Department of Agriculture, the Idaho DEQ and from local weather stations. Weather data was primarily obtained from a station 2 miles away. Data gaps were filled with data from weather stations 35 and 40 miles away, as well as estimation techniques.

Stream reaches lacking channel geometry or known depth/flow relationships were assigned data from a similar segment, or calculated from data received from the state. The F-tables within BASINS differed greatly from the F-tables calculated from local data. Flow rate predictions did not appear to be sensitive to the channel geometry.

Calibration was performed for the entire mixed land-use watershed as a whole. The resulting parameters were then assigned to each subwatershed. The model was executed at the subwatershed discretization, and the results combined to test the initial parameter calibration. The initial parameters applied to each subwatershed resulted in predictions with “remarkable similarity” to the initial modeling run with the entire watershed as a single unit.

5.7 How is BASINS being used for TMDL development?

Two Georgia TMDL submittals, Big Creek and Turkey Branch, for fecal coliform were reviewed. Sixteen data points were gathered to calculate four geometric means for four 30-day periods. Both submittals indicated that two of the four geometric means violated Georgia state standards.
The state standard for fecal coliform is a geometric mean of 200 counts/100 ml for May-October, and 1000 counts/100 ml for November-April. Big Creek and Turkey Branch fecal coliform samples are presented in tables 5.5 and 5.6.

Table 5.5. 1998 Fecal Coliform Monitoring Data for Big Creek, Georgia.

Date	MPN/100ml	Geometric Mean
Feb. 25	330	
March 4	80	
March 11	460	
March 25	50	157
June 10	50	
June 16	50	
June 18	<20	
June 24	85	45
July 22	510	
July 29	330	
August 4	20	
August 12	1,300	257
October 7	220	
October 14	220	
October 20	3,500	
October 28	490	537

Non-point sources were identified and parameterized with assistance from the Natural Resources Conservation Service. Point sources were addressed by assuming that 40% (Big Creek) or 20% (Turkey Branch) of septic systems leaked and 5% (Big Creek) or 2.5% (Turkey Branch) of the permitted design flow of the municipal water pollution control plant was lost via leaks, with an average fecal coliform concentration of 10,000 counts/100 ml in wastewater.

Table 5.6. 1998 Fecal Coliform Monitoring Data for Turkey Branch, Georgia.

Date	MPN/100ml	Geometric Mean
Feb. 25	230	
March 4	790	
March 18	80	
March 24	80	185
April 8	490	
April 15	530	
April 22	35,000	
May 6	85	1,115
July 8	<20	
July 15	<20	
July 22	50	
August 5	170	43
October 1	330	
October 8	11,000	
October 22	330	
October 29	1,700	1,195

Fecal coliform loading rates were estimated using spreadsheet applications for various land uses. The estimated loading rates were then used in the HSPF modeling. NPSM was used to simulate runoff and in-stream transport. The objectives of the numerical modeling were to:

- Simulate time varying behavior of fecal coliform deposition on the land and the transport to water bodies
- Use a continuous simulation period to identify the critical conditions for use in the development of the TMDL.
- Incorporate seasonal effects on the production and fate of fecal coliform bacteria.

TMDLs were developed from 10-year simulation periods with 30 day critical periods. The initial model setup used default parameters for South Georgia. These default parameters were adjusted later during calibration. Parameters used for Turkey Branch were calibrated based on weather data 20 miles north of the watershed, and flow data from the Alapaha River at Statenville, Georgia, in the Suwanee River Basin. Parameters used for Big Creek were based on weather data 43 miles southwest of the watershed, and flow data from Okapilco Creek which is 25 miles east-southeast of Big Creek. One year, January 1, 1998 to December 31, 1998, was used for model calibration. Fecal coliform was calibrated to the 16 observations in tables 5.4 and 5.5. Land-use types were determined from Georgia's Multiple Resolution Land Coverge (MRLC) data based on Landsat Thematic Mapper images and classified on a modified Anderson level one and two system. The allocation model was handled by assigning NRCS recommended parameters representing BMPs, and reducing loading rates from urban land, septic tanks, leaky sewers and animal access to streams. The allocation model results were compared to the calibrated model to detemine needed load reductions.

Big Creek model results included that 90% of the watershed is rural and that primary fecal coliform sources are agricultural. The critical period was identified as the 30 days before the highest observed concentration, October 20, 1998. EPD states that "achieving water quality standards during this time period ensures that….standards can be achieved for the ten-year period." Precipitation data did not show a corresponding storm event on the day of highest observed concentration.

The Big Creek study concluded that often a high observed value was not simulated due to lack of rainfall data in representing localized storms or due to an unknown source. The Turkey Branch study concluded that geometric means calculated using 30 inputs from the simulation may be lower than the geometric means calculated from the four observed values because 30 inputs will be less sensitive to high values. The Big Creek study called for a 32% reduction, and the Turkey Branch study called for a 77% reduction in load allocations.

