

GIS and Water Quality Modeling

for

Watershed Management

by

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Prince George's County, Maryland

and

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National Taiwan Ocean University

Four Components

Watershed Protection System

(Planning level model)

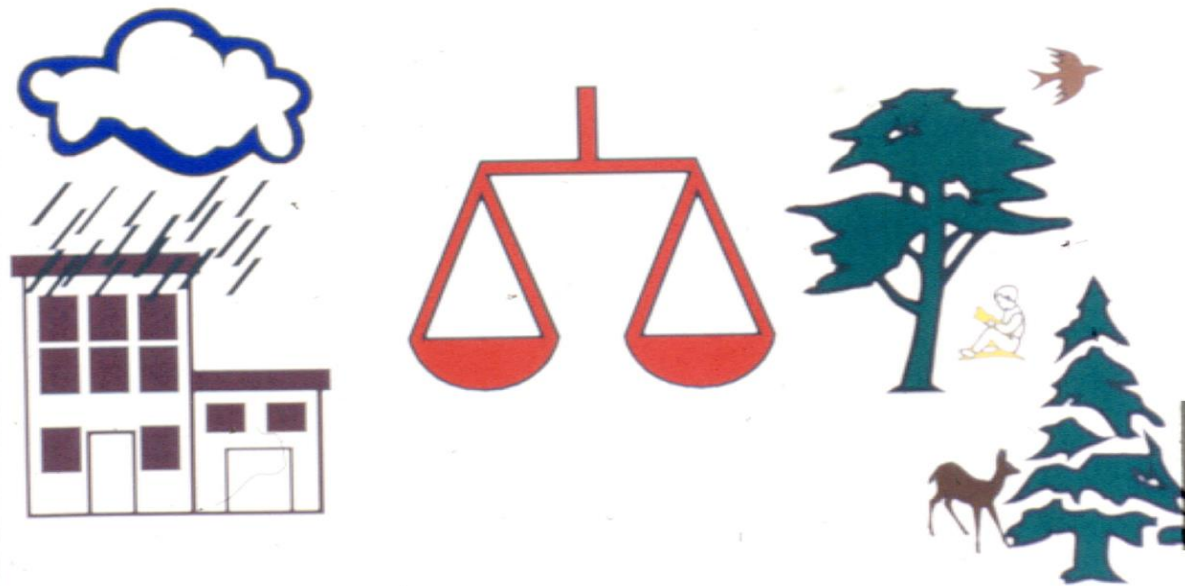
GIS-Based HSPF Models

(Detailed Watershed Simulation)

BASINS

Case Study using BASINS

THE WATERSHED PROTECTION SYSTEM



The WPS USER MANUAL -- DRAFT
Prince George's County, MD
Tetra Tech, Inc
November 1994

(1) Planning Level Model

Watershed Protection System

Watershed simulation model for Planning-level analysis

Watershed management methods

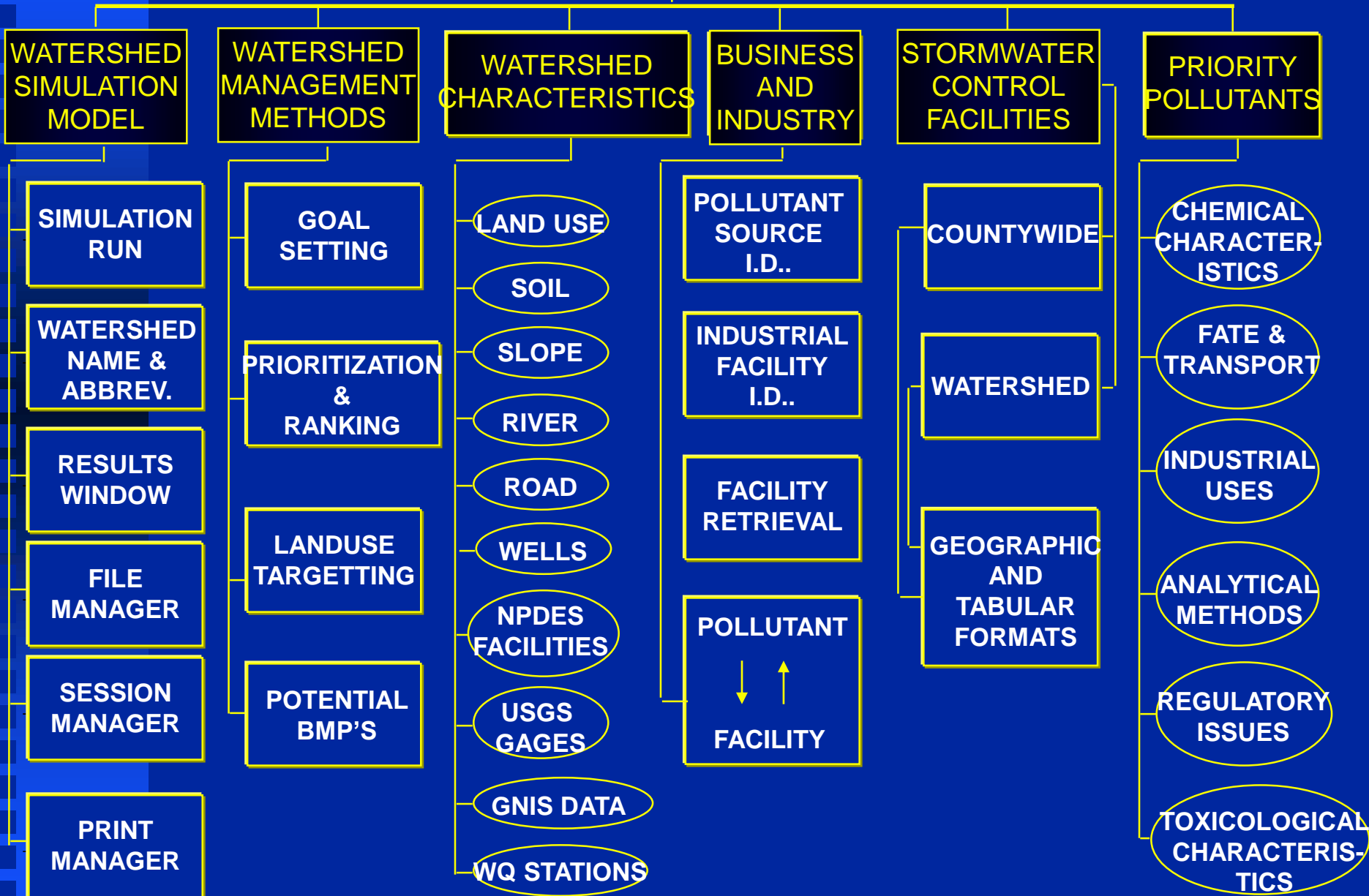
Watershed characteristics and Data overlays

Stormwater management practices module

Industrial and commercial facility module

Priority pollutant characteristics

WATERSHED PROTECTION SYSTEM



Simulation Methodology

Run SWMM for small individual land use watershed

Adjust model parameters to monitoring data

Run SWMM 9 land uses for 12 pollutants

8 years of continuous simulation using hourly time step

Land Use Types Simulated

Low density residential: $>1/2$ ac/lot

Medium density residential: $1/2 - 1/8$ ac/lot

High density residential: $< 1/8$ ac/lot

Commercial

Industrial

Open space

Forest

Agriculture

Bare land

Constituents Simulated

Flows

Biological Oxygen

Demand

Chemical oxygen
demand

Total suspended solids

Dissolved suspended
solids

Total phosphorous

Dissolved phosphorus

Total nitrogen

Ammonia & Organic
nitrogen

Copper

Cadmium

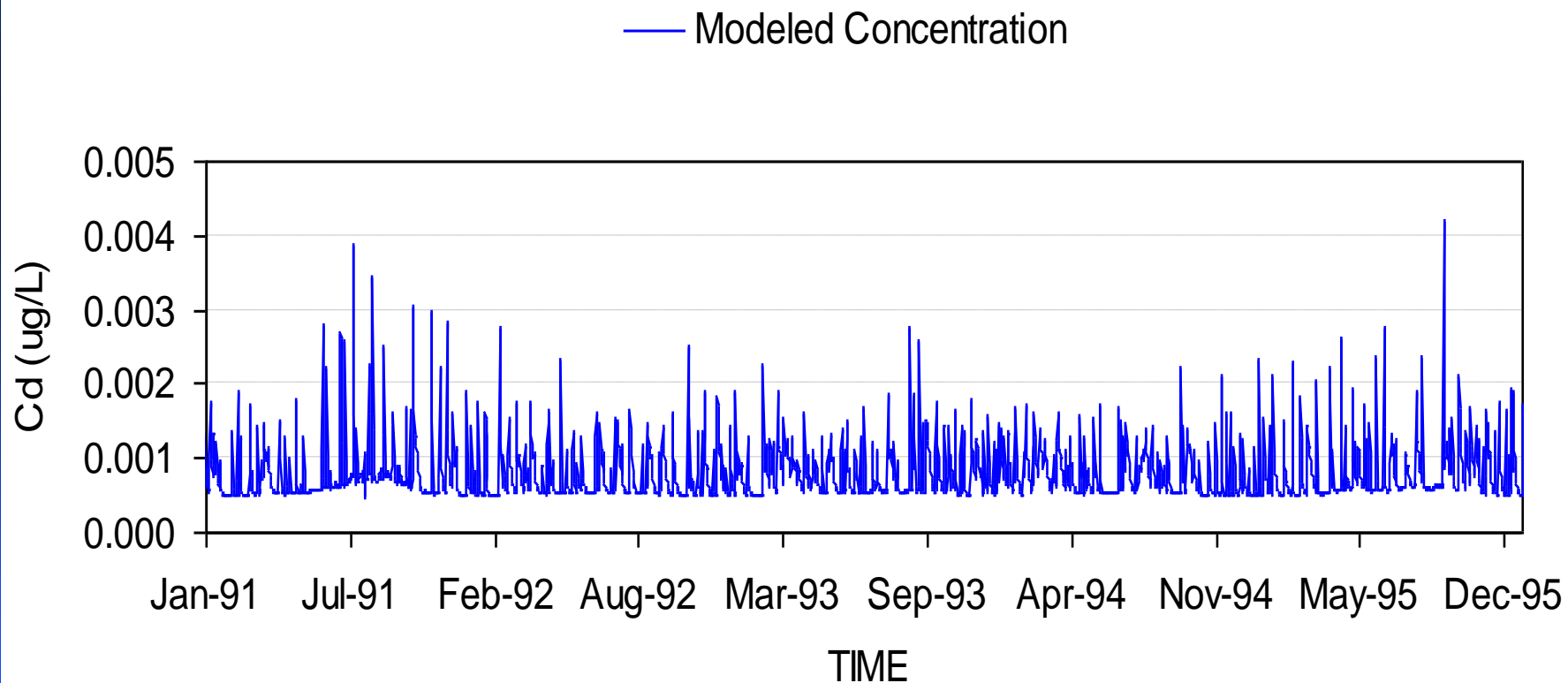
Zinc

Lead

Flow / Pollutant Hourly Time Series

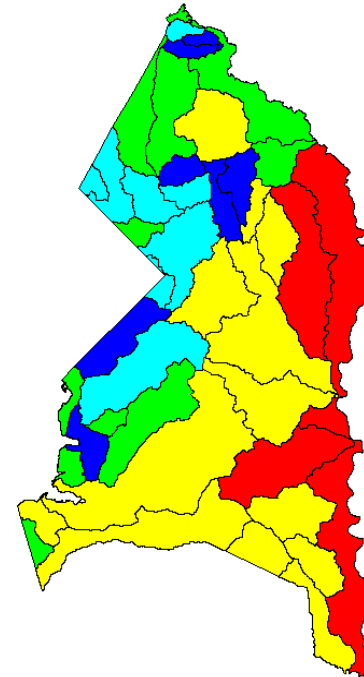
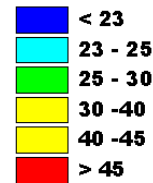
Heavy Metal

Residential Land Use

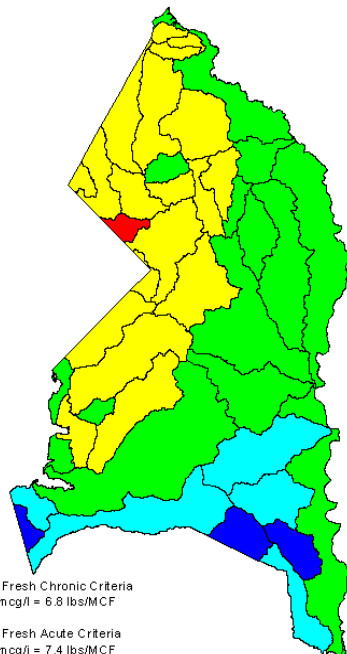


Pollutant Loadings Distribution

MEAN ANNUAL TOTAL PHOSPHOROUS LOADINGS (lbs/MCF)



MEAN ANNUAL ZINC LOADINGS (lbs/MCF)



EPA Fresh Chronic Criteria
110 mcg/l = 6.8 lbs/MCF

EPA Fresh Acute Criteria
120 mcg/l = 7.4 lbs/MCF

To Prioritize
Watersheds based on
Pollutant Loadings

WATERSHED MANAGEMENT METHODS

Select option for operation.

GOAL SETTING

PRIORITIZATION & RANKING

LANDUSE TARGETING

EXIT MENU

HELP

Exit W.P.S.

ARC PLOT

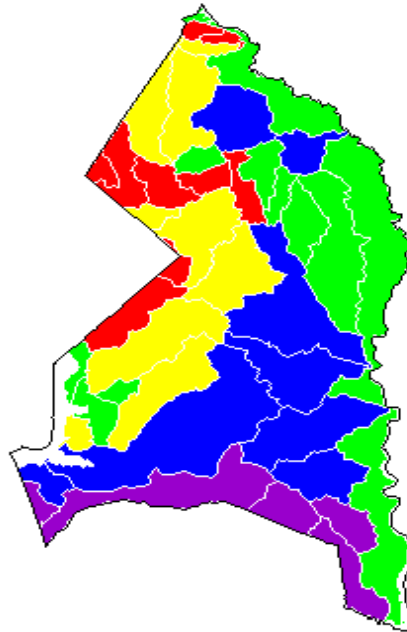
Pan/Zoom ▾

X,Y: 7.14813,7.18504

R a n k i n g

BOD5

B O D 5 m c f i n l b s / M c f



- Red: > 1040'
- Yellow: '1040 to 950'
- Blue: '870 to 780'
- Purple: '< 780'

950 to 870

Select indicator

Select ranges

Select from the above window

to view optional ranking table.



Prioritize Watersheds

(2) Application of GIS-Based HSPF Model

Hydrological Simulation Program
- FORTRAN

Detailed Watershed Management Model

Continuous simulation of hydrology
and water quality in a watershed

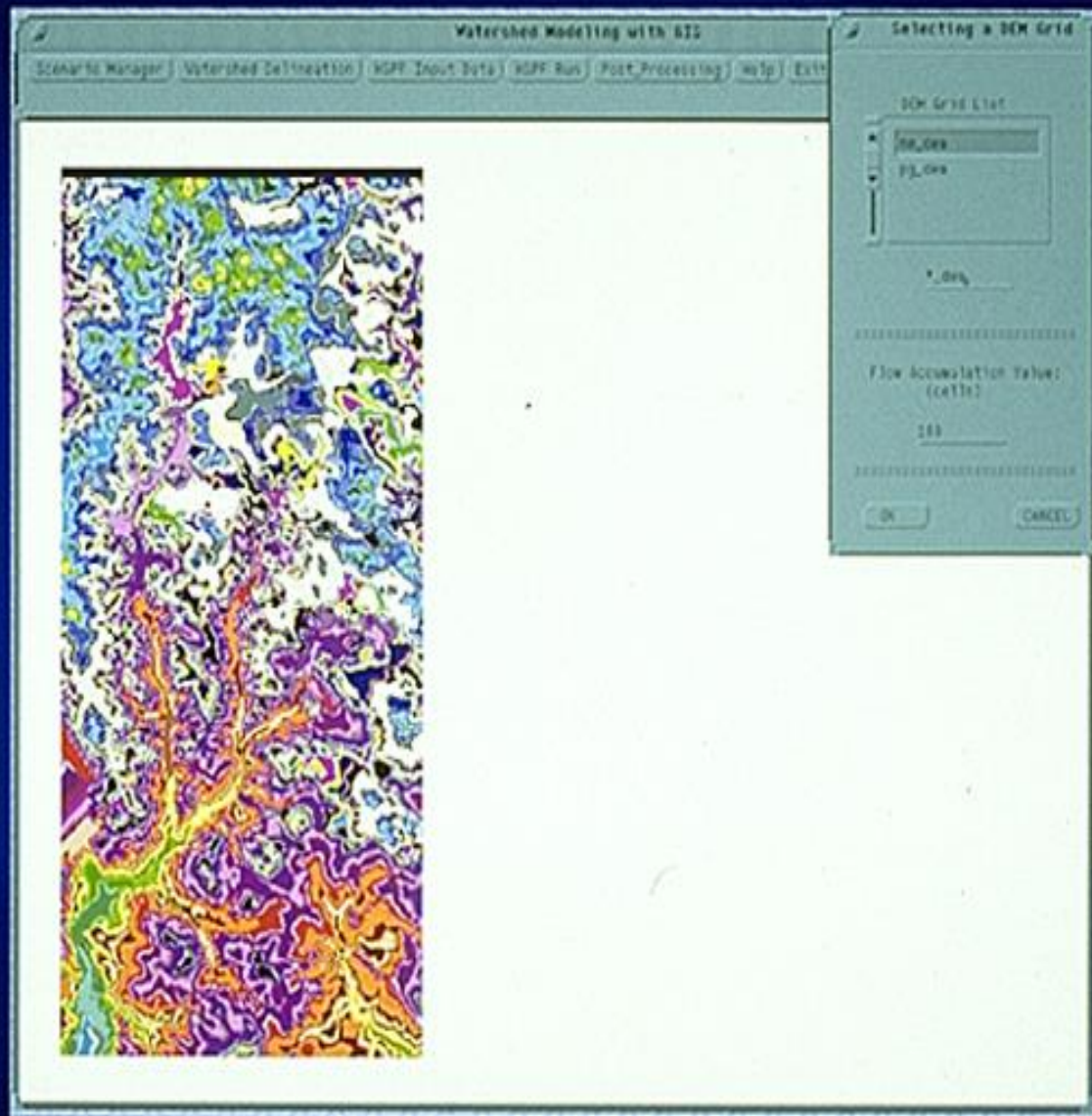
Spatial and temporal variability of flow
and pollutant loadings

location, duration and frequency of wet and dry
conditions

simulation of alternative management
scenarios

Prediction of future condition

**Select DEM for
subbasin
analysis and
delineation**



Automatically Delineate Sub-Watershed Boundary

The image shows a screenshot of a software interface for watershed modeling. The main window is titled "Watershed Modeling with GIS" and has several tabs: "Scenario Manager", "Watershed Delineation", "HSPF Input Data", "HSPF Run", and "Post_Proc". The "Watershed Delineation" tab is active, displaying a map of a watershed area. The map shows a large, irregularly shaped watershed boundary outlined in red. Inside this boundary, several smaller sub-watershed boundaries are outlined in green. A network of stream channels is also visible, colored in green.

