Review of the BASINS Model and Preliminary Application to Meander Creek Watershed

By

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Meander Creek Watershed

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ABSTRACT

The City of Youngstown obtains its drinking water from the Meander Creek Reservoir formed by Mineral Ridge Dam built in 1932 for water supply on Meander Creek five miles (8 km) northwest of Youngstown. The area covered by the water body is approximately 1867 acres and the size of watershed is approximately 54271 acres. Meander Creek Reservoir is operated by the Mahoning Valley Sanitary District (MVSD) and is considered a surface water source. The increasing frequency of taste and odor problem in Meander Creek Reservoir over the past decade coincides with a period of rapid development (mostly residential) in the reservoir watershed. Development invariably results in increased runoff, sediment export, and nutrient loading to adjacent streams and lakes. A watershed analysis for nonpoint source pollutants and a water quality study were performed using Better Assessment Science Integrating Point and Non-Point Sources (BASINS), a multipurpose environmental analysis system developed by United State Environmental Protection Agency (USEPA). A Geographical Information System (GIS) was developed for the watershed, which includes data layers for land use, soil type, topography, water resources, roads, political boundary, and wetlands. Estimates of flow conditions and loading of solids, nitrogen, and phosphorus to reservoir were obtained by applying the Hydrological Simulation Program Fortran (HSPF) and PLOAD models within BASINS. HSPF simulation of the watershed provides information that could be of considerable help in formulating management decisions to address problems related to loading.

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CHAPTER 1

INTRODUCTION

1.1 Nonpoint Source Pollution

Pollutant sources are usually classified as point and nonpoint. Pollution originating from a single source, such as a discharge pipe from a factory or sewage plant, is termed point source pollution. Pollution that does not originate from a single source, or point, is termed nonpoint source pollution (NPS). NPS pollution arises from many everyday activities that take place in residential, commercial, and rural areas and is carried by storm water runoff to streams. Examples of nonpoint source pollution include soil erosion from farmland and construction sites, rural and urban pesticide and fertilizer runoff, failing septic systems, animal waste, motor oil, antifreeze, and salt applied to roadways. When it rains, these items are washed from the land into waterways by way of surface runoff and storm drains. Because concrete and asphalt don't absorb rainwater, runoff from urban and suburban areas is much greater than from undisturbed areas with adequate vegetation (USEPA 2001).

1.2 Ohio's TMDL Program

The Total Maximum Daily Load (TMDL) program, established under Section 303(d) of the Clean Water Act (33 U.S.C. 1313), focuses on identifying and restoring polluted rivers, streams, lakes and other surface water bodies. A TMDL is a written, quantitative assessment of water quality problems in a water body and contributing sources of pollution. It specifies the amount a pollutant needs to be reduced to meet water quality standards (WQS), allocates pollutant load reductions, and provides the basis for taking actions needed to restore a waterbody. The TMDL program requires states to develop TMDLs for waters on the 303(d) list. Section 303(d) requires the identification and prioritization of waters not meeting in-stream water quality standards. The TMDL includes a distribution of pollutant loading (allocation) that results in attainment of water quality standards (USEPA, 2001). The five key steps in the TMDL program are:

- Identify water quality-limited water (303(d) list)
- Prioritize water quality-limited waters.
- Develop the TMDL plan for each water quality limited stream segment.
- Implement the water quality improvement for each segment.
- Assess water quality improvement for each segment.

1.3 Meander Creek Reservoir

The City of Youngstown obtains its drinking water from the Meander Creek Reservoir located on Meander Creek about five miles (8 km) northwest of Youngstown, OH. Mineral Ridge Dam, built in 1932 for water supply, formed the Reservoir. The Mahoning Valley Sanitary District (MVSD) treats approximately 28 million gallons per day of raw water from Meander Creek Reservoir and pumps it to customers in Youngstown, Niles and surrounding areas.

"Cucumber" odor has, on occasion, been a problem in the finished water of the Mahoning Valley Sanitary District treatment plant. The problem usually occurs during mid-winter (January or February). The most likely cause of the odor is the alga *Synura petersenii* Korshikov. The cause of the occasional "blooms" that produce the odor problems is not known, however it is believed that development in the watershed may be a contributing factor. The Ohio Environmental Protection Agency (OEPA) has scheduled Meander Creek for TMDL analysis in the year 2010.

1.4 The BASINS Model

Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) is a multipurpose environmental analysis system for use by regional, state, and local agencies in performing watershed- and water-quality-based studies. It was developed by the U.S. Environmental Protection Agency's (USEPA's) Office of Water to address three objectives:

- To facilitate examination of environmental information.
- To support analysis of environmental systems.
- To provide a framework for examining management alternatives.

BASINS was also conceived as a system for supporting the development of total maximum daily loads (TMDLs). Section 303(d) of the Clean Water Act requires states to develop TMDLs for water bodies that are not meeting applicable water quality standards by using technology-based controls. Developing TMDLs requires a watershed-based approach that integrates both point and nonpoint sources. BASINS can support this type of watershed-based point and nonpoint source analysis for a variety of pollutants (USEPA, 2001a).

1.5 **Goals of Study**

The goal of this study were to:

1) Review the NPS modeling capabilities of BASINS.
2) Apply BASINS to model NPS pollution in the Meander Creek Watershed.

CHAPTER 2

STRUCTURE AND CAPABILITIES OF BASINS

2.1 Overview of BASINS

A geographic information system (GIS) provides the integrating framework for BASINS. The assessment component, working under the GIS umbrella, allows users to quickly evaluate selected areas, organize information, and display results. The modeling component module allows users to examine the impacts of pollutant loadings from point and nonpoint sources. Working together, these modules support several specific aspects of watershed-based analysis by

- Identifying and prioritizing water-quality-limited waters.
- Supplying data characterizing point and nonpoint sources and evaluating their magnitudes and potential significance.
- Integrating point source and nonpoint source loadings and fate and transport processes.
- Evaluating and comparing the relative value of potential control strategies.
- Visualizing and communicating environmental conditions to the public through tables, graphs, and maps (USEPA 2001).

BASINS comprises a suite of interrelated components for performing the various aspects of environmental analysis. The components include (1) nationally derived databases with Data Extraction tools and Project Builders; (2) assessment tools (TARGET, ASSESS, and Data Mining) that address large- and small-scale characterization needs; (3) utilities to facilitate organizing and evaluating data; (4) tools for Watershed Delineation; (5) utilities for classifying land use, soils, and water quality observations; (6) Watershed Characterization Reports that facilitate compilation and output of information on selected watersheds; (7) an instream water quality model, *QUAL2E*; (8) two watershed loading and transport models, Hydrological Simulation Program - Fortran (HSPF) and Soil and Water Assessment Tool (SWAT); and (9) PLOAD, a simplified GIS based model that estimates nonpoint source (NPS) loads of pollution on an annual average basis. A graphical representation of the BASINS components and their operating platform is shown in Figure 1 below (USEPA 2001).

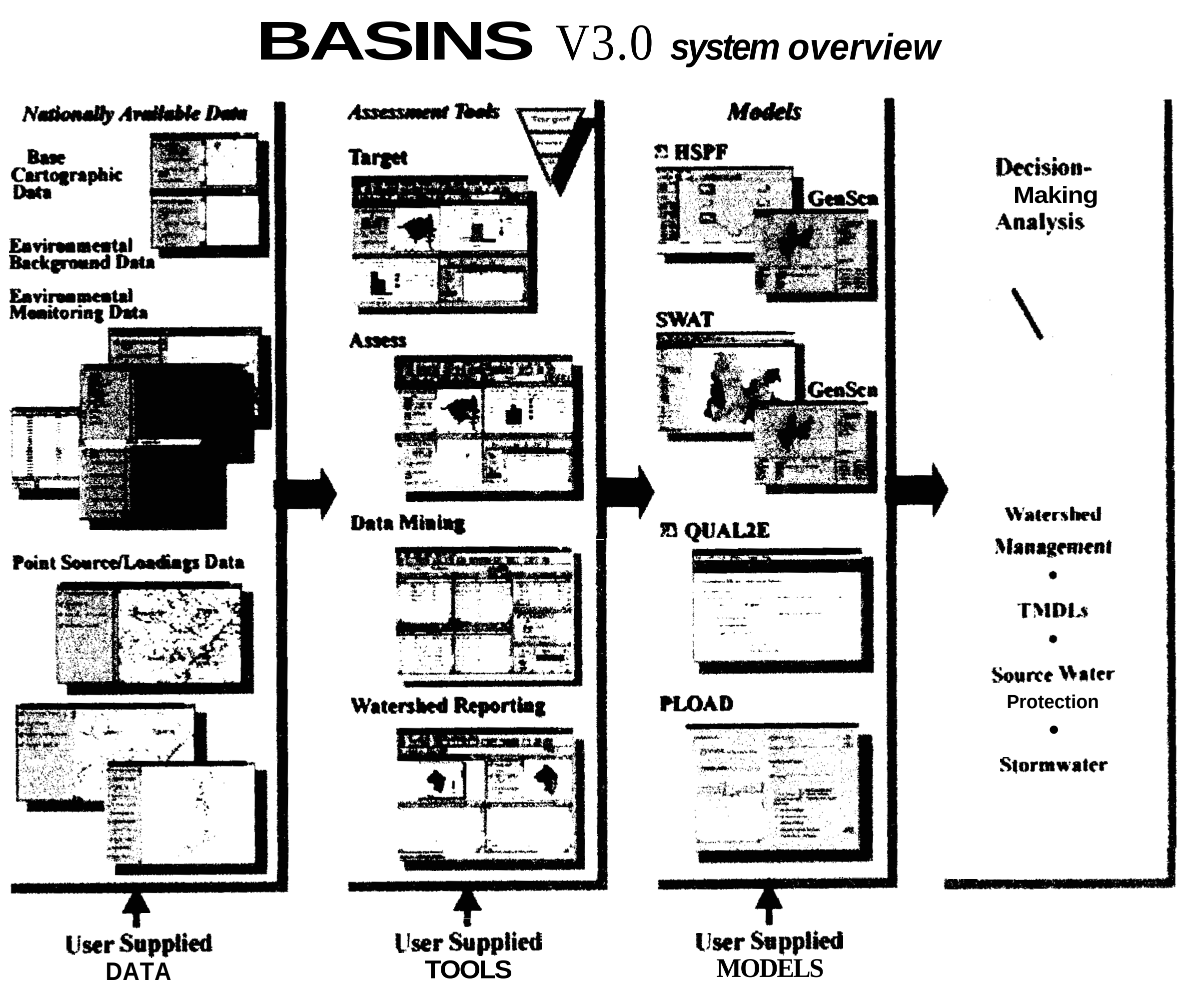


Figure 1. BASINS version 3.0 (USEPA 2001)

The BASINS physiographic data, monitoring data, and associated assessment tools are integrated in a customized geographic information system (GIS) environment. The GIS used is Arc View 3.1 developed by Environmental Systems Research Institute, Inc. The simulation models are integrated into this GIS environment through a dynamic link in which the data required to build the input files are generated in the Arc View environment and then passed directly to the models. The models themselves run in either a Windows or a DOS environment. The results of the simulation models can also be displayed visually and can be used to perform further analysis and interpretation.

2.2 Watershed Modeling Tools

The water quality modeling tools available in BASINS include the following:

- In-stream model:
  - *QUAL2E*, a water quality and eutrophication model.
- Watershed Models:
  - *WinHSPF* is an interface to the Hydrological Simulation Program FORTRAN (HSPF) model, version 12. HSPF is a watershed-scale model for estimating in-stream concentrations resulting from loadings from point and nonpoint sources.
  - SWAT is a physical-based, watershed-scale model that was developed to predict the impacts of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land uses and management conditions over long periods of time. SWAT2000 is the underlying model that is run from the BASINS Arc View interface.

- Loading model:
    - PLOAD, a pollutant loading model. PLOAD estimates nonpoint sources of pollution on an annual average basis, for any user-specified pollutant, using either the export coefficient or "Simple Method" approach.

2.3 Geographical Information System (GIS) for Meander Creek Watershed

A GIS for Meander Creek Watershed was developed using BASINS tools to download the information from nationally derived databases. The tables in this section show the types of data extracted and formatted to facilitate watershed-based analysis and modeling. The databases were compiled from a wide range of federal sources. The data were selected based on relevance to environmental analysis, national availability, and scale and resolution.

Four types of data may be extracted for use in the BASINS analysis system (USEPA 2001)

- Base cartographic data
- Environmental background data
- Environmental monitoring data
- Point sources/loading data

2.3.1 Base Cartographic Data

Base cartographic data include administrative boundaries, hydrologic boundaries, and major road systems. These data are essential for defining and locating study areas and defining watershed drainage areas. The base cartographic data products included in BASINS are presented in Table 1.

Table 1. Base cartographic data

Data Product	Source
Hydrologic Unit Boundaries	U.S. Geological Survey (USGS)
Major Roads	Federal Highway Administration
Populated Place Locations	USGS
Urbanized Areas	Bureau of the Census
State and County	USGS

2.3.2 Environmental background data

Environmental background data provide information to support watershed characterization and environmental analyses. These data include informat-ion on soil characteristics, land use coverage, and the stream hydrography. Table 2 lists the environmental background data included in BASINS.

Table 2. Environmental background data

BASINS Data Product	Source
Ecoregions Level III	U.S. Environmental Protection Agency
National Water Quality Assessment	USGS
1996 Clean Water Needs Survey	USEPA
State Soil and Geographic (STATSGO) Database	U.S. Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS)
Managed Area Database	University of California, Santa Barbara
Reach File Version 1 (RF1)	USEPA
Reach File Version 3 (RF3) Alpha	USEPA
National Hydrography Dataset	USGS
Digital Elevation Model (DEM)	USGS
Land Use and Land Cover	USGS

2.3.3 Environmental Monitoring Data

BASINS contains several environmental data products developed from existing national water quality databases. These databases were converted into locational data layers to facilitate the assessment of water quality conditions and the prioritization and targeting of water bodies and watersheds. When available for a watershed, these data can be used to assess the current status and historical trends of a given water body and also to evaluate the results of management actions. Table 3 lists the environmental monitoring data included in BASINS.

Table 3. BASINS Environmental monitoring data

BASINS Data Product	Source
Water Quality Monitoring Stations and	USEPA
Bacteria Monitoring Stations and Data	USEPA
Water Quality Stations and Observation Data	USEPA
National Sediment Inventory (NSI)	USEPA
Gage Sites	USGS
Weather Station Sites	National Oceanic and Atmospheric Administration (NOAA)
Drinking Water Supply (DWS) Sites	USEPA
Watershed Data Stations and Database	NOAA

2.3.4 Point Source / Loading Data

BASINS also includes information on pollutant loading from point source discharges. The location, type of facility, and estimated loading are provided. These loadings are also used to support evaluation of watershed-based loading summaries combining point and nonpoint sources. Potential source loading locations from hazardous waste sites and air emissions are also included. Table 4 lists the point sourcelloading data included in BASINS.

Table 4. BASINS point source / loading data

BASINS Data Product	**Source**
Permit Compliance System (PCS) Sites and Computed Annual Loadings	USEPA
Industrial Facilities Discharge (IFD) Sites	USEPA
Toxic Release Inventory (TRI) Sites and Pollutant Release Data	USEPA
Superfund National Priority List Site	USEPA
Resource Conservation and Recovery Information System (RCRIS) Sites	USEPA
Minerals Availability System/Mineral Industry Location System (MAS/MILS)	U.S. Bureau of Mines

CHAPTER 3

NUTRIENTS AND WATER QUALITY

It is important to have a basic understanding of nutrient processes in a watershed and how excessive or insufficient nutrients can affect water quality and designated uses of water. Excess nutrients in a water body can have many detrimental effects on designated or existing uses, including drinking water supply, recreational uses, aquatic life use, and fishery use. For example, drinking water supplies can be impaired by nitrogen when nitrate concentration exceeds 10 mg/L and cause methemoglobinemia (blue baby syndrome) in infants. Water supplies containing more that 100 mg/L of nitrate can also taste bitter and can cause physiological distress.

Although these are direct impacts that can be associated with excessive nutrient loading, waters more often are listed as impaired by nutrients because of their role in accelerating eutrophication. Eutrophication, or the nutrient enrichment of aquatic systems, is a natural aging process of a waterbody that transforms a lake into a swamp and ultimately into a field or forest. This aging process can accelerate with excessive nutrient inputs because of the impact they have on productivity, in absence of other limiting factors, such as light. (USEPA, 1999)

A eutrophic system typically contains an undesirable abundance of plant growth, particularly phytoplankton, periphyton, and microscopic organisms (algae), which exist as individual cells or a group together as a clump or filamentous mats.