Both studies concluded with the same recommendations. Recommendations included the adoption of NRCS Best Management Practices such as maintaining riparian buffers and covering poultry litter stacks, reducing animal access to streams, and agronomical manure application rates. EPD also recommended continuous monitoring of the watershed to verify the unknown sources. EPD plans to determine the water quality conditions that result from BMP implementation on the next phase of monitoring of the 5-year river basin rotation cycles.

5.8 Can BASINS be applied across a range of watershed scales?

A delineation analysis was performed to explore the consistency of flow predictions across different watershed scales.

Analysis Methods

A sensitivity analysis of the effect of watershed delineation on BASINS/HSPF results was performed. All other variables, such as parameters and function tables, were kept constant within each modeling run. A total of 42 modeling runs were executed.

Flows within 771 mi^2 basin, labeled A (for “All”), within the Upper Oconee Watershed were simulated with HSPF. The pour point for the modeled area was just below the confluence of the Middle and North Oconee Rivers. The watershed was divided roughly in half and modeled as two subwatersheds, labeled E (East) and W (West). Each half was again divided into halves (NE, SE, NW, SW) and each subwatershed was modeled. Figure 5.1 displays the watershed delineations. Figure 5.1 also illustrates the results from delineating based on two different reach files.

The simulation was limited to 1970 through 1995 because this was the entire period of record for the Athens Municipal Airport weather data provided within BASINS. Three modeling runs were performed on each of the seven watersheds, for each selected output. First, each watershed was modeled with default parameters included in BASINS. Then each watershed was modeled using parameters from the HSPFParm database. Last, each of the seven watersheds was modeled with the HSPFParm parameters and finer resolution F-tables.

The F-tables provided within BASINS Reach File 1 are estimations. The default function tables were at a very coarse resolution, jumping from a depth of 2.7 feet to 136.4 feet. We estimated the intermediate depths, areas, volumes, and flows by multiplying each by a constant. The HSPFParm parameters are from the Virginia Piedmont and are the parameters the EPA scientists at Athens have used for modeling in the Georgia piedmont (Johnston 2000).

Output included monthly average flow and yearly maximum flow for each parameterization scenario over each area. Reach Outflow (RO) of the REACHRES module was the selected output because the units are cubic feet per second, which corresponds to USGS flow data. Flows were delivered to each watershed pour point. There was no routing from each of the northern quarters through the southern quarters. Routing is important during storm events because there is large variability in flows from one day or hour to the next. Routing is less important under average conditions because the flow from one hour or day is highly correlated to the flows of the following hour or day. Observed flows at the USGS Penfield gaging station (02218300) were compared to modeling flows.

The model output were analyzed through regression techniques, flow frequency curve comparison, hydrograph observations, and water yield summaries. Regression analysis included:

- Total flow was plotted against the sum of the East and West sub-flows.
- East flow was plotted against the sum of the Northeast and Southeast sub-flows.
- Total flow was plotted against the sum of the flows for all four sub-watersheds (e.g. Northeast + Southeast + Northwest + Southwest).
- A linear regression was performed on each to compare the flows of the unified watersheds to the summed flows of the sub-watersheds.

Table 5.7 displays a summary of the modeling runs. Table 5.8 summarizes the land use data by watershed. Table 5.9 includes the default and the Virginia Piedmont parameters. Table 5.10 includes a sample default F-table and Table 5.11 includes an extended F-table.

Table 5.7. Scale/Delineation Modeling Applications.

Watershed	Parameters	Output
Total (A)	Default	Monthly
East	Virginia Piedmont	Average
West	Virginia Piedmont + Finer Resolution F-table	Yearly Max
Northeast		
Southeast		
Northwest		
Southwest		

Table 5.8 Delineation Area and Land Use.

Delineation Area	Total %	Forest	Ag	Pervious Urban	Impervious Urban	Barren
Total	100.0	56.6	36.8	3.2	3.2	0.2
East	38.9	57.3	35.2	3.6	3.6	0.4
West	61.1	56.1	37.8	2.9	2.9	0.2
Northeast	22.9	60.3	35.7	1.8	1.8	0.2
Southeast	16.0	52.9	34.6	6.1	6.1	0.6
Northwest	40.5	56.2	38.4	2.6	2.6	0.0
Southwest	20.6	56.1	36.8	3.6	3.6	0.0