Overlaid on the right side of the map is a "Scenario Manager" dialog box. It contains the following information:

- Search Scenario By:** A list with three options: "Scenario Names", "Watershed Names" (which is selected), and "Landuse-Watersheds".
- List of Watershed Names:** A list of six scenario names: "pg00001_wsc", "pg00002_wsc", "pg00003_wsc", "pg00004_wsc", "pg00009_wsc" (which is selected), and "tt00000_wsc".
- Scenario Description:** A text area containing the following text: "This study area of sub-watersheds is generated by WM-GIS. It will be used to overlay with landuse data to generate HSPF input data."
- Buttons:** "OK", "NEW", "RETURN", and "DELETE".

Automatically Determine Land Use Distribution for each Sub-Watershed

The image shows a screenshot of the 'Watershed Modeling with HSPF' software interface. The main window displays a map of a watershed area, divided into numerous sub-watersheds. The map is color-coded, with various shades of green, yellow, and red, representing different land use types. A blue line indicates the main watershed boundary, and smaller blue lines delineate the sub-watersheds. The map is viewed from a top-down perspective.

Overlaid on the right side of the map is a 'Scenario Manager' dialog box. The dialog box has a title bar that reads 'Scenario Manager'. Below the title bar, there are several sections:

- Search Scenario By:** A list box containing three options: 'Scenario Names', 'Watershed Names', and 'Landuse-Watersheds'. 'Landuse-Watersheds' is currently selected.
- List of Landuse-Watersheds:** A list box containing six entries: 'chen1_w1u', 'chen2_w1u', 'pg00000_w1u', 'pg00003_w1u', 'pg00004_w1u', and 'pg00009_w1u'. 'pg00009_w1u' is currently selected.
- Scenario Description:** A text area containing the following text: 'This study area of sub-watersheds is generated by WM-GIS. It will be used to overlay with landuse data to generate HSPF input data.'

At the bottom of the dialog box, there are four buttons: 'OK', 'NEW', 'RETURN', and 'DELETE'.

HSPF Interface

*Pollutant
selection for
HSPF
simulation*

Nonpoint Source Model [C:\Basins\Modelout\test02.prj]

Project Functions Default Help

Nitrogen Cycle
 Phosphorus Cycle

Dissolved Oxygen
 Dissolved Carbon Dioxide

General Quality

Selected Pollutants

ZINC, TOTAL (AS ZN)
PARATHION

Pollutant List

1, 2, 4-TRIMETHYL- BENZEN
1, 3, 5-TRIMETHYL- BENZEN
1,1 DICHLORO 1,2,2,2 TETR
1,1 DICHLORO 2,2,2- TRIFLU
1,1,1 TRICHLORO- 2,2,2TRII
1,1,1,2,2-PENTA- FLUOROE1
1,1,1-TRICHLORO- ETHANE
1,1,2,2-TETRACHLORO-ETH.
1,1,2-TRICHLORO- ETHANE
1,1,2-TRICHLORO- TRIFLUO
1,1-DICHLORO-1- FLUOROE

Pesticide 1

OK
Cancel

HSPF Interface

*Weather
data
assignment
screen*

The screenshot shows the HSPF Nonpoint Source Model interface. The main window title is "Nonpoint Source Model [C:\Basins\Modelout\test02.prj]". The menu bar includes "Project", "Functions", "Default", and "Help". The toolbar contains various icons for file operations, simulation, and data management. A "Simulation Time" dialog box is open, showing the following details:

Select WDM file: C:\Basins\Models\NPSM\Tutorial.wd [Browse...]

Time Span in WDM File:

	Date	Hour
Start	01/01/1963	00
End	12/31/1983	24

Simulation Time:

	Date	Hour
Start	01/01/1980	00
End	12/31/1980	24

Assign to Weather Stations (selected) / Assign to Reaches

Station: DE Wilmington Airport [v]

Assign by GIS

Selected Reaches:

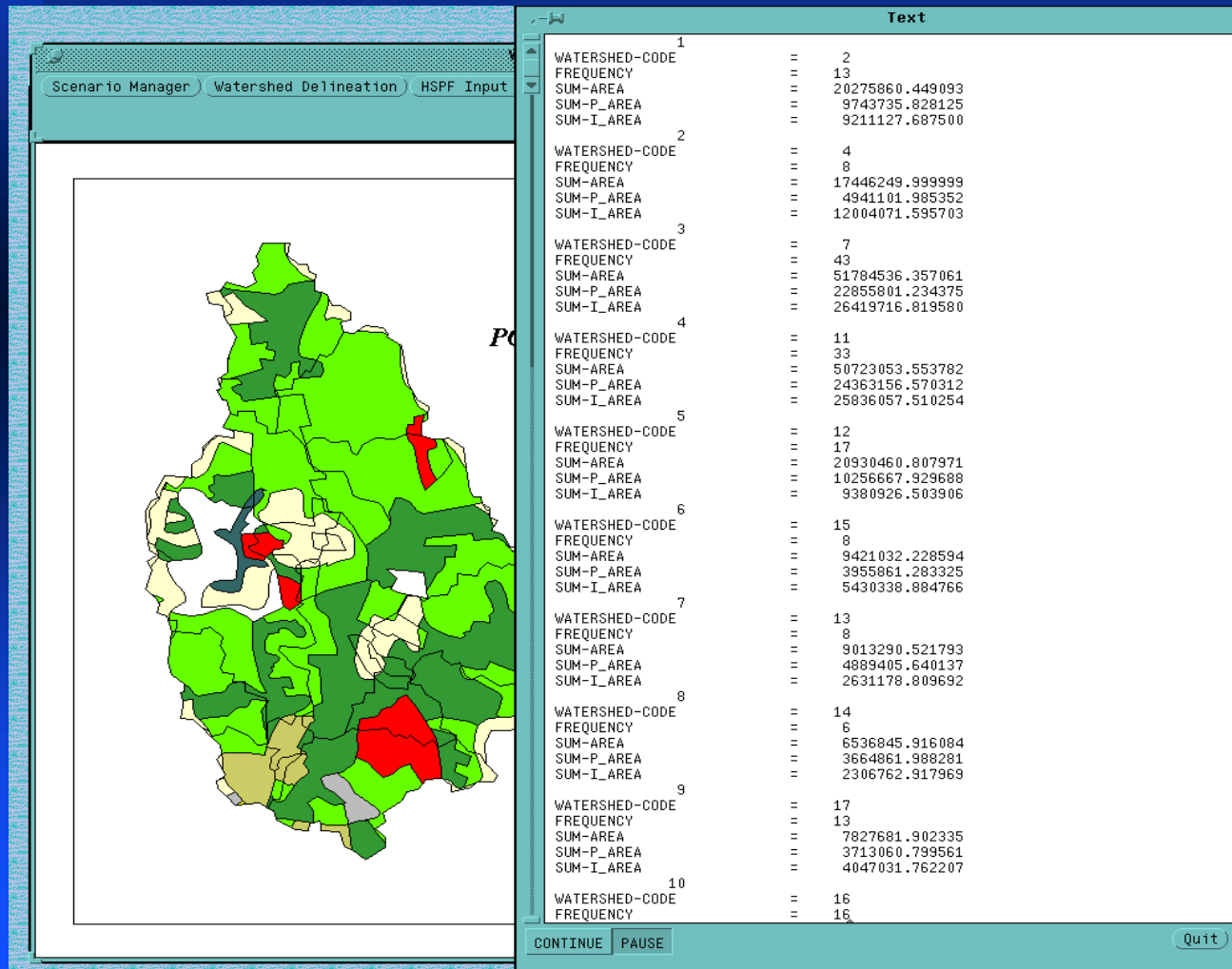
- NANTICOKE R - DE Wilmington Air
- NANTICOKE R, - DE Wilmington Air
- NANTICOKE R, - DE Wilmington Air
- *B - DE Wilmington Airport

Unassigned Reaches:

- NANTICOKE R,

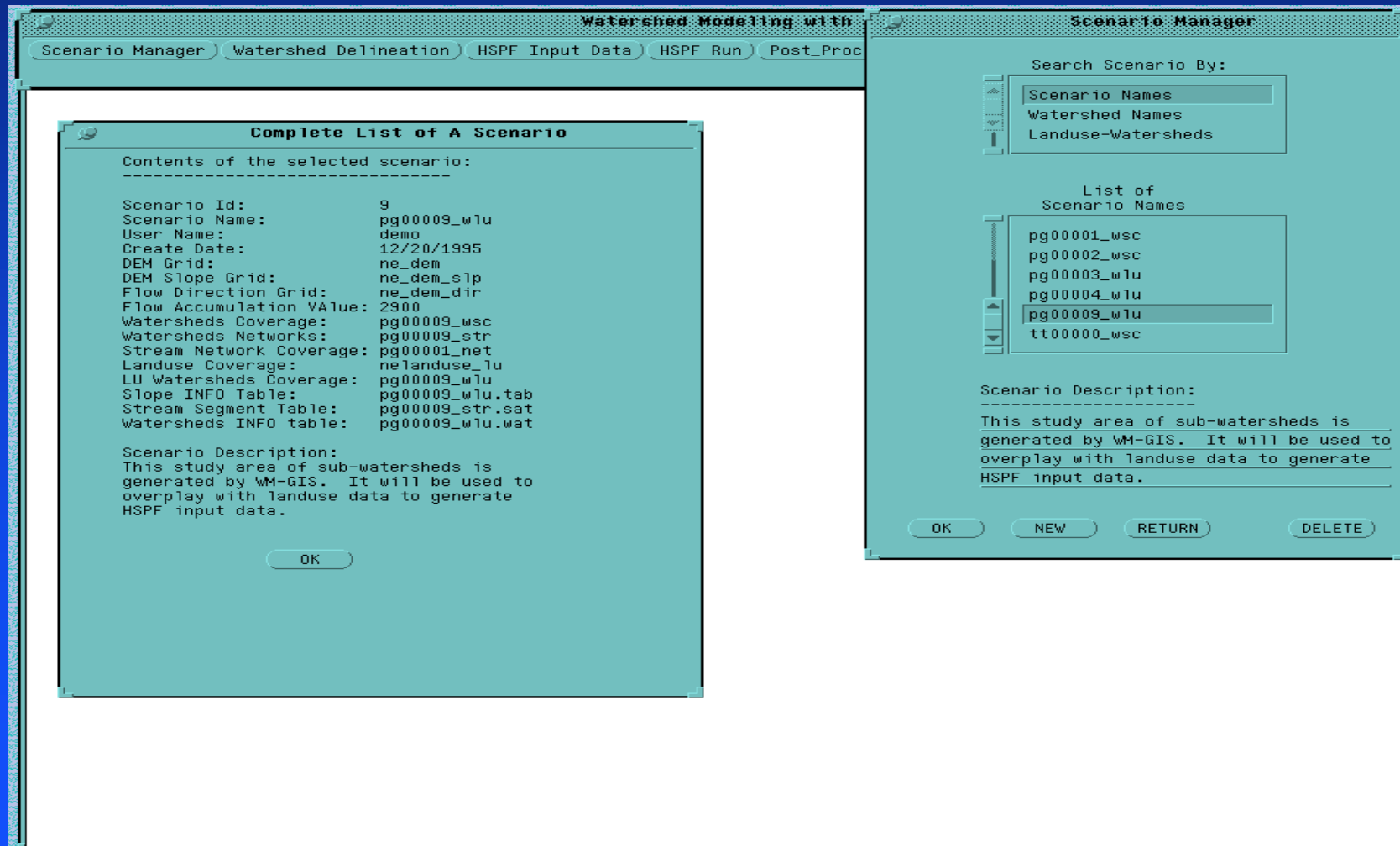
Double click to deselect. / Double click to select.

Automatically Assign Hydrologic & Water Quality Parameters (each Land Use in each Sub-Watershed)



For Both
Pervious
and
Impervious
areas

Provide Point Sources Data, if Any



HSPF Interface

Reach data screens including F-tables and F-tables generator.

The screenshot displays the HSPF software interface with three main windows:

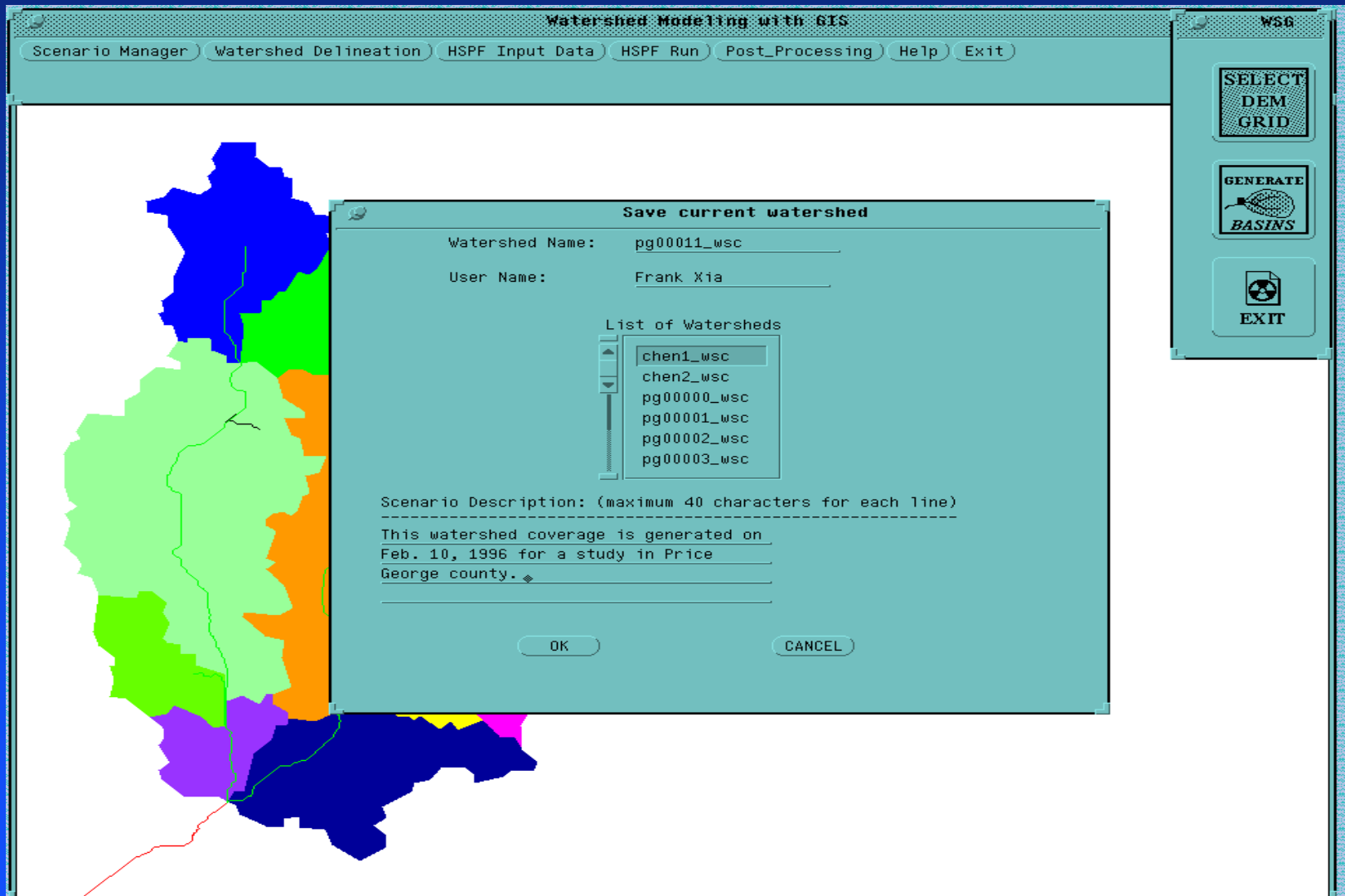
- Nonpoint Source Model [C:\Basins\Modelout\test02.prj]**: The main application window with a menu bar (Project, Functions, Default, Help) and a toolbar containing various icons for file operations and modeling.
- Reach Editor**: A window with four buttons: "Add/Remove Reaches", "Setup Reach Network", "Reach Characteristics", and "F-Tables". A "Done" button is located at the bottom.
- F-Tables**: A window titled "Display FTABLE for" with a dropdown menu set to "NANTICOKE R" and an "Import/Export..." button. It contains a table with the following data:

	Depth (ft)	Area (acres)	Volume
1	0.0000	6.7684	0.000
2	0.0259	6.7935	0.175
3	0.2591	7.0196	1.786
4	1.2750	8.0048	9.417
5	127.5000	252.8048	16469

- Trapezoidal Import Data Review**: A window displaying a table of reach data:

	Reach ID	L	Ym	Wm	
1	02070004001	48576.0000	15.1200	35.2600	0
2	02070004002	58080.0000	7.3200	15.1300	0

Automatically Generate REACH Data, Network and F-Tables



Generate summary information by land use category and automatically derive input data for watershed modeling with HSPF



HSPF Interface

*View and/or
edit
parameter
values and
options*

The screenshot displays the HSPF software interface. The main window is titled "Nonpoint Source Model [C:\Basins\Modelout\test02.prj]" and contains a menu bar with "Project", "Functions", "Default", and "Help". Below the menu bar is a toolbar with various icons. The "Input Data Editor" window is open, showing a tree view of parameters. The "NSUR" parameter is selected and highlighted. A dialog box titled "NSUR" is open, showing a list of "Available Land Units" with "Pervious1-URB" selected. The dialog box also includes buttons for "Assign To All", "Assign To Selected", a text input field containing "0.10", "Default Data", and "Get Data From GIS". At the bottom of the dialog box is a "View Map in GIS" button. The status bar at the bottom of the main window shows "Manning's n for the assumed overland flow plane" and "NUM 6:34 PM".