The eutrophication process can impair the designated uses of waterbodies as follows:

- ***Aquatic life and fisheries***. A variety of impairments can result from the excessive plant growth associated with nutrient loading. These impairments result primarily when dead plant matter settles to the bottom of a water waterbody, simulating microbial breakdown processes that require oxygen. Eventually, oxygen in the hypolimnion of a lake or reservoir can be depleted, which can change the benthic community structure from aerobic to anaerobic organisms. Oxygen depletion might also occur nightly throughout the waterbody because of plant respiration. Extreme oxygen depletion can stress or eliminate desirable aquatic life and nutrients (USEPA 1999).

- ***Drinking water supply.*** Diatoms and filamentous algae can clog water treatment plant filters and reduce the time between backwashings (the process of reversing water flow through the water filter to remove debris). Disinfection of water supplies impaired by algal growth also might result in water that contains potentially carcinogenic disinfection by-products, such as trihalomethanes. An increased rate of production and breakdown of plant matter also can adversely affect the taste and odor of drinking water.
- ***Recreational use.*** Excessive plant growth in a eutrophic water body can affect recreational water use. Extensive growth of rooted macrophytes, periphyton and mats of living and dead plant material can interfere with swimming, boating, and fishing activities, while the appearance of odors emitted by decaying plants impair aesthetic uses of the waterbody.

3.1 Nutrient Sources and Transport

Both nitrogen and phosphorous reach surface water at elevated rates as a result of human activities. Phosphorous, because of its tendency to sorb to soil particles and organic matter, is primarily transported in surface runoff with eroded sediment. Inorganic nitrogen, on other hand, does not sorb as strongly and can be transported in both particulate and dissolved phases in surface runoff. Fertilizer applied to cropland, residential lawns, and golf courses is a potential source of both nitrogen and phosphorous.

Dissolved inorganic nitrogen can be readily transported through the unsaturated zone (interflow) and ground water. Because nitrogen has a gaseous phase, it can also be transported to the land or water surface via atmospheric deposition. Phosphorous associated with fine-grained particulate matter also exists in the atmosphere. The sorbed phosphorous can enter natural waters by both dry fallout and rainfall. Finally, nutrients can be directly discharged to a waterbody via outfalls from wastewater treatment plants and combined sewer overflows. Table 5 presents common point and nonpoint sources of nitrogen and phosphorous and the approximate associated concentration.

Table 5. Sources of nutrient loading (Novotny and Olem, 1994)

Source	Nitrogen (mg/L)	Phosphorous (mg/L)
Urban runoff	3-10	0.2-1.7
Livestock operations	6-800 [a]	4 - 5
Atmosphere (wet deposition)	0.9	0.015 [b]
Untreated wastewater	35	10
Treated Waste water (secondary treatment)	30	10

a As organic nitrogen; b Sorbed to airborne particulate

3.2 Nutrient Cycling

The transport of nutrients from their sources to the waterbody of concern is governed by several chemical, physical, and biological processes, which together compose the nitrogen or phosphorus cycle. Nutrient cycles are important to understand because of the information they provide about nutrient availability and the associated impact on plant growth.

3.2.1 Nitrogen

Nitrogen is plentiful in the environment. Almost 80 percent of the atmosphere by volume consists of nitrogen gas (N_2). Once introduced into the aquatic environment, nitrogen can exist in several forms - dissolved nitrogen gas (N_2), ammonia (NH_3 and NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), and organic nitrogen as proteinaceous matter or in dissolved or particulate phases. The most important forms of nitrogen in terms of their immediate impact on water quality are the readily available ammonium ions, nitrites, and nitrates (dissolved nitrogen). Particulate and organic nitrogen, because they must be converted to a usable form, are less important in the short term. Total nitrogen (TN) is a measurement of all forms of nitrogen.

Conversion into usable forms, both in the terrestrial and aquatic environments, occurs through the four processes of the nitrogen cycle. Three of the processes - nitrogen fixation, ammonification, and nitrification, convert gaseous nitrogen into usable chemical forms. The fourth process, denitrification, converts fixed nitrogen back to the gaseous N_2 state. (USEPA, 1999)

• **Nitrogen fixation-** the conversion of gaseous nitrogen into ammonia and ammonium ions (NH_3^+ and NH_4^+ respectively). Nitrogen-fixing organisms, such as blue-green algae (cyanobacteria) and the bacteria Rhizobium and Azobacter, split molecular nitrogen (N_2) into two free nitrogen molecules. The nitrogen ions combine with hydrogen molecules to yield ammonium ions (NH_4^+).

• **Ammonification-** a one-way reaction in which decomposer organisms break down wastes and nonliving organic tissues to amino acids, which are then oxidized to carbon dioxide, water, and ammonium ions. Equilibrium between ammonia and ammonium is maintained through reaction (1). Ammonia is then available for absorption by plant matter.

$$NH_4^+ \rightleftarrows NH_3 + H^+ \qquad (1)$$

• **Nitrification-** a two-step process by which ammonia ions are oxidized to nitrite and nitrate, yielding energy for decomposer organisms. Two groups of microorganisms are involved in the nitrification process. First, *Nitrosomonas* oxidizes ammonium ions to nitrite (NO_2^-) and water. Second, *Nitrobacter* oxidizes the nitrite ions to nitrate (NO_3^-), which is then available for absorption by plant matter (USEPA 1999).

• **Denitrification-** the process by which nitrates are reduced to gaseous nitrogen by facultative anaerobes. Facultative anaerobes, such as fungi, can flourish in anoxic conditions because they break down oxygen containing compounds (e.g., NO_3^-) to obtain oxygen. Nitrogen continuously cycles in the aquatic environment, although the rate is temperature-controlled and thus very seasonal. Aquatic organisms incorporate available dissolved inorganic nitrogen into proteinaceous matter. Dead organisms decompose, and nitrogen is released as ammonium ions and then converted to nitrite and nitrate, where the process begins again. If surface water lacks adequate nitrogen, nitrogen-fixing organisms can convert nitrogen from its gaseous phase to ammonia ions.

3.2.2 Phosphorus

The soluble inorganic phosphate forms, $H_2PO_4^-$, HPO_4^{2-}, and PO_4^{-3}, known as soluble reactive phosphorus (SRP), are readily available to plants. Some condensed phosphate forms, such as those found in detergents, are inorganic but are not available for plant uptake. Inorganic particulate phosphorus includes phosphorus precipitates, phosphorus adsorbed to particulate matter, and amorphous phosphorus. The measurement of all phosphorus forms in a water sample, including all the inorganic and organic particulate and soluble forms mentioned above, is known as total phosphorus (TP). TP does not distinguish between phosphorus currently unavailable to plants (organic and particulate) and that which is available (SRP). SRP is the most important form of phosphorus for supporting algal growth because it can be used directly. However, other fractions are transformed to more bioavailable forms at various rates dependent on microbial action or environmental conditions. In streams with relatively short residence times, it is less likely that the transformation from unavailable to available forms will have time to occur and SRP is the most accurate estimate of biologically available nutrients. In lakes, however, where residence times are longer, TP generally is considered an adequate estimation of bioavailable phosphorus.

Phosphorus undergoes continuous transformations in a freshwater environment. Some phosphorus will sorb to sediments or the other substrates in the water column and be removed from circulation. Phytoplankton, periphyton, and bacteria assimilate the SRP (usually as orthophosphate) and change it into organic phosphorus.

These organisms then may be ingested by detritivores or grazers, which in turn excrete some of the organic phosphorus as SRP. Some previously unavailable forms of phosphorus also convert to SRP. Continuing the cycle, the SRP is rapidly assimilated by plants and microbes.

Human activities have resulted in excessive loading of phosphorus into many freshwater systems. Overloads result in an imbalance of the natural cycling processes. Excess available phosphorus in freshwater systems can result in accelerated plant growth if other nutrients and other potentially limiting factors are available (USEPA, 1999).

3.3 Other Limiting Factors

Many natural factors combine to determine rates of plant growth in a waterbody. The first of these is whether sufficient phosphorus and nitrogen exist to support plant growth. The absence of one of these nutrients generally will restrict plant growth. In inland waters, typically phosphorus is the limiting nutrient of the two, because blue-green algae can "fix" elemental nitrogen from the water as a nutrient source. In marine waters, either phosphorus or nitrogen can be limiting. Although carbon and trace elements are usually abundant, occasionally they can serve as limiting nutrients. However, even if all necessary nutrients are available, plant production will not necessarily continue unchecked. Many natural factors, including light availability, temperature, flow levels, substrate, grazing, bedrock type and elevation, control the levels of macrophytes, periphyton, and phytoplankton in waters. Effective management of eutrophication in a waterbody may require a simultaneous evaluation of several limiting factors (USEPA, 1999).

• **Light Availability:** Shading of the water column inhibits plant growth. Numerous factors can shade waterbodies, including: (1) as plant production increases in the upper water layer, the organisms block the light and prevent it from traveling deeper into the water column; (2) riparian growth along waterbodies provides shade; and (3) particulates in the water column scatter light, decreasing the amount penetrating the water column and available for photosynthesis. With seasonally high particulate matter or shading (e.g., in deciduous forests), the high nutrients levels may cause excessive growth only during certain times of the year. For example, in streams where snowmelt is common in the spring suspended particulate matter could reduce light levels and results in low algal biomass. During stable summer flows, however, there may be lower levels of suspended matter and hence higher algal biomass.

• **Temperature.** Temperature affects the rates of photosynthesis and algal growth, and the composition of algal species. Depending on the plant, photosynthetic activity increases with temperature until a maximum photosynthetic output is reached, then photosynthesis declines (Smith, 1990). Moreover, algal community species composition in a waterbody often changes with temperature. For example, diatoms most often are the dominant algal species at water temperatures of 20 ° - 25 °C, green algae at 30 ° - 35 °C, and blue-green algae (cyanobacteria) above 35 °C (Dunne and Leopold, 1978; USEPA, 1986).

• **Water Velocity:** Water movement in large lakes, rivers, and streams influences plant production. Stream velocity has a two-fold effect on periphyton productivity. Increasing velocity to a certain level enhances biomass accrual but further increases can result in substantial scouring (Homer *et* al., 1990). Large lakes and estuaries can experience the scouring action of waves during strong storms. In rivers and streams, frequent disturbance from floods (monthly or more frequently) and associated movement of bed materials can scour algae from the surface rapidly and often enough to prevent attainment of high biomass (Homer *et* al., 1990). Rapid flows can sweep planktonic algae from a river reach, while low flows may provide an opportunity for proliferation.

• **Substrate.** The type of substrate available influences macrophytes and periphyton. Macrophytes prefer areas of fine sediment in which to root (Wright and McDonnell, 1986, in Quinn, 1991). Thus, the addition and removal of sediment from a system can influence macrophyte growth. Periphyton, because of its need to attach to objects, grows best on large, rough substrates. A covering of sediment over a rocky substrate decreases periphyton biomass (Welch ***et*** al., 1992).

• **Grazing.** Dense populations of algae-consuming grazers (e.g., zooplankton) can lead to negligible algal biomass, in spite of high levels of nutrients (Steinman, 1996). The existence of a "trophic cascade" (control of algal biomass by community composition of grazers and their predators) has been demonstrated for some streams (e.g., Power, 1990). Managers should realize the potential control of algal biomass by grazers, but they also should be aware that populations of grazers could fluctuate seasonally or unpredictably and fail to control biomass at times. Consideration of grazer populations might explain why some streams with high nutrients have low algal biomass.

• **Bedrock.** The natural effects of bedrock type also might help explain trophic state. Streams draining watersheds with phosphorus-rich rocks (such as rocks of sedimentary or volcanic origin) can be enriched naturally and, therefore, control of algal biomass by nutrient reduction in such systems might be difficult. Review of geologic maps and consultation with a local soil scientist might reveal such problems. Bedrock composition has been related to algal biomass in some systems (Biggs, 1995).

CHAPTER 4

TMDL DEVELOPMENT

4.1 Overview of Meander Creek Reservoir

The Meander Creek Reservoir is operated by the Mahoning Valley Sanitary District (MVSD) and is considered a surface water source that requires treatment prior to use as drinking water. Treatment includes chemical addition for softening, disinfection, fluoridation, taste and odor control, settling, coagulation, flocculation, and filtration. The Cities of Youngstown and Niles purchase the finished water from the MVSD and operate water distribution systems only. Youngstown distributes approximately 21 million gallons per day through 750 miles of pipelines to residents of Youngstown, Austintown, Boardman, Canfield Township, North Jackson and Liberty and sells bulk water to Mineral Ridge, Girard and the City of Canfield. (City of Youngstown, 2001)

4.1.1 **Taste and Odor Problem**

"Cucumber" odor is caused by release of the chemical trans-2, cis-6-nonadienal that is produced by the alga, *Synura petersenii* Korshikov (Hayes and Burch, 1989) and perhaps by *Uroglenopsis* (Mallevialle and Suffet, 1987). Of the two algal taxa purported to produce "cucumber" odor, only *Synura* have been collected from Meander Creek Reservoir. Of the approximately 12 species of *Synura*, only *Synura petersenii* is know to produce trans-2, cis-6-nonadienal (Wee *et al.*, 1994) the compound causing "cucumber" odors in water. *Synura petersenii* also produces 2-trans, 4-cis, 7-cis-decatrienal, which imparts fishy/cod liver oil odors to water, having a "cod liver oil" odor (Jutner, 1981). Schroeder and Martin (2002) confirmed the presence of *Synura pettersenii* Korshikov in Meander Creek Reservoir using scanning electron microscopy.

The "cucumber" odor in MVSD water is believed to be a relatively recent phenomenon, occurring only during the past 10 years. It is likely that general changes in trophic condition of Meander Creek Reservoir are associated with the recent occurrence of "cucumber" odors. However, each episode is probably associated with a specific set of environmental conditions, rendering the reservoir susceptible to growth of large populations of *S. petersenii*. *Spetersenii* are always present at low density or as cysts, and usually cause no odor in the water. Occasionally conditions become favorable for the production of sufficient abundance of *S. petersenii* to cause "cucumber" odor in the raw and finished water. The threshold density for production of objectionable odors by *S. petersenii* to about 100 colonies per ml (Mallevaille and Suffet, 1987) or about 6,000 cells per ml. When conditions are optimum, growth can be rapid. In Meander Creek Reservoir, rapid *Synura* growth is usually associated with cold temperatures, runoff events, and an increase in light associated with melting of ice cover (Schroeder and Martin, 2000).

4.2 TMDL Development for Meander Creek Watershed, OH

To develop a TMDL, it is necessary to have one or more quantitative measures that can be used to evaluate the relationship between pollutant sources and their impact on water quality. Such measurable quantities are termed indicators. For the purpose of developing a nutrient TMDL for Meander Creek Watershed, chlorophyll a was taken as the indicator. Figure 2 shows the components in TMDL developments.

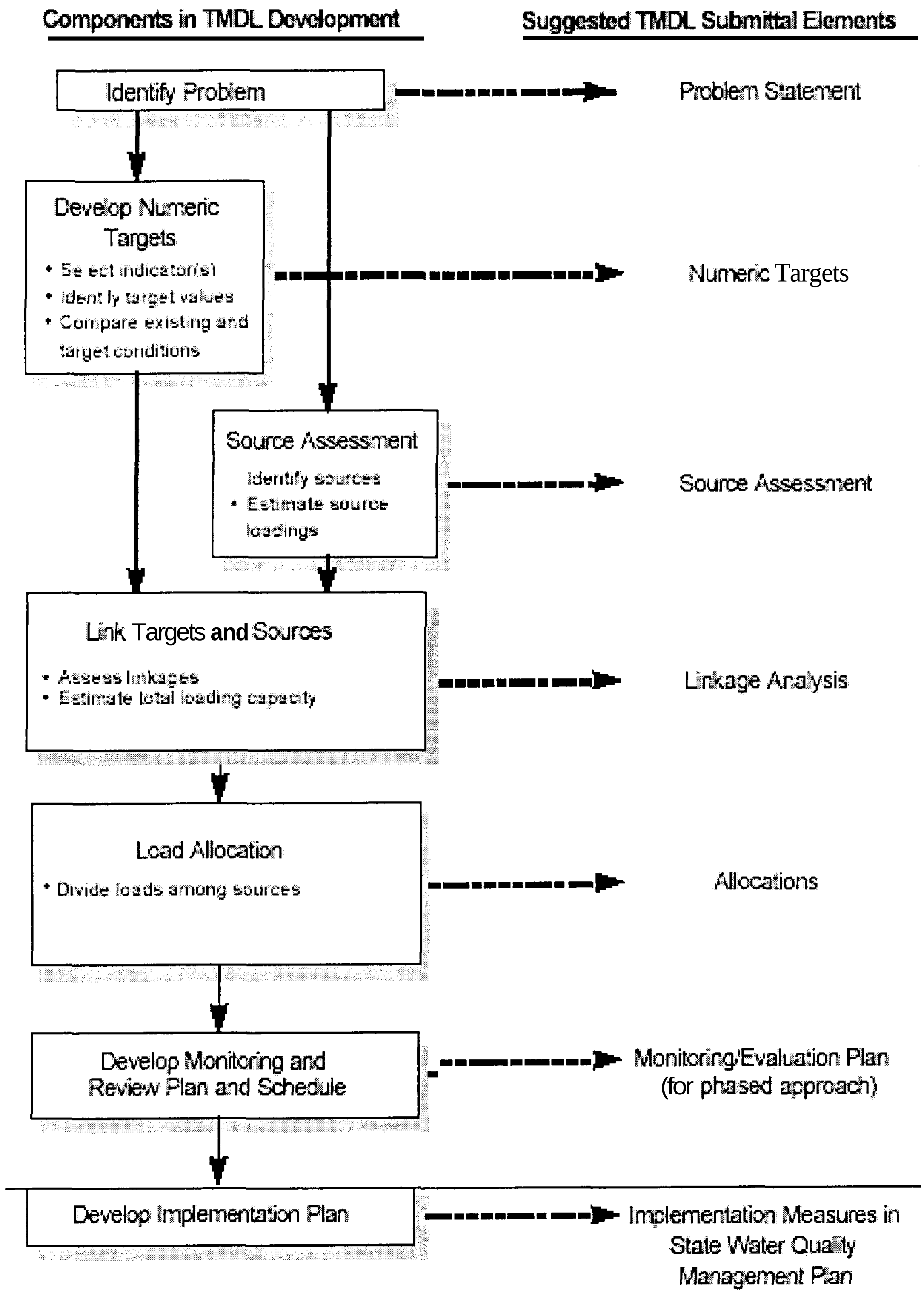


Figure 2. Components in TMDL development (Modified from USEPA, 1999)

4.2.1 TMDL Summary

A common first step in TMDL development is a summary listing of key water body characteristics and water quality standards. A TMDL summary for Meander Creek Reservoir is presented below.