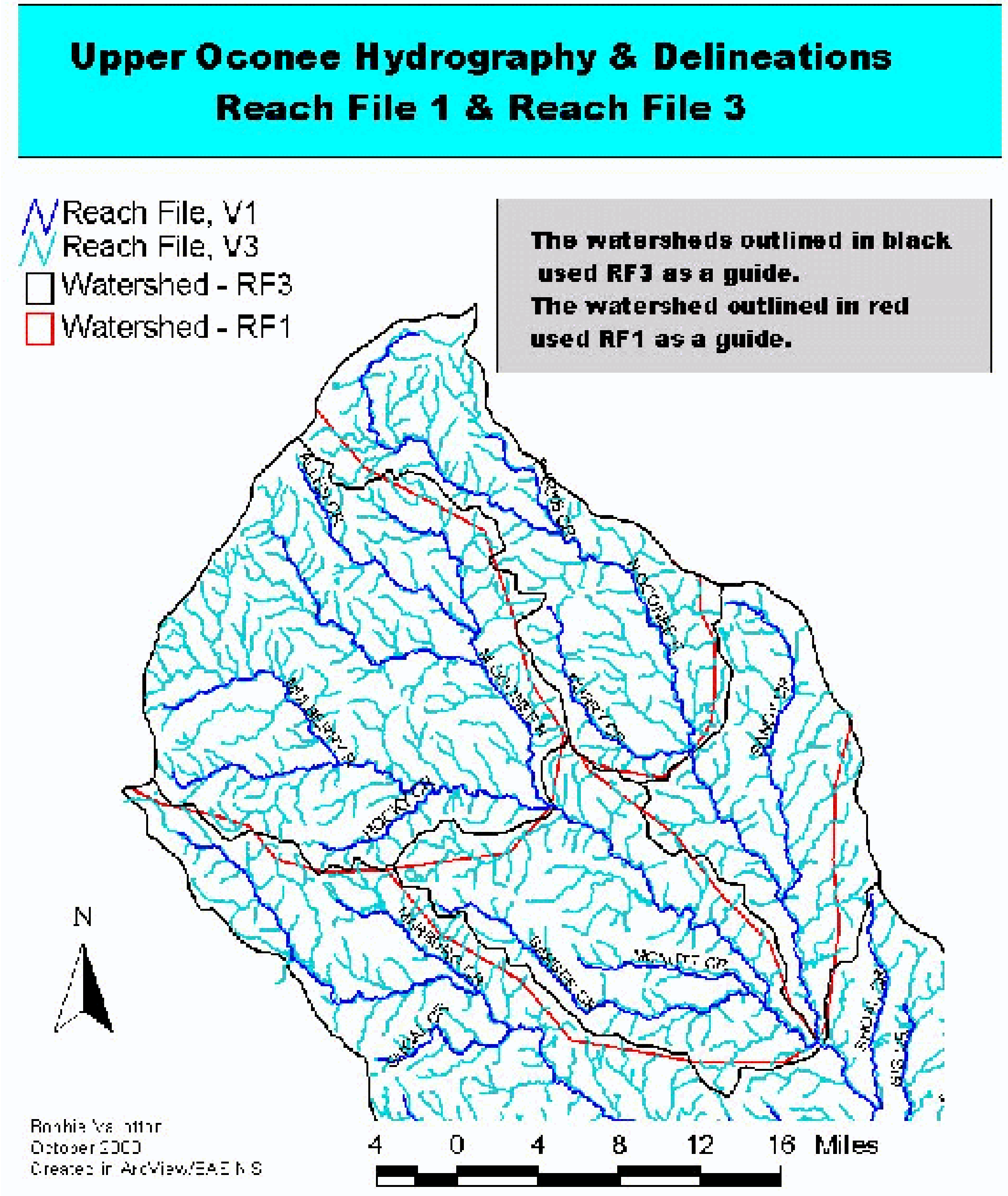

Figure 5.1. Area Modeled within the Upper Oconee

Table 5.9. Selected Parameters Used in the Modeling Applications.

Parameter	Default	Piedmont
LZSN	14.1	6.2
INFILT	0.16	0.035 - 0.055
AGWRC	0.98	0.98
UZSN	1.128	0.3 - 0.7
IRC	0.5	0.65 - 0.7
INTFW	0.75	1.2 -1.6
DEEPFR	0.1	0.1

Table 5.10. Default F-Table for the North Oconee River.

Depth (ft)	Area (acres)	Volume (acre-ft)	Outflow (cfs)
0	63.657	0	0
0.12	63.902	7.6534	1.6128
1.2	66.101	77.854	74.626
1.8	67.323	117.88	146.49
2.25	201.36	208.08	183.6
2.7	203.19	299.1	333.91
136.35	747.5	63828	101,550
270	1291.8	200,100	4,699,700

Table 5.11. Extended F-Table for the North Oconee River.

Depth (ft)	***Area (acres)***	***Volume (acre-ft)***	***Outflow (cfs)***
0	63.657	0	0
0.12	63.902	7.6534	1.6128
1.2	66.101	77.854	74.626
1.8	67.323	117.88	146.49
2.25	201.36	208.08	183.6
2.7	203.19	299.1	333.91
4	747.5	1000	1200
8	1291.8	2000	4500
10	6459	10000	22500
12	32295	50000	1.13E+05
14	1.61E+05	2.50E+05	5.63E+05

Delineation Results

Predicted mean monthly flows for the unified watershed, watershed A, were similar to the sum of predicted mean monthly subwatershed flows. The distributed mean discharges were from 98% to just over 100% of the unified mean discharges with R^2 of 0.99 for all three model runs.

Predicted yearly maximum flows of the unified watershed were also similar to the sum of the sub-flows, but with less consistency. The maximum discharges of the subwatersheds range from 68% to 128% of the unified watersheds for all three model runs; R^2 ranged from 0.96 to 0.99. The Piedmont parameters with the altered F-tables produced weaker correlations with smaller ranges, including subdued high-end values. The weaker correlations may be partially due to the absence of routing from the northern subwatersheds to the southern sub-watersheds for the maximum flows, because routing is important for storm events.