Nonpoint Source Model [C:\Basins\Modelout\test02.prj]

Project Functions Default Help

Input Data Editor

- PERLND
 - ATMP
 - ELDAT
 - AIRTMP
 - + [N/A] SNOW
 - P WATER
 - PWAT-PARM1
 - + PWAT-PARM2
 - + PWAT-PARM3
 - PWAT-PARM4
 - CEPSC
 - UZSN
 - NSUR**
 - INTFW
 - IRC
 - LZETP
 - + Monthly Input Param
 - + P WATER-STATE1
 - + [N/A] SEDMNT
 - + [N/A] PSTEMP
 - + [N/A] PWTGAS
 - + PQUAL

NSUR

Available Land Units

- Pervious1-URB**
- Pervious2-AGR
- Pervious3-FOR
- Pervious1-URB
- Pervious2-AGR
- Pervious3-FOR
- Pervious1-URB
- Pervious2-AGR
- Pervious3-FOR

Assign To All

Assign To Selected

0.10

Default Data

Get Data From GIS

View Map in GIS

Manning's n for the assumed overland flow plane

NUM 6:34 PM

Sample Output



Write - 02060008.TAL

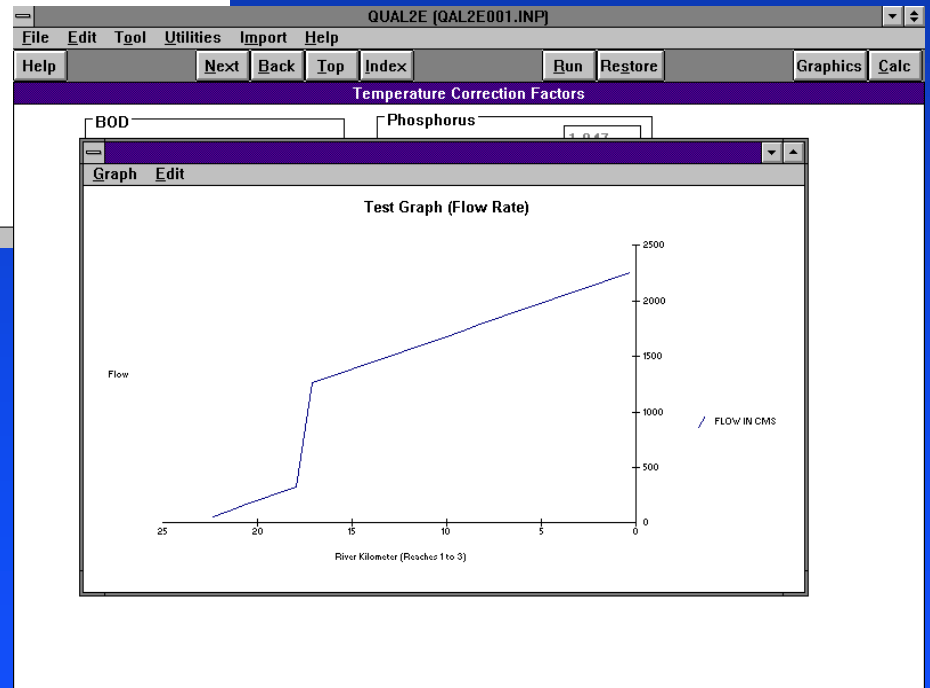
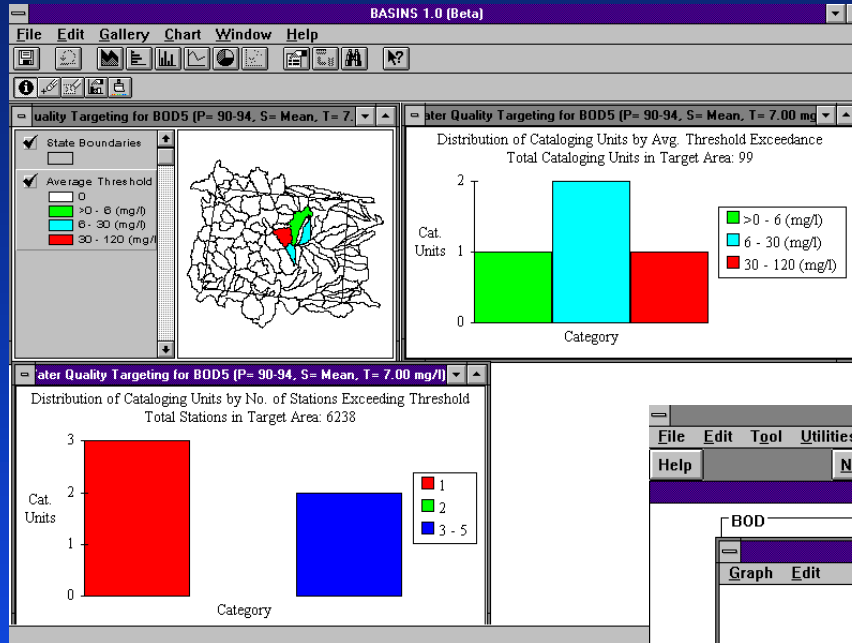
File Edit Find Character Paragraph Document Help

SIM Time: 20.000 intervals/inch
SIM Data for each curve (Point-valued first, then mean-valued):

SIM Label	LINTYP	INTEQ	COLCOD	TRAM	TRANCOD					
SIM QUNOFF	0	5	1	SUM	1					
SIM CBOIU (20 deg C)	0	5	1	SUM	1					
SIM ORGANIC NITROGEN	0	5	1	SUM	1					
SIM ORGANIC PHOSPHOR	0	5	1	SUM	1					
SIM DO	0	5	1	SUM	1					
SIM										
SIM										
SIM										
SIM										
SIM										
SIM										
SIM Time series (pt-valued, then mean-valued):										
SIM										
SIM Date/time		Values								
SIM										
SIM	1979	12	31	24	0	-0.10000E+31	-0.10000E+31	-0.10000E+31	-0.10000E+31	-0.10000E+31
SIM	1980	1	1	1	0	1417.2	1031.3	345.01	289.04	3764.4
SIM	1980	1	1	2	0	775.02	185.46	63.132	49.866	1682.9
SIM	1980	1	1	3	0	649.97	51.748	17.230	14.622	1285.3
SIM	1980	1	1	4	0	614.76	21.333	7.1030	6.0279	1174.1
SIM	1980	1	1	5	0	601.59	10.566	3.5181	2.9856	1133.1
SIM	1980	1	1	6	0	595.52	5.9292	1.9742	1.6754	1114.6
SIM	1980	1	1	7	0	592.18	3.6398	1.2119	1.0285	1104.9

Page 1

HSPF Outputs



Why Use GIS As a Modeling Platform

Save time and cost

Offer a wide range of modeling options

Allow a wide range of analysis

* Various scale, complexity and application domain

Replicable results ... defensible analysis

Flexibility and iterations

* Evaluation of a wide range of alternatives

Communicate to public and decision makers

Ease of Integration of complex models

Cost and Time Savings with GIS

(Conduct 3 Watershed Studies)

	<u>Cost</u>	<u>Time</u>	<u>Alt.</u>
1970's W/o GIS	84 FTE	6+yr.	3
Today W/ GIS	2.7 FTE	10 mo.	15

(3) *BASINS*

**BETTER ASSESSMENT SCIENCE
INTEGRATING
POINT AND NONPOINT SOURCES**



What Is BASINS?

Better **A**ssessment **S**cience
Integrating
Point and **N**onpoint **S**ources

Integrated GIS, data analysis and modeling system designed to support watershed-based analysis and TMDL development

Data: national data sets with options to import local data

Tools: provide quick access to analysis techniques for watershed assessment

Models: provide more detailed analysis and predictive evaluations to support studies

BASINS Facts and Requirements for Use

U.S. EPA Product - Office of Science and
Technology (OST)

Available for every state in the continental U.S.

Hardware and Software Requirements:

ArcView GIS Version 3.0a or 3.1

Windows 95, 98, or NT

133-MHz Pentium processor (at minimum)

250 mb hard disk space (at minimum)

32 mb of RAM

CD-ROM and color monitor

BASINS Applicability

Multi-purpose support system

Watershed management and basin planning

TMDL program

Source water protection

Pollutant trading

Multiple users

National assessment

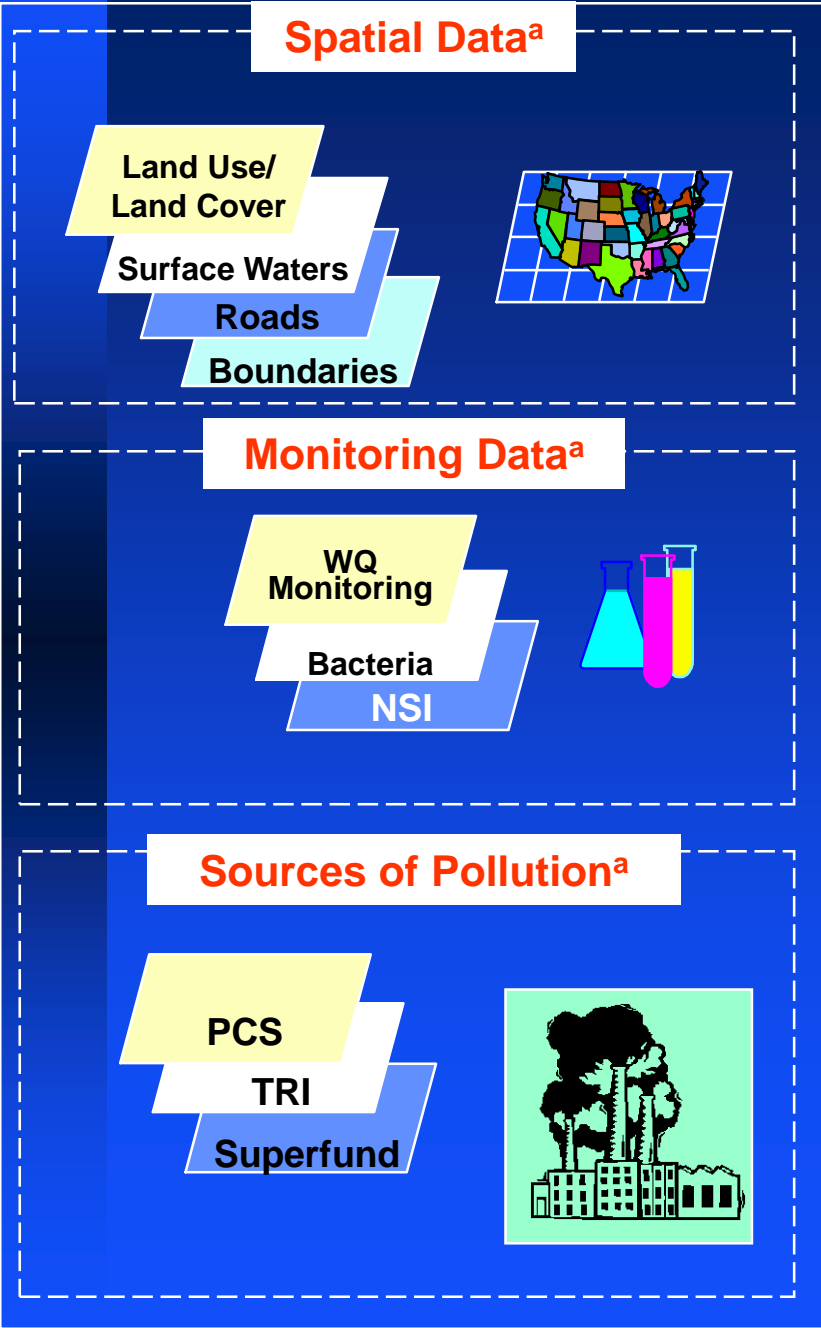
Regional assessment

States

Local governments

Private


BASINS Overview



Assessment Tools^a

- TARGET
- ASSESS 
- Data Mining
- Ws Delineation
- Reporting
- Import local data

Watershed and Water Quality Modeling

- NPSM^b
 - TOXIRoute
 - QUAL2E^c
- 

TMDL Watersheds
Source water protection

Decisions



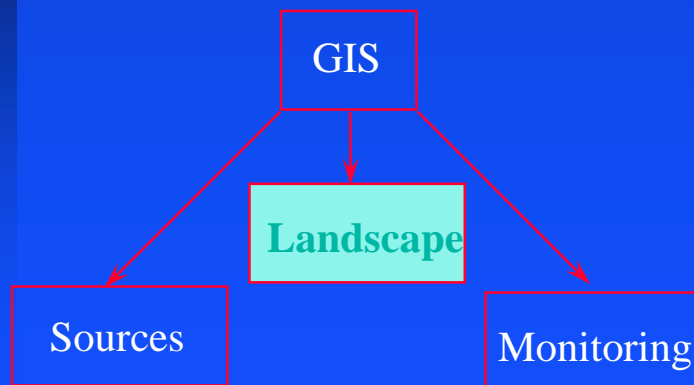
^a BASINS GIS Environment
^b Windows-based Interface
^c Windows Shell w/FORTRAN

BASINS Data Products

Spatial Data

Land use and land cover
Urbanized areas
Populated place locations
Reach file 1
Reach file 3
Major roads
USGS hydrologic unit
boundaries (accounting and
catalog units)

Drinking water supply sites
Dam sites
EPA region boundaries
State boundaries
County boundaries
DEM
Ecoregions
NAQWA study unit
boundaries
Managed area database
(Federal and Indian Lands)
Soil (STATSGO)



BASINS Data Products

Sources of Pollution

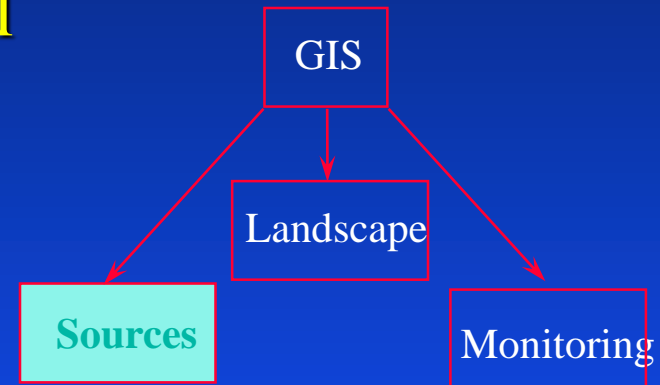
Permit Compliance System (PCS) sites and computed annual loadings

Industrial facility sites

Toxic Release Inventory (TRI) sites (annual releases)

Superfund national priority list sites

Hazardous and solid waste sites



BASINS Data Products

Environmental Monitoring Data

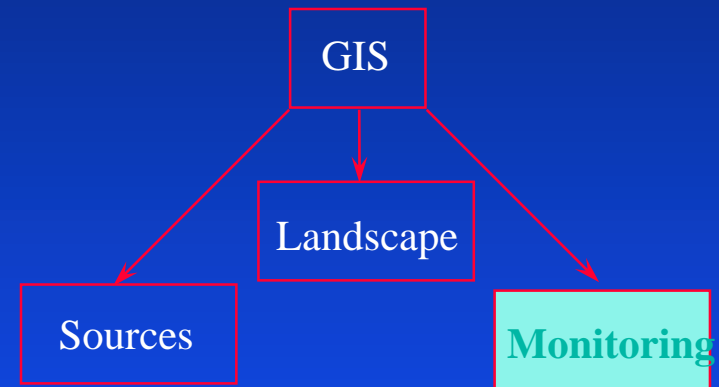
Weather station sites

USGS gauging stations

Dam sites

Classified shellfish area

1996 Clean water needs survey



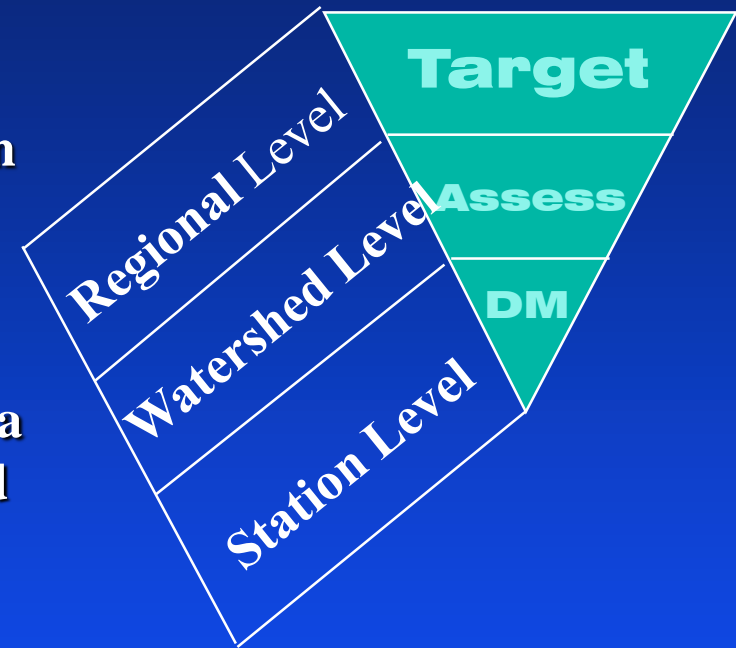
Assessment Tools included with **BASINS**

Target: Broad-based evaluation of watershed water quality and point source loadings.

Assess: Watershed-based evaluation of specific water quality stations and/or dischargers and their proximity to waterbodies.

Data Mining: Dynamic link of data elements using a combination of tables and maps. Allows for visual interpretation of geographic and historical data.

Watershed Reporting: Automated summary report system. Allows users to select types of information to be included. Automated generation of associated graphics and tables.



BASINS

Modeling Capabilities

Models to address multiple objectives

Source assessment

Receiving water evaluation

Models which operate on various scales

Local scale

Watersheds

Basins

Models which can be applied at various levels of complexity

Screening

Detailed

What Constitutes a Model?