Water Body Type:	Reservoir
Pollutant:	Phosphorous
Designated Uses:	Water Supply
Size of Waterbody:	1867 acres (755.5 hectares)
Size of Watershed:	54238 acres (21949 hectares)
Mean Depth of Reservoir:	15.3 ft (4.66 m)
Volume of Reservoir :	1.34×10^{9} ft^3 (3.79×10^{7} m^3)
Water Quality Standards:	Narrative.
Indicator1 Goal:	25 µg/L Chlorophyll a

4.3 Develop Numeric Targets

A TMDL is the sum of the individual waste-load allocations for point sources and load allocations for nonpoint sources and natural background with a margin of safety (CWA Section 303(d)(1)(c)). The TMDL can be generically described by equation (2).

$$TMDL = LC = WLA + LA + MOS \quad (2)$$

Where:

LC= loading capacity; the greatest loading a waterbody can receive without violating water quality standards.

WLA = waste-load allocation, or the portion of the TMDL allocated to existing or future point sources.

LA = load allocation, or the portion of the TMDL allocated to existing or future nonpoint sources and natural background.

MOS = margin of safety, or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. The margin of safety can be provided implicitly through analytical assumptions or explicitly by reserving a portion of loading capacity.

4.3.1 Loading Capacity

The model selected to relate total phosphorus to chlorophyll a concentrations is the Jones-Bachrnan model (Jones and Bachrnan, 1976)

$$CHL = 0.1413 * TP^{1.46} \tag{3}$$

Where:

CHL = the chlorophyll a concentration (μg/L)

TP = the annual average total phosphorus concentration (μg/L).

The indicator CHL was assigned a target value of 25 μg/L. Solving equation (3) for TP yields a target value of 34.6 μg/L.

The empirical phosphorus-loading model used to determine annual loading to the reservoir is shown in equation (4)

$$TP = L / z (\sigma + \rho) \tag{4}$$

Where:

L= areal annual average phosphorus loading rate, $mg/m^2 \cdot yr$

z = phosphorus sedimentation mean depth of lake (m).

σ = phosphorus loss rate coefficient, yr^{-1}

ρ = hydraulic flushing rate, yr^{-1}

The value of o can be estimated from 10/z (Vollenweider 1975). Taking z = 4.66 m

o = 1014.66 = 2.14 yr^{-1}

ρ for Meander Creek Reservoir is 1.94 yr^{-1} (Christou, 2002).

Substituting values in equation (4) yields

$L = 657.8\ mg \cdot m^{-2} \cdot yr^{-1}$

Then $L \times A = 657.8\ mg \cdot m^{-2} \cdot yr^{-1} \cdot (7.555 \times 10^{6}\ m^{2}) \cdot (1\ lb)/(453{,}600\ mg) = 10957\ lb/yr$

Since the Meander Creek Reservoir contains no significant point source loading, thus the entire loading capacity will be allocated to NPS and background loading (LA), and the margin of safety (MOS)

4.4 **Source Assessment**

The target value of 34.6 μg/L of total phosphorus in the reservoir was assumed, as a guide for nutrient management activities in the basin. The Watershed Characterization Report module in BASINS was used to assess existing conditions in the Meander Creek Watershed.

Watershed characterization is the key for understanding water quality issues and pollution sources in the watershed. In addition to evaluation of the watershed condition, it provides the necessary information to assess monitoring programs, identify data gaps, and develop watershed-water quality modeling strategies. The following maps and tables were generated as examples of information that can be obtained from BASINS.

4.4.1 Land Use

Figure 1 shows the land use distribution for the entire Meander Creek Watershed by major land use categories with details of the land use distributions presented in Table 6. Land use is closely related to NPS nutrient loading. When forest land is converted to agriculture or urban use, a substantial increase in nutrient export rates normally occurs.

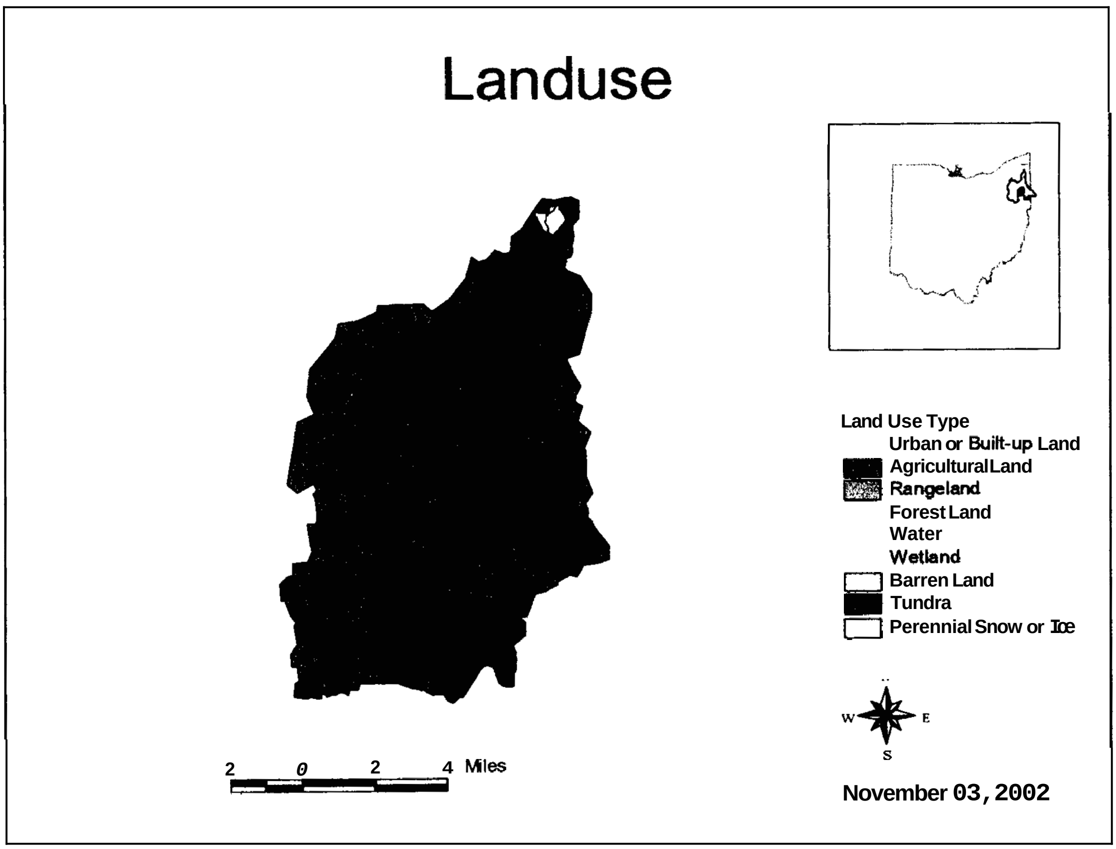


Figure 3. Land use distribution in Meander Creek Watershed.

Table 6. Detailed land use distribution.

Land Use Name and Code	Area (acres)
Urban or Built-up Land	
RESIDENTIAL-11	2579
COMMERCIAL AND SERVICES-12	767
INDUSTRIAL-13	38
TRANS, COMM, UTIL-14	1576
MXD URBAN OR BUILT-UP-16	314
OTHER URBAN OR BUILT-UP-17	103
Subtotal	5377
Agricultural Land	
CROPLAND AND PASTURE-21	37792
OTHER AGRICULTURAL LAND-24	2
Subtotal	37794
Forest Land	
DECIDUOUS FOREST LAND-41	5782
EVERGREEN FOREST LAND-42	2961
Subtotal	8743
Water	
LAKES-52	41
RESERVOIRS-53	1867
Subtotal	1908
Wetland	
FORESTED WETLAND-61	158
Subtotal	158
Barren Land	
STRIP MINES-75	291
Subtotal	291
Total	54271

4.4.2 Soil Erodibility

Figure 4 shows the soil erodibity for Meander Creek watershed using mean estimates and depth layer integration. A summary of soil erodibility is provided in table 7. Phosphorus has a strong tendency to adsorb to soil particles; greater phosphorus export rates would be expected from land with high soil erodibility.

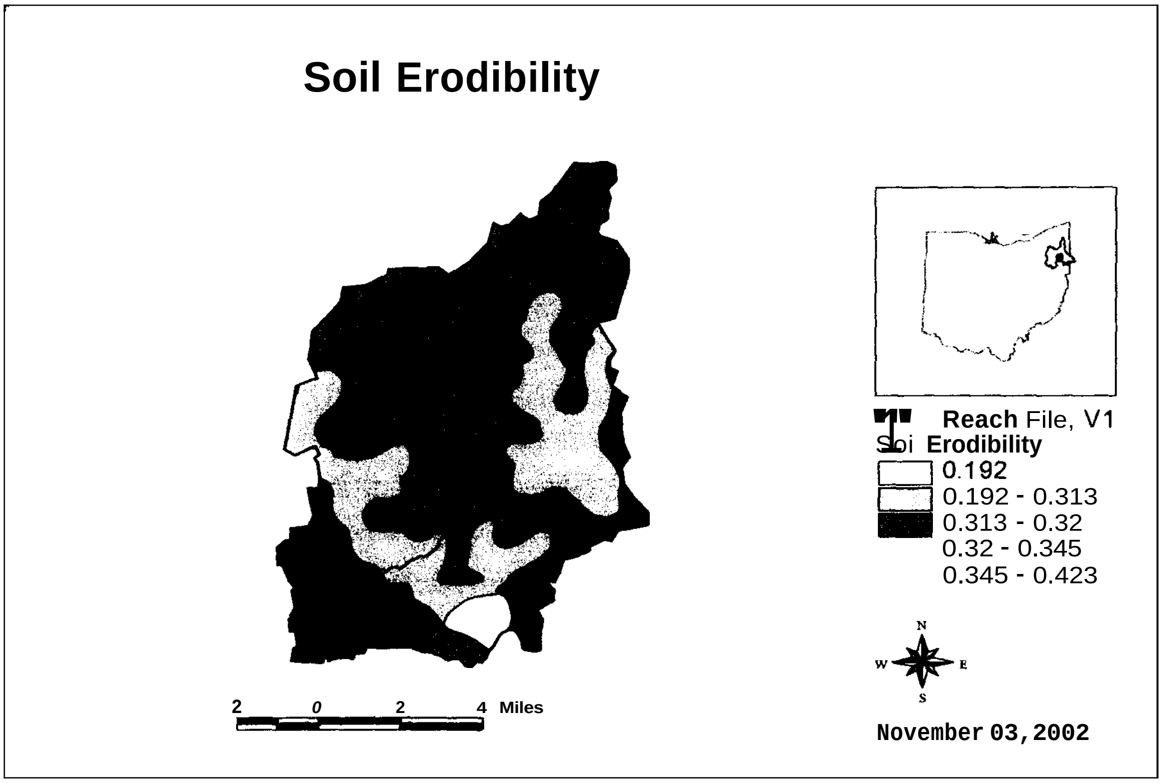


Figure 4. Soil erodibility in Meander Creek Watershed

Table 7. Soil erodibility for Meander Creek Watershed

Map Unit	Area (acre)	Soil Erodibility
OH059	582	0.34
OH069	4459	0.35
OH072	1094	0.19
OH082	13299	0.31
OH084	5701	0.42
OH126	29219	0.32

4.4.3 Water Table Depth

Figure 5 shows the water table depth for Meander Creek Watershed using mean estimates and depth layer integration. A summary of the data is provided in Table 8.

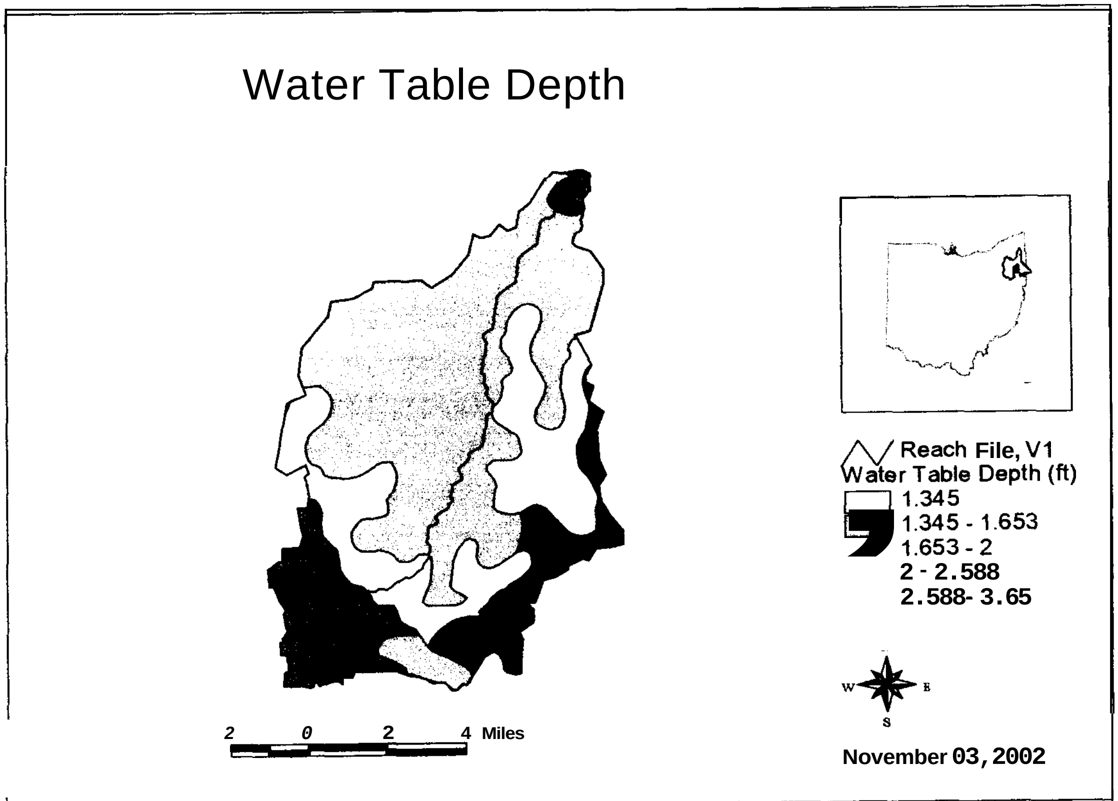


Figure 5. Water table depth in Meander Creek Watershed

Table 8. Water table depth (ft)

Map Unit	Area (acre)	Water Table Depth
OH059	582	2.00
OH069	4459	2.59
OH072	1094	3.65
OH082	3299	1.35
OH084	5701	1.97

4.4.4 Clay

Figure 6 shows the percentage clay distribution in soil of the Meander Creek Watershed. The data are summarized in Table 9. Fine–grained soils such as clay can adsorb large amount of phosphorus, and are important factor related to NPS loading, particularly from agricultural land.