Predicted flow frequency curves for each model run were plotted along with observed flow frequency curves for the Oconee River at Penfield (USGS station #02218300). Figure 5.2 displays flow-frequency curves for the unified watershed for the three different parameterizations along with the observed USGS data.

The model over-predicted flows for all simulations. The observed 10-year flow recurrence, based on twenty-one years of data, is 36,000 cfs. All predicted 10-year flows for watershed A are an order of magnitude higher than the observed.

The predicted 10-year event was 300,000 cfs for the default data, 260,000 cfs for the Piedmont parameters and default F-tables, and 160,000 cfs for the Piedmont parameters with extended F-tables.

One year of daily flows for watershed A using the Virginia Piedmont parameters and the extended F-tables are illustrated in Figure 5.11. Daily peak flows occur at the same time. The model over-predicted the peak flows and under-predicted baseflows.

Tables 5.12 and 5.13 summarize the predicted and observed mean monthly flows and water yields. Water yield is the mean flow divided by the drainage area. All predicted water yields are within 15% of the observed water yield for the area, calculated from USGS gaging station data. The USGS Water Yield contour map reports a range of 1.2 to 1.6 cfs/mi^2 for the water yield of the area (Carter 1983).

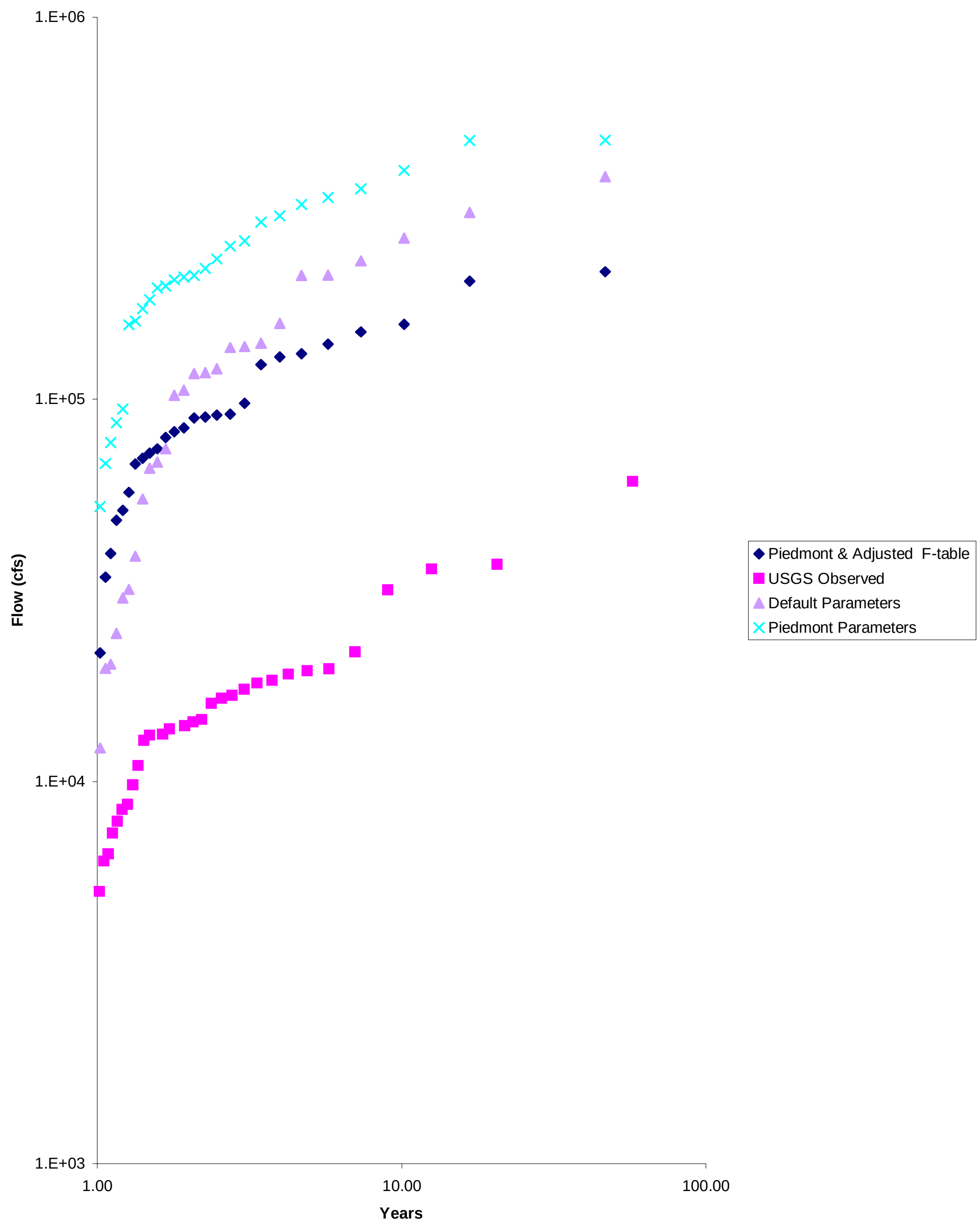

Figure 5.2. Flow Frequency Curves for 3 Simulations and 1 Observation.