Data

Algorithms

Output

Time series

Rainfall
Streamflow
WQ sampling

Spatial/Landscape

Soils
Topo
Cover
streams
Lakes

Kinetics data

Pollutant charact.
Fate & transport

Watershed Models

Hydrology
Buildup
Washoff
Erosion
Overland transport.
Fate & transport

Waterbody Models

Hydraulics
Hydrodynamic
Fate & transport
Scour & deposition
Algal growth

Time series
Summary statistics
% change/improvement
Violations
Classification maps
Impact maps

BASINS Nonpoint Source Model (NPSM)



HSPF (Hydrologic Simulation Program-FORTRAN)

Variable time step continuous simulation model
Predicts loadings in mixed land use settings for:

Watershed
Model

Nutrients

Toxics

Waterbody
Model

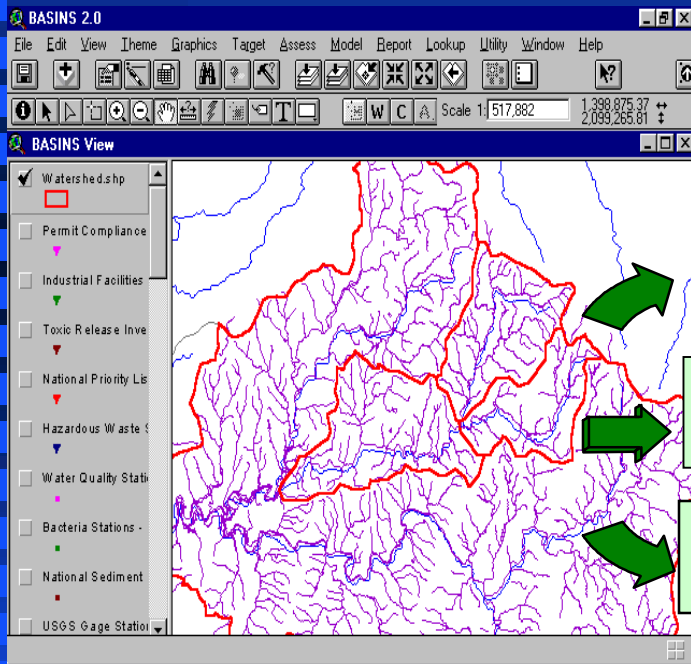
Bacteria

Sediment

Considers point source and nonpoint source
loadings

How NPSM fits into BASINS

A BASINS - GIS



C



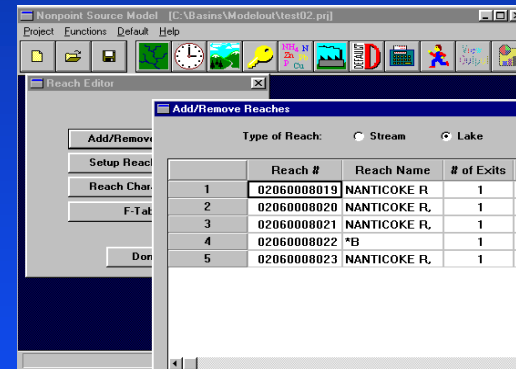
Meteorological Data

D



Landuse and pollutant specific Data

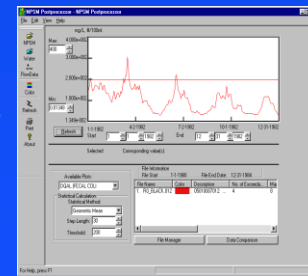
B NPSM Windows interface



E Core Model



F Post Processing



BASINS Stream Water

Quality Models



Qual2e

Steady state, one-dimensional river model
Provides more detailed, process oriented river modeling

Watershed
Model

Models up to 15 constituents

Waterbody
Model

Uses streeter-phelps for D.O. Modeling
Eutrophication and nutrient processes

BASINS Water Quality

Models



Toxiroute

Steady state, design flow

Evaluates instream concentrations for stream networks with multiple discharges

Incorporates nonpoint source loadings

Chemical fate is estimated by first order decay rate (half life)

Watershed
Model

Waterbody
Model

GIS Modeling Limitations

Data

Data

Data

Data

- * **Availability**
- * **Scale**
- * **Accuracy**

Modeling the Lower Beaverdam Creek

Using

BASINS

Lower Beaverdam Creek Watershed

Watershed area: 9,753 acres (15.24 Sq. Miles)

16.0 miles of EPA Reach File

Predominantly residential and industrial. Also contains some commercial, forested, and open areas.

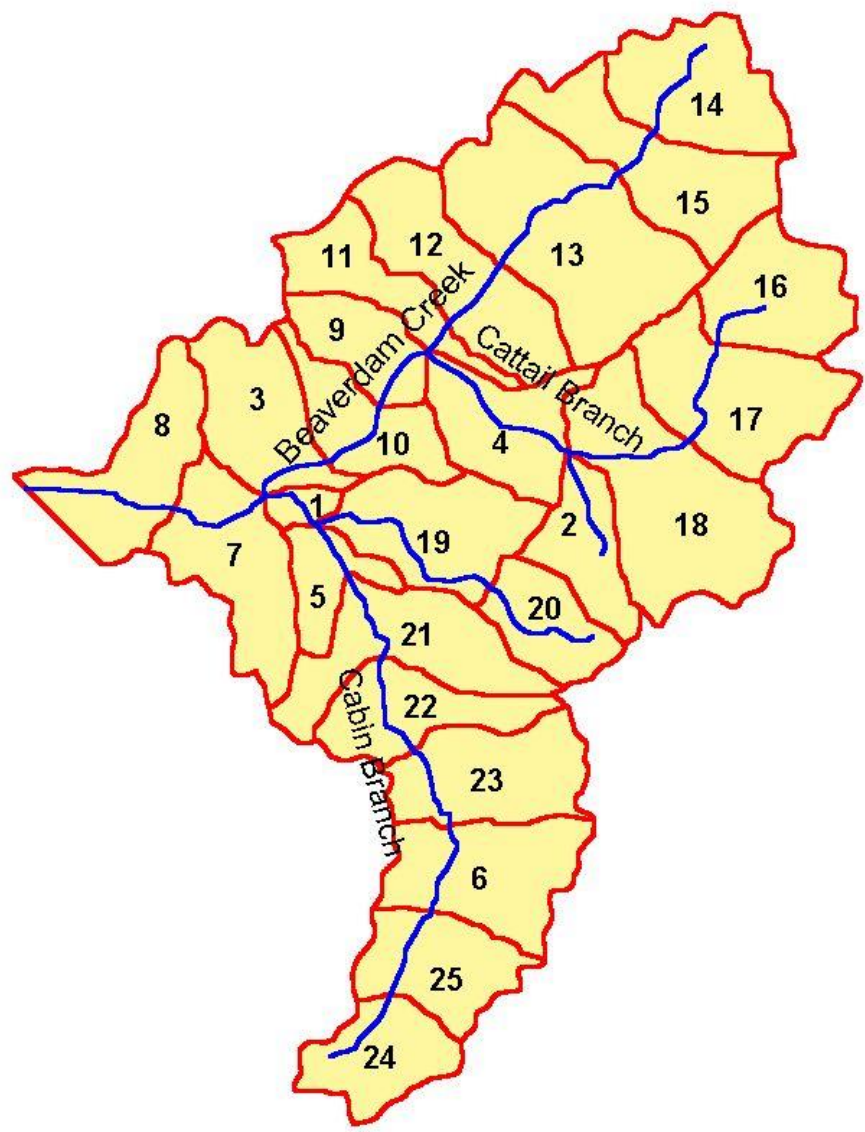
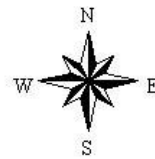
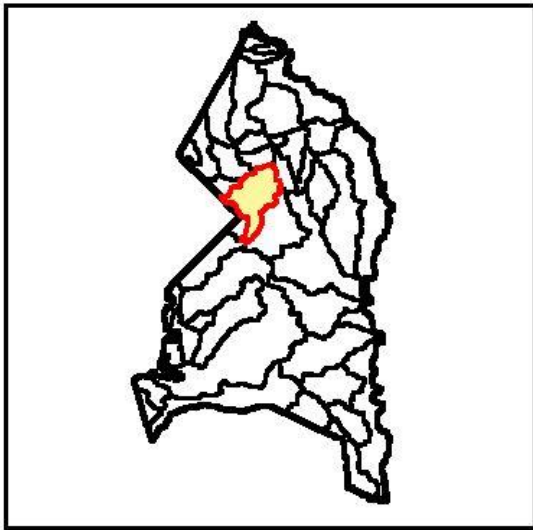
Primarily soil type:



deep, well drained, highly erodible soils

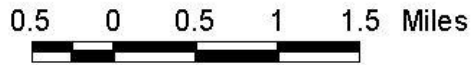
low permeability

primarily clay with a thin mantle of silt, sand, or loam

Significant impervious area results in high runoff potential



 Waterbodies
 Subwatershed Boundaries



Lower Beaverdam Creek Subwatersheds

Map Projection: State Plane - 1983
Maryland

Data Source: Prince George's County Watershed Data
U.S. EPA BASINS 2.0

LANDUSE

Grouped the County landuses into 8 categories:

Low-density Residential (urban)

Medium-density Residential (urban)

High-density Residential (urban)

Commercial (urban)

Industrial (urban)

Other Urban (urban)

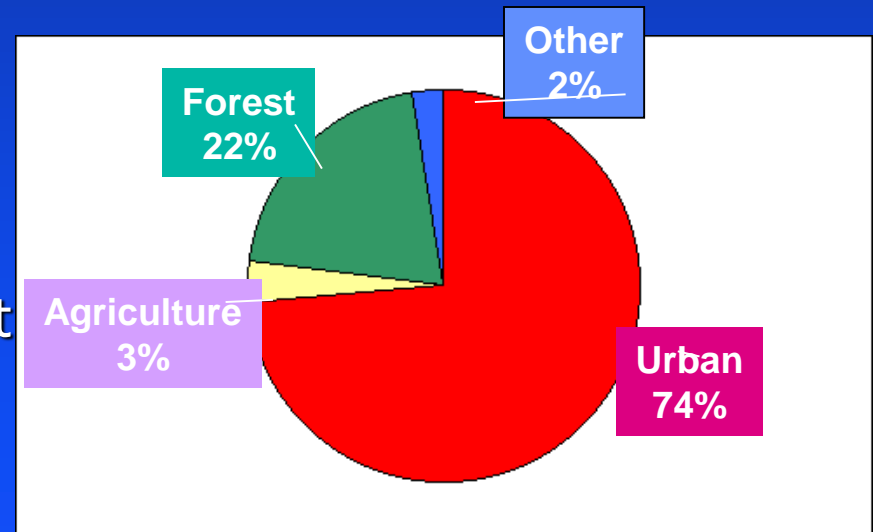
Agricultural (rural)

Forested (rural)

Rationale for grouping:

Primarily urban and forested land

Calibration sites used to develop the County Default Dataset represent residential, commercial, industrial, agricultural, and forested landuse-specific areas



Modeling Tasks and Requirements

Data processing and model setup

Calibration of the model for flow and water quality

Model execution and development of flow and pollutant loads

Key Data Used

BASINS data

Weather station data

Reach File, version 3.0 stream networks

Digital Elevation Model (DEM)

Prince George's County data

Landuse/land cover

Contours

Stream networks

Transportation/urban data

Watershed boundaries

Soil data

MODEL SETUP

The Lower Beaverdam Creek watershed was segmented into 11 subwatersheds.

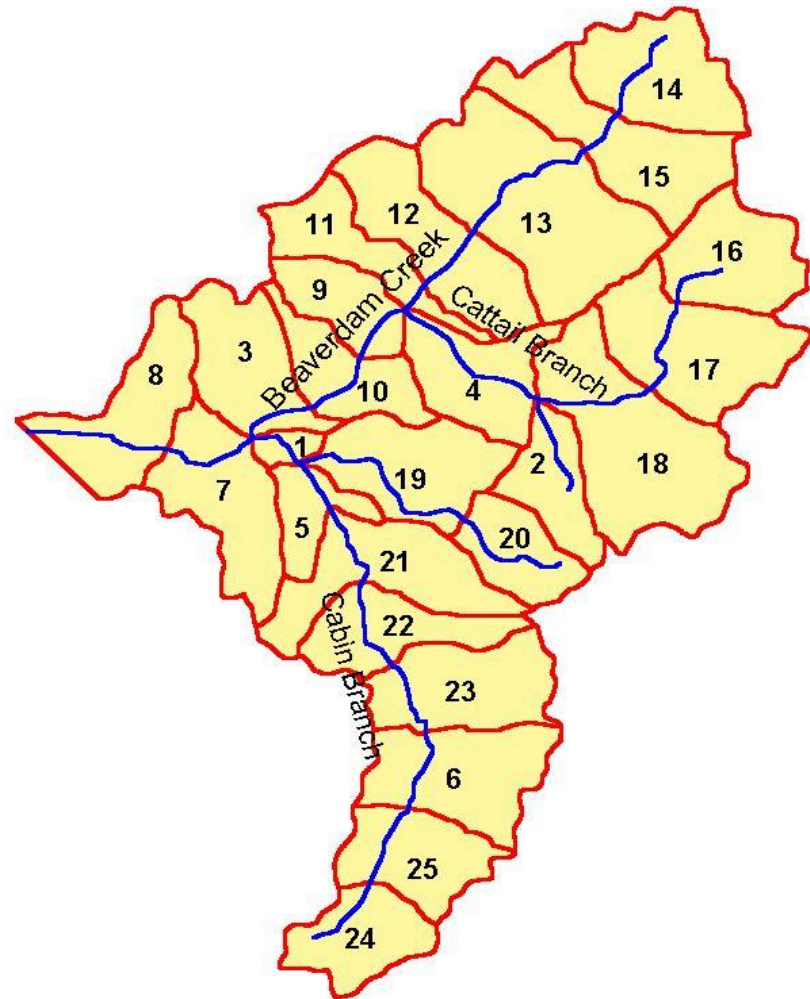
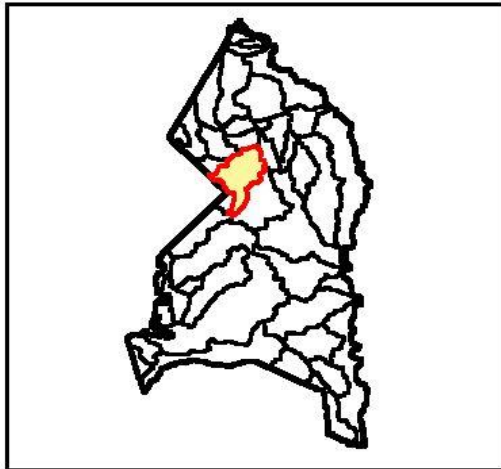
Delineations were based on County contour and stream network data



County landuse data were used to represent the subwatersheds.

A WDM file containing meteorological data representative of the watershed was developed.

Stream data were compiled and F-Tables (rating curves) developed.

Twenty Five (25) Sub-Basins



 Waterbodies
 Subwatershed Boundaries

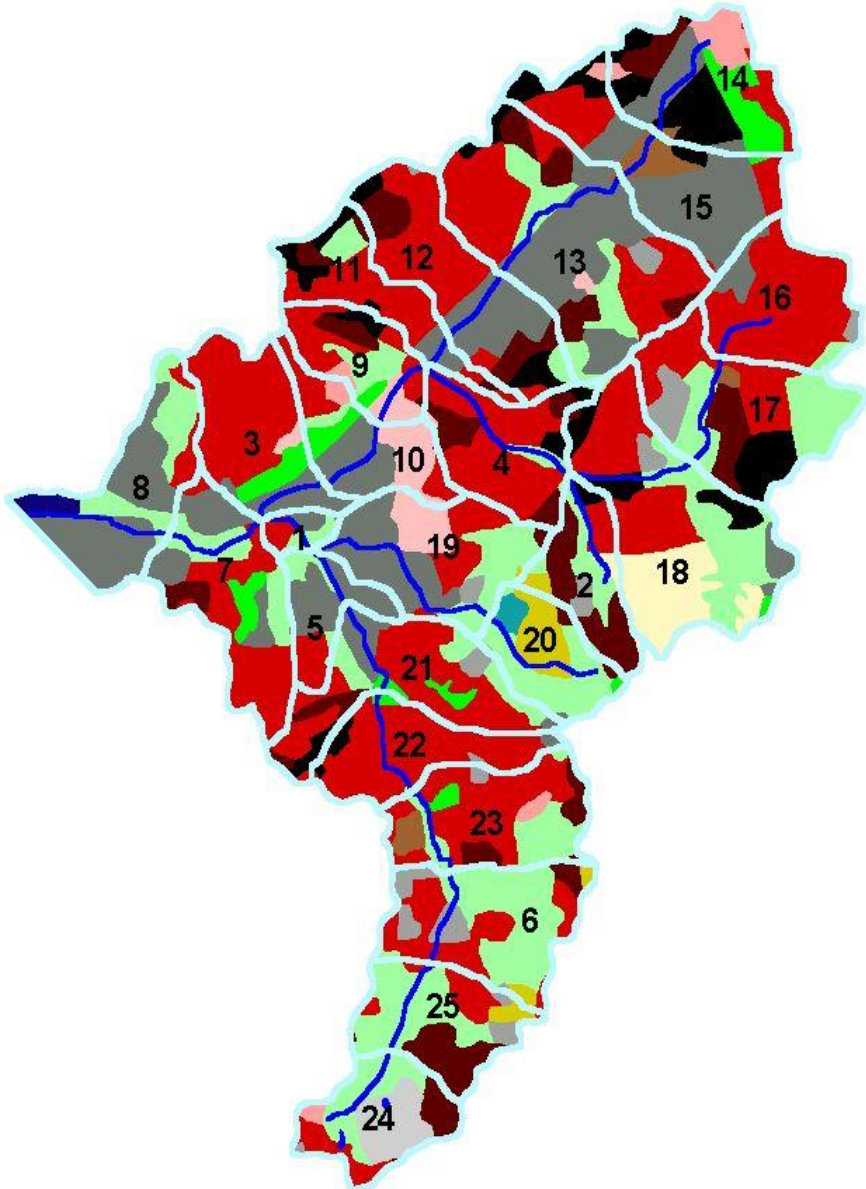
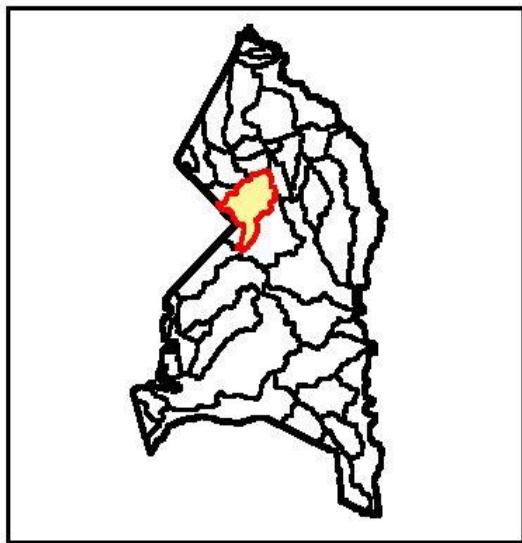
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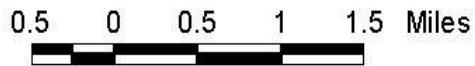
Lower Beaverdam Creek Subwatersheds

Map Projection: State Plane - 1983
Maryland

Data Source: Prince George's County Watershed Data
U.S. EPA BASINS 2.0



- Subwatershed Boundaries
- Waterbodies
- Landuse Types
 - Low-density Residential
 - Medium-density Residential
 - High-density Residential
 - Commercial
 - Industrial
 - Institutional
 - Extractive
 - Open Urban Land
 - Cropland
 - Pasture
 - Deciduous Forest
 - Mixed Forest
 - Brush
 - Water
 - Bare Ground
 - Wetlands



**Landuse Data
Lower Beaverdam Creek**

Map Projection: State Plane - 1983
Maryland

Data Source: Prince George's County Watershed Data
U.S. EPA BASINS 2.0

LOWER BEAVERDAM CREEK WATERSHED

Table 2. Landuse distribution by modeled landuse categories.