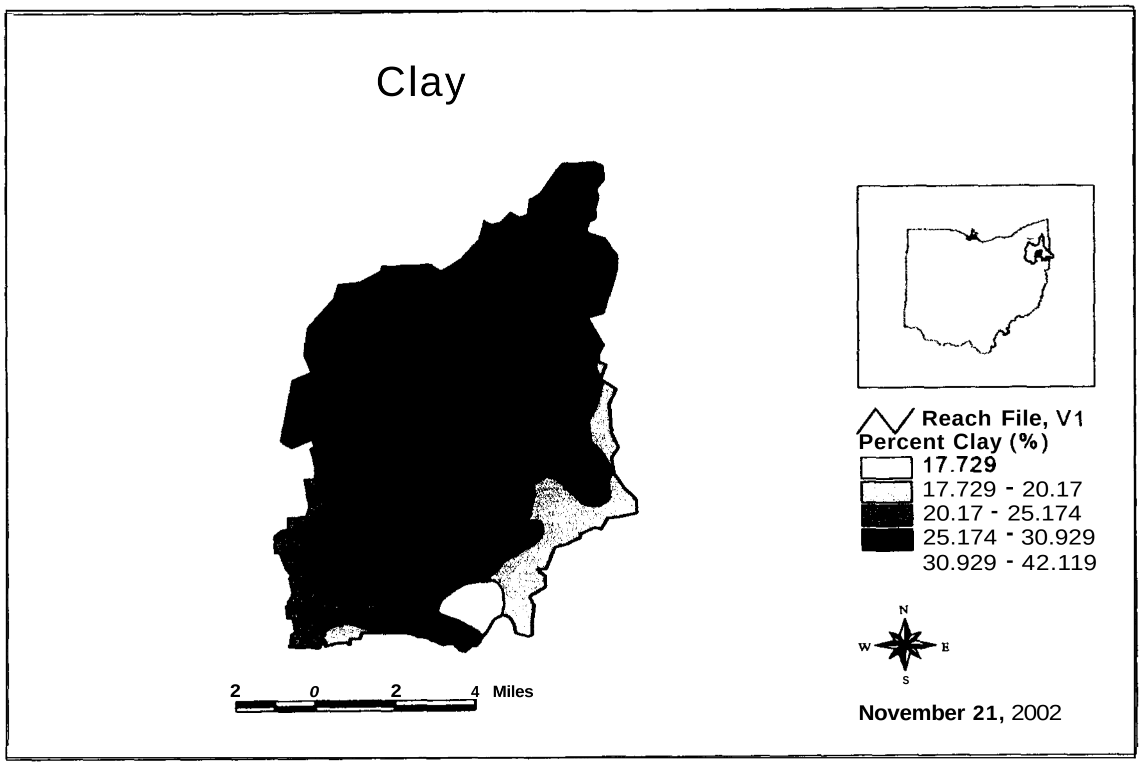


Figure 6. Percentage clay in Meander Creek Watershed

Table 9. Percentage clay for Meander Creek Watershed

Map Unit	Area (acre)	Percent Clay (%)
OH059	582	30.93
OH069	4459	20.17
OH072	1094	17.73
OH082	13299	42.12
OH084	5701	25.17
OH126	29219	30.53

4.4.4 Water Quality Summary

A Water Quality Summary report for total phosphorus in Meander Creek Watershed was generated using the BASINS report generator. This report shows total phosphorus measurements at various locations for the past 27 years. Figure 7 shows all the locations where total phosphorus was measured and details for each station are provided in the Tables 10.

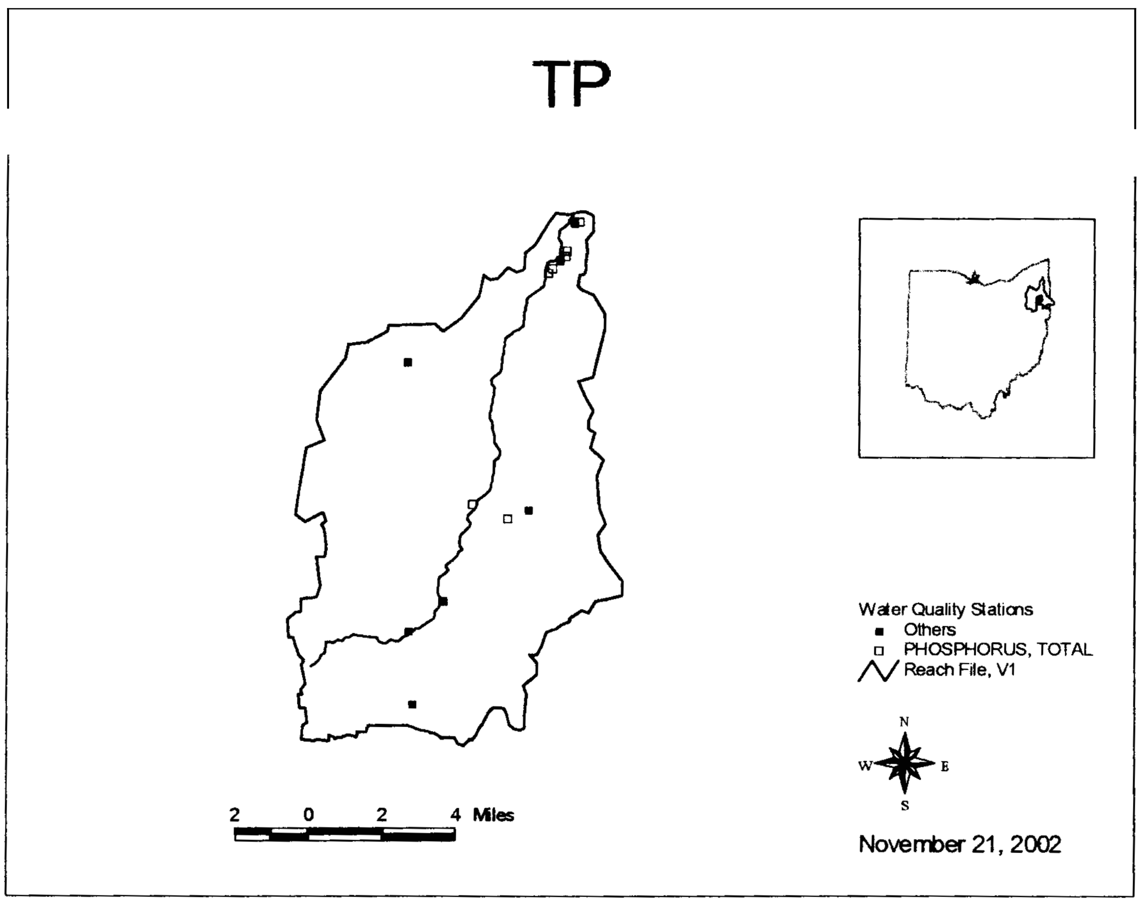


Figure 7. Locations of all stations set up to measure total phosphorus.

Table 10. Summary of total phosphorus measurements in Meander Creek Watershed.

(Location: SAWMILL C AB M C RE (I-2) NR MINERAL RIDGE OH, County: MAHONING, Watershed: 05030103, Reach Segment, Station No.410323080481700: PHOSPHORUS, TOTAL (Units: MG/L AS P).

Years	No of Obs	Mean	25th %	50th %	75th %
1970 - 1974	NO DATA				
1975 - 1979	2	0.05	0.03	0.05	0.07
1980 - 1997	NO DATA				

(Location: MEANDER C AB M C RE (I-1) NR MINERAL RIDGE OH, County: MAHONING, Watershed: 05030103, Reach Segment, Station No.410343080492200: PHOSPHORUS, TOTAL (Units: MG/L AS P).

Years	No of Obs	Mean	25th %	50th %	75th %
1970 - 1974	NO DATA				
1975 - 1979	2	0.02	0.02	0.02	0.02
1980 - 1997	NO DATA				

(Location: MEANDER C RE AB DAM (L-1) NR MINERAL RIDGE OH, County: TRUMBULL, Watershed: 05030103, Reach Seg Station No.410910080464500: PHOSPHORUS, TOTAL (Units: MG/L AS P).

Years	No of Obs	Mean	25th %	50th %	75th %
1970 - 1974	NO DATA				
1975 - 1979	2	0.01	0.01	0.01	0.01
1980 - 1997	NO DATA				

Table 10. Continued

(Location: MEANDER CREEK MILE - 0.79, County: TRUMBULL, Watershed: 05030103, Reach Segment, Station No.4MAO12020: PHOSPHORUS, TOTAL (Units: MG/L AS P).

Years	No of Obs	Mean	25th %	50th %	75th %
1970 - 1974	NO DATA				
1975 - 1979	2	1.29	0.03	1.29	2.56
1980 - 1997	NO DATA				

(Location: MEANDER CREEK NR NILES - MAIN ST. (S.R. 46), County: TRUMBULL, Watershed: 05030103, Reach Segment: 001, Station No.602380: PHOSPHORUS, TOTAL (Units: MG/L AS P).

Years	No of Obs	Mean	25th %	50th %	75th %
1970 - 1974	16	0.61	0.00	0.55	1.18
1975 - 1979	7	0.63	0.10	0.78	1.00
1980 - 1984	3	3.86	3.50	4.02	4.06
1985 - 1989	4	2.60	2.13	2.59	3.09
1990 - 1994	6	1.92	1.47	1.81	2.39

(Location: MEANDER CREEK DST MEANDER CREEK WWTP, County: TRUMBULL, Watershed: 05030103, Reach Segment, Station No.N03S68: PHOSPHORUS, TOTAL (Units: MG/L AS P).

Years	No of Obs	Mean	25th %	50th %	75th %
1970 - 1989	NO DATA				
1990 - 1994	5	2.62	2.09	2.44	3.23
1995 - 1997	NO DATA				

Table 10. Continued

(Location: MEANDER CREEK AT GIBSON ROAD (10.63), County: MAHONING, Watershed: 05030103, Reach Segment: 012, Station No.N03W17: PHOSPHORUS, TOTAL (Units: MG/L AS P).

Years	No of Obs	Mean	25th %	50th %	75th %
1970 - 1984	NO DATA				
1985 - 1989	4	0.02	0.00	0.00	0.05
1990 - 1997	NO DATA				

(Location: MEANDER CREEK JUST UPST MEANDER CREEK WWTP (2.0), County: TRUMBULL, Watershed: 05030103, Reach Segment: 012, Station No.N03W22: PHOSPHORUS, TOTAL (Units: MG/L AS P).

Years	No of Obs	Mean	25th %	50th %	75th %
1970 - 1989	NO DATA				
1990 - 1994	5	0.93	0.33	0.63	1.68
1995 - 1997	NO DATA				

(Location: MEANDER CREEK RESERVOIR L-1, County: TRUMBULL, Watershed: 05030103, Reach Segment, Station No.OH0223-378L-1: PHOSPHORUS, TOTAL (Units: MG/L AS P).

Years	No of Obs	Mean	25th %	50th %	75th %
1970 - 1989	NO DATA				
1990 - 1994	4	0.02	0.02	0.02	0.03
1995 - 1997	NO DATA				

The Water Quality Summary contains only eight observations of total phosphorus in Meander Creek Reservoir – four from period 1975 – 1979 and four from 1990 – 1994. The TP concentrations range from 0.01 to 0.03 mg/L, or 10 – 30 μg/L. Most of the measurements were taken near the dams, and thus are not adequate to characterize the spatial and temporal average TP concentration in the reservoir.

More data is available for Meander Creek below the dam; however, this section is affected by the Mineral Ridge Wastewater Treatment Plant discharge, and is not pertinent to this study. The Water Quality Summary report clearly points out the need for much more through and more recent monitoring of nutrients and trophic status in Meander Creek Reservoir

4.5 Link Target and Sources

Current annual average total phosphorus in Meander Creek Reservoir is not known with a high degree of certainty. Schroeder and Martin (2002) found that winter TP levels in Meander Creek Reservoir average about 30 μg/L. To allow for seasonal variations in TP and a margin of safety, the current TP level was increased (somewhat arbitrarily) by 30% to 39 μg/L. Total annual raw load of total phosphorus for existing condition was determined using equation (4).

$$TP = L / z (\sigma + p).$$

$$L = 772.4 \text{ mg}\cdot\text{m}^{-2}\cdot\text{yr}^{-1}$$

Or the mass loading rate, $W = L\cdot A = 12{,}686$ lb/ yr.

The approximate total phosphorus Load Capacity (LC) for the Reservoir was determined to be 10957 lb/yr. The estimated existing annual average Phosphorus loading is higher than the Load Capacity of the reservoir. Therefore, a load allocation for nonpoint sources is required, and best management practices (BMP’s) must be applied to reduce the TP load.

4.6 Load Allocation

For load allocation, pollutant loads from all type of land use in the watershed are required. For this, the PLOAD model included with BASINS was used.

4.6.1 PLOAD

PLOAD is a simplified GIS - based model for calculating pollutant loads from watersheds. PLOAD estimates nonpoint source (NPS) loads on an annual average basis for any user-specified pollutant. NPS loads can be calculated by using either the export coefficient or the EPA's "Simple Method" approach. Optionally, best management practices (BMPs), which serve to reduce NPS loads, and point source loads, may also be included in computing total watershed loads. Finally, there are several product alternatives that may be specified to show the NPS pollution results as maps and tabular lists, and to compare multiple sessions or scenarios.

The PLOAD application requires pre-processed GIS and tabular input data as listed below:

- GIS land use data
- GIS BMP site and area data (optional)
- Pollutant loading rate data tables
- Pollutant reduction BMP data tables (optional)
- Point source facility locations and loads (optional

4.6.2 Input Data for PLOAD

- **GIS Data:** Meander Creek Watershed boundary and land use GIS data coverage are required for PLOAD. The watershed boundary defines the areas for which the pollutant loads are calculated. The watershed coverage must have a code field containing unique identifiers for each watershed. The land use file is essential for calculating the pollutant loads. The land use coverage must also have a code field identifying the land use types, but these types need not be unique. Prior to calculating the pollutant loads, PLOAD will spatially overlay the watershed and land use coverage in order to determine the areas of the various land use types for each watershed. The land use coverage should encompass the entire watershed coverage.

- **Tabular Data:** PLOAD is used to estimate loading for any pollutant if event mean concentrations (EMC's) are available in data tables within the model. Pollutants commonly evaluated include TSS, nitrogen, lead, TDS, nitrate plus nitrite, zinc, BOD_5, TKN, COD, ammonia, phosphorus, and fecal coliform. The event mean concentration table lists assumed concentrations in runoff for each pollutant type and land use type.

Water resource engineers develop the table based on values available from the literature or analysis of local watershed storm water monitoring data. Event mean concentrations of TP for various kinds of land use used in PLOAD are given in Table 11.

The model also used the impervious factor table (Table 12), which identifies the percentage of imperviousness for each land use type. It is used to calculate the event mean concentration runoff coefficient. Water resource engineers and GIS analysts develop the impervious factor table by analyzing the impervious surfaces of different land uses on aerial photographs, or by using literature values.

Table 11. Event mean concentrations of total phosphorus (Raird *et al*, 1996)

LUCOD	LEVEL2	TP (mg/L)
11	RESIDENTIAL	0.28
12	COMMERCIAL AND SERVICES	0.10
13	INDUSTRIAL	0.10
14	TRANS, COMM, UTIL	0.33
15	INDUST & COMMERC CMPLXS	0.10
16	MXD URBAN OR BUILT-UP	0.10
17	OTHER URBAN OR BUILT-UP	0.10
21	CROPLAND AND PASTURE	1.00
22	ORCH, GROV,VNYRD,NURS,ORN	1.00
23	CONFINED FEEDING OPS	1.00
24	OTHER AGRICULTURAL LAND	1.00
32	SHRUB & BRUSH RANGELAND	0.14
41	DECIDUOUS FOREST LAND	0.14
42	EVERGREEN FOREST LAND	0.14
43	MIXED FOREST LAND	0.14
51	STREAMS AND CANALS	0.03
52	LAKES	0.03
53	RESERVOIRS	0.03
61	FORESTED WETLAND	0.14
62	NONFORESTED WETLAND	0.14
74	BARE EXPOSED ROCK	0.14
75	STRIP MINES	0.14
76	TRANSITIONAL AREAS	0.14

Table 12. Percentage imperviousness of various land uses (Raird *et al*, 1996)

LUCODE	LANDUSE NAME	Percent Imperviousness
11	RESIDENTIAL	25
12	COMMERCIAL AND SERVICES	85
13	INDUSTRIAL	70
14	TRANS, COMM, UTIL	65
15	INDUST & COMMERC CMPLXS	75
16	MXD URBAN OR BUILT-UP	60
17	OTHER URBAN OR BUILT-UP	15
21	CROPLAND AND PASTURE	2
22	ORCH,GROV,VNYRD,NURS,ORN	2
23	CONFINED FEEDING OPS	25
24	OTHER AGRICULTURAL LAND	2
32	SHRUB & BRUSH RANGELAND	2
41	DECIDUOUS FOREST LAND	2
42	EVERGREEN FOREST LAND	2
43	MIXED FOREST LAND	2
51	STREAMS AND CANALS	100
52	LAKES	100
53	RESERVOIRS	100
61	FORESTED WETLAND	2
62	NONFORESTED WETLAND	2
74	BARE EXPOSED ROCK	100
75	STRIP MINES	50
76	TRANSITIONAL AREAS	50

4.6.3 "Simple Method" Calculations

The Simple Method is designated for calculating pollutant loads in PLOAD. Two equations are required to calculate the loads for each specified pollutant type. First, the runoff coefficient for each land use type must be derived from equation *(5)*.

$$R_{VU} = 0.05 + (0.009 * I_U) \quad (5)$$

Where:

R_{VU} = Runoff Coefficient for land use type u, $\text{inches}_{\text{runoff}} / \text{inches}_{\text{rain}}$

I_U = Percent Imperviousness

Percent imperviousness is extracted from Table 13.