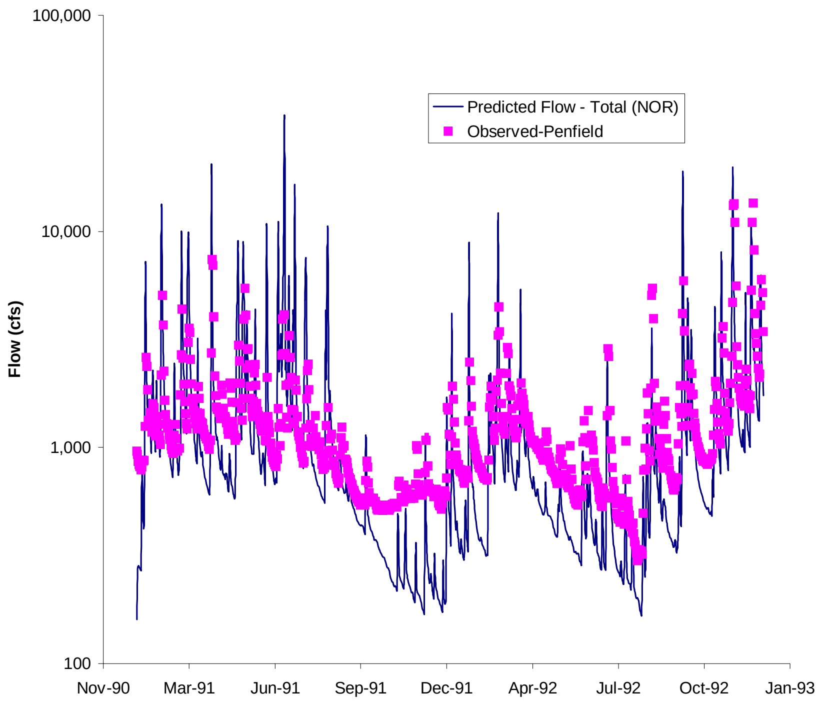

Figure 5.3. Simulated and Observed Daily Flows.

Table 5.12. Predicted Flow Data. Simulation Period 1970-1995

Delineation	***Drainage Area (mi^2)***	***Mean Flow (cfs)****	**Water Yield (cfs/mi^2)**	**% Error+**
Total	771	1196	1.55	12
East	300	466	1.55	12
West	471	731	1.55	12
Northeast	177	271	1.53	10
Southeast	123	197	1.60	15
Northwest	312	485	1.55	12
Southwest	159	248	1.56	12

* Mean of the monthly means

\+ Based on Oconee River Near Penfield. Water Year from 1977-1998

Table 5.13. USGS Gage Observed Flow Data.

USGS Gage Location	MOR near Arcade	MOR near Athens	OR near Penfield
USGS Gage Number	2217475	2217500	2218300
Drainage Area - mi^2	332	392	940
Years of Record	1987-1998	1902-1998	1977-1998
Annual Mean Flow (cfs)*	755	530	1311
Water Yield	2.27	1.35	1.39
Highest Annual Mean cfs (date)	755 (1998)	977 (1964)	2169 (1998)
Lowest Annual Mean Cfs (date)	185 (1988)	202 (1986)	498 (1986)
Instantaneous Peak Flow – cfs (date)	13,800 (Mar 1990)	19,600 (Feb 1902)	31,700 (Oct 1989)
Instantaneous Peak Stage - (ft)	25.34	25.5	25.52

*Annual mean = arithmetic mean of daily mean discharge
MOR = Middle Oconee River
OR = Oconee River

5.9 How well can BASINS support selected potential uses?

BASINS has potential to support several legal and policy directives, including TMDL development, Watershed Assessments, Source Water Assessments, the strategic implementation of conservation practices, watershed characterization, and local watershed management. The following discussion of options, issues, and limitations is organized into two sections: GIS ideas and issues, and NPSM (HSPF) ideas and issues.

GIS: Ideas and Issues

GIS supports the synthesis, analysis, and visualization of a wide range of information. Improved data organization allows scientists to discover relationships that may not have been otherwise revealed. Specialized maps can be created from an array of data layers to reveal new information. The GIS capabilities of BASINS can be used to support Source Water Assessments, land trusts, citizen access to publicly available data, citizen watershed groups, city planning, public education, and watershed characterization. Many of these enterprises require current land-use data supplemented with additional local data such as proposed development plans.

BASINS contains information that may support Source Water Assessments, required by the Safe Drinking Water Act. Hydrography can be overlayed with hazardous waste sites and drinking water sources for risk analysis. Watersheds can be delineated with pour points placed at the targeted drinking water facility. The watershed can then be characterized using spatial data layers, such as the Toxic Release Inventory sites, the Permit Compliance System data, the Industrial Discharge data, the National Sediment Inventory data and roads and railways. The user must consider data quality. For instance, we found that the reported physical locations of the Permit Compliance System dischargers may be at the actual point of discharge, the office building location, or elsewhere. Additional data can be imported such as the TIGER census data available from Georgia GIS Data Clearinghouse (http://gis.state.ga.us/Clearinghouse/clearinghouse.html), along with proposed development plans, often available from local planning commissions and Regional Development Centers. Trend analysis and model calibration pursuits may be complemented by the extensive source water measurements taken at drinking water facilities, such as turbidity, pH and coliforms. For example, Cox and Rasmussen (1999) retrieved and analyzed over sixty years of data from a drinking water facility for analysis of historical turbidity trends.