Landuse Categories	Area (ac)	Percentage of Total (%)
Low-density Residential	306.03	3.14
Medium-density Residential	3597.28	36.89
High-density Residential	772.90	7.93
Commercial	541.70	5.56
Industrial	2068.98	21.22
Agricultural	326.27	3.35
Forested	2137.57	21.92
Total	9750.73	100.00

Landuse Representation in the Model

Assigned impervious percentages to individual County landuse types

Used these percentages to divide landuse areas into separate pervious and impervious units

Development of a WDM File for Meteorological Data

(1) NOAA Data

from Reagan National Airport:

Air temperature

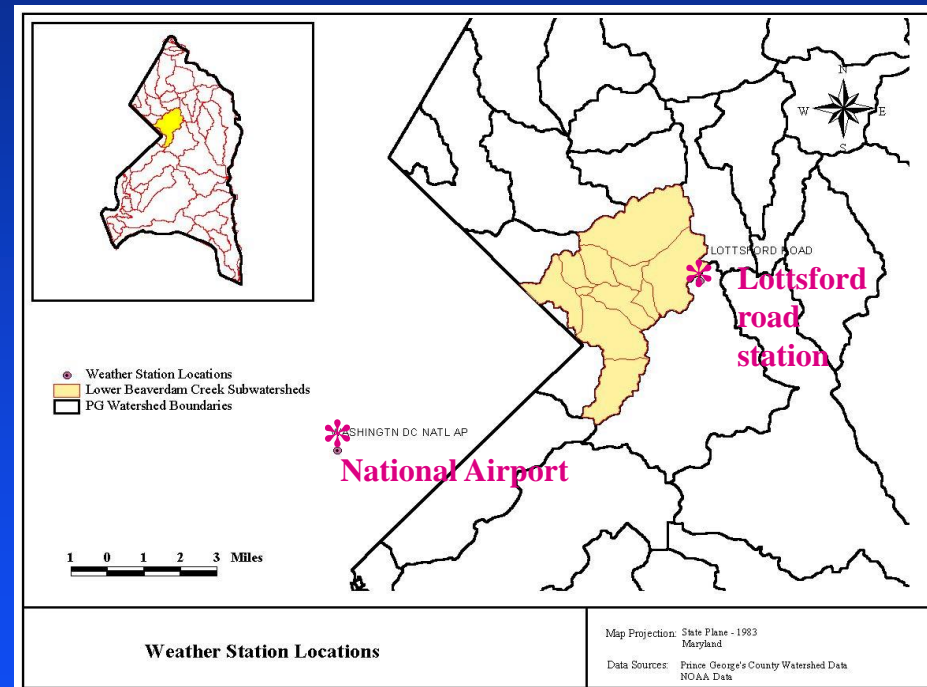
Dew point

Wind movement

Solar radiation

Cloud cover

Evapotranspiration



(2) County data

Hourly precipitation data from
the Lottsford Road weather station

Compilation of Stream Data and Development of F-Tables

Compiled stream dimensions and characteristics for development of HSPF F-tables. Used the following data and methods to represent each stream segment:

Field observations

Detailed county topography data

HEC-2 & TR-20 outputs

Sampling Program

Four years sampling data

Sample at 8 stations

5 land-use specific sites

3 in-stream stations

Dry weather monitoring

Four baseflow samplings at 8 stations

Wet weather monitoring

Eight or more storm samplings every year
at 8 stations

Monitoring Parameters

Flow measurements

pH and temperature

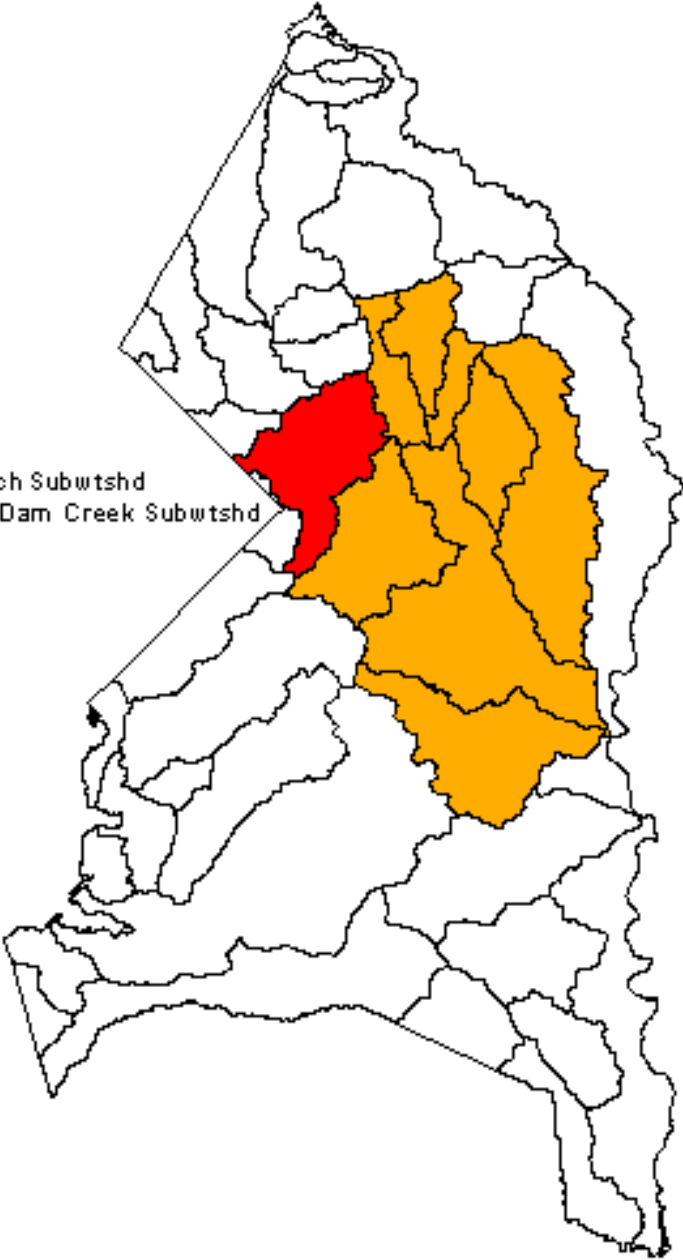
Four trace metals

Nutrients (Nitrogen and Phosphorus)

Conventional pollutants (BOD, TSS)

Oil and Grease

Fecal coliform

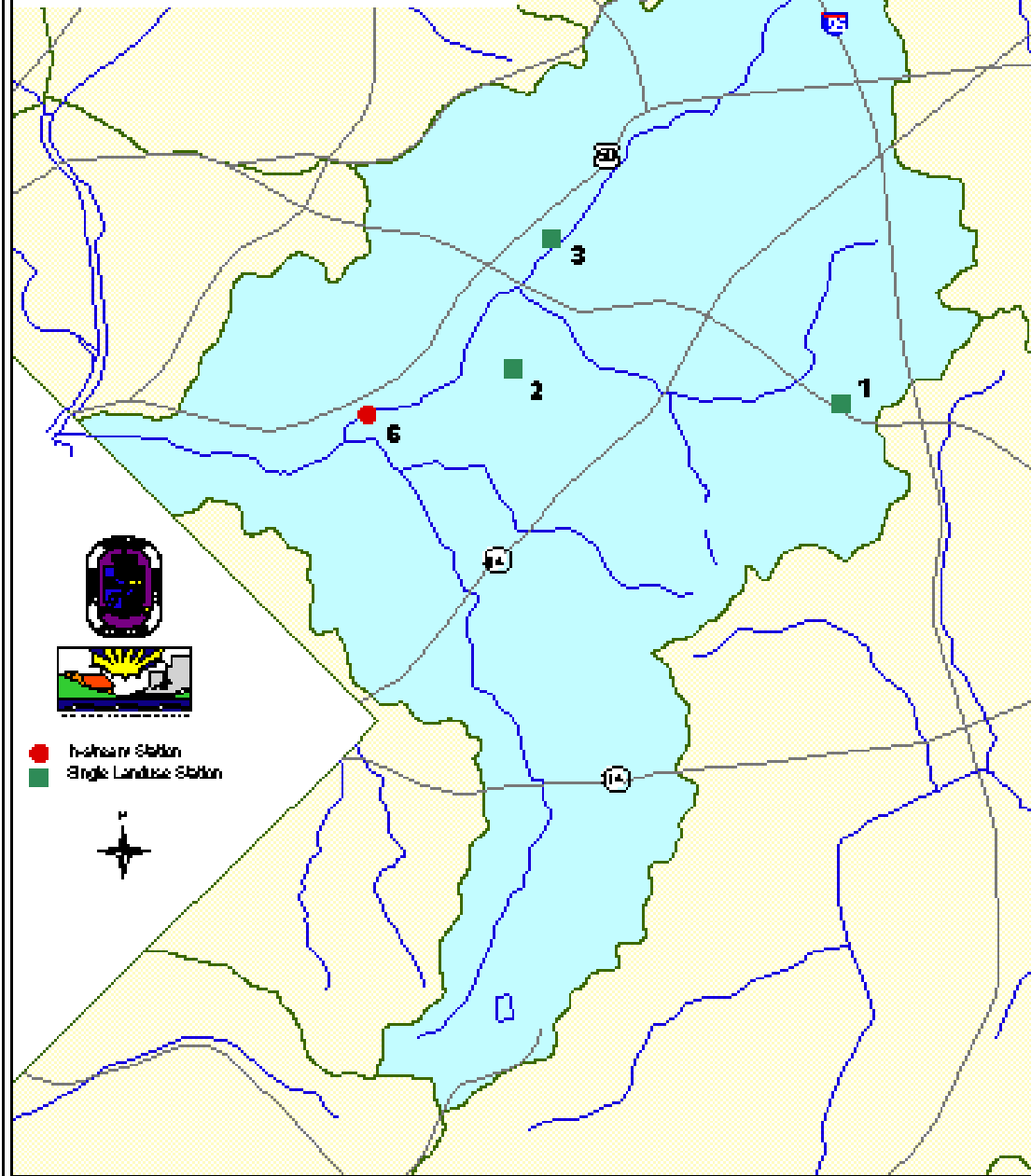


Western Branch Subwtshd
Lower Beaver Dam Creek Subwtshd

Sampling Watersheds

Long-Term Water Quality Monitoring Stations

Beaverdam Creek



Beaverdam Creek

Land use
specific basins

Residential
Commercial
Industrial

In-stream
stations

Beaverdam
Creek

HYDROLOGY CALIBRATION

Overall water balance

Compared annual modeled flow to observed flow at basin and subbasin outlets

Calculated watershed runoff coefficients as a ratio of flow to precipitation

High-flow low-flow distribution

Compared observed and modeled peak flows and baseflows

Storm flows

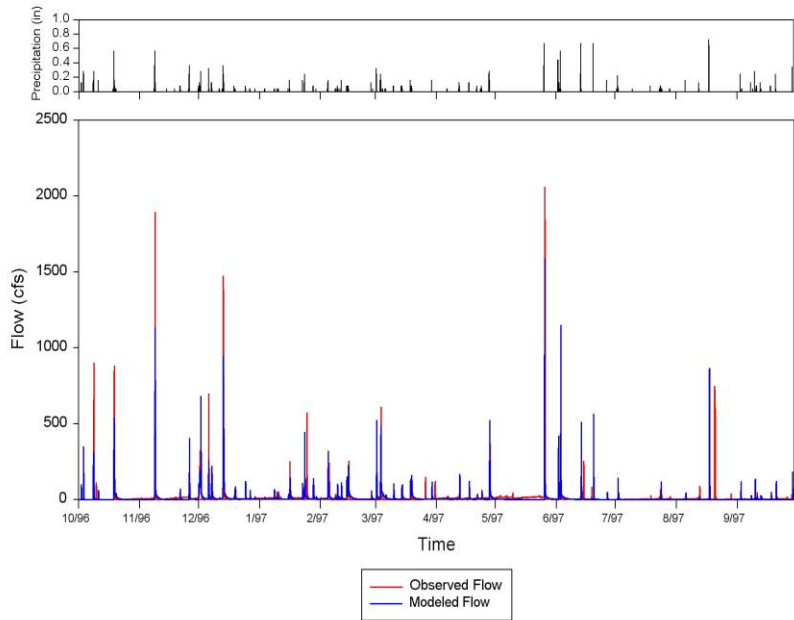
Analyzed storm flow volumes and hydrograph shapes

Considered distribution between surface runoff and interflow

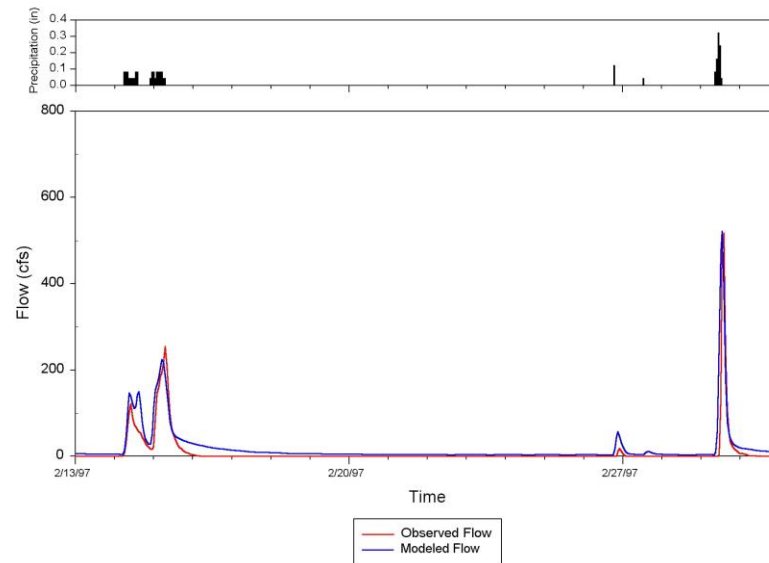
Seasonal variations

Analyzed seasonal variations in the flow regime

Time-series plot of hourly modeled and observed flow and precipitation - 1997 water year
Lower Beaverdam Creek at Station 006



Time-series plot of hourly modeled and observed flow and precipitation - selected storms
Lower Beaverdam Creek at Station 006



Annual water budget error: 11.6 %

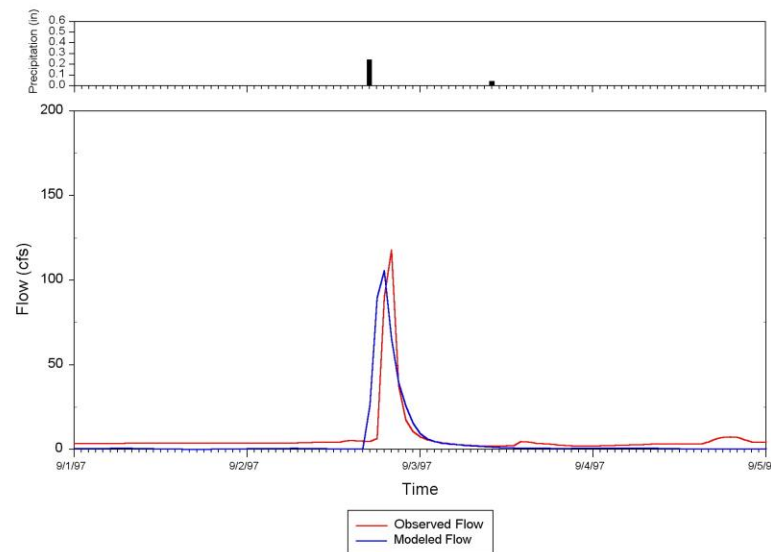
Error in peak flows (highest 10 % of flows): 1.5 %

Hydrology Calibration Results

Annual Budget

Selected Storms

Time-series plot of hourly modeled and observed flow and precipitation - selected storm
Lower Beaverdam Creek at Station 006



WATER QUALITY CALIBRATION

Performed for the following pollutants:

BOD-5

Total Nitrogen (TN)

Total Phosphorus (TP)

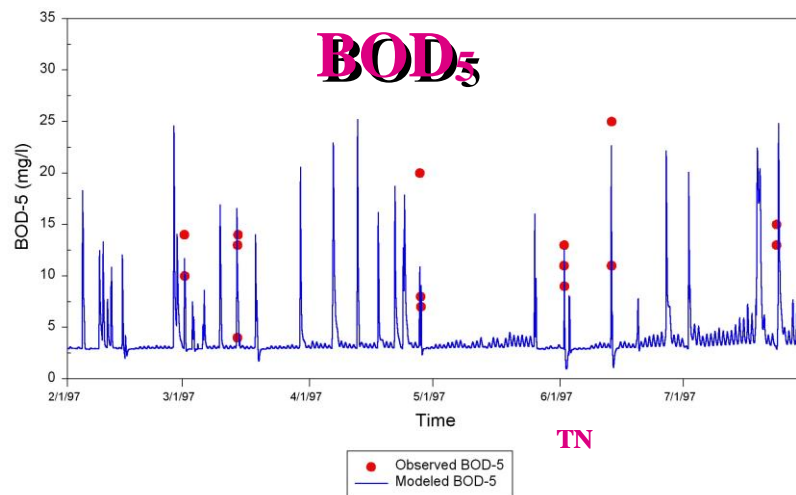
Zinc

Compared hourly concentrations to observed concentrations (from monitoring data)