The pollutant loads are then calculated by equation (6)

$$L_P = \Sigma_u (P * Pj * R_{VU} * C_U * A_U * 2.72112) \quad (6)$$

Where:

L_P = Pollutant load, lbs

P = Precipitation, inches/year

P_J = Ratio of storms producing runoff (default = 0.9)

R_{VU}= Runoff Coefficient for land use type u, $inches_{runoff}$ / $inches_{rain}$

C_U = Event Mean Concentration for land use type u, milligrams/liter

A_U = Area of land use type u, acres (In BASINS areas calculated from GIS data are in square meters. PLOAD converts areas from square meters to acres prior to using the information in the above equation)

4.6.4 Creating Layouts and Data Processing

PLOAD allows the creation of layouts for any session's output. Output generated in the session for land use in Meander Creek Watershed is shown in Figure 8. Making further use of the land data and loading rates derived from the event mean concentrations, and percentage imperviousness tables, total phosphorus loads from various sections of the Meander Creek Watershed were calculated. The results are shown on the map in Figure 9.

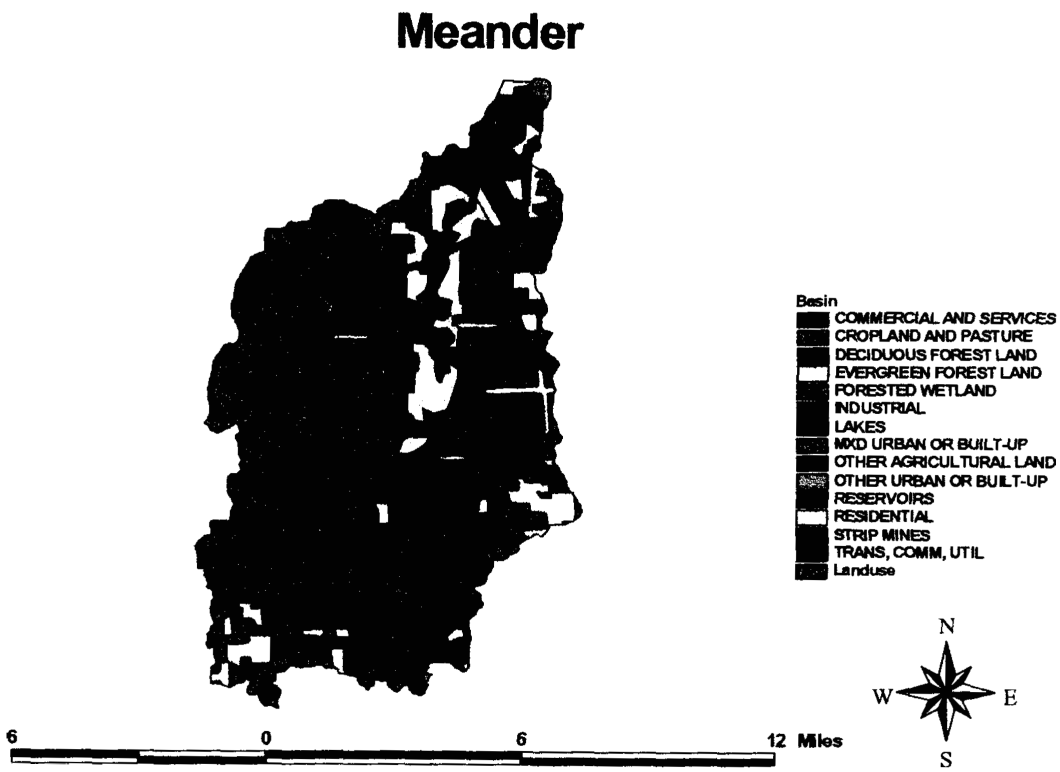


Figure 8. Land use for PLOAD calculations in Meander Creek Watershed.

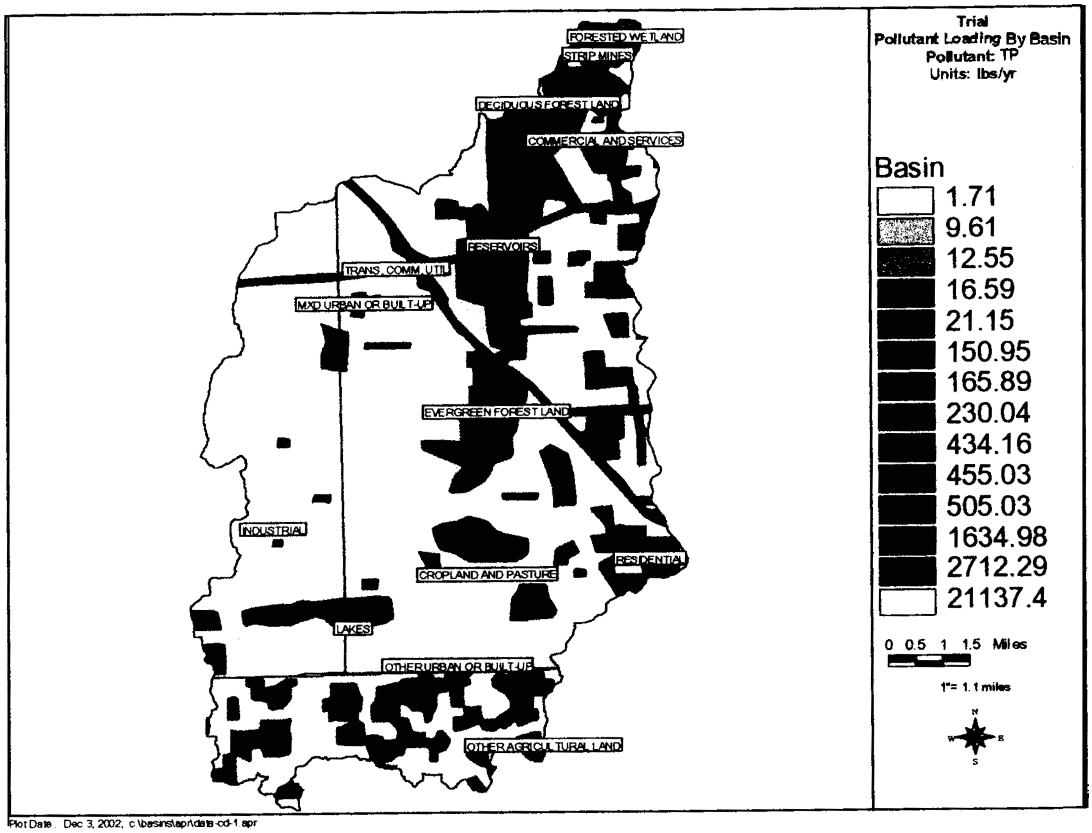


Figure 9. Total phosphorus load from Meander Creek watershed (lb/yr)

Adding the total phosphorus loading predicted by PLOAD for all sections of the watershed gives a total loading of 27470.39 lb/year. This was compared to the permissible total phosphorus loading (point and nonpoint sources) to Meander Creek Watershed, specified by USEPA. Meander Creek watershed was delineated and the "Assess" Module of BASINS was run to obtain the 1999 value of permissible total phosphorus loading for the watershed. The results are shown in Figure 10.

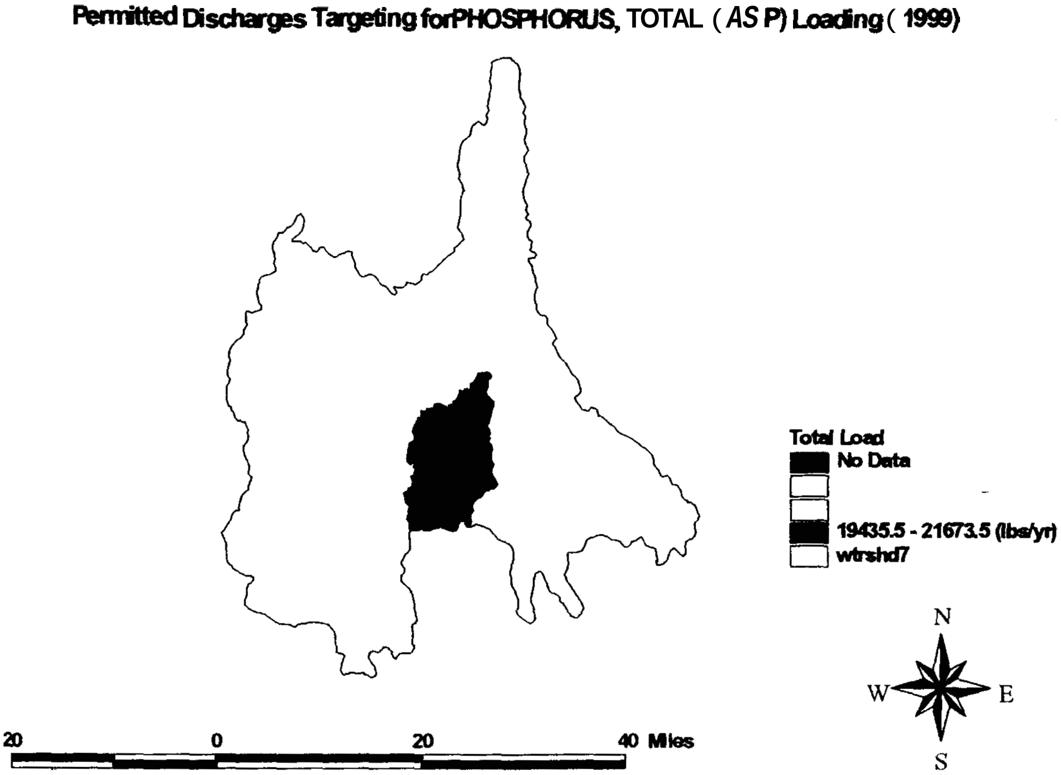


Figure 10. Permitted discharge value for total phosphorus

Comparing the NPS loading estimate from PLOAD and the permissible value gives a difference of 5797.4 lb/yr. Thus, a substantial reduction in NPS loading would be necessary to meet phosphorus loading and water quality goals for the watershed.

CHAPTER 5

WATER QUALITY MODELING

5.1 The Relationship Between Water Quality and Flow in Stream.

Water quality and flow are related in streams because some impairments are aggravated (or caused) by flow modifications that result from in-stream diversions or catchments. For nutrient TMDLs, stream flow directly influences many physical features (e.g., depth, velocity, turbulence, reaeration, and volatilization), while also indirectly influencing nutrient uptake by attached algae. The velocity and depth associated with a specific flow regime also define the residence time in a reach, which directly influences reach temperature and the spatial expression of decay rates. During TMDL development, it is important to identify the flow regimes necessary to satisfy designated uses and to identify situations where flow modifications might make use attainment difficult or impossible.

For Meander Creek, no data for flow is available since 1959. Hydrological Simulation Program-Fortran (HSPF) program is used to develop simulated flows for the Creek, and also to fill the gaps in monitoring data for nutrients in the creek and reservoir; simulated nutrient loading graphs were generated to analyze the historical conditions of the reservoir. For simulation, HSPF makes use of land use data, metrological data, pollutant loading data and water quality parameter values in the program.

5.2 Hydrological Simulation Program-Fortran (HSPF)

Hydrologic and water quality modeling with the Hydrological Simulation Program-Fortran (HSPF) involves managing large volumes of data. Among these data are parameters describing watershed characteristics, which often are derived from

Geographic Information Systems (GIS) layers such as sub-basin boundaries and land uses. Other parameters specify simulation options within HSPF. All of these parameters are input to HSPF by means of a text file, known as the User Control Input (UCI) file.

Figure 11 gives a diagrammatic description of the data requirements of the HSPF model and its interface with BASINS

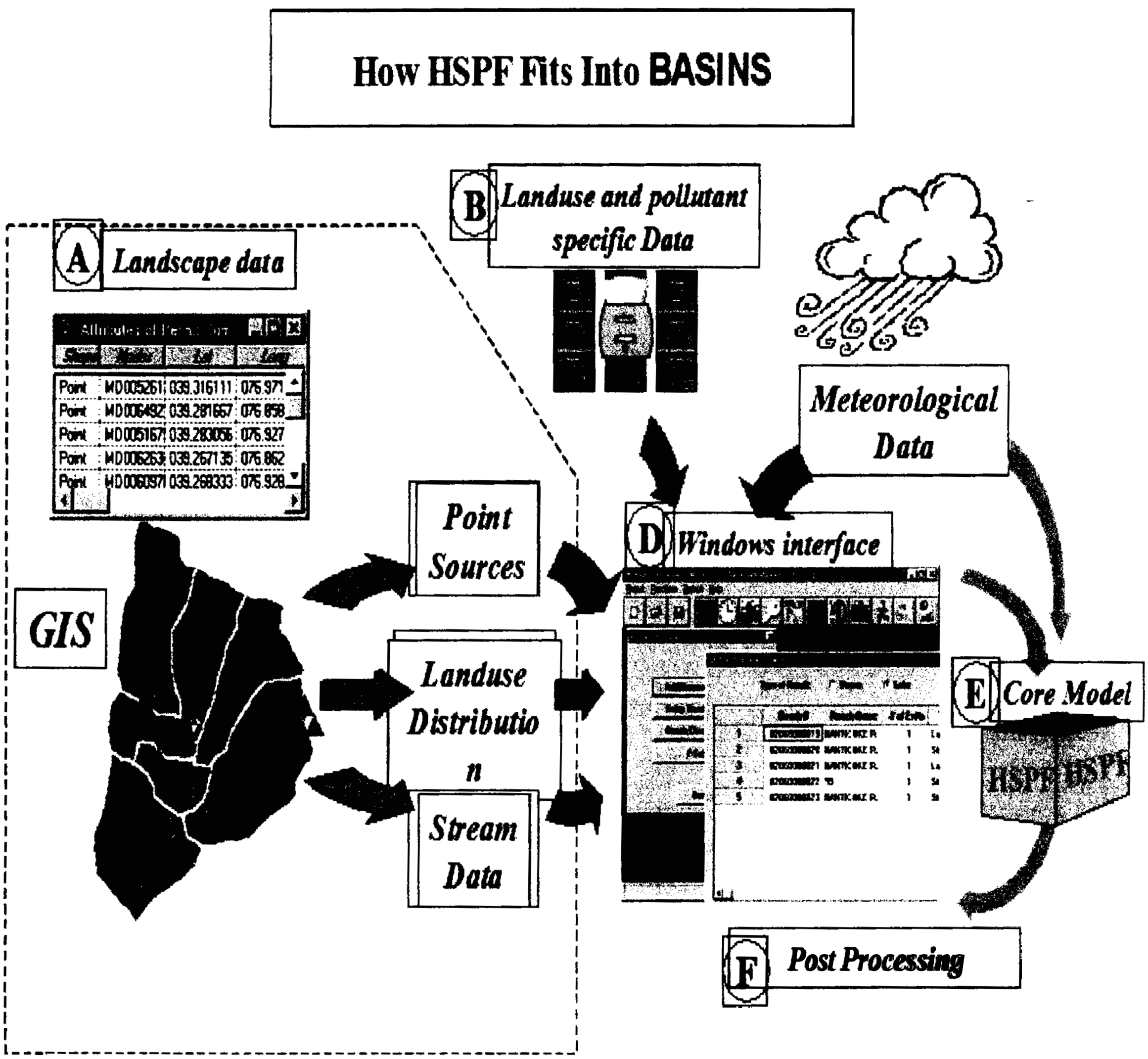


Figure 11. Data requirements for the HSPF model and interface with BASINS.

5.3 Architecture

Object design was key in development of WinHSPF, which is a Windows-based interface for HSPF. An object was created to store all of the information that is normally contained within the UCI file. This UCI object is accessible throughout WinHSPF, and enables the software to easily access model parameter values. All of the data traditionally stored in the UCI file are now stored in the UCI object in memory.