BASINS also supports legal directives that require publicly available data. The Emergency Planning and Community Right-to-Know Act of 1986 (42 U.S.C.A. §11001et seq.; EPCRTKA §301et seq.) requires industry and government to compile and make available to the public accurate information about the release of toxic chemicals. The EPA is required to maintain a "national toxic chemical inventory." The Toxic Release Inventory is included in BASINS along with many other environmental databases such as the Permit Compliance System, the Solid and Hazardous Waste Sites, and Industrial Discharges Inventory.

BASINS supports the watershed characterization component of Watershed Assessments by providing various spatial datasets organized in 8-digit Hydrologic Accounting Units, with the capability of accepting imported data. (Currently the *Target* and *Assess* assessment tools in BASINS will not integrate imported data unless the user modifies the Avenue scripts.) BASINS can also be used to identify priority watersheds by locating urban areas, growth regions, and rivers with many point source inputs. Similarly, land trusts and city planners can detect areas with development pressures. Environmental justice concerns can be examined by intersecting socioeconomic information from TIGER census data with hazardous waste sites, industrial discharges, and future zoning plans.

The water resource professionals (Chapter 3) expressed a need for pollutant source identification strategies. Scientific knowledge regarding pollutant source identification is weak. However, if source identification were better developed, BASINS could be used to illustrate sensitive and stressed areas. With updated land-use layers, BASINS could support locating environmental factors related to pollutants by querying for targeted land-uses and point sources.

In this time of growing public involvement in local land-use planning, BASINS can assist with public decision-making by illustrating the consequences of various policy choices. For example, riparian buffers can be generated and the stream buffers intersected with tax and proposed development maps to help analyze land value and tax ramifications. Land-use data can be queried for intact forest lands and agricultural lands, then intersected with a proposed development layer to illustrate the loss of intact forest and agricultural lands. These types of spatial analyses are useful for local land-use planning and possible with the BASINS package.

NPSM (HSPF): Ideas and Issues

The watershed modeling capabilities within BASINS has potential to support Watershed Assessments, TMDL development, and strategic implementation of land management alternatives. Legal requirements for Watershed Assessments and TMDLs include predictive modeling of future land use changes.

Predictive modeling of future land use changes is possible if adequate calibration data can be gathered. The watershed of interest can be modeled at forested, agriculture, current, and various build-out scenarios. The build-out schemes can include various flow remediation techniques, from traditional engineering detention ponds to landscape design mitigation alternatives.

Use of HSPF is advantageous because it can be applied to virtually any watershed; however, paramaterization is problematic due to data scarcity, non-unique parameter sets, and undefined prediction uncertainties. The equations in HSPF rely upon calibrated parameters that require extensive amounts of endemic data to accurately represent the system. A good fit of predicted to observed data does not ensure that the parameters represent the system because multiple sets of parameters can represent one outcome. HSPF has over one hundred parameters, resulting in the flexibility to model a wide range of conditions and the dilemma of many optimal solutions. The exact number of parameters depends on the number of land uses modeled. Parameterization does not ensure understanding of the system or what role each parameter plays. The parameters may be correlated, as well, adding additional unapparent uncertainties.

Prediction uncertainty issues have not been addressed within HSPF or BASINS. Studies often perform “validation” or “verification” of parameter estimations. The terms “validation” and “verification” are misleading and should not be used. Applying a model to another watershed does not validate or verify the model, but it only presents how well the model can be calibrated for those specific conditions, for that particular watershed. The plethora of parameters in HSPF allow superb curve fitting, but results in large predictive uncertainties. Additional parameters may elevate the goodness of fit, but may also increase confidence regions, degrees of freedom, and predictive uncertainties. Calibrated solutions with uncertainties may provide poor predictions for changing conditions.

TMDLs will certainly be challenged in court. The hundreds of parameters in HSPF may be subject to these legal challenges. Data scarcity has been managed by estimating the fitted model parameters based on “best professional judgment” and experience. The BASINS listserver postings record concern over the lack of parameter sets and the tendency for people to use whatever they can find. Estimating parameters based on “best professional judgement” is a subjective procedure, exposes predictions to the personal experiences of the model user, and may not be defensible. For example, the Georgia TMDL submittals reviewed in this chapter calibrated HSPF based on one year of data, with only 16 fecal coliform samples. The watershed was represented by rainfall at least 20 miles away, and calibrated on flows from a nearby watershed. Estimating, instead of calibrating, fitted parameters contributes additional, undefined uncertainties.