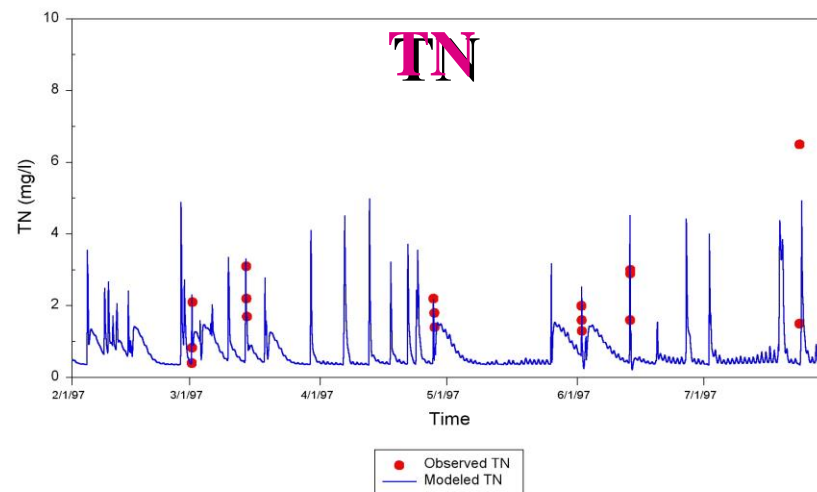
Adjusted key HSPF model parameters within a reasonable range to achieve an acceptable calibration

Assessed annual pollutant loads

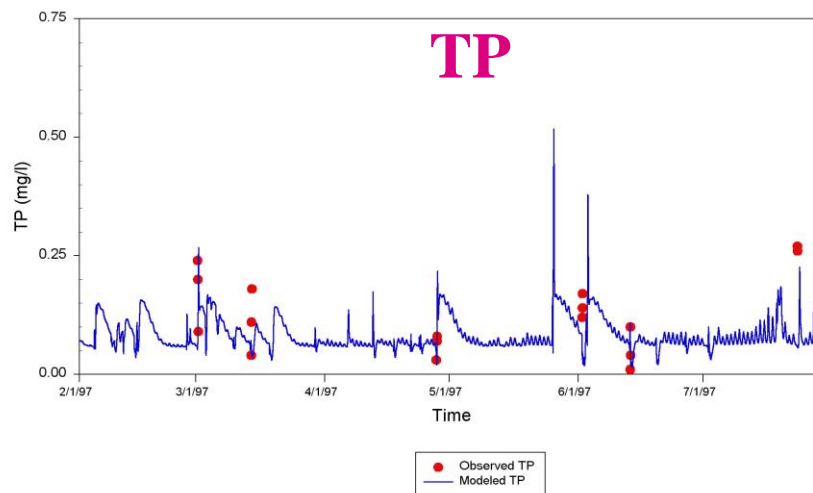
Calibration for Lower Beaverdam Creek at Station 006
Plot of precipitation and hourly modeled and observed BOD-5



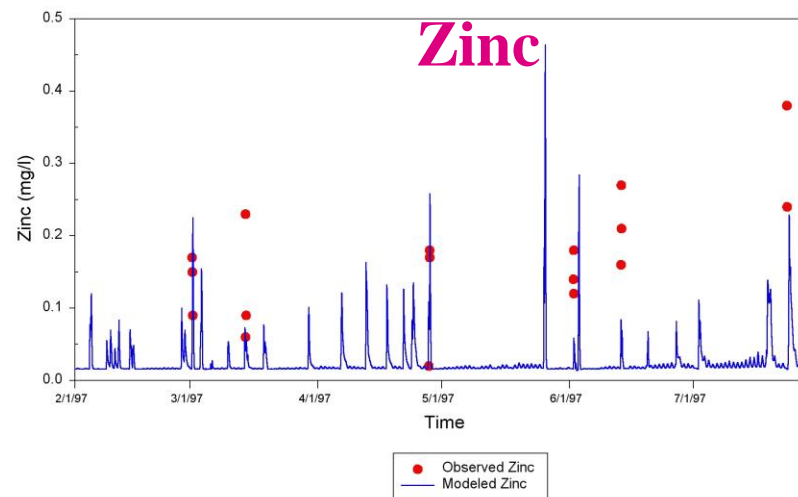
Calibration for Lower Beaverdam Creek at Station 006
Plot of precipitation and hourly modeled and observed TN



Calibration for Lower Beaverdam Creek at Station 006
Plot of precipitation and hourly modeled and observed TP

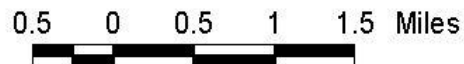
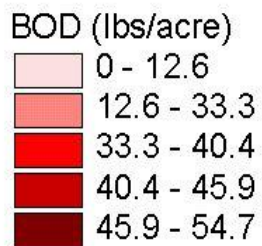
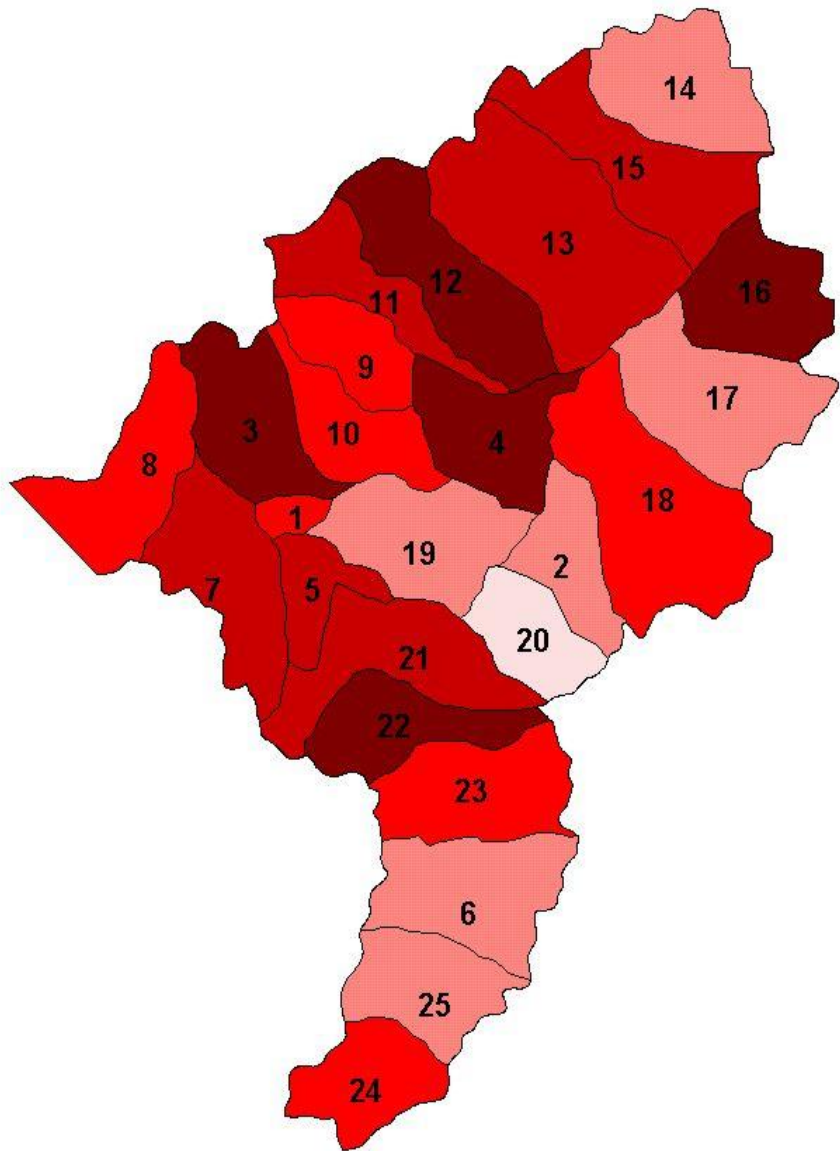
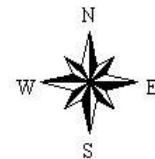
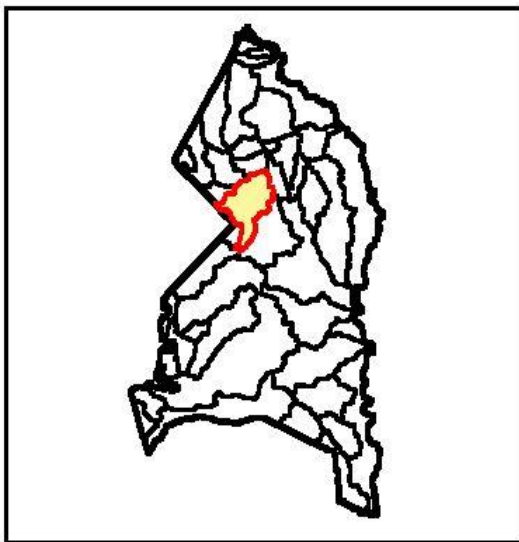


Calibration for Lower Beaverdam Creek at Station 006
Plot of precipitation and hourly modeled and observed Zinc



Simulated Pollutant Loadings

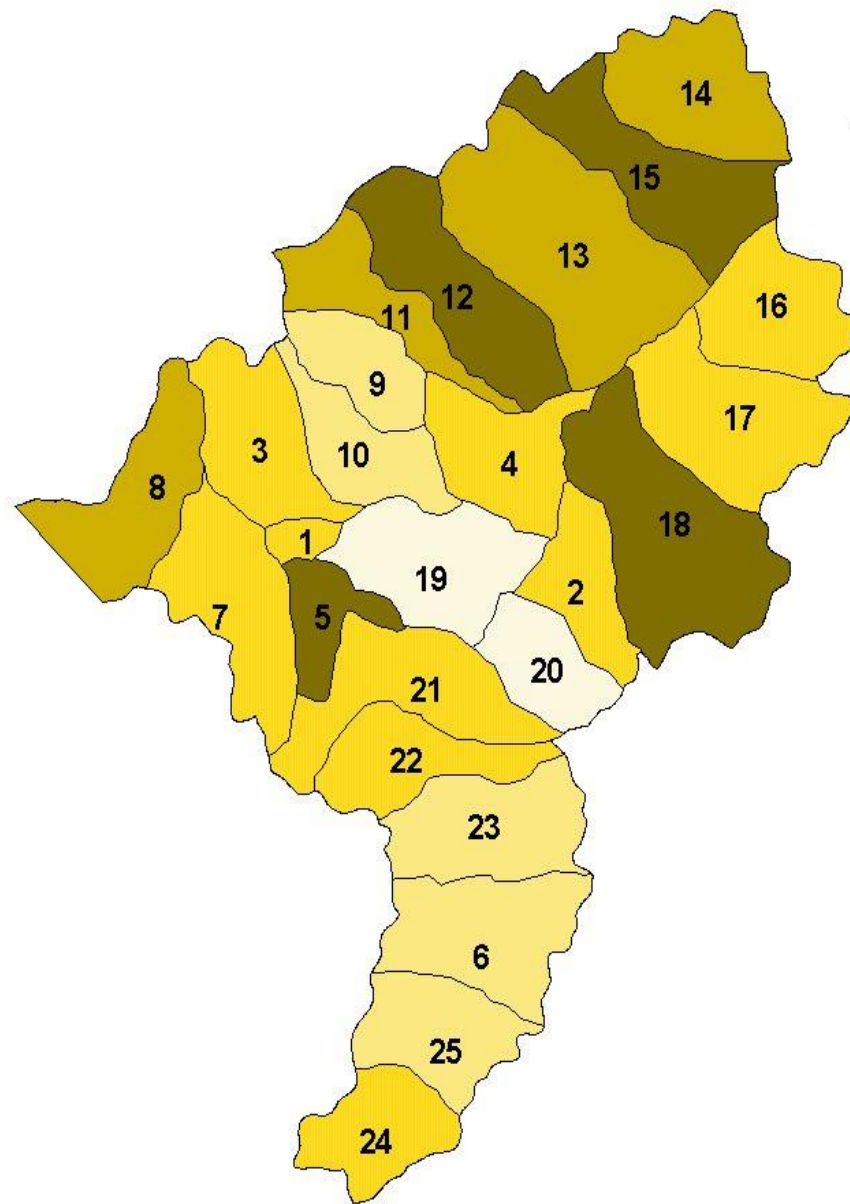
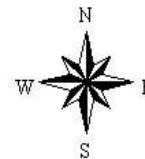
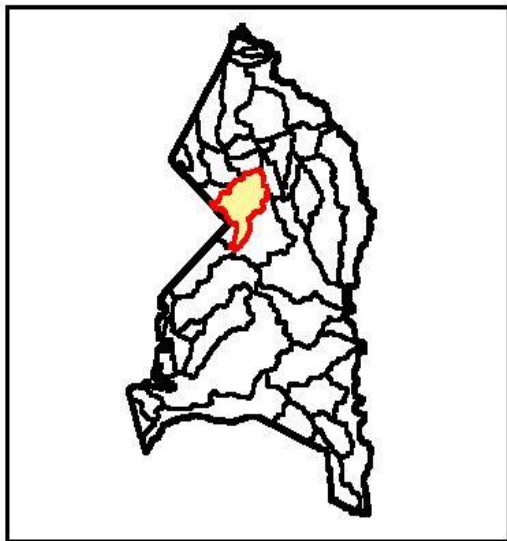
Subwatershed	Annual Nonpoint Source Load (lbs)						
	BOD	TN	TP	CD	CU	PB	ZN
1	2153	363	37	0.44	2.0	3.5	22
2	7920	1601	227	2.54	11.0	25.7	155
3	19806	2567	323	3.80	17.1	35.6	210
4	17205	2325	329	3.92	17.4	40.3	233
5	7837	1337	114	1.44	7.1	10.8	75
6	13613	2453	291	3.20	13.5	26.3	161
7	18889	2916	331	3.97	17.8	35.4	216
8	14964	2957	229	2.91	14.2	18.9	142
9	8907	1290	171	2.09	9.2	18.9	113
10	11120	1619	161	2.13	10.2	15.4	102
11	12992	1984	242	2.83	13.0	26.4	162
12	23673	3627	421	5.16	24.1	49.0	302
13	37852	6051	641	7.93	37.0	70.0	442
14	13932	2930	287	3.45	16.7	25.9	183
15	22063	3886	343	4.21	21.0	31.5	222
16	20318	2487	333	3.87	17.3	37.9	219
17	17407	3226	374	4.41	19.7	39.0	244
18	21859	4211	617	4.98	21.5	38.7	248
19	16546	2741	255	3.26	15.5	23.6	160
20	3166	1029	164	1.10	4.0	6.1	41
21	20143	2992	365	4.31	19.3	40.0	240
22	17104	2065	292	3.34	14.9	33.4	191
23	15625	2322	313	3.68	15.7	35.3	205
24	10044	1876	185	2.35	10.7	19.5	127
25	8776	1836	233	2.71	11.4	25.2	152



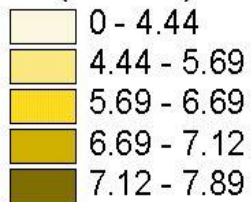
Annual BOD Unit Area Loads Lower Beaverdam Creek

Map Projection: State Plane - 1983
Maryland

Data Source: Prince George's County Watershed Data
U.S. EPA BASINS 2.0



TN (lbs/acre)



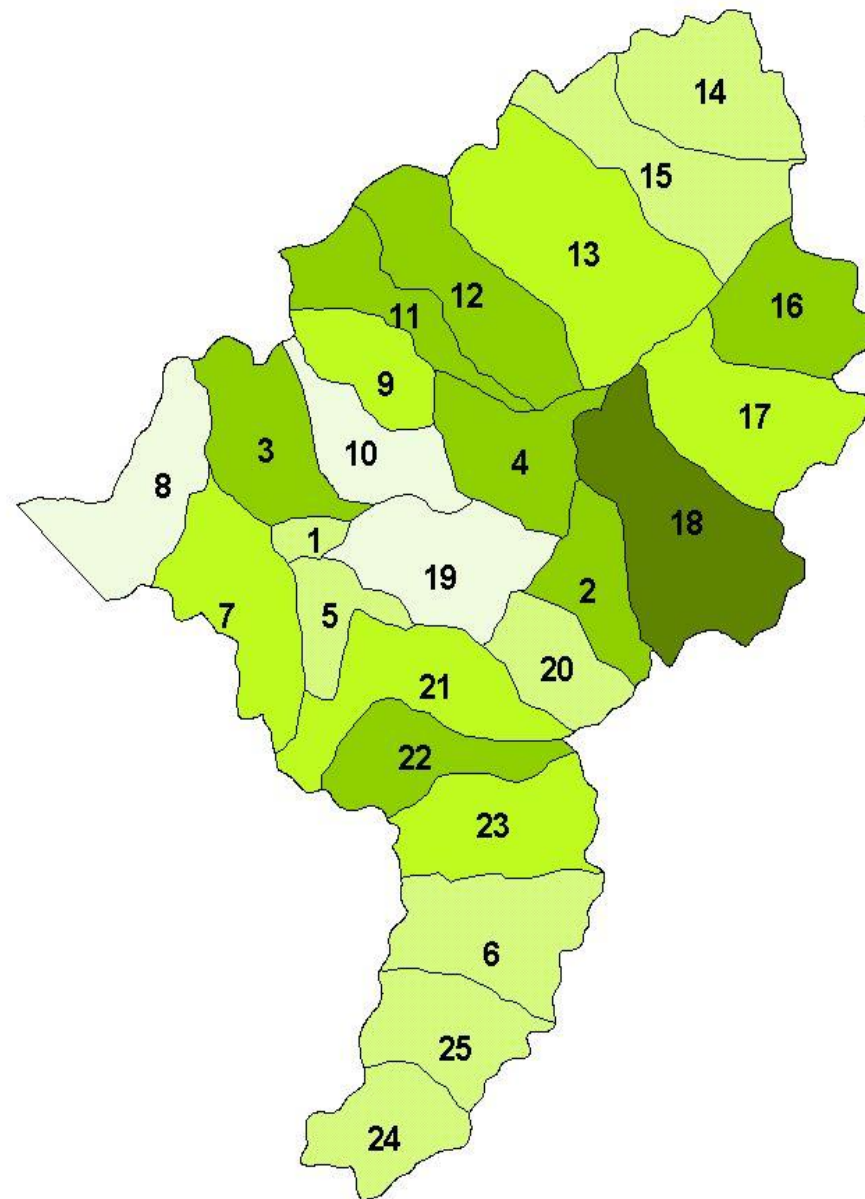
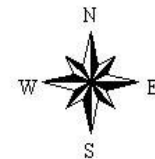
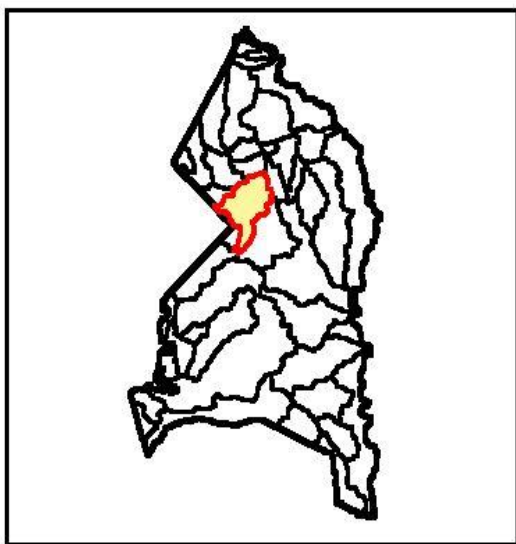
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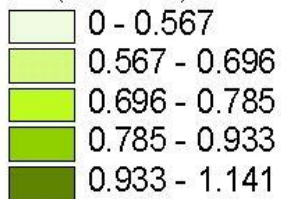
Annual Total Nitrogen Unit Area Loads Lower Beaverdam Creek