The HSPF model code is compiled into a dynamic link library (dll) for access by WinHSPF. The time-series data objects within WinHSPF use some calls to the Watershed Data Management (WDM) Fortran library of subroutines for time-series management. This scheme allowed the well-tested and well-documented WDM code to be preserved (USEPA, 2001a).

5.4 Hydrology in HSPF

All land use types are subdivided into one of two categories - pervious land units (forest, cropland, wetland) or impervious land units (paved surfaces). Each land use type has different algorithms for hydrologic computations. A diagrammatic representation of hydrology in HSPF is shown in Figure 12.

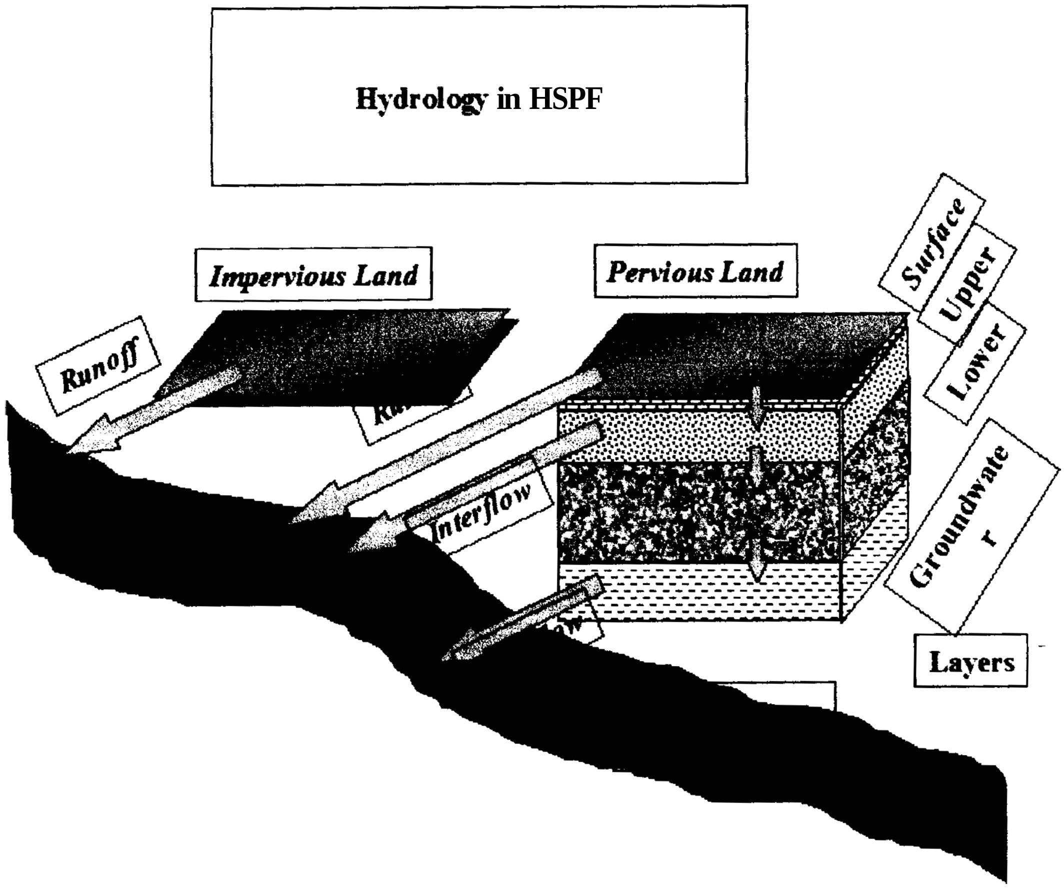
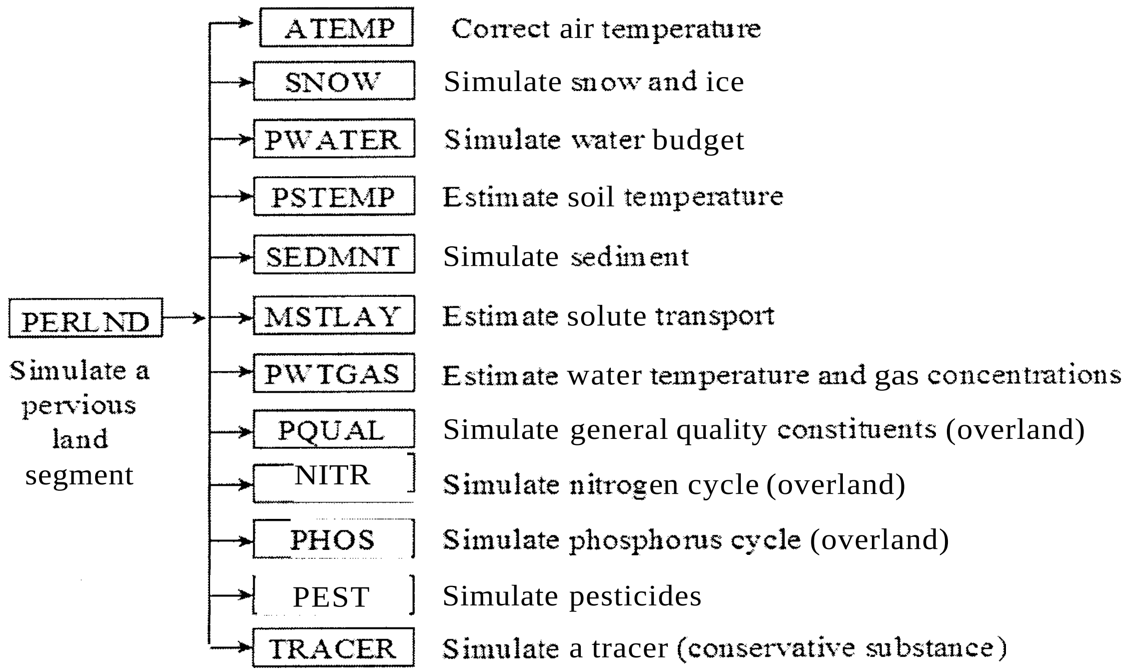


Figure 12. Hydrology in HSPF.

5.5 Input Data

Charts in Figure 13 describe the sequences of HSPF modules used to simulate runoff fiom pervious and impervious land. The site-specific input data, which was assembled fiom BASINS and embedded in HSPF, is shown in Appendix A The weather data file for Youngstown was imported via WDM*util* to WinHSPF from National Climatic Data Center (NCDC) website.

PERLND Structure Chart



IMPLND Structure Chart

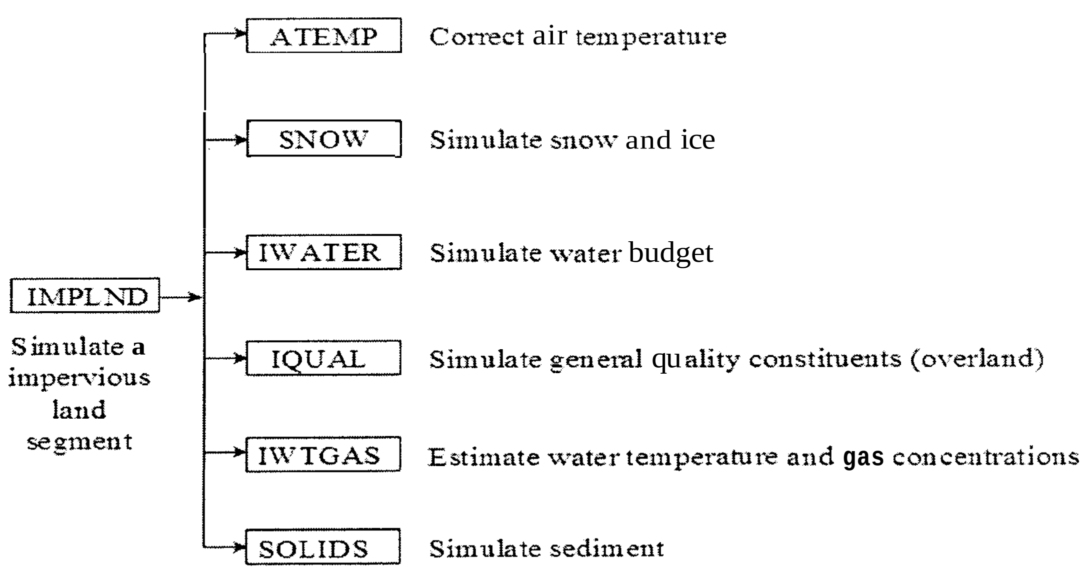


Figure 13. Descriptions of HSPF modules used to simulate runoff from pervious and impervious land.

5.6 Water Quality in WinHSPF

The HSPF input file was prepared in WinHSPF, and includes site-specific inputs (see Appendix A) as well as some water quality components. Running a simulation with these inputs enables one to see how the loads in the watershed affect water quality in the stream. Modeling was performed for the following nonpoint constituents:

- Water Temperature
- Dissolved Oxygen
- Total Suspended Solids
- Total Phosphorus
- BOD/Organics

For Meander Creek channel reach, HSPF was used to simulate the fate, transport, and delivery of the nutrient loads using Reaches Quality (RQUAL) module.

5.7 Results for WinHSPF

Once all the data are input, the HSPF model is run and output in viewed using the GenScn module. Various output scenarios were generated for land use and water quality assessment in the Meander Creek Watershed. All results were generated in the form of graphs.

5.7.1 Precipitation

Precipitation data for a 26 year period (1970-1996) was extracted from NOAA National Data Centers website to WDMutil and converted to a WDM file for display in GenScn graph as shown in Figure 14.

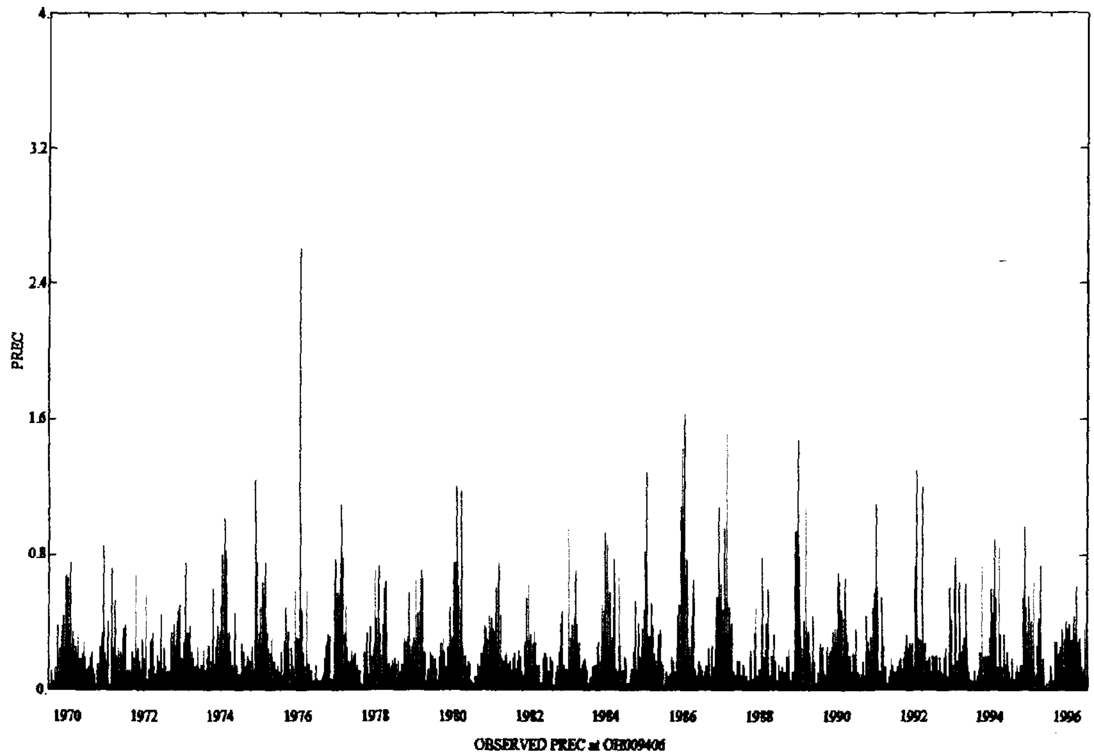


Figure 14. Precipitation in vicinity of Meander Creek Watershed (Source:NOAA)

5.7.2 Simulated Stream flow

The stream flow predicted by HSPF for Meander Creek over the same 26-year simulation period is shown in Figure 15. Average flow predicted for Meander Creek is 95 cfs. This is 6.3 % of the mean flow measured for the Mahoning River (1500 cfs at the USGS gaging station at Lowellville, OH.

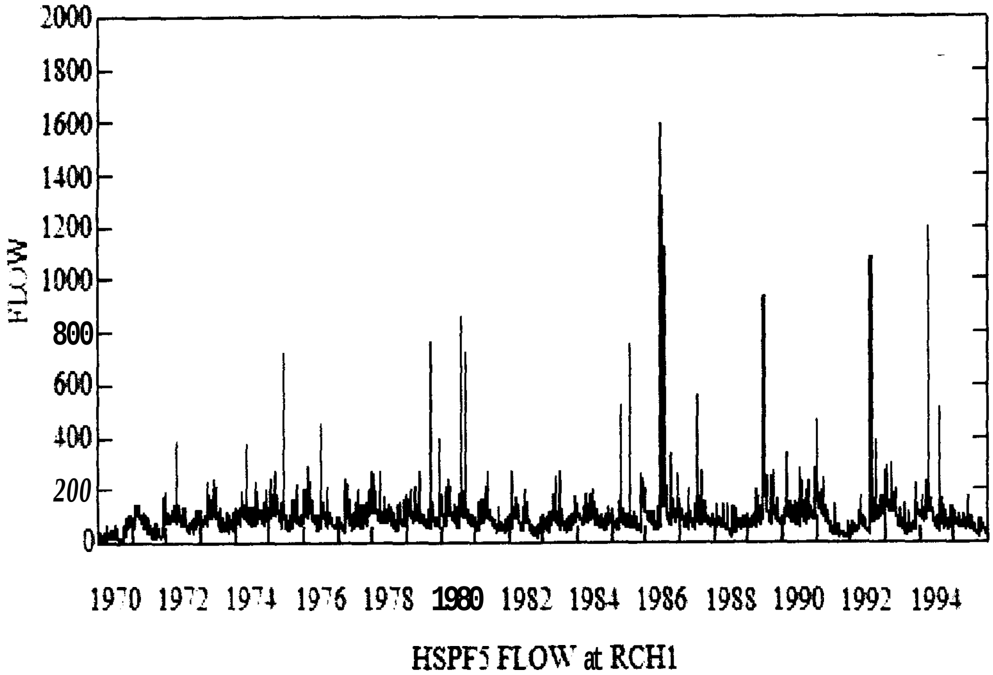


Figure 15. Simulated stream flow

5.7.3 Total Phosphorus

Predicted phosphorus concentrations are obtained for Meander Creek Reservoir using input data from Appendix A for Precipitation, runoff from pervious & impervious land segments, flow conditions, and the weather data file for Youngstown. The HSPF output for total phosphorus concentration in Meander Creek and Meander Creek Reservoir is shown in Figures 16 & 17 respectively.

The annual average predicted total phosphorus concentration for the reservoir is in the range of 50-60 μg/L. Monitoring results from Schroeder & Martin (2001, 2002) showed mean total phosphorus concentration of about 60 μg/L for the southern end of the reservoir and 28-30 μg/L near the dam. Thus, the predicted and measured values are somewhat higher than concentrations.