Data comparability issues are also important considerations for Watershed Assessments and TMDLs. Water quality data must be comparable when contrasting forestry, agriculture, and urban land-uses. Data comparability is essential for equitable waste allocation in TMDL procedures. The EPA STORET water quality data is compiled from assorted agencies, universities, and water labs with varying methods of collection and analysis.

Temporal land-use issues are not resolved. For instance, land-use data provides the amount of cropland in the watershed, but does not reveal the history of the land use -- if conventional fertilizer, poultry litter, or manure is used, or if the manure is fresh, day-old or week-old. Land-use histories may never be readily available. However, land use history affects hydrologic response, and should be considered.

Future versions of BASINS may support strategic implementation of management alternatives by the added capability to route flows and constituents through land-uses, including buffers (Johnston, 2000). The lumped parameter structure of HSPF prohibits spatial discretization of each watershed. In BASINS, overland flow, interflow and baseflow are deposited directly from each pervious land segment into the last reach of the watershed. HSPF has been used in the past to consider Best Management Practices by manipulating parameters to mimic assumed effects of BMPs, such as increased infiltration. Bicknell et al. (1985) demonstrated how HSPF could be used to model flow, sediment, pesticides, and nitrogen for BMP planning by adjusting parameters to imitate conservation tillage and crop residue. Soil moisture retention, interception, Manning's resistance coefficient, and land cover parameters were increased and sediment production from tillage was decreased. Adjusting fitted parameters from assumptions and best judgment may be controversial if policy decisions are at stake.

Summary

The array of physical and chemical information organized at the watershed level within BASINS provides the opportunity for a wide range of analyses. Integrating data from the various activities occurring in a river basin is requisite to effective watershed management. BASINS serves as an excellent structure to organize information and interface spatial data with hydrologic models. However, providing an interface does not ensure intelligent integration. The interaction of a sea of data with modeling tools within a digital environment does not assure meaningful analysis.

CHAPTER 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Thesis Summary

Federal and state legislation requires Source Water Assessments, Watershed Assessments, Total Maximum Daily Loads, and publicly accessible data. Georgia water resource professionals need tools to help them implement legal directives, allocate resources, inform and educate the public, characterize watersheds, plan for the future, and identify pollutant sources. BASINS was created by the EPA to support TMDL development, and it may support additional watershed level analyses. One aspect of this thesis involved issues of coupling spatial analysis with hydrologic modeling within BASINS. We evaluated BASINS for use in Georgia based on interrogatory criteria selected from federal and state legislation, and from interviews with federal, state, and local water resources professionals in Georgia.

6.2 Conclusions

Modeling: Objective Analysis or Virtual Truthmaking?

Based on interviews conducted as part of this thesis, we found that agency scientists and managers need manageable analysis techniques that can be effectively conveyed to a wide range of stakeholders. The modeling tools supplied by EPA should meet the modeling needs of agency personnel. For example, adequate data must be available or reasonable to collect, calibration techniques should be objective and reproducible, and predictions should have definable uncertainties.

The expectations we have of watershed models play a role in how we view and use models. Models can define current understanding and help clarify remaining mysteries. Model accuracy is limited by current scientific knowledge, and cannot be expected to transcend scientific understanding. What should be expected is responsible use of models that includes honest presentations of the assumptions, the assorted data inputs and data quality, and the resulting uncertainties of predictions. Models should not be misused and subsequently cited to drive policy and land-use decisions that have social and economic effects. For instance, in Georgia, TMDLs have been developed using HSPF calibrated to one year of data, from mixed land-use watersheds, with weather stations that are 20 to 40 miles away. Weather plays a dominant role in defining hydrologic response, is spatially variable, and drives HSPF. HSPF should be calibrated to 4 or 5 years of data and land-cover unique parameters should be calibrated to watersheds with a dominant land-use. When land-use unique parameters are not calibrated, they must be estimated, using “best professional judgment” based on a scarce scientific data. Many 303(d) listed streams in Georgia are considered impaired due to fecal coliform, and subsequently modeled with HSPF. We question the wisdom of modeling ill-defined pathogen processes of unclear origin with one year of calibration data, consisting of 16 observations, and weather data that is miles away. We question the fairness of allocating pollution loads among landowners with mathematical models that depend on scarce scientific information and subjective, non-standardized, un-reproducible parameter estimations. Science has not clarified what the fecal indicator levels should be, identified definite sources, or explicated the fate and transport processes. Moreover, if the model tells us to reduce fecal contamination by 50% or 70%, will we do anything differently on the ground? The unresolved challenges of modeling with HSPF with scarce data beg for alternative approaches to watershed analyses. Watershed Assessments, Source Water Assessments, and other watershed scale analyses affect communities via local land-use decisions.

Alternatives To Predictive Modeling in Watershed Management

An alternative approach to predictive modeling would be to facilitate local stakeholder meetings for the creation of watershed management plans. Stakeholders, including farmers, foresters, and homeowners could voice their concerns, be advised on scientific understanding and concerns, and then discuss potential compromises and solutions. A watershed management plan that is devised and supported at the grassroots level may be more successful than an additional regulatory restriction that results from a modeling project. Long-term monitoring data could be coupled with spatial data for trend analysis and indicator tracking. Although trend analysis does not certify the future, trend analysis and indicator tracking allow the stakeholders to take account of where they were, where they are, and where they are going. The spatial and temporal data supplied within BASINS, and the spatial analysis capabilities of BASINS would support the development of stakeholder-based watershed management plans.