Map Projection: State Plane - 1983
Maryland

Data Source: Prince George's County Watershed Data
U.S. EPA BASINS 2.0



TP (lbs/acre)



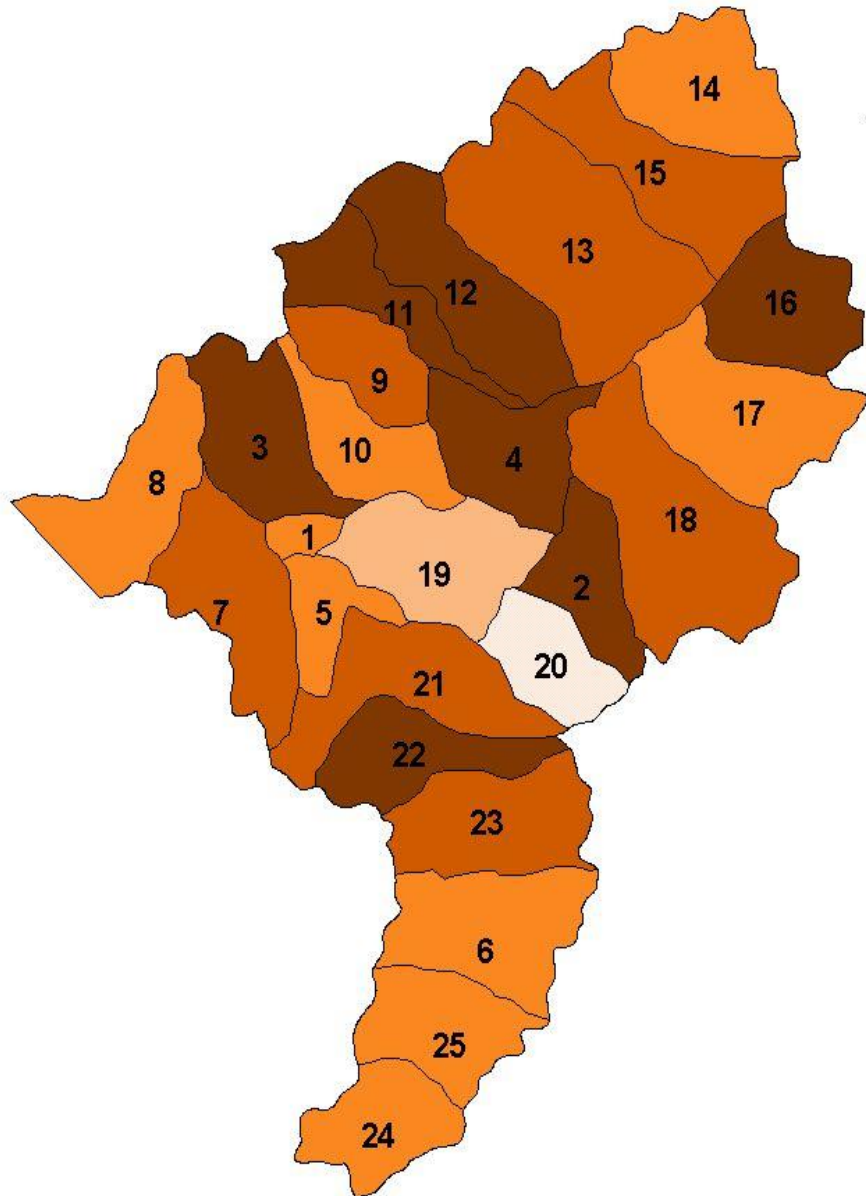
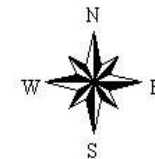
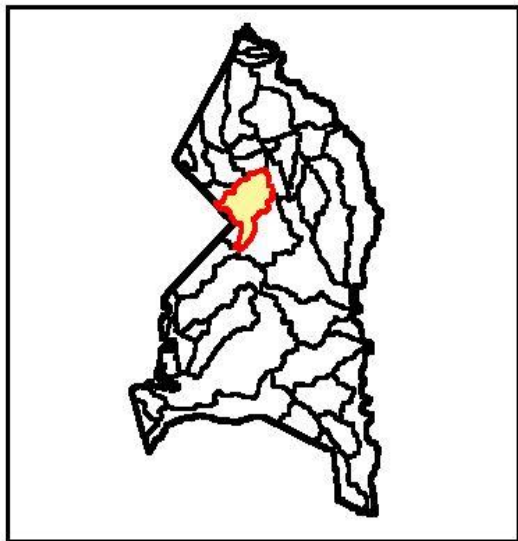
0.5 0 0.5 1 1.5 Miles



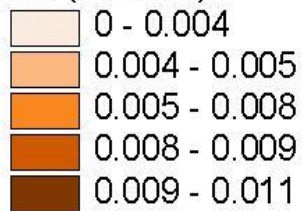
Annual Total Phosphorus Unit Area Loads Lower Beaverdam Creek

Map Projection: State Plane - 1983
Maryland

Data Source: Prince George's County Watershed Data
U.S. EPA BASINS 2.0



CD (lbs/acre)



0.5 0 0.5 1 1.5 Miles



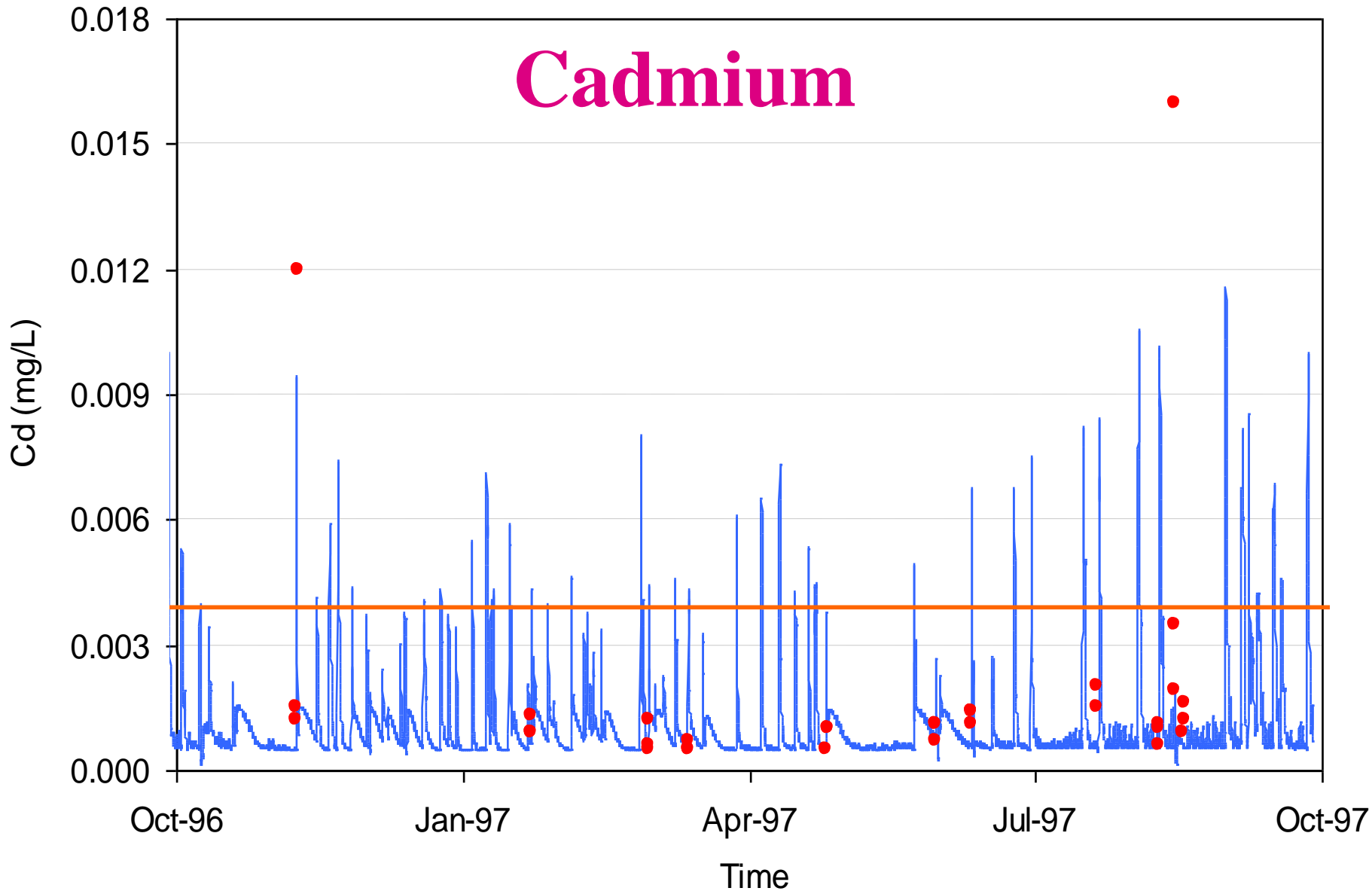
Annual Cadmium Unit Area Loads Lower Beaverdam Creek

Map Projection: State Plane - 1983
Maryland

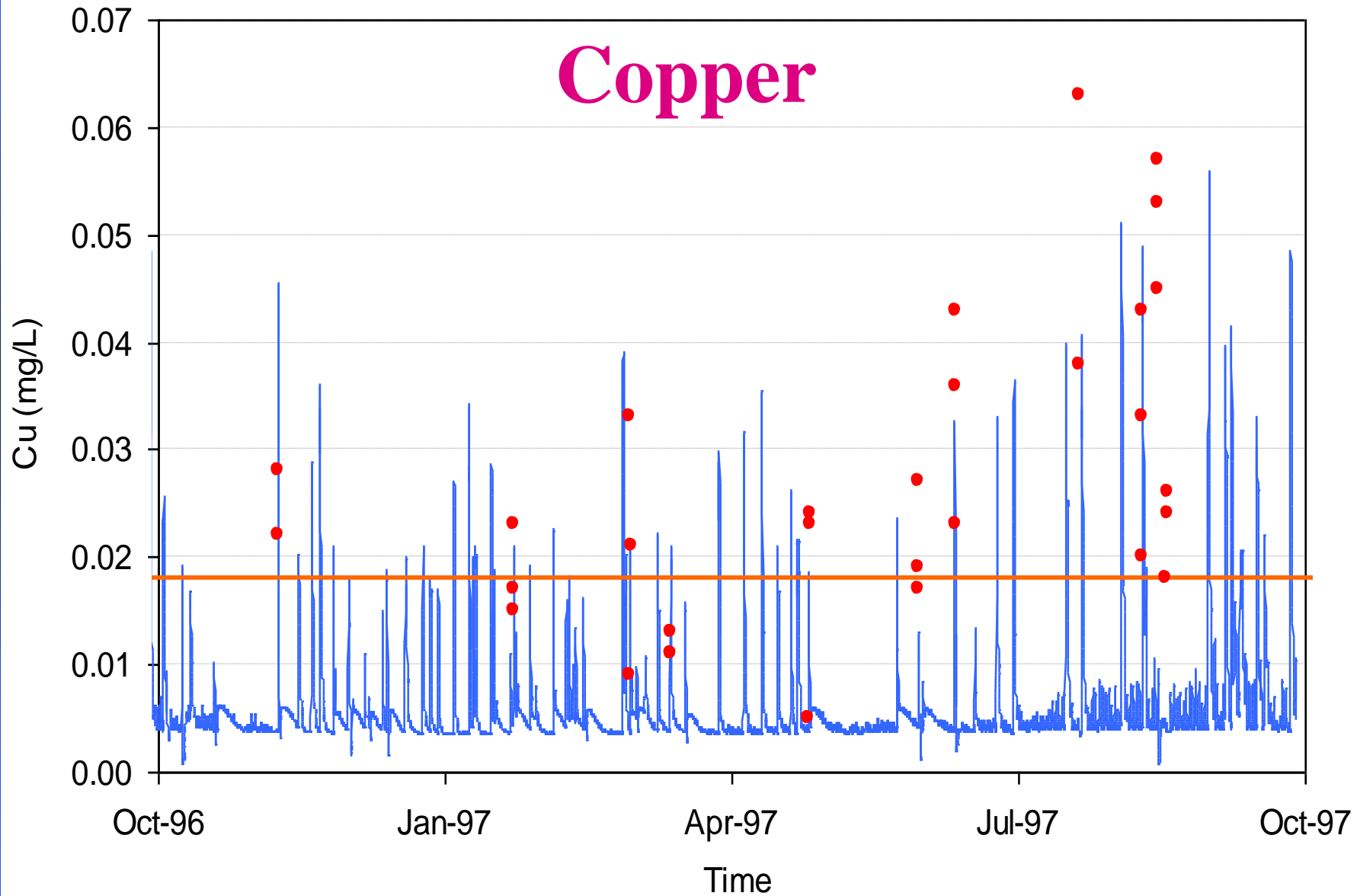
Data Source: Prince George's County Watershed Data
U.S. EPA BASINS 2.0

● Observed Cadmium (mg/L) — Modeled (Hourly) — Acute Standard (0.0039 mg/L)

Cadmium

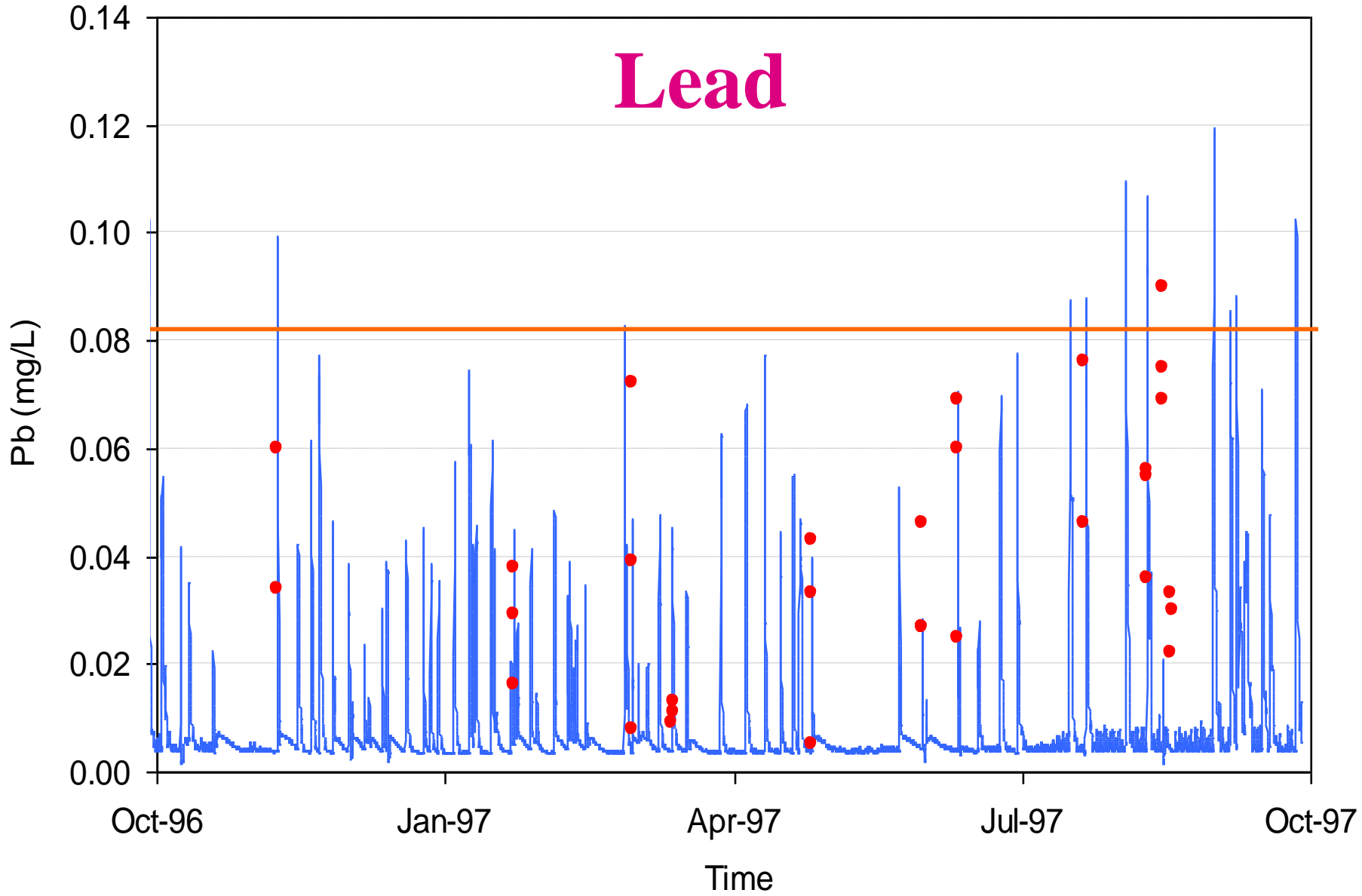


● Observed Copper (mg/L) — Modeled (hourly) — Acute Standard (0.018 mg/L)