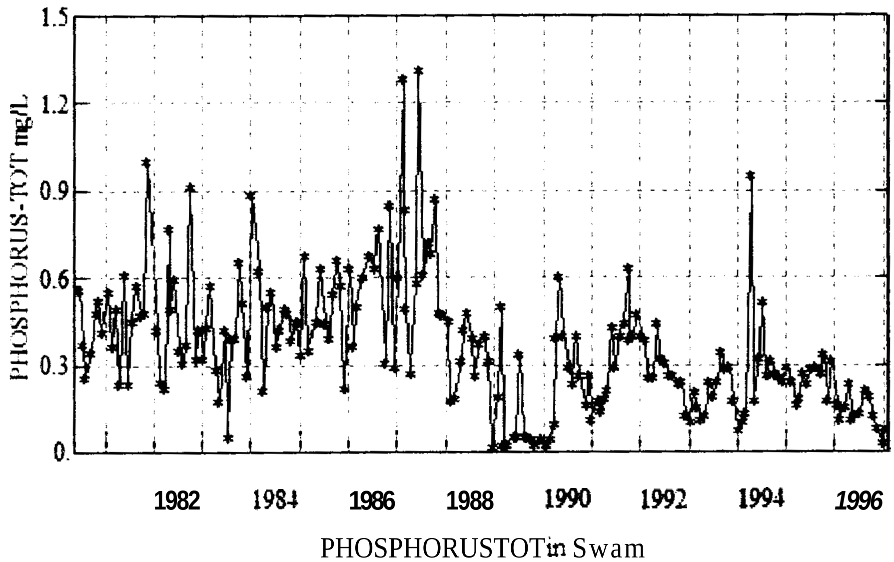


Figure 16. Simulated total phosphorus in Meander Creek

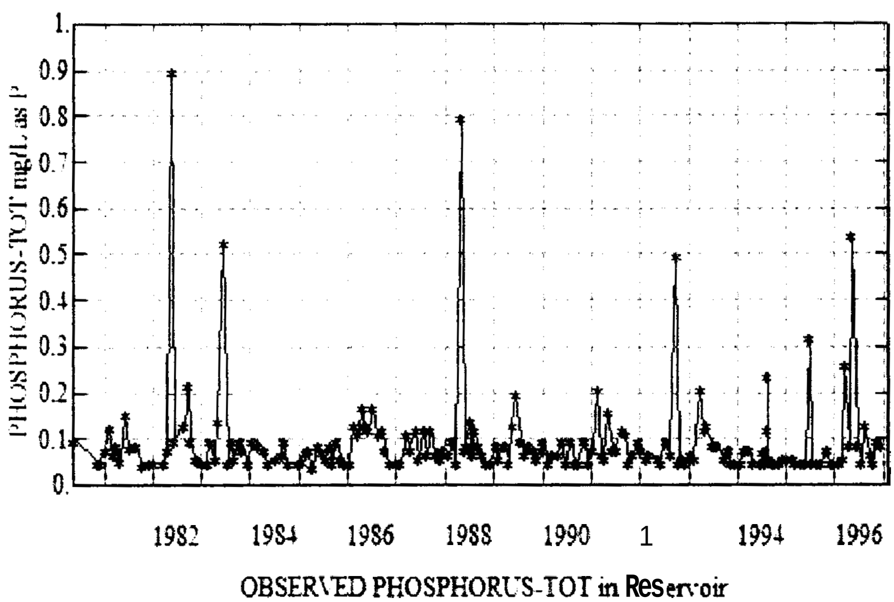


Figure 17. Simulated total phosphorus in Meander Creek Reservoir

5.7.4 Total Suspended Solids

Simulated total suspended solids concentration was generated using the input data for pervious land, impervious land (See Appendix A) and waterbody. The HSPF output for suspended solids concentration in Meander Creek Reservoir is shown in Figure 18.

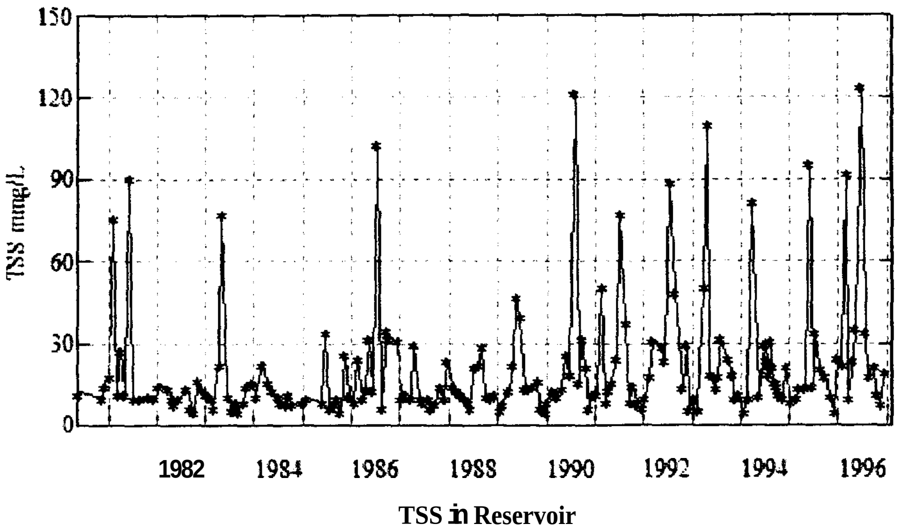


Figure 18. Simulated total suspended solids in Meander Creek Reservoir

Simulated annual average TSS concentration in the reservoir is approximately 10 mg/L, which is close to the mean of 10.2 mg/L measured by Mughis – Sohrawardy (2002) in Meander Creek under low flow conditions.

5.8.6 Simulated Dissolve Oxygen.

Simulated dissolved oxygen concentration was obtained in GenScn output Senario for HSPF using the data from Appendix A. As seen in Figure 19, the predicted annual average concentration is approximately 9 mg/ L. This is consistent with the observation by Schroeder and Martin (2001) that DO was close to saturation levels in the winter.

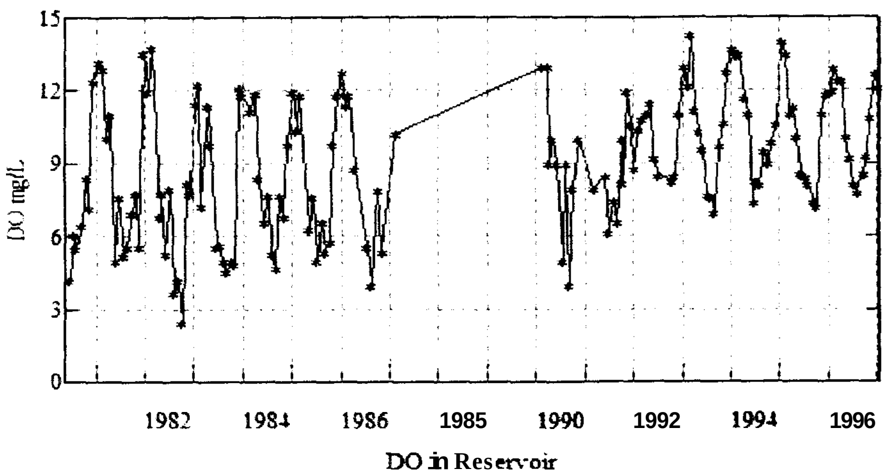


Figure 19. Dissolved oxygen concentration in Meander Creek Reservoir

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Water quality in Meander Creek Reservoir has been relatively good historically except for moderately high algal productivity that causes occasional taste and odor problems. Applying a TMDL procedure, a numeric target of 10957 lb/yr was developed for the annual total phosphorus loading capacity of Meander Creek Reservoir.

The BASINS model was obtained from USEPA along with geographic information system (GIS) data for Meander Creek Watershed. A Source assessment for total phosphorus was performed and simulated water quality parameters were determined, making use of the hydrological simulation model WinHSPF. GIS data for Meander Creek Watershed were used to produce a watershed characterization report. This report helps in watershed analysis of soil type, landuse, wetlands, and water quality.

The "Simple Method" developed by USEPA was applied to estimate total phosphorus loading from different land use categories using event mean concentrations and imperviousness data. The estimated nonpoint source loading of 27,470 lb/year was higher than the permissible total loading of 21,673 lb/yr assigned for Meander Creek watershed by USEPA. The majority of phosphorus loading comes from agriculture land, followed by urban land. Implementation of Best Management Practices (BMPs) will be necessary to meet the permissible phosphorus loading.

6.2 Recommendations

In order to reduce uncertainty in loading estimates and water quality predictions, more frequent monitoring of some key variables including flow, nutrients, suspended solids loading and concentrations in the water is needed.

Best Management Practices (BMPs) for nutrient control must be applied to meet the water quality goals. BMPs shown in Table 14 could be used to reduce loading for both agriculture and urban developments.

Table 14. Management BMPs

Agriculture	Nutrient management Proper live- to-stock ratio Waste composition plan Crop residue management Live stock waste management
Urban land	Zoning ordinances Site plan review Pubic education Spill control programs Road maintenance Septic system pump-out schedule

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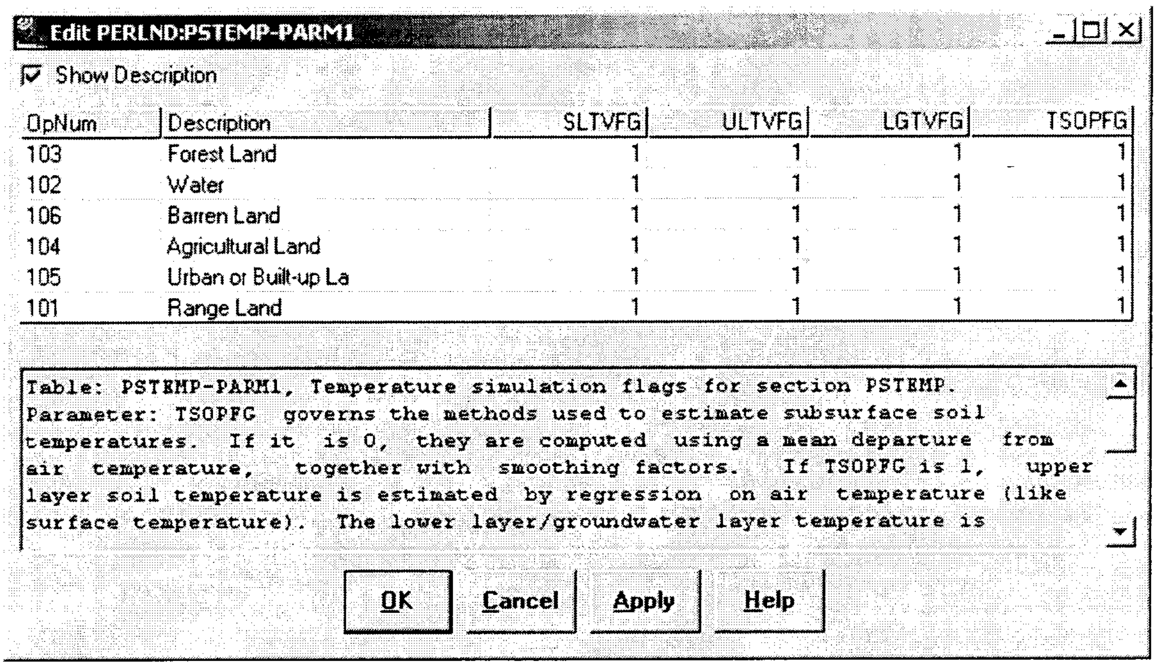
Appendix A

Data Inputs for HSPF

PERLND: Pervious Land

PSTEMP-PARM1: This is the first set of input parameters for PSTEMP


Edit PERLND:PSTEMP-PARM1

Show Description

OpNum	Description	SLTVFG	ULTVFG	LGTVFG	TSOPFG
103	Forest Land	1	1	1	1
102	Water	1	1	1	1
106	Barren Land	1	1	1	1
104	Agricultural Land	1	1	1	1
105	Urban or Built-up La	1	1	1	1
101	Range Land	1	1	1	1

Table: PSTEMP-PARM1, Temperature simulation flags for section PSTEMP.
Parameter: TSOPFG governs the methods used to estimate subsurface soil temperatures. If it is 0, they are computed using a mean departure from air temperature, together with smoothing factors. If TSOPFG is 1, upper layer soil temperature is estimated by regression on air temperature (like surface temperature). The lower layer/groundwater layer temperature is

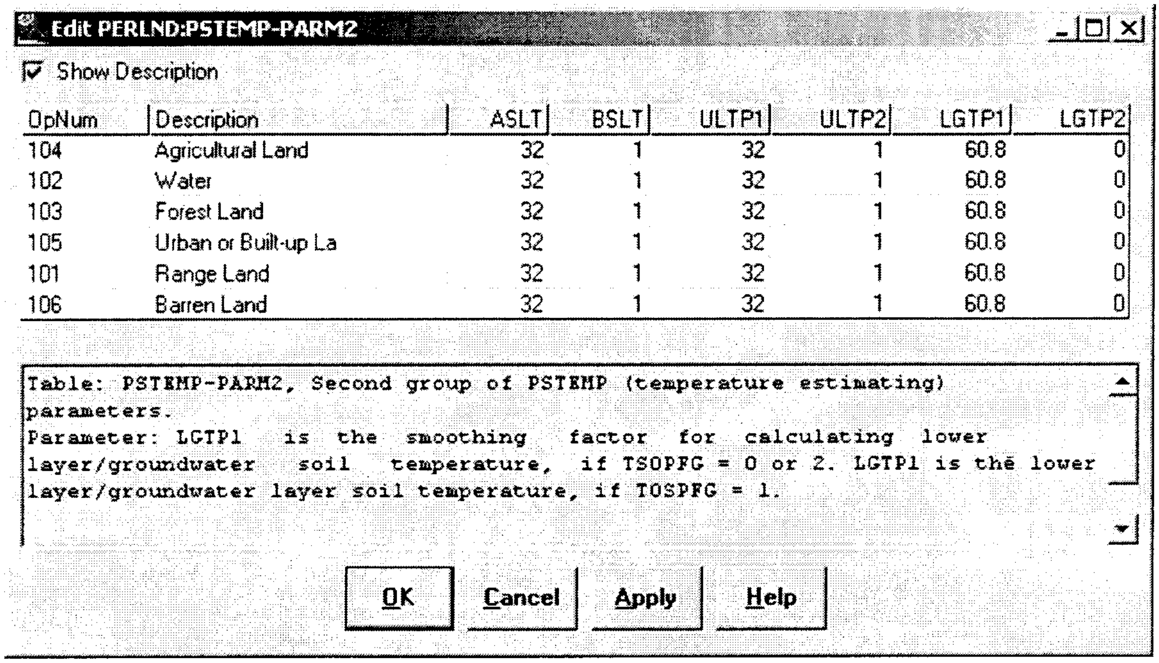
OK Cancel Apply Help

SLTVFG: if this is 1, parameters for estimating surface layer temperature can vary monthly.

ULTVFG: if this is 1, parameters for estimating upper layer temperature can vary monthly.

LGTVFG: if this is 1, parameters for estimating lower layer and active groundwater layer temperature calculations can vary monthly.

PSTEMP-PARM2. This is the second group of PSTEMP (temperature estimating) parameters. The following list gives explanations of each parameter.



OpNum	Description	ASLT	BSLT	ULTP1	ULTP2	LGTP1	LGTP2
104	Agricultural Land	32	1	32	1	60.8	0
102	Water	32	1	32	1	60.8	0
103	Forest Land	32	1	32	1	60.8	0
105	Urban or Built-up La	32	1	32	1	60.8	0
101	Range Land	32	1	32	1	60.8	0
106	Barren Land	32	1	32	1	60.8	0

ASLT is the surface layer temperature when the air temperature is 32 degrees F (0 degrees C). It is the intercept of the surface layer temperature regression equation.

BSLT is the slope of the surface layer temperature regression equation.

ULTP1 is the smoothing factor in upper layer temperature calculation.

ULTP2 is the mean difference between upper layer soil temperature and air temperature.

LGTP1 is the smoothing factor for calculating lower layerlgroundwater soil temperature.

LGTP2 is the mean departure from air temperature for calculating lower layer/groundwater soil temperature.