Policy

The intimate relationship between land-use and water quality and the delegation of zoning powers to local governments makes the local political body the central venue for many environmental programs. In Georgia, the various environmental regulations can work in symphony within the Georgia Planning Act of 1989. The Georgia Planning Act encourages local governments to develop comprehensive plans that integrate the various environmental programs into the local planning landscape. Source Water Assessment Plans, Watershed Assessments for Domestic Wastewater Systems, Nonpoint Source Management Strategies, River Basin Management Planning, the Erosion and Sedimentation Control Act, and TMDLs, among other legal initiatives, support and constrain the local comprehensive plans.

The data from each program can be shared, and the results can establish current conditions and issues. This information can then help local governments and citizens guide their counties into a sustainable future with an agreeable quality of life.

As difficult questions fall upon local citizens and their governing bodies, the role of predictive modeling in Watershed Assessment will be defined. The difficulties of modeling, from location of necessary data, to calibration, to interpretation of results after a myriad of assumptions and estimations, often overwhelm local resources. Exiguous financial, human, and temporal resources of local governments do not provide room for extensive predictive modeling projects. BASINS somewhat addresses these concerns by providing a free suite of models, linked to GIS, with prepackaged data. However, the prepackaged data is too coarse and sparse for most local scale analyses, including the development of TMDLs for stream segments. Due to these difficulties modeling has been executed by regulators, consultants, and academics.

Predictive modeling for watershed management implies a delegation of power. A person created the model, a person defines the parameters, and a person draws conclusions from the results. We need to consider how the various decisions and assumptions made along the way affect the local citizen. These issues will increase in importance as TMDLs are developed, constrain local land-uses, and are challenged in court. For instance, due to little or no monitoring data from watersheds with a single dominant land-use, the modeler must decide relative parameter values for each land-use, essentially determining the relative results. If the modeler believes that agricultural land-use has higher pesticide loading than urban areas, he will represent this in the parameterization, and the model results will reflect this bias. We cannot simply model for the sake of numerical composition. We also cannot model our watersheds by shrouding a series of subjective estimations in a numerical cape. We need to reevaluate what we think we know, how we know it, and what the implications of it are. We need to avoid getting caught up in the momentum of modeling and ask ourselves several questions. In the end, will we do anything differently? Have we been enlightened? Is the benefit worth the effort?

BASINS: Envoy of Science and Policy

Scientists must be able to communicate knowledge gained from data and analysis, as well as limitations of data and analysis, in order to maintain public trust. BASINS has great potential to serve as a visual envoy of geographic and scientific data between scientists, managers, the public, and policy-makers. While BASINS is not a sovereign remedy for the woes of watershed management, BASINS assists with data organization and analysis. Compiling data within BASINS provides an opportunity for us to take a look at where we are and where we need to go. A propitious outfall of BASINS may be the drive for improved, comparable monitoring methods. The interviewed farmer summed up many water resources issues facing Georgia well when he said, " …if you have a high concentration of chickens, and urban growth, and you are cutting your buffers, something has to give…". The citizens will decide what will "give" in local commission and planning meetings. The tortuous pursuits of public, environmental, and economic health converge at the community level. As stated by one the interviewees, "in the end, planning is a public process, not a scientific one. "

6.3 Recommendations

The utility of BASINS could be enhanced with the following improvements. Suggested improvements include additions to the software capabilities and support data.

- Modeling the future would benefit from a better understanding of the past and the present. Comprehensive long-term monitoring of our watersheds is needed to improve understanding of the natural hydrologic system, to track human impacts on water quality, to improve understanding of the effectiveness of management practices, for pollutant source identification, and to support modeling efforts.
- BASINS would be more valuable with the addition of a watershed model that is better suited to the needs and resources of state and local agencies, and the inclusion of methods for predictive uncertainty analysis.
- More published TMDL case studies using BASINS are needed.
- The BASINS Listserve is an invaluable resource. The BASINS manual and the training documents fail to include many important details. The problems encountered by users along with answers and work-arounds are discussed on the BASINS Listserve. A compilation of the important discussions, answers and work-arounds organized by subject, not month, would benefit BASINS users.

- The utility of BASINS would be enhanced if additional datasets were included and if the current datasets were continually updated on the BASINS web site.
- Coverages of section 303(d) listed streams and section 305(b) data would be beneficial.
- Current land-use would amplify BASINS applications. Land use by year would compliment the temporal water quality data for trend and source analysis.
- Biological data would impart another dimension to BASINS. The spatial, temporal, acute, and chronic distributions of pollution are not completely characterized by physical and chemical data. The health of aquatic fauna is an important measure of stream health. Biologic assessment data should be included within BASINS.
- Demonstration projects for sustainable agriculture, forestry, and urban and suburban development need to be funded. People need to be able to see, touch, and feel what sustainable living would be like in order to say, “I want this” and “I’m willing to pay for it.”

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