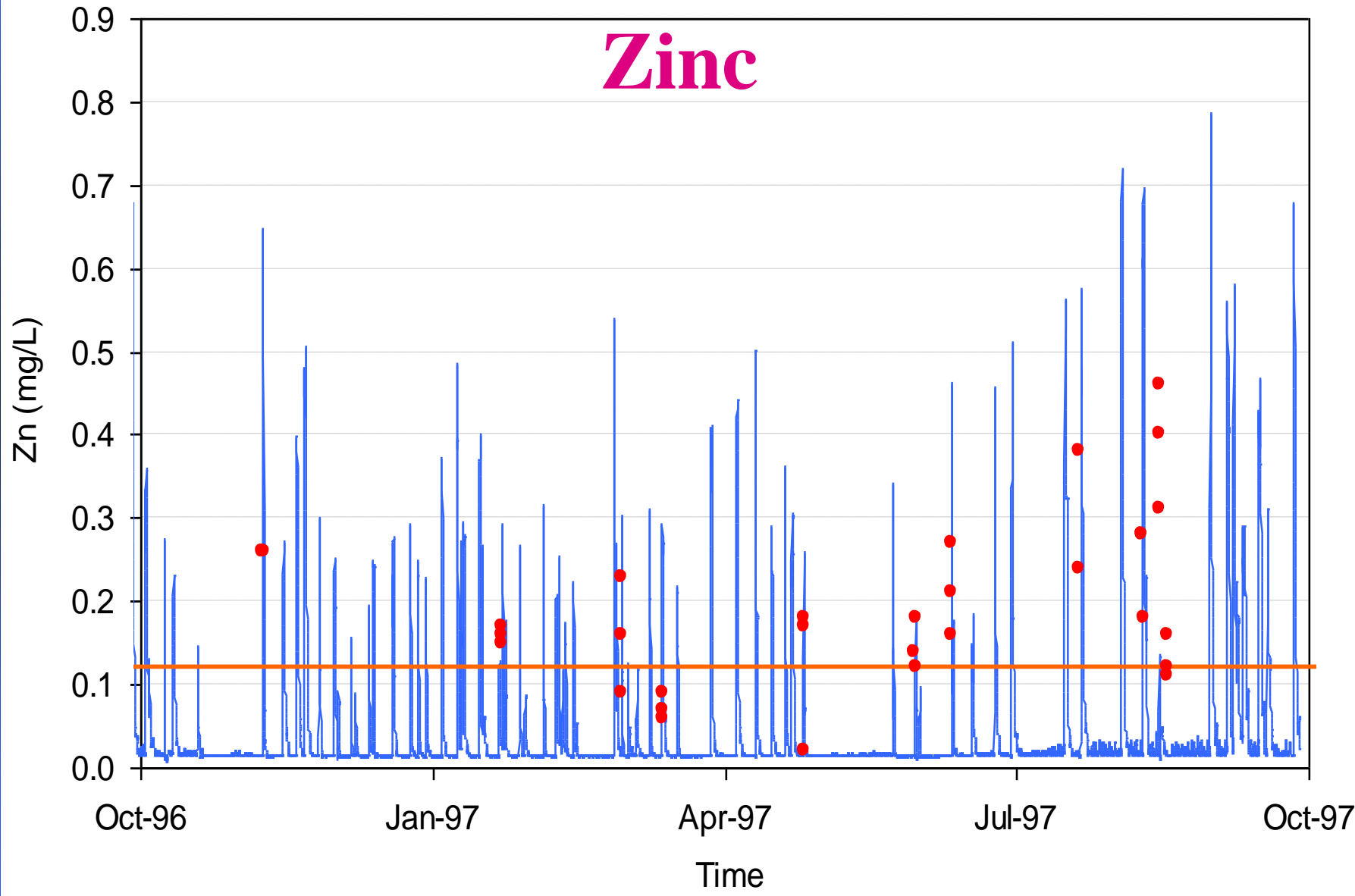


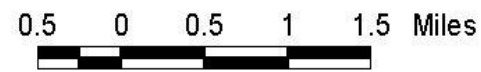
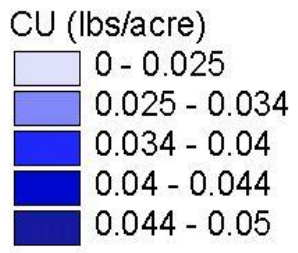
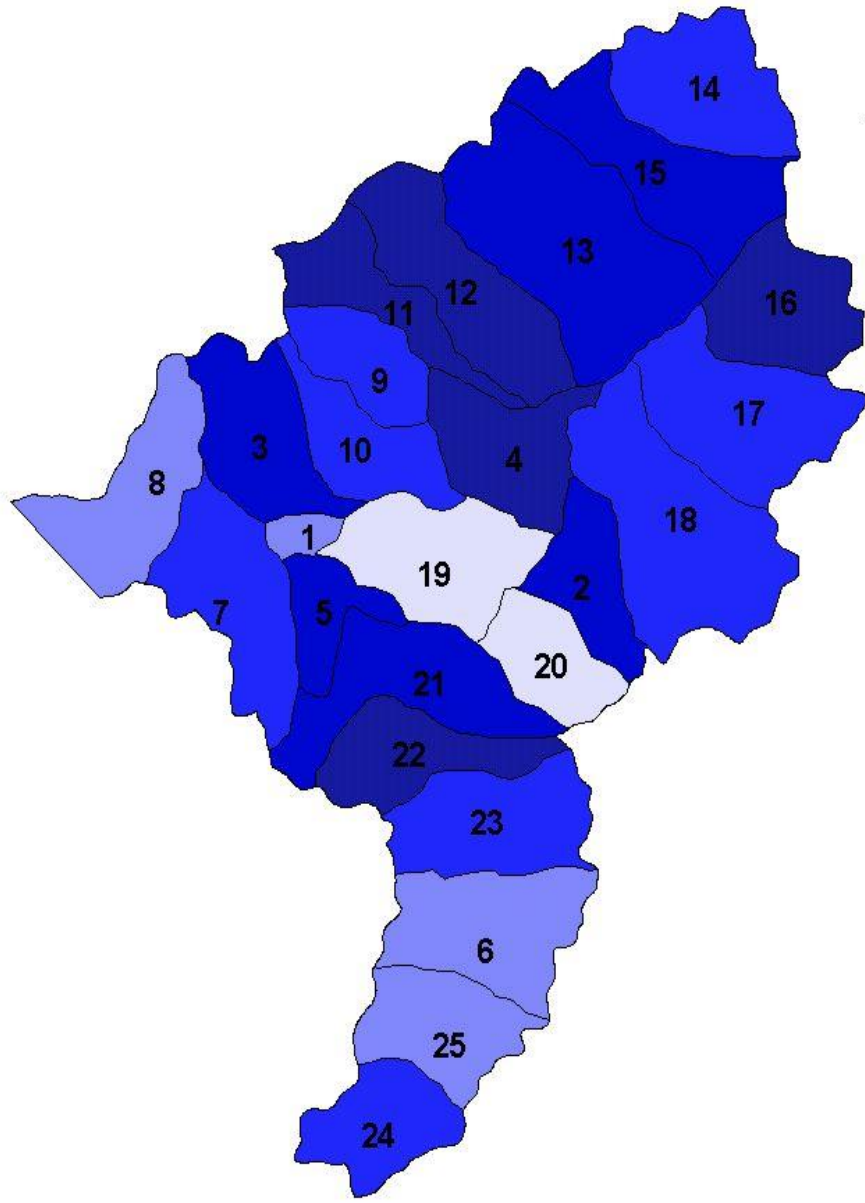
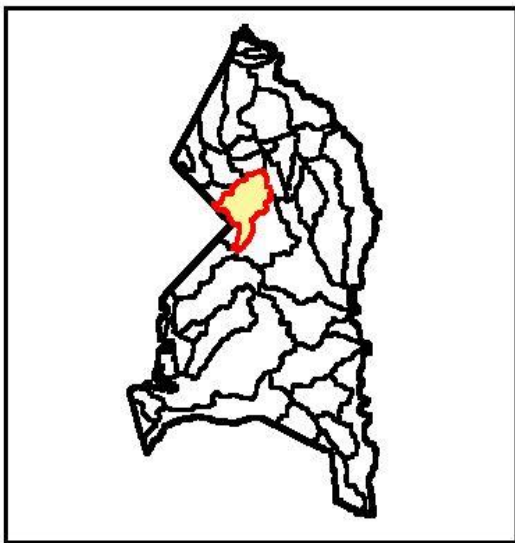
● Observed Lead (mg/L) — Modeled (Hourly) — Acute Standard (0.082 mg/L)

Lead



● Observed Zinc (mg/L) — Modeled (Hourly) — Acute Standard (0.12 mg/L)

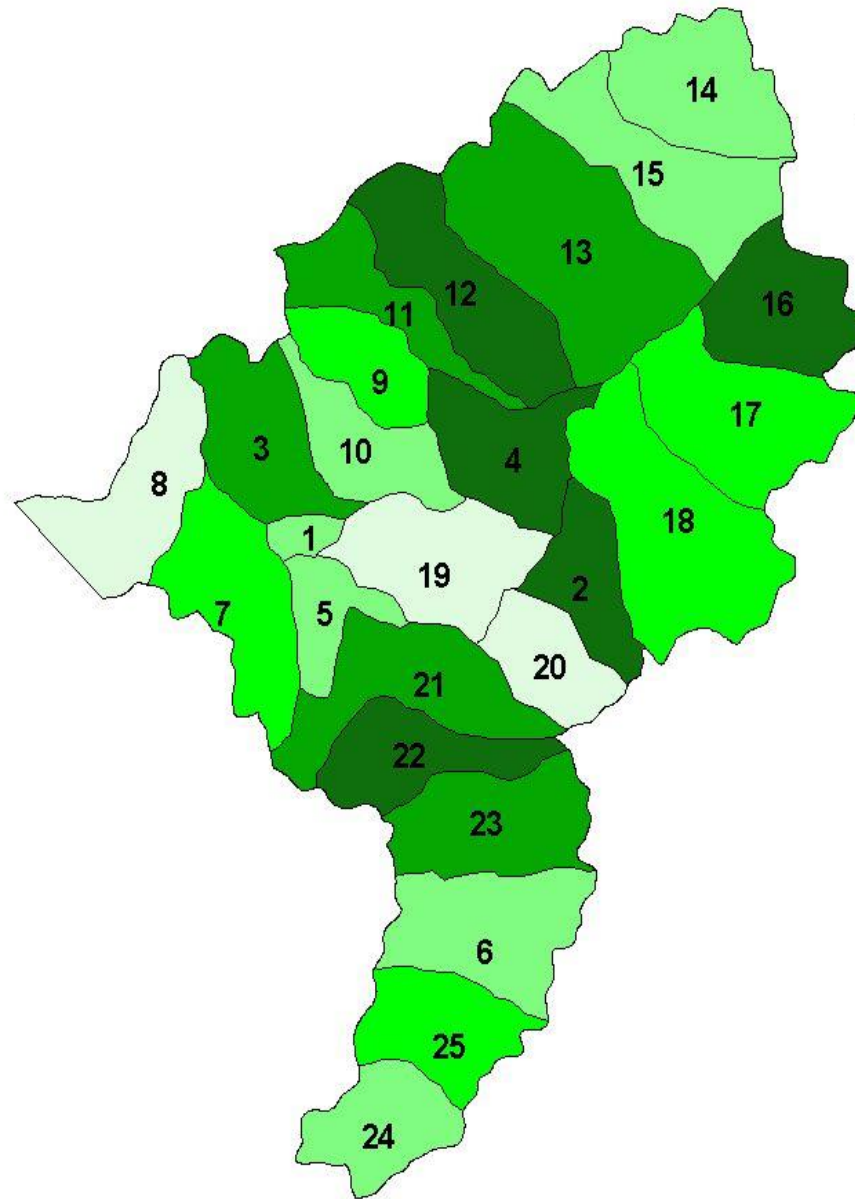
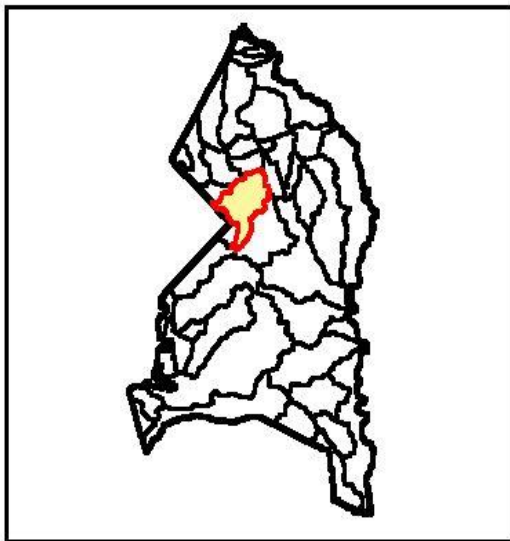




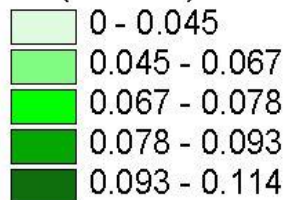
Annual Copper Unit Area Loads Lower Beaverdam Creek

Map Projection: State Plane - 1983
Maryland

Data Source: Prince George's County Watershed Data
U.S. EPA BASINS 2.0



PB (lbs/acre)



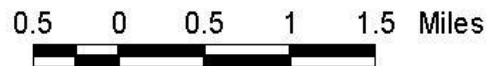
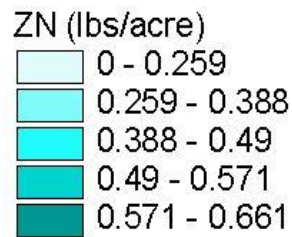
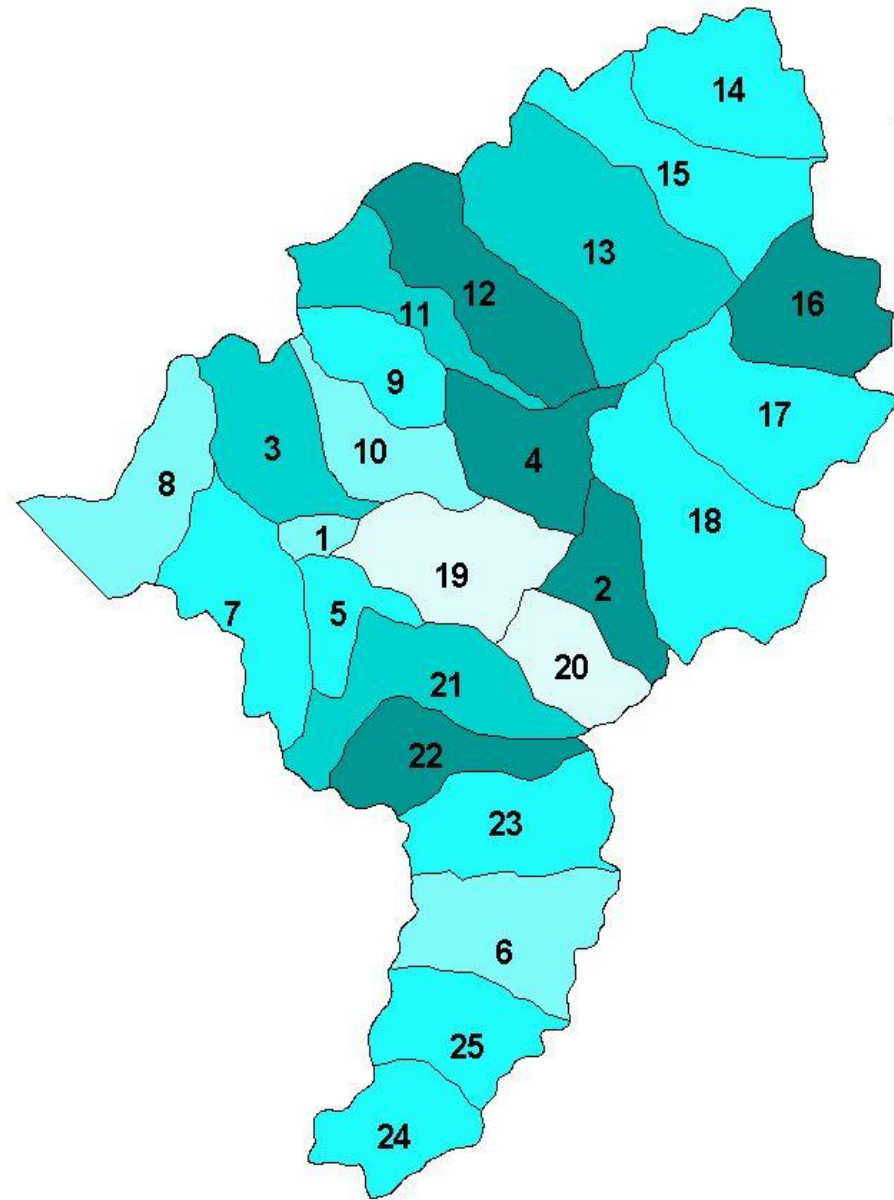
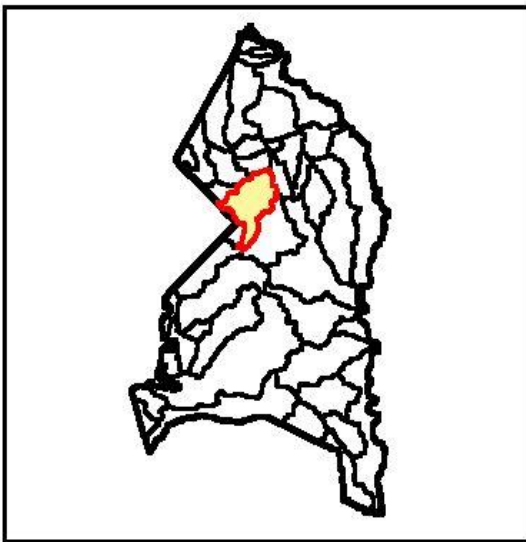
0.5 0 0.5 1 1.5 Miles



Annual Lead Unit Area Loads Lower Beaverdam Creek

Map Projection: State Plane - 1983
Maryland

Data Source: Prince George's County Watershed Data
U.S. EPA BASINS 2.0



Annual Zinc Unit Area Loads Lower Beaverdam Creek

Map Projection: State Plane - 1983
Maryland

Data Source: Prince George's County Watershed Data
U.S. EPA BASINS 2.0