MON-ASLT: Monthly values of surface layer temperature at start of each month

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Range Land	29	29	30	34	54	60	60	60	58	40	35	30
Water	30	30	32	38	52	57	58	57	55	42	36	32
Forest Land	33	33	35	41	52	54	55	55	53	47	40	35
Agricultural	29	29	30	34	54	60	60	60	58	40	35	30
Urban	30	30	32	38	52	57	58	57	55	42	36	32
Barren Land	29	29	30	34	54	60	60	60	58	40	35	30

MON-BSLT (deg F/F): Monthly values of the slope of the surface layer temperature regression equation at the start of each month.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Range	0.55	0.55	0.65	0.7	0.8	0.8	0.8	0.75	0.7	0.65	0.6	0.6
Water	0.5	0.5	0.55	0.65	0.75	0.75	0.75	0.75	0.7	0.65	0.6	0.6
Forest	0.4	0.4	0.42	0.5	0.55	0.6	0.6	0.6	0.6	0.55	0.45	0.42
Agricultura	0.55	0.55	0.65	0.7	0.8	0.8	0.8	0.75	0.7	0.65	0.6	0.6
Urban	0.5	0.5	0.55	0.65	0.75	0.75	0.75	0.75	0.7	0.65	0.6	0.6
Barren	0.55	0.55	0.65	0.7	0.8	0.8	0.8	0.75	0.7	0.65	0.6	0.6

MON-ULTP1 (deg F): Monthly values of the smoothing factor in upper layer temperature calculation at the start of each month.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Range	34	34	35	37	42	52	54	54	52	43	37	35
Water	36	36	37	40	45	48	48	48	48	45	40	38
Forest	36	36	37	40	45	48	48	48	48	45	40	38
Agricultura	34	34	35	37	42	52	54	54	52	43	37	35
Urban	35	35	36	39	43	48	50	50	50	44	38	36
Barren	34	34	35	37	42	52	54	54	52	43	37	35

MON-ULTP2 (Deg F): Monthly values of the mean difference between upper layer soil temperature and air temperature at the start of each month.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Range Land	0 .3	0.3	0.35	0.45	0.55	0.65	0.7	0.7	0.7	0.65	0.55	0.35
Water	0.22	0.22	0.25	0.4	0.5	0.55	0.55	0.55	0.55	0.5	0.45	0.25
Forest Land	0.22	0.22	0.25	0.4	0.5	0.55	0.55	0.55	55	0.5	0.45	0.25
Agricultural	0.3	0.3	0.35	0.45	0.55	0.65	0.7	0.7	0.7	0.65	0.55	0.35
Urban	0.25	0.25	0.3	0.4	0.5	0.6	0.65	0.65	0.65	0.55	0.45	0.3
Barren Land	0.3	0.3	0.35	0.45	0.55	0.65	0.7	0.7	0.7	0.65	0.55	0.35

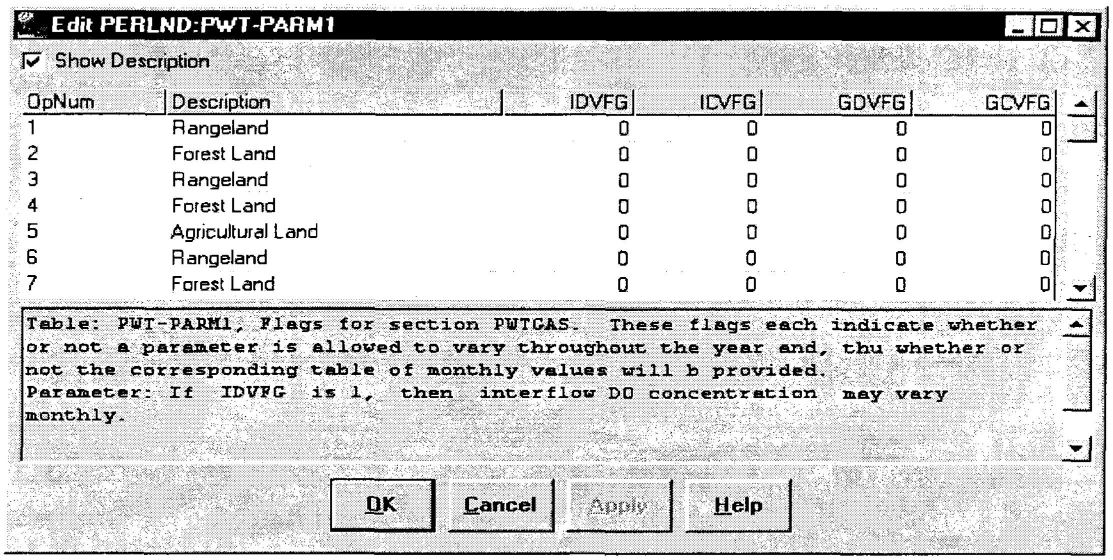
PSTEMP-TEMPS (Deg F): PSTEMP initial temperature parameters.

		AIRTC	S LTMP	ULTMP	LGTMP
101	Range Land	32	32	32	49
102	Water	32	32	32	49
103	Forest Land	32	32	32	49
104	Agricultural Land	32	32	32	49
105	Urban or Built-up	32	32	32	49
106	Barren Land	32	32	32	49

PWTGAS:

PWT-PARM1. Flags for section PWTGAS. These flags each indicate whether or not a parameter is allowed to vary throughout the year, and whether or not the corresponding table of monthly values will be provided.

If GCVFG is 1, then groundwater C02 concentration may vary monthly.



Edit PERLND:PWT-PARM1

Show Description

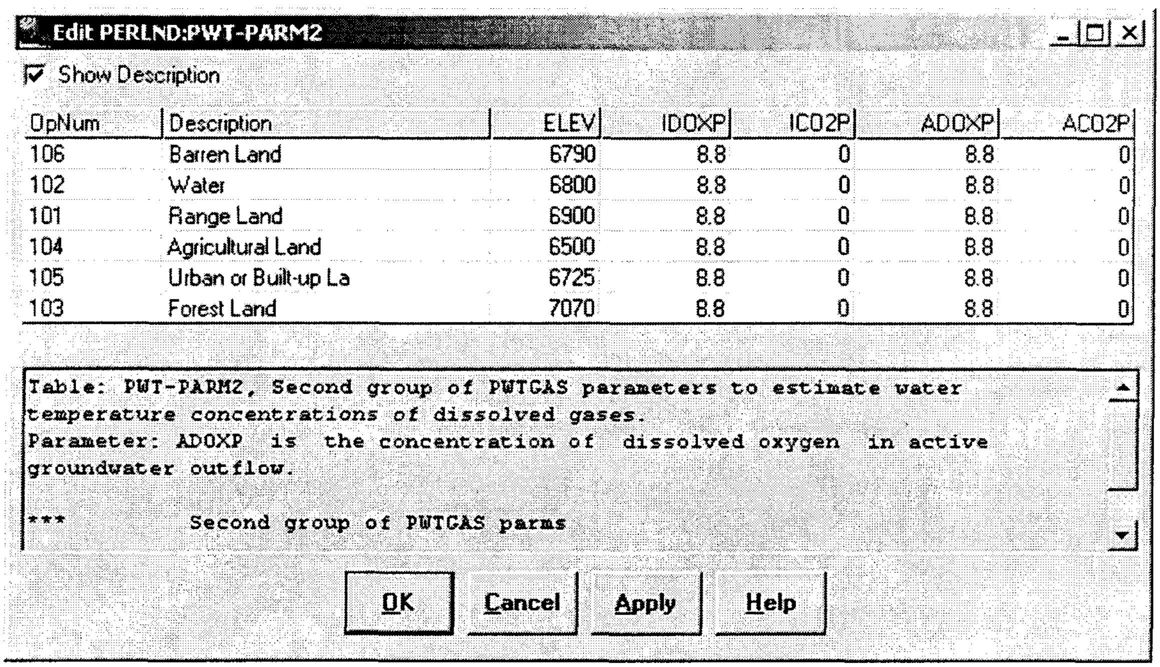
OpNum	Description	IDVFG	ICVFG	GDVFG	GCVFG
1	Rangeland	0	0	0	0
2	Forest Land	0	0	0	0
3	Rangeland	0	0	0	0
4	Forest Land	0	0	0	0
5	Agricultural Land	0	0	0	0
6	Rangeland	0	0	0	0
7	Forest Land	0	0	0	0

Table: PWT-PARM1, Flags for section PWTGAS. These flags each indicate whether or not a parameter is allowed to vary throughout the year and, thu whether or not the corresponding table of monthly values will b provided.
Parameter: If IDVFG is 1, then interflow DO concentration may vary monthly.

OK Cancel Apply Help

PWT-PARM2: Second group of PWTGAS parameters to estimate water temperatures and concentrations of dissolved gases.

Parameter: ACO2P is the concentration of dissolved C02 in active groundwater outflow



Edit PERLND:PWT-PARM2

Show Description

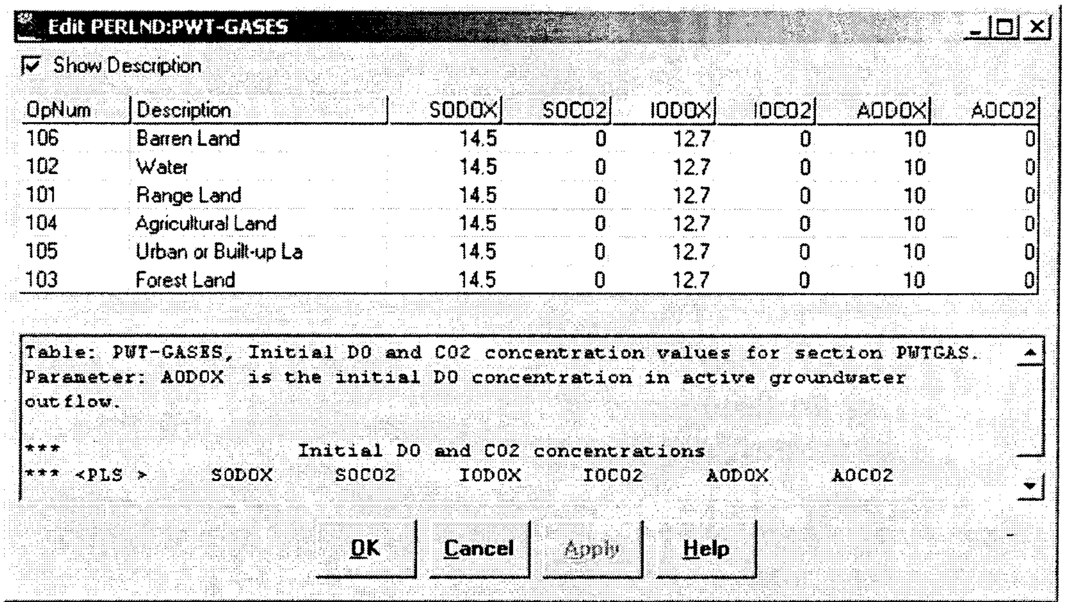
OpNum	Description	ELEV	IDOXP	ICO2P	ADOXP	ACO2P
106	Barren Land	6790	8.8	0	8.8	0
102	Water	6800	8.8	0	8.8	0
101	Range Land	6900	8.8	0	8.8	0
104	Agricultural Land	6500	8.8	0	8.8	0
105	Urban or Built-up La	6725	8.8	0	8.8	0
103	Forest Land	7070	8.8	0	8.8	0

Table: PWT-PARM2, Second group of PWTGAS parameters to estimate water temperature concentrations of dissolved gases.
Parameter: ADOXP is the concentration of dissolved oxygen in active groundwater outflow.

*** Second group of PWTGAS parms

OK Cancel Apply Help

PWT-GASES (mg/l): Initial DO and CO2 concentration values for section PWTGAS.



OpNum	Description	SODOX	SOCO2	IODOX	IOCO2	AODOX	AOCO2
106	Barren Land	14.5	0	12.7	0	10	0
102	Water	14.5	0	12.7	0	10	0
101	Range Land	14.5	0	12.7	0	10	0
104	Agricultural Land	14.5	0	12.7	0	10	0
105	Urban or Built-up La	14.5	0	12.7	0	10	0
103	Forest Land	14.5	0	12.7	0	10	0

```
Table: PWT-GASES, Initial DO and CO2 concentration values for section PWTGAS.
Parameter: AODOX  is the initial DO concentration in active groundwater
outflow.

***                    Initial DO and CO2 concentrations
*** <PLS >      SODOX     SOCO2     IODOX     IOCO2     AODOX     AOCO2
```

SODOX - The initial DO concentration in surface outflow.

SOCO2 - The initial CO2 concentration in surface outflow.

IODOX - The initial DO concentration in interflow outflow.

IOCO2 - The initial CO2 concentration in interflow outflow.

AODOX - The initial DO concentration in active groundwater outflow.

AOCO2 - The initial CO2 concentration in active groundwater outflow.

QUAL-PROPS:

Edit PERLND:QUAL-PROPS

Show Description — Occurrence 1

QUALID	QTYID	QSDFG	VPFWFG	VPFSFG	QSOFG	VQOFG	QIFWFG	VIQCFG	QAGWFG	VAQCFG
NH3	lbs	0	0	0	2	1	1	3	1	3
NH3	lbs	0	0	0	2	1	1	3	1	3
NH3	lbs	0	0	0	2	1	1	3	1	3
NH3	lbs	0	0	0	2	1	1	3	1	3
NH3	lbs	0	0	0	2	1	1	3	1	3
NH3	lbs	0	0	0	2	1	1	3	1	3

QUAL-INPUT: table contains storage on surface and non-seasonal parameter values for each PLS.

Edit PERLND:QUAL-INPUT

Show Description — Occurrence 1

OpNum	Description	SQO	POTFW	POTFS	ACQOP	SQOLIM	WSQOP	IOQC	AOQC
101	Range Land	0.0007	0	0	0	0.003	0.5	0	0
102	Water	0.0005	0	0	0	0.003	0.2	0	0
103	Forest Land	0.0004	0	0	0	0.003	1.5	0	0
104	Agricultural Land	0.0007	0	0	0	0.003	0.5	0	0
105	Urban or Built-up La	0.0025	0	0	0	0.003	0.5	0	0
106	Barren Land	0.0007	0	0	0	0.003	0.5	0	0

SQO - The initial storage of QUALOF on the surface of the PLS(permeable land surface)

POTFW - The washoff potency factor for a QUALSD. A potency factor is the ratio of constituent yield to sediment (washoff or scour) outflow.

POTFS - The scour potency factor for a QUALSD. A potency factor is the ratio of constituent yield to sediment (washoff or scour) outflow.

ACQOP - The rate of accumulation of QUALOF if QSOFG is positive. If QSOFG is negative, then ACQOP is the concentration of QUALOF in the surface outflow in mg/l.

SQOLIM - The maximum storage of QUALOF if QSOFG is positive.

WSQOP - The rate of surface runoff which will remove 90 percent of stored QUALOF per hour.

IOQC - The concentration of the constituent in interflow outflow (meaningful only if this is a QUALIF).

AOQC - The concentration of the constituent in active groundwater outflow (meaningful only if this is a QUALGW).

Landuse	SQO for N02-NO3	SQOLIM for NO2-NO3	WSQOP for N02-NO3
Range Land	0.005	0.003	0.5
Water	0.0006	0.003	0.2
Forest Land	0.0003	0.003	1.5
Agricultural Land	0.005	0.003	0.5
Urban or Built Up Land	0.012	0.003	0.6
Barren Land	0.005	0.003	0.5

Landuse	SQO for Ortho P	SQOLIM for Ortho P	WSQOP for Ortho P
Range Land	0.38	0.003	0.5
Water	0.04	0.003	0.2
Forest Land	0.017	0.003	0.7
Agricultural Land	0.38	0.003	0.5
Urban or Built Up Land	0.04	0.003	0.6
Barren Land	0.38	0.003	0.5

Landuse	SQO for BOD	SQOLIM for BOD	WSQOP for BOD
Range Land	5	0.003	0.5
Water	1	0.003	0.2
Forest Land	1	0.003	0.7
Agricultural Land	5	0.003	0.5
Urban or Built Up Land	3	0.003	0.6
Barren Land	5	0.003	0.5

IMPLND: **Impervious land**

QUAL-INPUT table contains storage on surface and nonseasonal parameter values for each impermeable land surface (ILS). This table should be repeated for each quality constituent.

SQO - The initial storage of QUALOF on the surface of the ILS.

POTFW - The washoff potency factor for a QUALSD. A potency factor is the ratio of constituent yield to sediment (washoff or scour) outflow.

ACQOP - The rate of accumulation of QUALOF if QSOFG is positive.

SQOLIM - The maximum storage of QUALOF if QSOFG is positive.

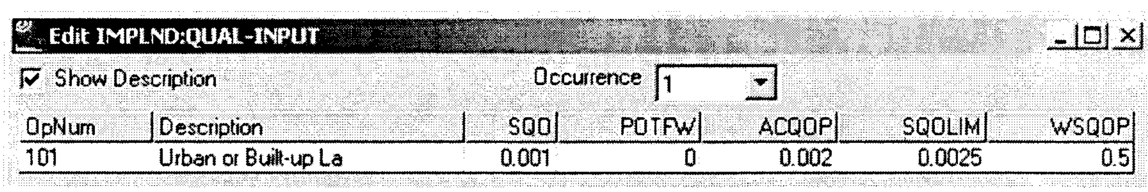
WSQOP - The rate of surface runoff that will remove 90 percent of stored QUALOF per hour.

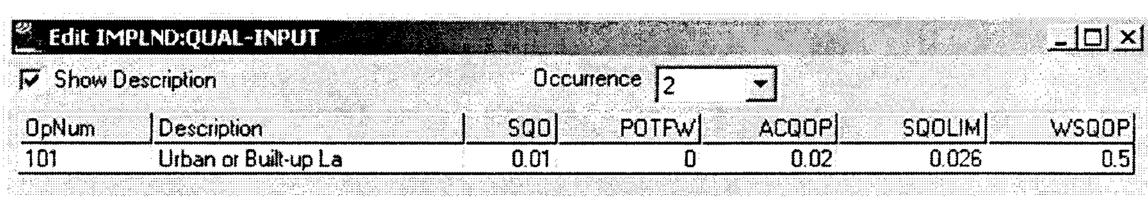
Occurrence 1 – NH3

Occurrence 2 – NO2-NO3

Occurrence 3 – Ortho P

Occurrence 4 – BOD





Edit IMPLND:QUAL-INPUT

☑ Show Description   Occurrence 3

OpNum	Description	SQO	POTFW	ACQOP	SQOLIM	WSQOP
101	Urban or Built-up La	0.005	0	0.002	0.01	0.5

Edit IMPLND:QUAL-INPUT

☑ Show Description   Occurrence 4

OpNum	Description	SQO	POTFW	ACQOP	SQOLIM	WSQOP
101	Urban or Built-up La	1	0	0.15	2	0.5